The Perfect Sleeve Gastrectomy

A Clinical Guide to Evaluation, Treatment, and Techniques

Michel Gagner
Almino Ramos Cardoso
Mariano Palermo
Patrick Noel
David Nocca
Editors

Springer

EXTRAS ONLINE

The Perfect Sleeve Gastrectomy

Michel Gagner • Almino Ramos Cardoso
Mariano Palermo • Patrick Noel • David Nocca
Editors

The Perfect Sleeve Gastrectomy

A Clinical Guide to Evaluation, Treatment, and Techniques

Springer

Editors
Michel Gagner
Department of Surgery
Sacré-Coeur Hospital
Montréal, QC
Canada

Almino Ramos Cardoso
Bariatric Surgery
Gastro Obeso Center
Sao Paulo
Brazil

Mariano Palermo
Diagnomed
University of Buenos Aires
Buenos Aires
Argentina

Patrick Noel
Emirates Specialty Hospital
Dubai
United Arab Emirates

David Nocca
CHU Montpellier
Saint Gely du Fesc
France

ISBN 978-3-030-28935-5 ISBN 978-3-030-28936-2 (eBook)
https://doi.org/10.1007/978-3-030-28936-2

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Foreword

"Everything should be made as simple as possible, but not simpler".

Albert Einstein

The air-conditioned room at the restaurant in the Upper East Side felt like a shelter from the heat wave of the early summer of 1999 in New York City. My colleagues and I had just arrived in town to start our minimally invasive surgery fellowship at Mount Sinai and some of us were still struggling to fight the jet lag during the dinner.

"Tomorrow is going to be a great day" – said suddenly Dr Michel Gagner, interrupting my explanation of the meaning of *Tiramisu* for my non-Italian colleagues around the table. The next day – he explained – he would make an attempt to perform biliopancreatic diversion with duodenal switch (BPD) through a laparoscopic approach. Although we did not know much about duodenal switch at the time, it seemed clear we had arrived just in time to see a surgical first!

That night, however, none of us could predict that the following day would actually start the process that ultimately led to the "discovery" of sleeve gastrectomy.

In the late 1990s laparoscopic surgery was expanding rapidly; some procedures, however, had not yet been conquered by the laparoscopic revolution. Among them was the BPD. Demonstrating the feasibility of the laparoscopic approach for BPD-DS was important, as it would expand the benefits of minimally invasive surgery to patients with the most severe forms of obesity.

The classic biliopancreatic diversion (BPD), originally introduced by Nicola Scopinaro in Italy in 1976, involved a horizontal gastrectomy and a 50 cm long common channel. To decrease the incidence of marginal ulceration and long-term malnutrition, the classic BPD was modified by Hess in the United States and Marceau in Canada to include a vertical ("sleeve") gastrectomy with duodenal switch and a longer common channel (from 50 to 100 cm).

On a morning of early July, Dr Gagner successfully performed the first laparoscopic BPD-DS. Every step of the procedure was made difficult by the high BMI of the patient (>80 kg/m^2) but it was the sleeve gastrectomy, despite its apparent simplicity, that provided the greatest challenge. Which position for the trocars? What bougie size and how to advance it? How to avoid twists and strictures? How to treat the staple line? How to best expose the fundus? None of these steps were standardised yet. At the time there wasn't a book like this to provide instructions, technical tips and wisdom from two decades of surgical practice.

Challenges, however, can provide powerful inspiration.

In fact, it was the challenge of performing such a complex operation in high BMI patients and the need to reduce operative time and surgical risk that led Dr Gagner to conceive a staged-approach to laparoscopic BPD-DS. The strategy was to perform sleeve gastrectomy (SG) as the first step, followed by the intestinal bypass few months later. As soon as few patients underwent first stage laparoscopic BPD-DS, however, it became clear that sleeve gastrectomy alone was able to cause rapid and substantial weight loss. This unexpected observation inspired Dr Gagner's idea that laparoscopic sleeve gastrectomy could be used as a new bariatric operation.

The day Dr Gagner performed the first laparoscopic BDP-DS was for me an eventful day. At the time, I was still uncertain as to whether I would pursue endocrine or cancer surgery but one thing I thought I knew for sure: I did not want to be a bariatric surgeon. As interesting as a surgical first could be, I did not anticipate that the experience of that day would teach me lessons that could majorly impact my future clinical practice. As the day unfolded, however, I was fascinated by the technical challenges of that surgery and, even more, by the oddities of its effects –so much that by the end of the day I would have committed my career to bariatric, oops! metabolic surgery.

Impressed by the technical complexity, risks and costs associated with extensive stapling and long operative time, I wondered it there was a way to simplify BPD and facilitate the laparoscopic approach. Before Dr Gagner was able to leave the operating room, visibly tired and ecstatic at the same time, I asked him if there was a reason why major intestinal re-routing and gastric resection were both necessary for BPD to work. In the end, with only 100 cm of common channel, could there be enough malapsortion to do the trick? Why to add a gastric resection? I asked these questions under the assumption that Dr Gagner would be able to point me to some mechanistic studies of gastrointestinal physiology that had informed the design of BPD or other bariatric procedures. He admitted that he did not know the answers but encouraged me to go to the library, that same day, to find out.

Despite my best efforts at researching the literature, that afternoon I could not find the information I was looking for. In fact, although bariatric surgery had been practiced since the 1950s, at the turn of the century there were still no real mechanistic studies behind the design of bariatric procedures. The surgical anatomy of bariatric surgery was largely based on the simplistic notion that to induce weight loss one could either restrict the stomach's size to reduce food intake or bypass the intestine to reduce nutrient absorption. In heavier patients one could combine restriction and malabsorption for greater weight loss. Weight loss would then explain all other clinical benefits of bariatric surgery. Paper after paper reiterated the "mantra" of restriction and malabsorption; surprisingly, however, neither animal nor clinical studies had put these assumptions to the test of scientific investigation.

Frustrated, I was about to leave the library when I noted something really odd in one of the BPD papers that I was unexcitedly reading: in a series of over 2000 patients who had undergone BPD, blood glucose levels were reported as normal in all patients as early as one month after surgery. "Someone must have had type 2 diabetes among those 2000 patients with morbid obesity" – I thought. "How comes nobody has it 4 weeks after an operation? Could BPD or similar GI surgeries actually fix what is broken in diabetes?" It was this question that, after an otherwise unproductive visit to the library, ended up changing the path of my professional career.

When Dr Gagner reported remarkable weight loss results from first stage laparoscopic BPD, sleeve gastrectomy took the world of bariatric surgery by storm. Almost overnight, the procedure became popular around the world, overtaking both gastric banding and gastric bypass as the most commonly performed bariatric operations.

To both surgeons and patients, sleeve gastrectomy looked conceptually and practically simple. Simple to perform, with no risk of dreadful anastomotic complications. Simple to understand, with no confusing anatomic re-routing of intestinal limbs. Making the stomach smaller, but not too small, sleeve gastrectomy appealed to both surgeons and patients: it would make one eat less than the average diet but not too much less to be worried about it.

It did not take very long to realize, however, that sleeve gastrectomy is simple, but not that simple. It was soon appreciated that the lack of anastomosis did not necessarily mean there was no risk of leaks. And that leaks from sleeve gastrectomy were not benign. Predictably, a long-staple line exposed to risk of bleeding. The idea that one could "calibrate" the sleeve to modulate weight loss or "re-sleeve" the stomach to treat weight regain made intuitive sense, but revealed less effective than expected. Dysphagia, reflux were not unusual complaints.

The introduction of sleeve gastrectomy concurred with the dawn of a new era for bariatric and metabolic surgery. In a field historically prone to quick enthusiasm and easy disappointment for even the earliest empirical evidence, the turn of the century brought about more rigorous mechanistic research and evidence-based medicine, raising the standards of surgical innovation. Improved scientific evidence and continuous pressure from the unrelenting epidemics of obesity and diabetes attracted the interest of scores of clinicians and scientists from the most diverse medical disciplines. In a relatively short time, the field of bariatric/metabolic surgery was dramatically transformed, perhaps more than any other field of surgery.

As surgical therapies started to be considered potential alternatives to conventional medical treatments of type 2 diabetes, assessment of their safety and efficacy required methods that are in line with those used to evaluate pharmacologic interventions. This provided a strong incentive for randomized clinical trials, standardization of surgical techniques and improved mechanistic understanding.

Over the last two decades, systematic refinements of surgical technique have improved safety of sleeve gastrectomy. Its clinical outcomes have been investigated in countless clinical studies, including randomized clinical trials. The findings of these studies now support sleeve gastrectomy as one of the standard of care therapies of type 2 diabetes and obesity.

Mechanistic research has also shown that SG exerts powerful effects on gut hormones, bile acid metabolism, microbiota among other aspects of GI physiology, revealing how manipulations of the stomach's anatomy influences not only gastric but also intestinal mechanisms of weight regulation and glucose metabolism.

It is now clear that it is indeed for the complexity of its physiology, rather than its apparent simplicity, that sleeve gastrectomy represents an invaluable tool in the treatment and understanding of obesity and type 2 diabetes. In such complexity lies the opportunity to refine indications, understand contraindications and personalise the choice of the procedure, according to disease-stage, patients' characteristics and needs.

This book is therefore a welcome, timely resource to help navigate the complexity of a large body of new evidence and inform the clinical practice of novice surgeons as well as more experienced ones.

A chapter of this book also takes a look at the future. In which direction are we going next? What is the future of sleeve gastrectomy, and more in general, of bariatric and metabolic surgery?

As an old saying goes, making predictions is very difficult, especially about the future. Sleeve gastrectomy was not predicted; it was not invented, nor it was designed. It was discovered through the ability to be open-minded about the opportunities offered by unexpected observations.

The events in the summer of 1999 show that the future of surgery, like professional careers can take unpredictable paths; standing prepared for the unexpected is the only way to shape our future.

London, UK Francesco Rubino

Preface

What is really this book about and how it came to fruition?

I think the spark came from Dr Mariano Palermo of Buenos Aires inspiring leadership and enthusiasm, after he was ending the "*ATLAS DE TECNICAS EN CIRUGIA BARIATRICA Y METABOLICA*" published by Editorial Amolca, which involved co-editors Agustin Rodriguez, Mariano Palermo, Miguel Farina, Edgardo Serra and myself. I did receive a copy recently, in person from Mariano, in Buenos Aires on April 4th 2019. Previously also, "Global Bariatric Surgery, The Art of Weight Loss Across The Borders", edited by Drs. Rami Lutfi, Mariano Palermo, and Guy Bernard Cadiere, antedated this book. Mariano has a contagious process while being mentally stimulated to do another project, feel something, especially to do something creative in writing, and to communicate and teach a younger generation.

This project, is very appropriate, as we are 20 years after the first laparoscopic sleeve gastrectomy performance (as part of a duodenal switch) in Mount Sinai Hospital in New York, July 2nd, 1999. He has assembled a great team of co-editors, leaders in their field and respective areas, so we have a global perspective on this operation that has taken the world literally by storm. It is not perfect, and I always have said to students, fellows and residents, that an operation is never a finality, it is a work in progress, like an asymptotic curve, arbitrarily getting close but never attaining complete perfection, needing constant readjustments and improvements.

So, I received an email on October 4th 2018 from Mariano Palermo and Almino Ramos Cardoso who is currently the President of IFSO; "Hello Michel, we were talking recently with Almino, and he proposed to write a book. "The perfect sleeve".

What do you think?". I responded the same day, "Cool", and a series of emails between us and a preliminary list of 31 subjects matters for chapters was initially circulated. Mariano also sent an email to the publisher Springer. By October 11th, Richard Hruska, executive director for clinical medicine at Springer had given the thumbs up to the project. In the subsequent days, it became important to add colleagues from more continents, as the book project became an extensive international endeavour, and Pr David Nocca, an early adopter of the procedure, which subsequently modified it to prevent reflux, and Dr Patrick Noel, an excellent clinical surgeon who has perfected his own technique, accepted and became co-editors on October 17th. So the "The Perfect Sleeve Gastrectomy – A Clinical Guide to Evaluation, Treatment, and Techniques", came about and Springer was chosen as a publisher, for their worldwide expertise and horizons. The final chapter list was produced on October 19th, and invitations to authors were sent October 29th. All chapters were finished in record time, by March 18th, and production started.

According to the World Health Organization, obesity with or without diabetes, has become a major global problem that continues to spread in both developed and developing countries, it costs more than any other health problem due to its prevalence and threatened to break governmental budgets due to expensive complications management such as heart and liver diseases, joint replacements, as well as disability and loss of production. Sleeve gastrectomy is the most common bariatric procedure performed worldwide, more than 55% of all bariatric procedures are sleeve gastrectomies, in Asia, this is more than 70% of all weight loss operations. This book discusses all the approaches and gives the readers, all the tools to perform the perfect sleeve.

Today, weight loss surgery is the only evidence-based therapy for the severely obese patient; the metabolic diabetic subject, with low complication rate and outstanding results in the long term. Minimally invasive technology to these complex operations made them more acceptable to patients due to decreased pain, faster recovery, and better cosmesis and less overall complications. In these exciting times, our five international co-editors (one of them, is the creator of the laparoscopic sleeve) wanted to capture the global standards of practice at a time of change, excitement, and accompanying controversies, regarding this now accepted common procedure.

We aim to shed light on best practices, to give a reliable reference to guide the practising physician anywhere in the world, and from whatever speciality (family physicians, internist, surgeon, gastroenterologist or endoscopist) to navigate through the many current options of therapy in this swiftly changing field. We aim to provide high definition, edited, illustrations and also videos of these techniques accompanying didactic chapters done by the opinion leaders of the day. In this treatise, we give the reader all the tips and tricks, instruments, to perform a perfect sleeve. For this, we focus first on the clinical problems of the patients and the indications for the sleeve. Regarding the technical aspects, we describe the technique step by step (including videos) and also detail the staplers with their accompanying various staples, different sizes of the bougies, sutures and reinforcements. Complications management is particularly important, they could be very severe, and several chapters are dedicated to the different approaches to treat them by endoscopy, laparoscopy and percutaneous image-guided surgery. Also revisional surgery, in this book, is described, to achieve the best patients outcomes. Finally, the last section of the book, with reminiscence over the last lessons learned after 20 years since the laparoscopic sleeve is described, and an added overview on how we imagine the future of the most common bariatric procedure performed worldwide will evolve and progress, is ending this book.

Montréal, QC, Canada Michel Gagner
Sao Paulo, Brazil Almino Ramos Cardoso
Buenos Aires, Argentina Mariano Palermo
Dubai, United Arab Emirates Patrick Noel
Saint Gely du Fesc, France David Nocca

Acknowledgements

I dedicate this book to my family, who morally supported me during those years in Cleveland, New York, Miami, Doha, and Montreal.
To France, Xavier, Guillaume and Maxime.
I dedicate also this book to all my residents and fellows for the last 30 years, many who are authors, co-editors, the impetus of this excellent book, making me proud with their own accomplishments.

"Nous sommes nos choix" – Jean-Paul Sartre

Michel Gagner

The Perfect Sleeve will be a very useful book as it is based in very practical guides, tips and tricks about how to achieve a safe an effective Sleeve Gastrectomy. Considering we could do it in a couple of months I should acknowledge all the authors and editors regarding the involvement and dedication specially to Mariano Palermo who has embraced the idea since the beginning and has done a tremendous effort to materialize our ideas. Also my big thanks to Michel Gagner, David Nocca and Patrick Noel for all the work with their chapters and also the support for based in friendship having the others chapters on time.

This book is dedicated to the friendship and camaraderie, the big help of my partners Nestor Bertin and Raphael Lucena that allow me to continue doing some science and my loved family Manoela, Gabriel, Julia and Lucas.

Almino Ramos Cardoso

To my wife Gabriela, my two children Agustina and Lucas, my parents Mario and Loly and my grandmother Lucila for supporting me every day.
To my professors and friends, authors and co-authors in this book for teaching me and share their knowlegde, but also for sharing their friendship.

Mariano Palermo

To my colleague and friend Mariano who invited me to take part in this scientific journey and to my dream team Imane and Marius for their unconditional support and precious help. To all of our patients from everywhere. With my gratitude.

Patrick Noel

To the bariatric Unit of Montpellier University Hospital, France. Marius Nedelcu, MD, PHD, Toulon France. Marcelo Loureiro MD, PhD, Curitiba, Brasil. Michel Gagner, MD PhD, Montreal, Canada.

David Nocca

Contents

Contributors

Marianela Aguirre Ackermann Nutrition and Diabetes of CIEN (Center of Obesity, Diabetes and Bariatric Surgery), Corrientes, Buenos Aires, Misiones and Formosa, Argentina

Universidad Nacional del Nordeste, Corrientes, Argentina

Jaber Al-Ali Department of Medicine, Faculty of Medicine, Kuwait University, Kuwait City, Kuwait

Vance L. Albaugh Bariatric and Metabolic Institute, Cleveland Clinic, Cleveland, OH, USA

Rene Aleman Department of General Surgery, The Bariatric & Metabolic Institute, Cleveland Clinic Florida, Weston, FL, USA

Ali Aminian Bariatric and Metabolic Institute, Cleveland Clinic, Cleveland, OH, USA

Mohit Bandari SAIMS University, Head of Department at the Mohak Bariatric and Robotic Surgery Center, Indore, India

Eduardo Lemos De Souza Bastos Division of Gastrointestinal Surgery, Marilia Medical School, Marilia, Brazil

Gastro Obeso Center, Advanced Institute for Metabolic Optimization, Sao Paulo, Brazil

Helmuth T. Billy Metabolic and Bariatric Surgery, St. John's Regional Medical Center, Oxnard, CA, USA

Metabolic and Bariatric Surgery, Community Memorial Hospital, Ventura, CA, USA

Bariatric Surgery, Hamad General Hospital, Doha, Qatar

Camilo Boza Department of Digestive Surgery, Clinica Las Condes, Santiago, Chile

Vitor Ottoboni Brunaldi Gastrointestinal Endoscopy Unit, University of São Paulo Medical School, São Paulo, Brazil

Josemberg Marins Campos Centro de Obesidade e Diabetes, Hospital Santa Joana Recife, Recife, PE, Brazil

Sonja Chiappetta Department of Obesity and Metabolic Surgery, Ospedale Evangelico Betania, Naples, Italy

Elias Choulseb The Sleeve Gastrectomy Center, Jackson North Medical Center, North Miami Beach, FL, USA

Jorge Daes Department of Minimally Invasive Surgery, Clinica Portoazul, Barranquilla, Colombia

Giovanni Dapri International School Reduced Scar Laparoscopy, Brussels, Belgium

Carlos Federico Davrieux Department of Minimally Invasive Surgery, DAICIM Foundation, City of Buenos Aires, Buenos Aires, Argentina

Department of General Surgery, Sanatorio de la Mujer, Rosario, Santa Fe, Argentina

Camilo Duque S. Department of Digestive Surgery, Clinica Las Condes, Santiago, Chile

Guillermo Emilio Duza CIEN-Diagnomed Center (Center of Obesity, Diabetes and Bariatric Surgery), Buenos Aires, Argentina

University of Buenos Aires (UBA), Buenos Aires, Argentina

Luciana J. El-Kadre Gávea Metabolic Center for Diabetes and Obesity, Sao Lucas Copacabana Hospital, Rio de Janeiro, RJ, Brazil

Alex Escalona Department of Surgery, Faculty of Medicine, Universidad de los Andes, Santiago, Chile

Silvia Leite Faria Brasília Gastrosurgery, Brasília, DF, Brazil

Timothy M. Farrell Department of Surgery, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

José Manuel FORT Endocrine, Metabolic and Bariatric Unit, Vall d'Hebron University Hospital, Universitat Autònoma de Barcelona, Center of Excellence for the EAC-BC, Barcelona, Spain

Ricardo Funke Department of Digestive Surgery, Clinica Las Condes, Santiago, Chile

Michel Gagner Department of Surgery, Sacré-Coeur Hospital, Montréal, QC, Canada

Manoel Galvao Department of Surgery, University at Buffalo, Jackson North Medical Center, Miami, FL, USA

Mariano Gimenez University of Buenos Aires, Buenos Aires, Argentina

Percutaneous Surgery, IHU-IRCAD, Strasbourg, France

DAICIM Foundation, Buenos Aires, Argentina

Andres Hanssen Department of Surgery, Clinica Portoazul, Barranquilla, Colombia

Jacques M. Himpens Delta CHIREC Hospitals, Brussels, Belgium

St Pierre University Hospital, Brussels, Belgium

Antonio Iannelli Digestive Surgery and Liver Transplantation Unit, Centre Hospitalier Universitaire de Nice – Archet 2 Hospital, Nice, France

Université Côte d'Azur, Nice, France

Moises Jacobs Department of Surgery, University at Buffalo, Jackson North Medical Center, Miami, FL, USA

Daniel B. Jones Department of Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA

Miguel Josa Department of Surgery, Hospital Clínico San Carlos, Madrid, Spain

Mojdeh S. Kappus Department of Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA

Mousa Khoursheed Department of Surgery, Kuwait Health Sciences Center, Jabriya, Kuwait

Department of Surgery, Faculty of Medicine, Kuwait City, Kuwait

Matthew D. Kroh Chief of the Digestive Disease Institute at Cleveland Clinic Abu Dhabi, Abu Dhabi, United Arab Emirates

Marina Kurian Department of Surgery, NYU Langone Heath, New York, NY, USA

Joshua P. Landreneau General surgeon in Cleveland, Cleveland Clinic and Cleveland Clinic Fairview Hospital, Cleveland, OH, USA

Jose Luis Leyba Universidad Central de Venezuela, Hospital Universitario de Caracas, Clínica Santa Sofia, Caracas, Venezuela

Salvador Navarrete Llopis Clínica Santa Sofía, Caracas, Venezuela

Andrew Luhrs Department of Surgery, Brown University, Providence, RI, USA

Rami Lutfi University of Illinois, Chicago, USA

Thierry Manos Clinique Bouchard, Marseille, France

Francesco Martini Digestive and Bariatric Surgery Unit, Joseph Ducuing Hospital, Toulouse, France

Emanuele Lo Menzo Department of General Surgery, The Bariatric & Metabolic Institute, Cleveland Clinic Florida, Weston, FL, USA

Jan Paul Mulier Department of Anaesthesiology & Intensive care AZ Sint-Jan Brugge KULeuven & UGent Brugge, Flanders, Belgium

Felipe Muñoz Hospital Dr. Gustavo Fricke, Universidad de Valparaíso, Viña del Mar, Chile

Marius Nedelcu Centre de Chirurgie de l'Obesite (CCO), Clinique Saint Michel, Toulon, France

Manoel Galvao Neto Surgery Department, Florida International University, Miami, FL, USA

David Nocca CHU Montpellier Saint Eloi, Montpellier, France

CHU Montpellier, Département de Chirurgie Digestive, Hôpital St Eloi, Montpellier, France

Patrick Noel Emirates Specialty Hospital, Dubai, United Arab Emirates

Brittany Nowak Department of Surgery, NYU Langone Heath, New York, NY, USA

Mariano Palermo Diagnomed, University of Buenos Aires, Buenos Aires, Argentina

Marco G. Patti Department of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Department of Surgery, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Gustavo Plasencia Department of Surgery, University at Buffalo, Jackson North Medical Center, Miami, FL, USA

Almino Ramos Cardoso Bariatric Surgery, Gastro Obeso Center, Sao Paulo, Brazil

Jaideepraj Rao Upper GI, Bariatric & Minimal Access Surgery, Tan Tock Seng Hospital, Singapore, Singapore

Luiz Fernando dos Reis Falcão Department of Anaesthesiology, Professor of Anaesthesiology, Universidade Federal de São Paulo, Sao Paulo, Brazil

Raul J. Rosenthal Department of General Surgery, The Bariatric & Metabolic Institute, Cleveland Clinic Florida, Weston, FL, USA

Andrés Sánchez-Pernaute Department of Surgery, Hospital Clínico San Carlos, Madrid, Spain

Philip R. Schauer Bariatric and Metabolic Institute, Cleveland Clinic, Cleveland, OH, USA

Francisco Schlottmann Department of Surgery, Hospital Aleman, Buenos Aires, Argentina

Edgardo Emilio Serra Bariatric Surgery and Mini-invasive Surgery of CIEN (Center of Obesity, Diabetes and Bariatric Surgery), Corrientes, Buenos Aires, Misiones and Formosa, Argentina

Muhammad Shahbaz Department of General Surgery, Weifang People's Hospital, Weifang, Shandong, China

Ranjan Sudan Department of Surgery, Brown University, Providence, RI, USA

Samuel Szomstein Department of General Surgery, The Bariatric & Metabolic Institute, Cleveland Clinic Florida, Weston, FL, USA

Antonio Torres Department of Surgery, Hospital Clínico San Carlos, Madrid, Spain

Carlos Vaz Robotic Surgery Unit, Center for the Treatment of Obesity and Diabetes Hospital CUF Infante Santo, Lisbon, Portugal

Ramon Vilallonga Endocrine, Metabolic and Bariatric Unit, Vall d'Hebron University Hospital, Universitat Autònoma de Barcelona, Center of Excellence for the EAC-BC, Barcelona, Spain

Rudolf Alfred Weiner Sana-Klinikum Offenbach, Department for Obesity Surgery and Metabolic Surgery, Offenbach, Germany

Sylvia Weiner Krankenhaus Nordwest, Department for Obesity Surgery, Metabolic Surgery and MIC Surgery, Frankfurt, Germany

Wah Yang Department of Metabolic and Bariatric Surgery of the First Affiliated Hospital of Jinan University, Guangzhou, China

Carlos Zerrweck National University of Mexico UNAM, Head of Department at The Obesity Clinic Hospital General Tláhuac, Mexico City, Mexico

Natan Zundel Department of Surgery, University at Buffalo, Jackson North Medical Canter, Miami, FL, USA

Part I
Operative Preparation and Background

Chapter 1
The History of Laparoscopic Sleeve Gastrectomy

Michel Gagner

1.1 Introduction

Quelqu'un m'a dit que tout autour
De mon nombril se trouve la vie
La vie des autres, la vie surtout…. (Daniel Belanger, Montreal 1996, from the song "Sortez-moi de moi")

The development of Dr. N. Scopinaro concerning the standard biliopancreatic diversion named commonly "BPD" is well-known since the end of the 1970s and early 1980s of the last century; however, this procedure has fallen in disfavor and is now not omitted due to too many malnutrition reports, high revision rates, liver failures, babies born with failure to thrive from BPD mothers, severe micronutrient deficiencies, dumping syndromes, ulcerations, and so on [1]. The evolution of the BPD is reminiscent and parallel to the jejuno-ileal bypass, for almost the same reasons, perhaps less. This led to a new generation of hypoabsorptive surgeries [2], from malabsorption to hypoabsorption by the late 1980s, to early 1990s, by the surgeons who recognized the clinical implications and deleterious effects of the BPD.

It was Dr. Doug Hess, in Bowling Green, Ohio, who performed the first open biliopancreatic diversion with duodenal switch, commonly called "DS," in May of 1988 [3]. His rationale has the description of dog's experiments from De Meester [4], which are taken from Mann-Williamson in the twenties published in Annals of Surgery, in which the duodenal switch with an intact stomach results in a high per-

M. Gagner (✉)
Department of Surgery, Sacré-Coeur Hospital, Montréal, QC, Canada
e-mail: Gagner.Michel@cliniqueMichelGagner.com

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_1

centage of ulcerations [5]. Hence, the needs for a gastrectomy to decrease the acid load on the duodenal anastomosis. However, the description of the gastrectomy part is a "vertical gastrectomy," which removes a large portion of the fundus and the greater curvature, the term "sleeve gastrectomy" is not mentioned. The drawing shows a gastrectomy with a significant distance from the GE junction. He uses a 40 Fr dilator, one to two finger breaths from the bougie, making a 2–3 cm diameter gastric tube, applying 3–4 times of a stapler ILA-100, to remove only the greater curvature. The staple line is inverted with serosal to serosal sutures. The volume is measured at around 150 ml on average, 100–175 ml. This is larger by 2–3-fold of what a stand-alone sleeve gastrectomy is today, of 40–60 ml.

In the issue of Obesity surgery of November 1995, we have the paper from the team of Picard Marceau of Quebec city, Quebec, on "Biliopancreatic diversion with a new type of gastrectomy: Some previous conclusions revisited" [6], a revision of his 1993 paper, hence the experience of Dr. Marceau started in 1990 [7].

Dr. Marceau describes three modifications to the BPD technique: (1) replacing the distal gastrectomy with a "65% parietal cell gastrectomy" along the greater curvature, note that this is not called "sleeve gastrectomy," (2) a derivation consisting of a duodeno-ileal switch proximal to the ampulla of Vater, and (3) the common channel which is increased to 100 cm [6]. The initial paper of 1993 describes a "two-thirds parietal gastrectomy" involving only the greater curvature [7]. Marceau felt that the new gastrectomy had given a similar gastric volume of the old BPD operation, and ad-hoc stomach of at least 200 ml.

Marceau et al. have published an interesting paper comparing the effect of sleeve gastrectomy alone and the duodenal switch without sleeve. During 2001–2009, among 1762 patients scheduled for BPD-DS 48 had duodenal switch (DS) and 53 sleeve gastrectomy (SG) as first-stage procedures [8]. These cases were done initially with an open technique and most probably laparoscopically in 2006 when Dr. Laurent Biertho joined their practice in November 2006 after a clinical fellowship in Hamilton, Ontario, Canada, where laparoscopic duodenal switch was not performed, and Roux-en-Y gastric bypass was the only approved bariatric operation in Ontario at the time, but he was a research fellow earlier at Mount Sinai School of Medicine in my lab during the early 2000s, where laparoscopic duodenal switch and laparoscopic sleeve gastrectomy were clinically performed.

It does not appear that before 2001 they had done sleeve gastrectomy alone, and since they have been doing more duodenal switch without sleeves during that interval, they may have been in the camp of doing a hypoabsorptive operation rather than "restrictive," and this came from a personal conversation with Dr. Picard Marceau during a meeting, several years ago. Dr. P Marceau was opposed to the idea of doing a sleeve gastrectomy first, opening the possibility of doing a DS later. Because, according to their early experience, they had greater weight loss with a DS without sleeve, he believed that this "staged" procedure should be done first, when most authors, including myself, have argued that not doing an anastomosis under tension is preferable in sicker patients, and doing a sleeve first decreases this risk.

Of the 53 sleeve gastrectomy, 3 were done between 2001 and 2006, and 48 had been done between 2006 and September 2009. I think most DS without sleeve were not done as a planned 2-stage procedure but rather as an alternative to abandon the whole procedure, in their words, this was preferable than doing nothing and aborting. In fact, 8 had a sleeve added to the DS part, and 5 had a DS added to a sleeve part, confirming the previous assertion that only 8% had a second-stage DS after the sleeve during this interval time. We also have to remember that this is in the laparotomy era where bowel loops were in the hands of surgeons and have an easier assessment of the tension and anastomosis possibilities.

Their conclusion of those studies is therefore incorrect, as they were not organized in two stages. This is confirmed by the time interval between the definite procedures of 28 months. Subsequently, with the addition of Dr. L Biertho in their team in 2006, the philosophy had changed to use sleeve gastrectomy as a first procedure of a two-stage strategy, and this has been confirmed with their recent publication, where by 2014, the sleeve gastrectomy numbers were 378 or 47.3% and laparoscopic duodenal switch at 422, or 52.7% [9]. Further, their latest publication on the second-stage DS has confirmed that after sleeve gastrectomy, a DS confers the same weight loss at 3 years, as if they had a full DS in the first place, contradicting their earlier report on this in 2014, where they had concluded "one-stage BPD-DS is superior to the staged operation over the long term" [10]. Perhaps, with a larger cohort, or perhaps because the laparoscopic sleeves were performed with a more restrictive component, these latest laparoscopic results are now different.

I was always the believer that an animal experiment could prepare surgeons to the major obstacles of new surgical challenges. This was taken from my days of research at McGill University, especially at the Royal Victoria Hospital in the mid-1980s, under the auspices of Dr. Armour Forse and the chairmanship of Lloyd D. MacLean. After a small animal swine pilot project in May 1999, where Dr. Gregg Jossart who was a clinical fellow in laparoscopic/bariatric surgery at Mount Sinai School of Medicine in New York under my directorship who is now an attending bariatric surgeon in San Francisco, assisted by Dr. John de Csepel, who was my research fellow and resident at the time from the same institution, who is now a medical director for Medtronic, and Dr. Stephen Burpee, resident at the time who is now an attending bariatric surgeon in Tucson Arizona, we performed a Laparoscopic Duodenal Switch Feasibility study in six pigs, which was eventually published later in 2001 [11].

This laboratory effort was to understand the intricacies and technical difficulties of performing such surgeries in humans. After I initiated the laparoscopic Roux-en-Y gastric bypass program at Mount Sinai in 1998, strong from my experience with the same surgery since 1995 at the Cleveland Clinic in Ohio, and animal experiment of laparoscopic Roux-en-Y gastric bypass with our clinical fellow Dr. Mario Potvin at the Centre de Recherche de l'Hotel-Dieu de Montreal in 1993 [12], who is now an attending surgeon in Rochester Minnesota, I embarked on July 2, 1999, to perform the first Laparoscopic DS at Mount Sinai Hospital in New York. Dr. Christine Ren, our newest fellow of 1 day, a finishing surgical resident from the NYU program, assisted me, NYU had no or minimal laparoscopic bariatric surgery experience at the time.

This consisted of a laparoscopic sleeve gastrectomy, followed with a circular stapler duodeno-ileostomy, end to side, antecolic, and a side-to-side ileo-ileostomy using a linear stapler and hand-sewn closure of the enterostomy. Initially, mesenteric defects were not closed, but later than a year afterwards, a 2.6% mesenteric internal hernia incidence was noted, and routine closure of both mesenteric defects was initiated. It is remarkable today, that I had initiated this on patients with BMI > 60 kg/m^2, as it was my belief at the time, even today, that hypoabsorptive operations should be done in this category of super-super obesity [13].

We initiated quite a series of patients such by December 1999, and abstract was submitted to the 2000 annual meeting of ASBS, American Society of Bariatric Surgery, usually held in June, and accepted for an oral presentation [14]. Dr. Gregg Jossart came back for a visit to Mount Sinai NY in the fall of 1999, just before the annual meeting of the American College of Surgeons, accompanied by Dr. Robert Rabkin, his partner at the time in San Francisco, interested in learning the laparoscopic DS procedure, which they initiated afterward with a hand-assisted technique, not with complete laparoscopy. Dr. Jossart and Rabkin have presented their initial experience at SAGES 2001, with 79 cases done, 27 lap-assisted and 52 hand-assisted which started in October 1999 until July 2000 [15]. At the Annual meeting of ASBS in June 2000, a video was presented from Dr. Jossart, Dr. R. Rabkin, and Dr. Booth from Biloxi, and with the abstract mentioning that they had started the full laparoscopic technique in January of the same year [16].

By serendipity, I could not perform a complete laparoscopic DS early in our experience, due to ventilator problems, and tight pneumoperitoneum in spite of maximum relaxation, and decided to abort after completion of the sleeve gastrectomy, which to this day, was always done first. My observation of weight loss led me to believe that this group of high-risk patients, i.e., BMI > 60 kg/m^2, would be amenable to do the procedure in two steps with a 6-month interval. As, a later review of our data had confirmed the higher mortality and morbidity rate of full laparoscopic DS in BMI > 60 kg/m^2. This led me to do the first presentation on laparoscopic sleeve gastrectomy "alone" at Dr. Phillip Schauer's meeting in Feb 20–25, 2001, in Snowbird, Utah, on sleeve gastrectomy as a two-stage procedure. The reception was lukewarm, and because nobody was really doing laparoscopic duodenal switch at the time, it had generated no interest from the audience, except for one person in attendance. I believe it was either Dr. Peter Crookes or Dr. Gary Athone who were practicing at USC Los Angeles at the time, who came forward at the coffee break and confided to me that they had done a handful of patients with an *open* technique, as a salvage, but that they were not published and thought there was no interest in the subject at the time. They subsequently published this experience in 2004 and 2006, but I wondered if they would have published it, if it were not from my experience laparoscopically [17, 18].

Subsequently, with Dr. Christine Chu, another clinical fellow, who is now working for Kaiser Permanente Northern California Bariatric Surgery Center, an abstract was sent for presentation at the annual meeting of SAGES in the spring of 2002. The abstract was published in Surgical Endoscopy, and this constitutes the first publication on the subject, entitled "Two-stage laparoscopic BPD/DS. An Alternative

Approach To Super-Super Morbid Obesity," many co-authors represented my partners and bariatric fellows at the time 2001–2002, at Mount Sinai Hospital and School of Medicine in NY, NY [19]. From July 1999 until July 2001, 102 laparoscopic duodenal switches had been done, of which seven were by two stages completed, and did not include also the sleeve alone that had not been converted for multiple reasons, including patients who refused a second stage. The presentation took place on March 15, 2002, at the New York Hilton Hotel, and was the first series to be presented at an official societal meeting presentation on laparoscopic sleeve gastrectomy.

I was part of the World Congress program in 2002, as it was combined for IFSES, the International Federation of Societies of Endoscopic Surgery, and this was a few months after the September 11, 2001 events, which still attracted a large crowd in New York City, they were even discussions to delay or cancelled the meeting. Fortunately, we had put an outstanding postgraduate laparoscopic bariatric course at Mount Sinai School of Medicine, with many live surgeries, which included laparoscopic duodenal switch and sleeve gastrectomy as a stand-alone procedure. There was also an animal lab and a cadaver laboratory, where those techniques were taught. Many participants still talk to me about this event as one of the turning points in their career. During the same congress, Dr. Shoji Fukuyama, MD; Christine Chu, MD; Won Woo Kim, MD; and myself also presented a video of the two-stage procedure at the video session V02 on March 15, 2002 [20]. Further, David Voellinger presented a poster, another clinical fellow that year, which is now an attending bariatric surgeon in Charlotte North Carolina, entitled "Laparoscopic Sleeve Gastrectomy is a safe and effective Primary Procedure for Biliopancreatic Diversion With Duodenal Switch," because it had been turned down for an oral presentation a poster abstract [21]. It included a series of 24 patients; initial mean weight was 414 lbs., with mean BMI of 65 (range 58–76). Mean operative time was 114 minutes. Average LOS was 3 days (range 2–7) with a median of 3 days. Follow-up at 3 weeks, 3 months, and 6 months after LSG resulted in an excess weight loss of 11 +/−3%, 23 +/−5%, and 32 +/−5% and mean BMI of 60, 56, and 49. No major morbidity and no mortality occurred in this population. The conclusion was: Laparoscopic sleeve gastrectomy is feasible and can be performed with minimal morbidity as the primary stage of LBPDDS in the superobese. It also results in substantial short-term weight loss and should allow for a safer operation during second stages [21].

The manuscript submitted was turned down by Dr. MacFarlane who was the main editor of Surgical Endoscopy at the time, for lack of long-term follow-up!! And this is why our second series has been published 1 year after, in 2003, in a different journal, more open-minded to the subject in Obesity Surgery, by our clinical fellow at the time Dr. JP Regan, on "Early experience with two-stage laparoscopic roux-en-Y gastric bypass as an alternative in the super-super obese patient" which is much quoted in the bariatric surgical literature [22]. As much commercial insurances were denying duodenal switches, and patients ended up, after their approval, with a second-stage Roux-en-Y gastric bypass. As I said, this was not my first cohort of patients, there were only seven patients who had an initial sleeve and several months later, mean of 11 months underwent a gastric bypass, from a BMI of 63–50 kg/m^2 after a sleeve, and then to 44 kg/m^2, 2.5 months later. The very first manuscript series was published as a book chapter, with delays, in 2005, which many referenced today, as the first series of laparoscopic sleeve gastrectomy [23].

As I said earlier, Dr. Gregg Jossart who is now Director, minimally invasive surgery, California Pacific Medical Center, San Francisco, California, and Dr. Gary Anthone who is Director, Bariatric Surgery Program, Nebraska Methodist Hospital, Omaha, Nebraska, have written a short piece on the history of sleeve gastrectomy in the Bariatric Times in 2010 [24]. In 1997, Dr. Gary Anthone was performing an open duodenal switch on a 13-year-old girl with a history of common bile duct stones [17]. Intraoperatively, the common bile duct stones could not be completely cleared, and elected to just do an open sleeve gastrectomy in order to leave access for a postoperative endoscopic retrograde cholangiopancreatography (ERCP). From 1997 to 2001, he performed 21 open sleeve gastrectomies in high-risk patients with super-morbid obesity [17]. The pouch was approximately 100 ml in volume (currently pouch volume is approximately 60 cc or less) and the patients achieved 40–50% excess weight loss (EWL). By October 2005, he had reported on 118 open sleeve gastrectomies with similar results [18].

Dr. Tretbar, after an experience of open gastric plication, with and without mesh wrapping, with disastrous results, had designed an open vertical gastroplasty using a TA90 stapler to staple the stomach vertically downward from the angle of His, which he published in 1981, but this had not taken in USA; most believed that a banded vertical gastroplasty was preferable [25]. Perhaps also because the stapling was done on a shorter distance with a larger bougie.

In UK, Prof. D. Johnston from the Academic Department of Surgery and Centre for Digestive Diseases, at the Leeds General Infirmary in Leeds, had an interesting experience by modifying the popular divided vertical banded gastroplasty, the so-called MacLean Procedure [26, 27], to a non-banded longer vertical gastroplasty, done open by laparotomy. They called it the “Magenstrasse and Mill operation” and published a short cohort in 2001, of 39 patients at 3 years, while evaluating weight loss, plasma leptin levels, and insulin resistance [28]. A more extensive series was published in Obesity Surgery in 2003, with the aim of producing a simpler, more physiological type of gastroplasty that would dispense with implanted foreign material such as bands and reservoirs [29]. The “Magenstrasse,” or “street of the stomach,” is a long narrow tube fashioned from the lesser curvature, which conveys food from the esophagus to the antral “Mill.” According to Johnston, normal antral grinding of solid food and antro-pyloro-duodenal regulation of gastric emptying and secretion are preserved. Of 100 patients with morbid obesity operated with this procedure between 1992 and 1998, using mostly a bougie 32 French, followed-up for 1–5 years, with a mean preoperative BMI of 46.3 kg/m^2. They had no mortality, for an open laparotomic procedure, and major complications occurred in 4% of patients, mild heartburn was “fairly common” in one-third of patients, and weight loss was 60% of excess weight, achieved within 1 year of operation, after which it has plateaued for 5 years. Prof. Johnston had initiated in 1987 this procedure, with a 40 French bougie first, which he gradually decreased to 32 Fr, at 5–6 cm from the pylorus, where a circular stapler had been fired, under hyoscine injection.

Prof. Michael J. McMahon of the General Infirmary at Leeds, strong from the experience of Prof. Johnston with M&M, has performed from January 2000 until December 2001 laparoscopic sleeve gastrectomy in 20 patients. Of note, Prof. Michael J. McMahon had visited Prof. Michel Gagner at Mount Sinai School of Medicine during this time interval, where the laparoscopic sleeve gastrectomy had been performed 7 months earlier in duodenal switch patients. The technique, described in their manuscript of 8-year results, is identical to the technique used at Mount Sinai, except for a smaller bougie of 32 Fr, the one that was currently used for M&M in Leeds. At 8 years, 55% of patients had more than 50% EWL [30].

In San Francisco, Dr. Gregg Jossart, an early adopter of sleeve gastrectomy, started to offer the procedure with a 32 French caliber pouch (30–60 cc) to lower BMI patients, in November 2002 [31]. I had several conversations with him encouraging them to start the laparoscopic two-stage procedure in San Francisco. The results of 216 patients compared successfully the other stapling procedures and adjustable gastric banding with 75–85% EWL at 2 years of follow-up [31].

Dr. Jacques Himpens from Brussels Belgium, an early adopter of the technique, has been convinced after video transmission of surgeries performed from Mount Sinai NY to Brussels and Europe and had published some 6-year results in the Annals of Surgery, a milestone paper, where sleeves were performed between November 2001 and October 2002, in which the technique was not fully understood, especially around the fundus and left crus dissections [32].

Two additional posters at SAGES annual meeting in 2002 mentioned some aspects of early sleeve gastrectomy developments. Dr. Hazem Elariny from Virginia started in 2001 and had presented 30 patients of a laparoscopic non-banded vertical gastroplasty with sleeve gastrectomy [33]. Dr. Val Andrei from New Jersey was our clinical fellow at Mount Sinai NY, at the same time as Dr. Jossart, and described three cases of laparoscopic duodenal switches, one laparoscopic, one hand–assisted, and another converted from laparoscopic to open [34].

But this antedated by 1 year, the SAGES annual meeting of 2001, where Dr. Theresa Quinn, who is working as a general surgeon in Wisconsin, our clinical fellow that year, presented on our updated experience “Laparoscopic Biliopancreatic Diversion with Duodenal switch: The early Experience” [35].

Since it had been clearly demonstrated that two-stage procedures, with a laparoscopic sleeve gastrectomy performed first, had lowered tremendously the mortality to zero, and gave an acceptably low morbidity rate in these high-risk patients, I fully embraced the procedure from the very beginning [36].

I then embarked on the big challenge of educating a large population of gastrointestinal surgeons worldwide in this new procedure. We started to show and teach this technique to visitors at Mount Sinai from 1999, and in official bariatric courses we had regularly. The very first international specific course on Laparoscopic Sleeve Gastrectomy was at Doral Golf Course in 2005, and Dr. Jacques Himpens was an invited foreign faculty. Afterwards, six International consensus conferences were established under my leadership and directorship, starting with the first one in New York City in October 25–27, 2007. The proceedings were published in 2008 [37].

Following this success, five more International Consensus conferences were held in New York City, Miami, Montreal, and London, of which the first five ones have been published. Each of them had a large component of live surgeries from various surgeons demonstrating the easiness and intricacies of their operation, coming from all continents. A didactic session had sessions on the mechanisms, rationale and indications, contraindications of that particular year, followed by management and recognition of complications, conversions, and revisions [38–41]. Worth mentioning was also the Expert consensus meeting organized by Dr. Raul Rosenthal in Florida, sponsored by Ethicon Endosurgery, to establish consistency in the technical performance of sleeve gastrectomy, led to highly cited paper in 2012 [42].

1.2 Conclusion

In summary, the laparoscopic sleeve gastrectomy has evolved from an open vertical gastrectomy in duodenal switch procedure to a laparoscopic Duodenal Switch on July 2, 1999, at Mount Sinai School of Medicine, which included the first laparoscopic sleeve gastrectomy in humans by the author, and has evolved by serendipity to a two-stage approach for higher risk patients at Mount Sinai School of Medicine in 2000, using the laparoscopic sleeve gastrectomy alone as an interim procedure.

Concomitantly, in UK, it has evolved from the open Margenstrasse-Mill operation of Prof. D. Johnston from Leeds to a laparoscopic sleeve gastrectomy by Prof. Michael J. McMahon from the same institution also in 2000. Therefore, the earliest North American experience was in higher-risk patients with super-morbid obesity as a safer staged procedure, but this quickly developed into a single-stage option for lower BMI patients. This procedure is easier and safer in higher BMI patients, due to the lack of an intestinal bypass, which eliminates anastomotic tension and dehiscence, with subsequent leak, sepsis, and higher mortality. The isolated open sleeve gastrectomy was performed earlier but not reported until 2004, and was not publicized before as an adjunct to the management of bariatric patients by Dr. Gary Anthone. Marceau's team in Quebec City has had cases in open "parietal cell gastrectomy" fashion from 2001, and laparoscopic in 2006, so this is much later after the development of laparoscopic sleeve gastrectomy as a stand-alone procedure.

References

1. Gagner M. For whom the bell tolls? It is time to retire the classic BPD (Bilio-Pancreatic Diversion) operation. Surg Obes Relat Dis. 2019,. in press;15:1029.
2. Gagner M. Hypoabsorption not malabsorption, hypoabsorptive surgery and not malabsorptive surgery. Obes Surg. 2016;26(11):2783–4.

3. Hess DS, Hess DW. Biliopancreatic diversion with a duodenal switch. Obes Surg. 1998;8:267–82.
4. DeMeester TR, Fuchs KH, Ball CS, et al. Experimental and clinical results with proximal end-to-end duodeno-jejunostomy for pathologic duodenogastric reflux. Ann Surg. 1987;206:414–24.
5. Mann FC, Williamson CS. The experimental production of peptic ulcer. Ann Surg. 1923;77(4):409–22.
6. Lagace M, Marceau P, Marceau S, Hould FS, Potvin M, Bourque RA, Biron S. Biliopancreatic diversion with a new type of gastrectomy: some previous conclusions revisited. Obes Surg. 1995;5:411–8.
7. Marceau P, Biron S, Bourque RA, et al. Biliopancreatic diversion of a new type of gastrectomy. Obes Surg. 1993;3:2–36.
8. Marceau P, Biron S, Marceau S, Hould FS, Lebel S, Lescelleur O, Biertho L, Kral JG. Biliopancreatic diversion-duodenal switch: independent contributions of sleeve resection and duodenal exclusion. Obes Surg. 2014;24(11):1843–9.
9. Biertho L, Lebel S, Marceau S, Hould FS, Lescelleur O, Marceau P, Biron S. Laparoscopic sleeve gastrectomy: with or without duodenal switch? A consecutive series of 800 cases. Dig Surg. 2014;31(1):48–54.
10. Biertho L, Thériault C, Bouvet L, Marceau S, Hould FS, Lebel S, Julien F, Tchernof A. Second-stage duodenal switch for sleeve gastrectomy failure: a matched controlled trial. Surg Obes Relat Dis. 2018;14(10):1570–9.
11. DeCsepel J, Burpee S, Jossart GJ, Gagner M. Laparoscopic biliopancreatic diversion with a duodenal switch for morbid obesity: a feasibility study in pigs. J Laparoendosc Adv Surg Tech A. 2001;11(2):79–83.
12. Potvin M, Gagner M, Pomp A. Laparoscopic Roux-en-Y gastric bypass for morbid obesity: a feasibility study in pigs. Surg Laparosc Endosc. 1997;7(4):294–7.
13. Ren CJ, Gagner M. Early results of laparoscopic biliopancreatic diversion with duodenal switch for morbid obesity: a case series. Obes Surg. 2000;10:131.
14. Ren CJ, Patterson E, Gagner M. Early results of laparoscopic biliopancreatic diversion with duodenal switch: a case series of 40 consecutive patients. Obes Surg. 2000;10(6):514–23.
15. Jossart GH, Nuglozeh-Buck D, Rabkin RA. A laparoscopic technique for duodenal switch: experience with 79 patients. Surg Endosc. 2001;15:S103.
16. Jossart G, Booth DJ, Rabkin R. A laparoscopic procedure for biliopancreatic BPD with duodenal switch. Obes Surg. 2000;10:133.
17. Almogy G, Crookes PF, Anthone GJ. Longitudinal gastrectomy as a treatment for the high-risk super-obese patient. Obes Surg. 2004;14:492–7.
18. Hamoui H, Anthone GJ, Kaufman HS, Crookes PF. Sleeve gastrectomy in the high-risk patient. Obes Surg. 2006;16:1445–9.
19. Chu C, Gagner M, Quinn T, Voellinger DC, Feng JJ, Inabnet WB, Herron D, Pomp A. Two-stage laparoscopic BPD/DS. An alternative approach to super-super morbid obesity. Surg Endosc. 2002;16:S187.
20. Fukuyama S, Chu C, Kim WW, Gagner M. The second stage of laparoscopic biliopancreatic diversion BPD. In: SAGES 2002 annual meeting, New York, NY, Manual proceedings, New York, Hilton & Towers. V047.
21. Voellinger D, Gagner M, Inabnet W, Chu C, Feng J, Mercado A, Quinn T, Pomp A. Laparoscopic sleeve gastrectomy is a safe and effective primary procedure for biliopancreatic diversion with duodenal switch. Poster abstract, SAGES 2002 manual proceedings, PF020. Surg Endosc. 2002;16:S245.
22. Regan JP, Inabnet WB, Gagner M. Early experience with two-stage laparoscopic roux-en-Y gastric bypass as an alternative in the super-super obese patient. Obes Surg. 2003;13:861–4.
23. Gagner M, Inabnet W, Pomp A. Laparoscopic sleeve gastrectomy with second stage biliopancreatic diversion and duodenal switch in the superobese. In: Inabnet W, DeMaria E, Ikramuddin S, editors. Laparoscopic bariatric surgery. Philadelphia: Lippincott Williams & Wilkins; 2005. p. 143–50.
24. Jossart GH, Anthone G. The history of sleeve gastrectomy. Bariatric Times. 2010;7(2):9–10.

25. Tretbar LL, Sifers EC. Vertical stapling: a new type of gastroplasty. Int J Obes. 1981;5:538.
26. MacLean LD, Rhode BM, Sampalis J, et al. Results of the surgical treatment of obesity. Am J Surg. 1993;165:155–62.
27. MacLean LD, Rhode BM, Forse RA, Nohr R. Surgery for obesity – an update of a randomized trial. Obes Surg. 1995;5(2):145–50.
28. Carmichael AR, Johnston D, King RF, Sue-Ling HM. Effects of the magenstrasse and mill operation for obesity on plasma leptin and insulin resistance. Diabetes Obes Metab. 2001;3(2):99–103.
29. Johnston D, Dachtler J, Sue-Ling HM, King RF, Martin lG. The magenstrasse and mill operation for morbid obesity. Obes Surg. 2003;13(1):10–6.
30. Sarela AI, Dexter SP, O'Kane M, Menon A, McMahon MJ. Long-term follow-up after laparoscopic sleeve gastrectomy: 8–9-year results. Surg Obes Relat Dis. 2012;8(6):679–84.
31. Lee CM, Cirangle PT, Jossart GH. Vertical gastrectomy for morbid obesity in 216 patients: report of two-year results. Surg Endosc. 2007;21(10):1810–6.
32. Himpens J, Dobbeleir J, Peeters G. Long-term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252:31–24.
33. Elariny H. Early results of laparoscopic non-banded vertical gastroplasty with sleeve gastrectomy – without duodenal switch in the treatment of morbid obesity. Surg Endosc. 2002;16:S241.
34. Andrei VE, Kortbawi P, Mehta V, Johnson BA, Villapaz A, Ramos C, Hancox W, Carey JC, Brolin RE. Laparoscopic bariatric surgery for the treatment of super-obesity: biliopancreatic diversion with duodenal switch and Roux-en-Y Gastric bypass with a long limb: 24 month follow-up. Surg Endosc. 2002;16:S241.
35. Quinn T, Gagner M, Ren C, de Csepel J, Kini S, Gentileschi P, Herron D, Inabnet W, Pomp A. Laparoscopic biliopancreatic diversion with duodenal switch: the early experience. Surg Endosc. 2001;15:S158.
36. Kim WW, Gagner M, Kini S, et al. Laparoscopic vs. open biliopancreatic diversion with a duodenal switch: a comparative study. J Gastrointest Surg. 2003;7(4):552–7.
37. Deitel M, Crosby RD, Gagner M. The first international consensus summit for sleeve gastrectomy (SG), New York City, October 25–27, 2007. Obes Surg. 2008;18(5):487–96.
38. Gagner M, Deitel M, Kalberer TL, Erickson AL, Crosby RD. The second international consensus summit for sleeve gastrectomy, March 19–21, 2009. Surg Obes Relat Dis. 2009;5(4):476–85.
39. Deitel M, Gagner M, Erickson AL, Crosby RD. Third international summit: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2011;7(6):749–59.
40. Gagner M, Deitel M, Erickson AL, Crosby RD. Survey on laparoscopic sleeve gastrectomy (LSG) at the fourth international consensus summit on sleeve gastrectomy. Obes Surg. 2013;23(12):2013–7.
41. Gagner M, Hutchinson C, Rosenthal R. Fifth international consensus conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6.
42. Rosenthal RJ, International Sleeve Gastrectomy Expert Panel, Diaz AA, Arvidsson D, Baker RS, Basso N, Bellanger D, Boza C, El Mourad H, France M, Gagner M, Galvao-Neto M, Higa KD, Himpens J, Hutchinson CM, Jacobs M, Jorgensen JO, Jossart G, Lakdawala M, Nguyen NT, Nocca D, Prager G, Pomp A, Ramos AC, Rosenthal RJ, Shah S, Vix M, Wittgrove A, Zundel N. International sleeve gastrectomy expert panel consensus statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8(1):8–19.

Chapter 2
Main Indications

Rami Lutfi, Carlos Federico Davrieux, and Mariano Palermo

2.1 Introduction

Laparoscopic sleeve gastrectomy (LSG) is the fastest growing bariatric operation today, and in many countries, it is the most common. It carries equivalent benefit for the metabolic syndrome of the morbidly obese patient as in any other stapling operation [1, 2]. History indicates that this technique began as a first step procedure in complex operations performed on higher-risk patients [3]. Procedures such as Roux-en-Y Gastric Bypass (RYGB) or Biliopancreatic Diversion-Duodenal Switch (BPD-DS) in superobese patients or with significant comorbidities carry high risk of perioperative morbidity and mortality. For this reason, surgeons have considered "staging" the operation in order to shorten the initial operative time and, hence, decrease the perioperative risk; by the time, the intestinal bypass is performed, patients would have lost enough weight to decrease their comorbidities, ASA class, and BMI, making the operation safer and technically easier.

Weight loss was significant after the sleeve gastrectomy, and many patients were satisfied with the results and did not want to proceed with what was supposed to be the second stage [4, 5].

This led surgeons to start looking at the sleeve as a stand-alone procedure for weight loss.

R. Lutfi
University of Illinois, Chicago, USA

C. F. Davrieux (✉)
Department of Minimally Invasive Surgery, DAICIM Foundation, City of Buenos Aires, Buenos Aires, Argentina

Department of General Surgery, Sanatorio de la Mujer, Rosario, Santa Fe, Argentina

M. Palermo
Diagnomed, University of Buenos Aires, Buenos Aires, Argentina

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_2

2.2 Indications

Just as obesity is a multifactorial disease, success after bariatric surgery is also multifactorial. Behavioral changes can be as important as the choice of the specific bariatric operation to determine long-term success or failure of surgery. This makes it near impossible to compare the results of these surgeries and makes the specific indication and preference hard to define. To add to the controversy, the definition of success after bariatric surgery remains an area of controversy. Some may consider normalizing BMI to be the definition of success, while others consider it to be maintaining >50% EWL. What is interesting about bariatric surgery is that patients may have different goals than their surgeons. They may judge success based on things that mean more than a scale number. Many base their success on improvement of quality of life (QOL), resolution of comorbidities, or simply the sense of well-being that may not require as much weight loss as the surgeons may aim for. In a field under heavy scrutiny like bariatric surgery, many patients seek safety first, and put it ahead of efficacy. They tend to look for a "simple" concept that they can easily understand, and shy away from complex procedure that they perceive to be riskier, even if not supported by evidence. Surveys have shown that fear is the top reason why patients do not seek bariatric surgery [6].

For these reasons, the sleeve gastrectomy gained popularity quickly and have risen to the top of commonly performed bariatric operations. Patients liked limiting the operation to the stomach without having to cause major changes in the intestinal structure (as opposed to gastric bypass), with the simple concept of making the stomach smaller while maintaining the metabolic effects, resulting from removing the fundus (as opposed to the gastric band, which is safe and simple, but not a metabolic operation).

In addition to being a popular concept, we see these particular scenarios to favor the choice of the sleeve gastrectomy as opposed to other operations:

- Young patients and those over 60 years: in young patients with associated severe comorbidities and long life expectancy. This is partly due to the fact that it is associated with fewer long-term malabsorptive metabolic complications compared to other techniques (RYGB or BPD-DS) [7]. In addition, as we consider obesity to be a chronic progressive disease, these young patients, despite their best effort, may go on to regain weight as they get older. This is especially true with special social, economic, and other changes like pregnancy down the road. Having the sleeve gastrectomy would be ideal for a revisional, second-stage malabsorptive operation in the future of these patients. In elderly patients, who usually have higher morbidity and mortality, LSG stands out for its shorter operative time, rapid recovery, and low rate of complications.
- Revisional operation in the face of therapeutic failure of a previous technique such as gastric banding: LSG has been shown to have good results in weight loss with a low rate of complications in patients who had therapeutic failure with other bariatric procedures [8]. This, however, remains a controversial subject and the choice of a revision must be based on the skills of the surgeon and the medical history as well as the current anatomy.

- Intraoperative indication in the presence of anatomical findings that prevent or complicate another bariatric procedure: an example is unexpected situs inversus [9, 10]. Also severe central distribution of intra-abdominal fat that makes the intestinal bypass high risk as far as reaching the gastric pouch in a bypass, or performing the distal anastomosis in a switch. This is why it is critical to assess the feasibility of the operation in these more complex patients before dividing the intestine and committing to the malabsorptive operation. Having anesthetic struggles with these high-risk patients (high peak airway pressure, hemodynamic problems, etc.) may be an indication to convert to a shorter and simpler operation.
- Previous surgeries can make gastric bypass or duodenal switch harder to perform even in the hands of experts due to dense adhesions, or deep pelvic ones. This is a challenge as an accurate measurement of the intestinal length is needed, in addition to placing the intestine in the correct orientation before making divisions and anastomosis. Sleeve gastrectomy offers the advantage of limiting the operative field to the upper abdomen and disregarding any other adhesions of the omentum or intestine [11].
- Patients with high surgical risk due to severe comorbidities such as heart failure and respiratory compromise would definitely benefit from this technique since it is simpler and requires shorter operative time [7].
- Young female patients of reproductive age with expectation of pregnancy: bariatric surgery favors the pregnancy rate [12]. This is because obesity is associated with menstrual disorders, abortions, anovulation, and infertility, among others. In addition, it is related to complications during pregnancy, such as gestational hypertension, preeclampsia, gestational diabetes mellitus, thrombosis and thromboembolism, dystocia, higher rate of cesarean sections, and fetal macrosomies. Some studies have shown that malabsorptive bariatric surgeries present an important congenital nutritional risk, especially BPD-DS, while RYGB confers some risk, although less [13]. Due to the low nutritional deficiency in LSG, this technique has greater probabilities of success in obtaining and carrying out a pregnancy without problems.
- Patients with gastric pathology that requires prolonged endoscopic follow-up: its indication is clear in patients who live in endemic areas with risk of gastric cancer, such as Japan, Chile, Colombia, or other areas [7]. Performing RYGB or BPD-DS would prevent follow-up through gastric endoscopy.
- Patients who require anticoagulation eventually: this concept is based on techniques such as RYGB or BPD-DS associated with marginal anastomotic ulcers. The risk of bleeding in this type of patients is greater, so they would benefit from using a technique that does not require anastomosis, such as LSG [14]. In addition, it improves the absorption of anticoagulant medication.
- Smoking patients: smoking alone represents a risk factor for patients. It is also associated with other comorbidities, such as cardiovascular and respiratory diseases. In addition, the relationship between smoking and gastric mucosal injury is well known. This set of factors puts at risk the postoperative results of patients undergoing bariatric surgery, and increases the rate of complications [15]. To optimize and reduce postoperative complications, it is recommended that the

patient quit smoking before performing bariatric surgery. Because it is a difficult habit to combat, in smokers of hierarchy, LSG is chosen to avoid the complications associated with anastomotic ulcers, and it is easier to prepare the patient during the preoperative period. It is advisable to achieve a tobacco-free period of 1 year for RYGB and 3 months for LSG [16].

- Patients requiring other nonbariatric surgery: such as incisional hernia repair or organ transplantation. Occasionally, the previous weight loss in obese patients who must undergo these procedures allows better results to be obtained [7]. In this way, the decrease in intra-abdominal fat or liver volume favors other nonbariatric surgeries.

2.3 Contraindications and Limitations

A fundamental factor in any bariatric surgery is the maintenance of long-term weight loss. Some surgeons consider that this is a weak point in LSG, because *sleeve dilation* is always a worry for surgeons and patients in the long term. Because it is a restrictive procedure, it coud potentialy lose its effectiveness when the stomach increases in size after several years of surgery [17]. This is especially true in poorly performed sleeves with retained fundus that may expand gradually, causing severe GERD symptoms and eventually weight regain.

Patients with severe metabolic syndrome, especially with *type 2 diabetes mellitus* (T2DM), have shown greater benefit when they underwent RYGB and BPS-DS than to LSG [18]. Although LSG is effective in the short to medium term (1–3 years), RYGB seems to have the most favorable risk-benefit profile.

It is a recommended practice to search along the left crus for the presence of a *hiatus hernia*, which should be repaired if it exists. The presence of a hiatus hernia by itself is not a contraindication for sleeve gastrectomy as long as it is identified and repaired, but a large paraesophageal hernia is considered a contraindication by most [19]. Patients with severe reflux should not be considered for LSG [20].

Some authors do not consider *gastroesophageal reflux disease* (GERD) to be an absolute contraindication [19, 21] to sleeve gastrectomy, although this aspect remains controversial and long-term follow-up studies are required. GERD has been described *"*de novo*"* in patients undergoing LSG [22]. This is due to many factors such as the high pressure tube and the "flattening" of the angle of His. Rebecchi et al. consider that in patients without previous evidence of GERD, the occurrence of *"*de novo*"* reflux is uncommon [23]. The authors recommend obtaining objective measures to accurately determine the distal acid exposure as there is a significant discrepancy between subjective and objective findings in heartburn patients. We believe that technical issues, such as a missed hiatal hernia, retained fundus, and narrow or angled sleeve, are often the reasons behind many of the GERD issues after sleeve gastrectomy. A well-constructed sleeve, causing optimal weight loss with the absence of hiatal hernia, should not commonly cause GERD. Therefore, we do not consider GERD to be a contraindication to this operation.

Although the incidence of *Barrett's esophagus* is low (1.3%), it should be taken into account. While esophageal cancer remains uncommon overall despite the increased risk, losing the ability to perform a gastric pull-up after esophagectomy forces surgeons to use the colon, making this operation, more complex and resulting in a higher morbidity [19]; therefore, the authors and most surgeons still consider Barrett's esophagus an absolute contraindication.

2.4 Technical Aspects and Advantages

There are some aspects that make this procedure more attractive with respect to others.

Feasibility and Safety The sleeve feasibility and safety have been widely studied [24]. It does not use implants such as the adjustable gastric band, which represents an advantage in terms of infections and erosion. Some authors report that a lower learning curve is required. We believe this is true, but also strongly believe that while it is an "easier" operation that does not require suturing skills, it should not be taken lightly. Shortcomings in the technique can lead to catastrophic outcomes such as a chronic leak from a tight incisura, or refractory reflux from a retained fundus, or a chronic dyshagia from a twisted sleeve. From the economic point of view, it is potentially associated with a lower cost due to a short hospital stay in some centers [25, 26] compared to other procedures, and a lower rate of complications (many long-term complications do not occur with the sleeve, such as internal hernias [14], anastomotic ulcers [7], and others).

2.5 Conclusion

Laparoscopic sleeve gastrectomy is a safe and effective metabolic operation that earned a well-deserved spot on top of all available options. In the right hands, and for the right indication, the sleeve should be the first operation of choice in the battle against the chronic progressive disease of obesity.

References

1. le Roux CW, Heneghan HM. Bariatric surgery for obesity. Med Clin North Am. 2018;102(1):165–82.
2. Lutfi R, Palermo M, Cadière G-B. Global bariatric surgery. 1st ed. Switzerland: Springer; 2018. https://doi.org/10.1007/978-3-319-93545-4.
3. Mognol P, Marmuse JP. Sleeve gastrectomy: a new approach to bariatric surgery. J Chir (Paris). 2007;144(4):293–6.

4. Diamantis T, Apostolou KG, Alexandrou A, et al. Review of long-term weight loss results after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2014;10(1):177–83.
5. Runkel N, Colombo-Benkmann M, Hüttl TP, et al. Bariatric surgery. Dtsch Arztebl Int. 2011;108(20):341–6.
6. Rosenthal RJ, Morton J, Brethauer S, et al. Obesity in America. Surg Obes Relat Dis. 2017;13(10):1643–50.
7. Tucker ON, Szomstein S, Rosenthal RJ. Indications for sleeve gastrectomy as a primary procedure for weight loss in the morbidly obese. J Gastrointest Surg. 2008;12(4):662–7.
8. Berende CA, de Zoete JP, Smulders JF, et al. Laparoscopic sleeve gastrectomy feasible for bariatric revision surgery. Obes Surg. 2012;22(2):330–4.
9. Aziret M, Karaman K, Ercan M, et al. Laparoscopic sleeve gastrectomy on a morbidly obese patient with situs inversus totalis: a case study and systematic review of the literature. Obes Res Clin Pract. 2017;11(5 Suppl 1):144–51.
10. Catheline JM, Rosales C, Cohen R, et al. Laparoscopic sleeve gastrectomy for a super-super-obese patient with situs inversus totalis. Obes Surg. 2006;16(8):1092–5.
11. Major P, Droś J, Kacprzyk A, et al. Does previous abdominal surgery affect the course and outcomes of laparoscopic bariatric surgery? Surg Obes Relat Dis. 2018;14(7):997–1004.
12. Froylich D, Corcelles R, Daigle CR, et al. The effect of pregnancy before and/or after bariatric surgery on weight loss. Surg Obes Relat Dis. 2016;12(3):596–9.
13. Shekelle PG, Newberry S, Maglione M, et al. Bariatric surgery in women of reproductive age: special concerns for pregnancy. Evid Rep Technol Assess (Full Rep). 2008;169:1–51.
14. Lalor PF, Tucker ON, Szomstein S, et al. Complications after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2008;4(1):33–8.
15. Signorini FJ, Polero V, Viscido G, et al. Long-term relationship between tobacco use and weight loss after sleeve gastrectomy. Obes Surg. 2018;28(9):2644–9.
16. Inadomi M, Iyengar R, Fischer I, et al. Effect of patient-reported smoking status on short-term bariatric surgery outcomes. Surg Endosc. 2018;32(2):720–6.
17. Daskalakis M, Weiner RA. Sleeve gastrectomy as a single-stage bariatric operation: indications and limitations. Obes Facts. 2009;2(Suppl 1):8–10.
18. Koliaki C, Liatis S, le Roux CW, et al. The role of bariatric surgery to treat diabetes: current challenges and perspectives. BMC Endocr Disord. 2017;17(1):50.
19. Gagner M, Hutchinson C, Rosenthal R. Fifth international consensus conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6.
20. Crawford C, Gibbens K, Lomelin D, et al. Sleeve gastrectomy and anti-reflux procedures. Surg Endosc. 2017;31(3):1012–21.
21. Felsenreich DM, Kefurt R, Schermann M, et al. Reflux, sleeve dilation, and Barrett's esophagus after laparoscopic sleeve gastrectomy: long-term follow-up. Obes Surg. 2017;27(12):3092–101.
22. Himpens J, Dapri G, Cadière GB. A prospective randomized study between laparoscopic gastric banding and laparoscopic isolated sleeve gastrectomy: results after 1 and 3 years. Obes Surg. 2006;16(11):1450–6.
23. Rebecchi F, Allaix ME, Giaccone C, et al. Gastroesophageal reflux disease and laparoscopic sleeve gastrectomy: a physiopathologic evaluation. Ann Surg. 2014;260(5):909–14; discussion 914-5.
24. Trastulli S, Desiderio J, Guarino S, et al. Laparoscopic sleeve gastrectomy compared with other bariatric surgical procedures: a systematic review of randomized trials. Surg Obes Relat Dis. 2013;9(5):816–29.
25. Picot J, Jones J, Colquitt JL, et al. Weight loss surgery for mild to moderate obesity: a systematic review and economic evaluation. Obes Surg. 2012;22(9):1496–506.
26. Padwal R, Klarenbach S, Wiebe N, et al. Bariatric surgery: a systematic review of the clinical and economic evidence. J Gen Intern Med. 2011;26(10):1183–94.

Chapter 3
Special Indications: Cirrhosis, Inflammatory Bowel Disease, and Organ Transplantation

Eduardo Lemos De Souza Bastos and Almino Ramos Cardoso

3.1 Introduction

LSG is a faster, simpler procedure that does not lead to any change in the original anatomy of the small bowel, technically addressing only the stomach. While the maintenance of the intestinal absorption surface may raise concerns about an unfavorable factor for satisfactory weight loss and favorable for weight recovery in the long-term postoperative, the LSG technical features may be quite advantageous in patients with some non-obesity-related diseases, where a procedure with shorter operative time without affecting the small bowel anatomy may be quite advisable. Cirrhosis, inflammatory bowel diseases, and pre- and post-solid organ transplantation are some of these issues addressed in this chapter on special indications of LSG.

3.2 Sleeve and Cirrhosis

Steatosis, inflammation, and fibrosis are stages of pathological liver damage very commonly associated with obesity and present in about 80–90% of morbidly obese patients undergoing bariatric surgery (BS) [1, 2]. Nonalcoholic fatty liver disease

E. L. D. S. Bastos (✉)
Division of Gastrointestinal Surgery, Marilia Medical School, Marilia, Brazil

Gastro Obeso Center, Advanced Institute for Metabolic Optimization, Sao Paulo, Brazil

A. R. Cardoso
Bariatric Surgery, Gastro Obeso Center, Sao Paulo, Brazil

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_3

(NAFLD) is the most common asymptomatic chronic liver disease featured by several degrees of liver steatosis [3]. Nonalcoholic steatohepatitis (NASH) generally represents the next step in the natural progression of steatosis, marked by more pronounced inflammation of liver tissue which may evolve to liver fibrosis, cirrhosis, and, finally, end-stage liver disease (ESLD) and/or hepatocellular carcinoma [4–8]. Furthermore, NAFLD/NASH strongly contributes to the onset of insulin resistance in obese individuals [2, 9], and therefore has been considered the hepatic manifestation of the metabolic syndrome. About 75% of obese patients with NAFLD already suffer with NASH and approximately 2–4% are unexpectedly diagnosed with cirrhosis [1, 2, 10]. Currently, a true epidemic of nonalcoholic liver damage is under way, undoubtedly linked to the exponential increase of the obesity in recent decades. However, the pathophysiological mechanism that connects these two pathological conditions is still under debate, but seems to be complex and multifactorial [11].

Cirrhosis is an advanced chronic liver disease that can be histologically defined by the development of regenerative nodules surrounded by fibrous bands in response to chronic liver injury [12, 13], leading to hepatic dysfunction and portal hypertension. Based on the etiology, cirrhosis is commonly divided in alcoholic and nonalcoholic, and viral hepatitis and evolution from NALFD/NASH have been the most prevalent sources of nonalcoholic cirrhosis. Given the successive efforts of hepatitis B vaccination programs, NASH has now been the prime concern as a source of nonalcoholic cirrhosis and has become a relevant indication for liver transplantation (LT) [14, 15]. In addition to this strong epidemiological relationship, obesity appears to be an independent factor for clinical decompensation in patients with compensated liver disease, making the weight reduction an important therapeutic measure [16, 17].

In the last decades, BS has emerged as the most effective treatment for morbidly obese individuals, providing sustained weight loss and long-term control of comorbidities, improvement of quality of life, and reduction of mortality, especially related to cardiovascular events [18]. With the growing number of BS around the world [19, 20], and considering the high association between morbid obesity and liver damage, the expected number of bariatric procedures on patients with different clinical degrees of cirrhosis has a trend to increase in the next future.

Undiagnosed and compensated liver cirrhosis is only suspected intraoperatively in over 90% of morbidly obese patients who underwent BS [21], although there may not be a strong relationship of trust between the macroscopic appearance of the liver and the histopathological findings. Thus, liver biopsy remains the most accurate method for the diagnosis of cirrhosis [22]. A survey evolving 126 surgeons and 86,500 bariatric procedures found 125 cases of cirrhosis unexpectedly, resulting in an overall incidence of 0.14% [23], rising an old dilemma if the BS should be continued or aborted in such cases.

The full spectrum of liver damage associated with obesity seems positively affected after weight loss induced by BS. A published review that analyzed paired liver biopsies before and after BS, mainly Roux-en-Y gastric bypass (RYGB), found around 90%, 80% and 65% of improvement or resolution of steatosis, inflammation, and fibrosis, respectively [24]. Therefore, weight reduction, with the subsequent change in metabolic and inflammatory profile, has been the most important therapeutic strategy for NALFD/NASH at the moment. Furthermore, the expected benefits of BS on liver damage may overpass the effects of weight loss but also corroborate to indirect effects of improved insulin resistance and general pro-inflammatory state [25].

Despite these benefits of BS on obesity-related liver damage, both obesity and cirrhosis are clinical conditions that seem to be associated with higher incidence of perioperative morbimortality after any major surgical procedures [26, 27]. Cirrhotic patients can reach an overall postoperative mortality of up to 12% and 30% in early and late period, respectively [28]. Additionally, in a comprehensive review addressing the mortality rate in cirrhotic patients undergoing various non-transplant surgical procedures has shown a range of 8–25%. This wide range can be related to severity of liver disease, type of surgery, demographics of patient population, and expertise of the surgical team, among others. However, the authors also considered that this disappointing outcome could be mitigated, at least in part, by optimizing some clinical conditions, such as coagulopathy, ascites, renal dysfunction, hyponatremia, hepatic encephalopathy, malnutrition, and cardiac and pulmonary conditions, whenever possible [29]. Otherwise, major surgeries must be postponed indefinitely or, at least, temporally delayed in cirrhotic patients.

The severity of hepatic damage and dysfunction should always be considered in the establishment of mortality risk, and it must be weighed at the time of indication of the BS. The Child-Turcotte-Pugh score, a combination of clinical and laboratory parameters, is closely correlated with postoperative mortality rates. In Child A, B, and C, the mortality is around 10%, 30%, and 80%, respectively [30–32]. Regarding the model for end-stage liver disease (MELD), a common score used for inclusion in waiting list for LT, it seems to be strongly related to the postoperative mortality. Higher score, higher mortality, and a score greater than 8 is generally considered as a cutoff line for poor outcome [33, 34].

In addition to assessing liver function, the presence of portal hypertension, increased portal vein pressure due to liver abnormalities seen in cirrhosis, i.e., fibrosis and regeneration nodules, should be also carefully investigated in the preoperative period. Venous pressure gradient greater than 10 mmHg is clinically significant as a bad prognostic factor in cirrhosis since it is usually associated with gastroesophageal varices, ascites, and splenomegaly with thrombocytopenia [35, 36]. Faced on cirrhosis with portal hypertension, preoperative portal decompression through transjugular intrahepatic portosystemic shunt (TIPS) may be applied in reducing perioperative complications and mortality rates [37], but potential benefits have to be weighed against the risk of the device placement. A recent case series involving 13 cirrhotic patients with portal hypertension who underwent laparoscopic bariatric surgery (LSG, $n = 10$) showed satisfactory weight loss, high percentage of comorbidities resolution, low rate of morbidity, and zero mortality at 1 year, allowing to infer that bariatric surgery can be safe and effective in highly selected cirrhotic patients with portal hypertension. Four out of 10 patients who underwent LSG were also submitted to TIPS placement (3 before, 1 after LSG) to relieve portal pressure [38].

Traditionally, advanced liver diseases such as cirrhosis, especially with portal hypertension, are usually considered as a relative contraindication for major elective surgery given the higher rate of complication and mortality [39, 40]. Thus, morbidly obese patients with cirrhosis undergoing BS may be considered as even being at greater risk. To endorse this, large population-based studies comparing patients with cirrhosis (compensated and decompensated) undergoing BS had shown longer hospitalization and greater in-hospital mortality rates than those without cirrhosis [27, 41].

Considering the association of obesity and cirrhosis as a high-risk surgical condition, the minimally invasive laparoscopic approach should always be preferable, since it seems to be safer and provide better outcomes in comparison with open BS [42, 43]. On the other hand, the choice of the optimal technique remains very controversial, especially regarding the discussion of the two most commonly performed procedures today, LSG and RYGB. However, LSG seems to be a safe technique in this group of patients [44].

Bariatric procedures with some degree of small bowel dysfunction (bypass) can be harmful to the liver. Jejunoileal bypass, a malabsorptive bariatric operation widely employed in the last century, has largely been abandoned because of significant morbimortality due to electrolyte disturbances, malnutrition, metabolic complications, and, in some cases, liver injury culminating in cirrhosis [45–47]. After the jejunoileal bypass era, hepatic decompensation was also been scarcely reported after current bariatric procedures with intestinal bypass, such as biliopancreatic diversion with duodenal switch (BPD-DS), RYGB, and one anastomosis gastric bypass (OAGB) [48–51]. Additionally, bariatric procedures that impair nutrients absorption, especially proteins, may be of concern in cirrhotic patients with higher protein demand [52–54]. And finally, techniques including gastroduodenal bypass become the postoperative access to the biliary tree more laborious and may render a possible future orthotopic liver transplant a more challenging procedure.

Moreover, high malabsorptive procedures with extensive gut bypass can promote an expressive and rapid weight loss during the initial 6 months, which may be associated with an excessive lipolysis and subsequent transfer of large amounts of long-chain fatty acids from visceral adipose tissue to the liver via the portal vein [54]. Such metabolic changes may be the source of scanty reported cases of fulminant steatohepatitis or progression of liver histology [55–59].

Although RYGB can also be performed in medically optimized patients with well-compensated liver damage [60], a faster, technically simpler procedure may be advantageous in the scenario of greater surgical risk (obesity and cirrhosis). Comparing to noncirrhotic patients, the LSG performed in compensated Child-A cirrhotic patients has shown similar outcomes regarding weight-loss and postoperative complications, with no mortality observed in either group [61]. Likewise, a systematic review addressing the outcomes of bariatric procedures in Child-A and -B cirrhotic patients has shown the safety of the LSG in this group of patients, with low percentage of complications and liver decompensation, and zero surgery-related mortality, which was only seen in patients undergoing bariatric techniques with intestinal bypass [62]. In addition, LSG can also be quite beneficial in relation to the effects on obesity-related liver damage. Obese patients submitted to LSG showed improvement in the histological profile of the liver in 100% of the cases, besides significant changes in the metabolic parameters [2].

Furthermore, recent review addressing the management of morbidly obese cirrhotic patients suggested that LSG, a less challenging technique with a relatively short operating time, may be favored as a technique of choice in cirrhotic patients. Additionally, LSG ensures an easier postoperative endoscopic access to the biliary tree and is well tolerated if a subsequent LT is needed [63]. Based on these theoretical and already reported advantages, LSG has been increasingly advocated as the bariatric procedure of choice in cirrhotic patients. However, LSG should be employed with extreme caution in the setting of gastric varices (due to portal hypertension), since the potential bleeding can be threatening.

As the mortality rate and overall complications tend to drop even more when BS is performed at a high-volume reference center, it would be always advisable to referee these high-risk patients to the hands of more experienced bariatric surgeons, preferably with expertise in LSG.

In summary, an effective, faster, and technically simpler procedure such as LSG has gained popularity as the bariatric procedure of choice in the setting of high-risk patients as the carriers of morbid obesity and cirrhosis, since it has been shown a feasible and safe procedure, with optimal results and acceptable rates of complications and mortality.

3.3 Sleeve and Inflammatory Bowel Disease

Concurrently with the obesity epidemic, all diseases encompassed by inflammatory bowel disease (IBD) (Crohn's disease, ulcerative colitis, and unclassified colitis) have shown rising incidence and prevalence throughout the world [64, 65]. However, despite this actual trend in recent years, there has been a paucity of population-level studies reporting the obesity rate among IBD individuals, perhaps because IBD is traditionally associated with low body weight. Current prevalence of obesity among IBD patients seems to be quite similar with general population, with percentage around 30% [66], and the prevalence of morbid obesity has been reported at up to 5% [67–69]. Furthermore, an increase in mean body weight, from 21 to 27 kg/m^2, has been noted in the last years in IBD population [70].

There are several reasons to suspect that the increased prevalence of obesity and IBD may be connected, but the scientific knowledge that may link obesity to IBD remains poorly understood. Studies have shown a higher risk of Crohn's disease in obese people, mainly in young women [71–73]. On the other hand, a large prospective cohort study (EPIC study) including more than 300,000 adults in Europe found no association between obesity and IBD [74], perhaps because the authors included a more diverse population, with men and women, young and old, endorsing that obesity may be related to IBD depending on factors such as gender and age. Similarly, recent pooled analysis of the randomized controlled trials designed to report the outcomes of IBD patients with drug therapy showed no differences regarding clinical remission in patients with and without obesity, suggesting that obesity itself does not appear to be an unfavorable factor in the course of IBD [75, 76].

Despite the current increasing incidence and prevalence of obesity, BS and IBD [19, 65, 77], the medical literature reporting the outcomes of BS in patients with IBD is still sparse and is mainly based on small series of cases and case reports. Thus, the relationship between BS and IBD regarding both the new-onset and the worsening of the clinical features of IBD after BS as well as about the clinical course of patients with well-established IBD undergoing weight-loss surgery remains poorly understood to date.

The knowledge about the influence of BS surgery as a source of "de novo" IBD is also scarce and mostly based on case series. The largest published study enrolled a total of 44 patients with development of "de novo" IBD after BS and noted an intriguing higher incidence of Crohn's disease (70%), contrasting to the normal percentage distribution of IBD in the general population, suggesting a role of BS (or obesity itself) in the development of Crohn's disease [78]. Likewise, a multi-institutional case-control study suggested that a previous history of BS was associated with an increased risk of new-onset IBD, with a percentage of Crohn's disease (66%) also higher than in the general population [79]. It is important to point out that majority of patients enrolled in the aforementioned studies were submitted to RYGB.

However, the exact mechanism linking anatomical changes in the small bowel to the worsening or new onset of IBD could not yet be definitively proven. There has been a suggestion that intestinal bypass (with functional gut shortening), such as in RYGB, might promote sustained gut microbiota disarray (chronic dysbiosis) [80], which can work as a trigger in genetically susceptible patients and promote an exaggerated gut inflammatory reaction, resulting in the development of clinically manifest Crohn's disease [81].

A recent in-depth review summarized the available information regarding IBD patients undergoing BS, addressing both the "de novo" cases and the outcomes of BS in morbidly obese individuals with well-established diagnosis of IBD, and suggested that LSG should be the procedure of choice for obese patients with known Crohn's disease, taking into account the preservation of the small bowel from anatomical changes coupled with the observation that no IBD patient submitted to LSG presented worsening of the disease [82].

An interesting but not yet proven explanation of the development of "de novo" IBD is that, in fact, IBD was in the latent preclinical stage, and the mechanical and/or metabolic events brought about by BS could break the finely tuned gut equilibrium and accelerates the clinical manifestations. In this way, small case series ($n = 5$) of morbidly obese patients undergoing RYGB suggested some differences between early and later onset of IBD after BS: earlier onset would be more likely due to loss of gastric defenses in digestive process while in later onset, metabolic alteration involving fat metabolism and microbiome disarray can both be implicated [83]. However, given the small number of reports and scarce physiopathological studies to date, the theoretical pathophysiology that would connect IBD to BS might be just a random association.

About BS in patients with well-established IBD, two large studies using the database from Nationwide Inpatient Sample Analysis [84, 85] showed the safety and cost-effectiveness of the procedure in IBD-morbidly obese patients, which means that IBD does not appear to be a contraindication for weight-loss surgery. As well as in general morbidly obese population, the numbers of LSG as a procedure of choice significantly increased throughout the period of the study (from 2004 to 2014), but no conclusions could be drawn regarding bariatric technique in IBD patients. Regarding the type of IBD, once again Crohn's disease (63%) was the most prevalent, diagnosed in a ratio of 1.7:1 to ulcerative colitis (37%).

Recent studies reporting the weight loss procedure in patients with Crohn's disease showed that LSG was chosen as the first option in almost all cases, with satisfactory results and no exacerbation of IBD. On the contrary, the majority of patients experienced a decrease in both IBD medications and symptoms [69, 86–88]. Regarding BS in ulcerative colitis, the literature has reported a greater number of procedures with intestinal bypass, such as RYGB. It is perhaps a matter of coincidence, but two cases of exacerbation of the disease were observed, and one patient undergoing BPD/DS developed severe protein malnutrition [86–90].

The relationship between obesity, BS, and IBD can interfere in the decision-making of the surgeon in two scenarios: firstly, the possibility of a patient undergoing BS to develop a "de novo" IBD, more specifically Crohn's disease, and, secondly, morbidly obese candidates for BS with already diagnosed IBD, in clinical remission or not. In latter situation, it remains unclear whether BS itself, especially techniques with intestinal bypass, can act as a trigger for the development of clinical IBD by means of anatomical changes, dysbiosis with mucosal barrier dysfunction, or release of pro-inflammatory cytokines from adipose tissue due to quick weight loss [91].

In summary, BS in IBD patients seems to have similar results to those already widely demonstrated in morbidly obese patients without IBD, corroborating the claim that IBD should not be placed as a formal contraindication to BS. However, because Crohn's disease appears to be more common than ulcerative colitis in obese population, and also considering that this disease may evolve with long-term complications related to the small bowel, such as fistulas and strictures, which sometimes require extensive gut resections, it appears to be more reasonable and safer to opt for a technique that does not address the small bowel, such as LSG.

Still about special indications for LSG in small bowel diseases, it should be remembered intra-operative finding of severe adhesions, which may prevent the safe mobilization of the small bowel to provide a gastrojejunostomy. Such a situation can occur in Crohn's disease at a non-negligible frequency, as well as subsequently to previous abdominal or gynecological surgeries, especially after open approach. In such cases, a significant length of the small bowel involved into adhesions can be find, which approach may lead to an appreciable enlarge of the operative time and surgical risk, and a critical analysis of the benefit and the riskiness involved will lead the surgeon for a more careful decision, pending to the LSG in order to avoid putting the patient in non-justifiable dangerous situation. In addition, clinical history of gut resection (due to IBD complications or trauma, for instance) should raise the same care on the part of the bariatric surgeon.

3.4 Sleeve and Organ Transplantation

Morbid obesity is a serious disease that can be very deleterious to both patients with end-stage organ disease (ESOD) transplant candidates as well as to those already transplanted.

In obese individuals with ESOD and candidates for organ transplantation, a satisfactory weight loss may make the transplant procedure technically less demanding, reducing perioperative surgical risk. In addition, weight loss may provide remission or improvement of obesity comorbidities, lessening the pro-inflammatory state of obesity, enhancing the function and graft survival, and ultimately improving the final outcome. Finally, and perhaps more importantly, an effective and sustained management of obesity, no matter what path, can speed up patient's inclusion on the waiting list, exponentially increasing the probability of transplantation.

Although there is no statement for definitively denying organ transplantation in an obese individual, obesity has been considered a relevant, but relative, contraindication for transplantation, and a lot of transplant centers establish obesity as a constraining factor to the waiting list inclusion. Several guidelines have strongly recommended a prior weight loss, ideally targeting the BMI less than 30 kg/m^2, making the obesity a true barrier to being transposed by the obese patient who needs an organ transplant [92–95].

Given the usually poor clinical conditions of patients with ESOD, a structured conservative, multidisciplinary weight-loss program should always be the first option, though long-term efficacy is a pivotal limitation. When unsuccessful, especially for morbidly obese patients, BS may be an option.

In patients already submitted to organ transplantation, a "de novo" obesity or weight recidivism may raise concern about the impact of obesity comorbidities on the transplanted organ, such as the recurrence of NASH in patients submitted to LT and diabetic nephropathy in post-kidney transplantation (KT), for example. Similarly to the patients with ESOD in pre-transplant, the conservative multidisciplinary approach should also be the first option, reserving BS for unsuccessful situations.

Current discussions are focused primarily on whether BS is also a safe and effective strategy for obesity management in patients with ESOD and/or in those already transplanted. Furthermore, the effects of BS on graft function have not been well established so far, and the implications of changes in the gastrointestinal tract caused by the surgical technique on the immunosuppressive regimen required for these patients have also been of concern. Finally, the optimal timing to perform BS has also been controversial, whether before, concurrently, or after transplantation.

The majority studies of BS in the setting of solid organ transplantation relate to those of the kidney and liver, perhaps as consequences of cardiovascular disease frequently associated with obesity and metabolic syndrome, and as result of the natural evolution of NAFLD/NASH, respectively. Nonetheless, LSG was already reported after organ transplantation other than liver and kidney. A report of the outcomes in a case series of 10 patients who underwent organ transplantation (liver = 5; kidney = 4; and heart = 1) followed by LSG showed significant weight loss and remission of comorbidities, as well as preservation or even improvement of graft function [96]. Likewise, another case series of 10 patients submitted to LSG after organ transplantation (kidney = 6; liver = 2; and pancreas = 2) reported adequate weight loss, no impact on graft function, and zero complications and mortality [97]. In addition, a data analysis of 34 patients undergoing BS (LSG = 19; RYGB = 15) after organ transplantation (kidney = 26; liver = 4; liver and kidney = 1; pancreas and kidney = 2; and 1 heart = 1) reported successful weight loss and improvement in comorbidities in 80% of patients and suggested that both, LSG and RYGB, ensured good immunosuppressive maintenance together without graft rejection or dysfunction [98]. All the procedures of the aforementioned case series were performed through laparoscopic or robotic approach, without conversions.

KT in obese patients has been subject to controversial discussion. While some data have suggested that a higher recipient BMI is associated with delayed graft function, graft failure, surgical site infections, higher costs, and patient death [99–105], recent long-term observational study noted an increased risk of post-transplant T2DM in obese individuals but graft and recipient survival was not impacted [106]. Likewise, a systematic review with meta-analysis also concluded to similar patient survival in normal and high BMI individuals undergoing KT [107]. Despite these contradictory reports, a significant reduction in obesity is invariably required for inclusion in a KT waiting list.

The role of BS in obesity management in patients with end-stage renal disease (ESRD) is not well established yet and has been the subject of discussion. Nonetheless, BS, and notably Sleeve Gastrectomy (SG), seems to provide a safe and effective bridge to meet the inclusion criteria on the waiting list, and consequently increasing the possibilities of KT effectively being performed. A retrospective study that looked at 16 patients on hemodialysis for ESRD previously excluded from the waiting list because of weight criteria concluded that BS was an effective path to achieve KT, offering a safe approach to weight loss and improvement in comorbidities in the majority of patients [108]. Likewise, case series (n = 26) involving patients awaiting organ transplantation showed that all patients filled the BMI cutoffs for transplantation as early as 12 months after LSG, and one patient was withdrawn from the transplant list due to stabilization of renal function [109]. Similarly, another case series (n = 52) showed that LSG was an effective metabolic procedure in the management of obesity-related comorbidities, providing desired weight loss and control of comorbidities significantly faster than nonsurgical approach, although only six patients had effectively progressed to transplantation [110]. And finally, small case series reported a higher percentage of KT effectively performed after LSG, all with satisfactory outcomes [111].

Reports of BS after KT are mainly based on studies of small case series, and RYGB seems to be the most common procedure, followed by LSG [112]. A cohort study enrolling almost 200 subjects reported comparable weight loss but higher 30-day mortality for both listed and transplanted patients. However, all procedures were open surgeries, and predominantly RYGB [113]. Regardless of technique, sustained weight loss, control of comorbidities, and even improvement on graft function have been reported in KT recipients submitted to BS [114–117]. Recently, small case series reporting the outcomes of LSG on renal transplant patients ($n = 10$) showed satisfactory weight loss in most patients, but one patient underwent a second-stage BPD/DS diversion due to insufficient weight loss. A major complication (stricture) occurred in another patient and required conversion to a RYGB. No mortality or adverse effects on graft function and immunosuppression regimen was observed [115]. Similarly, a small case series ($n = 5$) did not observe changes in the immunosuppressive regimen in patients submitted to BS (RYGB and LSG) after KT [114]. Likewise, a retrospective review encompassing a 2-year follow-up of six patients undergoing SG after LT (3 by laparoscopy) reported excellent weight-loss without adversely affecting graft function and immunosuppression, but high median length of hospital stay and one major complication (leakage) followed by death due to multi-organ failure [118]. And lastly, a retrospective review from prospectively collected data, kidney transplant patients were submitted to LSG ($n = 5$) and encouraging results in terms of weight loss and control of comorbidities. In addition, post-surgical graft function and proteinuria level improved in 80% of patients [119].

In the setting of LT, the association with obesity has become more frequent, since obesity-related liver disease such as NAFLD/NASH is now one of three most common indications for listing for LT [120]. While some studies did not identify obesity as a predictor of poor prognosis, even when BMI was adjusted for ascites [15, 121, 122], others associated obesity with significantly lower post-LT survival, suggesting lower post-transplantation survival for obese LT recipient in comparing to a lean [123–125]. In addition, long-term post-LT outcomes could be impacted by obesity-related metabolic syndrome, such as NASH recurrence and T2DM [126]. Finally, access to available grafts may be impaired due to graft-to-body weight restrictions. Therefore, an effective and sustained weight loss is strongly recommended in LT recipients and in patients with ESLD who wish to undergo LT.

All these conflicting data regarding obesity in LT settings were gathered in a recent review addressing the impact of all BMI classes on postoperative outcomes in both graft and overall survival. Internal discrepancies of the enrolled studies made any reliable conclusion very difficult [127]. Based on these controversial data, the International Liver Transplantation Consensus Statement recommends that obesity should not constitute an absolute contraindication for LT [13].

Regarding the timing of bariatric procedure in LT settings, the theoretical advantages of prior management of obesity are to reduce the posterior difficulties in operative technique, beneficial impacts on clinical conditions provided by better control of comorbidities, as well as higher opportunity for transplantation, mainly living donor. On the other hand, patients with ESLD usually have impaired clinical and surgical conditions, increasing the risk of BS. After LT, control of obesity can avoid the deleterious impact of comorbidities on graft function and survival, mainly recurrence of NASH. A multicenter cohort study enrolled over 600 subjects undergoing LT and analyzed prognostic impact of obesity and its comorbidities on post-transplantation survival. Almost 20% of the patients died after a median follow-up of 6 years, and the presence of obesity, concomitantly to T2DM, was the major factor associated with reduced post-LT survival [128].

A literature review reporting BS prior, during, or after LT showed SG as the most common current procedure, followed by RYGB. Despite higher morbimortality, BS appeared to be feasible and safe [129]. Likewise, a comprehensive review of the management of obesity in the LT settings has concluded that the optimal timing of bariatric surgery depends in part on the clinical condition of each patient [120]. Lastly, recent comprehensive review addressing the role of BS in the setting of organ transplantation has concluded that BS should be applied only after LT, and the SG is strongly recommended due to lower mortality, improvement on graft function, and preservation of easier endoscopic access to the biliary tree [112]. Despite the higher median length of hospital stay and the record of a death due to staple-line leak (1/9–11%), a recent small case series showed SG as technically feasible after KT [130].

Because bariatric surgery appears to be a high-risk procedure in patients with ESLD, and post-transplant intervention has been associated with increased technical difficulty and complications, there have been few reports of sleeve gastrectomy concurrent with LT. Despite slightly increased morbidity, comparing with the non-surgical approach in the treatment of obesity, SG performed simultaneously with LT was associated with satisfactory and sustained weight loss and excellent control of comorbidities such as T2DM, hypertension and steatosis, and adequate graft function. Although based on case reports or small case series with short-term follow-up, and increased morbidity, the reported mortality of this combined procedure was zero [131–133]. Despite the advantage in addressing two diseases in a single operation and recovery, minimizing the technical difficulties usually found at in reoperation, long-term data are needed to determine if LT plus SG simultaneously is the best strategy.

In summary, BS appears to be feasible in patients with ESRD to achieve KT. Regarding the technique, both LSG and RYGB are effective against obesity in such situation, with satisfactory weight loss and control of comorbidities. However, due to a slightly lower percentage of mortality and major complications, LSG seems to be the most reasonable choice, although long-term data remain unclear. After KT, BS also shows comparable weight loss and control of comorbidities to nontransplanted patients but with higher rates of major complications and mortality, meaning that should be applied very carefully in well-selected patients. In patients with ESLD to achieve LT, complication rates and mortality do not seem to recommend the routine use of BS in the treatment of morbid obesity. After LT, although complication rates appear to be higher than in nontransplanted patients, BS may be employed, and SG should be favored due to the preservation of easier endoscopic access to biliary tree, low mortality, and even improve in graft function. Data on SG simultaneously to LT and experience in transplantation of organs other than the kidney and liver followed by BS are still scarce and do not allow for any scientifically reliable conclusion.

3.5 Conclusion

LSG seems to be feasible, safe, and effective in the setting of special situations of non-obesity-related diseases that may require a faster, technically simpler procedure, making LSG the most reasonable choice.

References

1. Lima M, Mourao S, Diniz M, et al. Hepatic histopathology of patients with morbid obesity submitted to gastric bypass. Obes Surg. 2005;15(5):661–9.
2. Esquivel CM, Garcia M, Armando L, et al. Laparoscopic sleeve gastrectomy resolves NAFLD: another formal indication for bariatric surgery? Obes Surg. 2018;28(12):4022–33.
3. Younossi ZM, Stepanova M, Afendy M, et al. Changes in the prevalence of the most common causes of chronic liver diseases in the United States from 1988 to 2008. Clin Gastroenterol Hepatol. 2011;9:524–30.
4. Matteoni CA, Younossi ZM, Gramlich T, et al. Non-alcoholic fatty liver disease: a spectrum of clinical and pathological severity. Gastroenterology. 1999;116(6):1413–9.
5. Caldwell SH, Hespenheide EE. Sub-acute liver failure in obese women. Am J Gastroenterol. 2002;97:2058–62.
6. Shimada M, Hashimoto E, Tania M, et al. Hepatocellular carcinoma in patients with nonalcoholic steatohepatitis. J Hepatol. 2002;37:154–60.
7. Hashizume H, Sato K, Takagi H, et al. Primary liver cancers with nonalcoholic steatohepatitis. Eur J Gastroenterol Hepatol. 2007;19:827–34.
8. Argo CK, Caldwell SH. Epidemiology and natural history of nonalcoholic steatohepatitis. Clin Liver Dis. 2009;13:511–31.
9. Marchesini G, Bugianesi E, Forlani G, et al. Nonalcoholic fatty liver, steatohepatitis, and the metabolic syndrome. Hepatology. 2003;37(4):917–23.
10. Subichin M, Clanton J, Makuszewski M, et al. Liver disease in the morbidly obese: a review of 1000 consecutive patients undergoing weight loss surgery. Surg Obes Relat Dis. 2015;11(1):137–41.
11. Verna EC, Berk PD. Role of fatty acids in the pathogenesis of obesity and fatty liver: impact of bariatric surgery. Semin Liver Dis. 2008;28(4):407–26.
12. Schuppan Schuppan D, Afdhal NH. Liver cirrhosis. Lancet. 2008;371(9615):838–51.
13. Tsochatzis EA, Bosch J, Burroughs AK. Liver cirrhosis. Lancet. 2014;383:1749–61.
14. Singal AK, Salameh H, Kuo YF, et al. Evolving frequency and outcomes of liver transplantation based on etiology of liver disease. Transplantation. 2013;95:755–60.
15. Wong RJ, Aguilar M, Cheung R, et al. Nonalcoholic steatohepatitis is the second leading etiology of liver disease among adults awaiting liver transplantation in the United States. Gastroenterology. 2015;148:547–55.
16. Berzigotti A, Garcia-Tsao G, Bosch J, et al. Obesity is an independent risk factor for clinical decompensation in patients with cirrhosis. Hepatology. 2011;54(2):555–61.

17. Leoni S, Tovoli F, Napoli L, et al. Current guidelines for the management of non-alcoholic fatty liver disease: a systematic review with comparative analysis. World J Gastroenterol. 2018;24(30):3361–73.
18. Sjostrom L, Peltonen M, Jacobson P, et al. Bariatric surgery and long-term cardiovascular events. JAMA. 2012;307(1):56–65.
19. Angrisani L, Santonicola A, Iovino P, et al. IFSO Worldwide Survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28(12):3783–94.
20. English WJ, DeMaria EJ, Brethauer SA, et al. American Society for Metabolic and Bariatric Surgery estimation of metabolic and bariatric procedures performed in the United States in 2016. Surg Obes Relat Dis. 2018;14(3):259–63.
21. Dallal RM, Mattar SG, Lord JL, et al. Results of laparoscopic gastric bypass in patients with cirrhosis. Obes Surg. 2004;14:47–53.
22. Dolce CJ, Russo M, Keller JE, et al. Does liver appearance predict histopathologic findings: prospective analysis of routine liver biopsies during bariatric surgery. Surg Obes Relat Dis. 2009;5:323–8.
23. Brolin RE, Bradley LJ, Taliwal RV. Unsuspected cirrhosis discovered during elective obesity operations. Arch Surg. 1998;133:84–8.
24. Mummadi RR, Kasturi KS, Chennareddygari S, et al. Effect of bariatric surgery on nonalcoholic fatty liver disease: systematic review and meta-analysis. Clin Gastroenterol Hepatol. 2008;6:1396–402.
25. Clanton J, Subichin M. The effects of metabolic surgery on fatty liver disease and nonalcoholic steatohepatitis. Surg Clin North Am. 2016;96:703–15.
26. Rizvon MK, Chou CL. Surgery in the patient with liver disease. Med Clin North Am. 2003;87:211–27.
27. Csikesz NG, Nguyen LN, Tseng JF, et al. Nationwide volume and mortality after elective surgery in cirrhotic patients. J Am Coll Surg. 2009;208:96–103.
28. Ziser A, Plevak DJ, Wiesner RH, et al. Morbidity and mortality in cirrhotic patients undergoing anesthesia and surgery. Anesthesiology. 1999;90(1):42–53.
29. Millwala F, Nguyen GC, Thuluvath PJ. Outcomes of patients with cirrhosis undergoing non-hepatic surgery: risk assessment and management. World J Gastroenterol. 2007;13(30):4056–63.
30. Garrison RN, Cryer HM, Howard DA, et al. Clarification of risk factors for abdominal operations in patients with hepatic cirrhosis. Ann Surg. 1984;199:648–55.
31. Mansour A, Watson W, Shayani V, et al. Abdominal operations in patients with cirrhosis: still a major surgical challenge. Surgery. 1997;122:730–5.
32. Teh SH, Nagorney DM, Stevens SR, et al. Risk factors for mortality after surgery in patients with cirrhosis. Gastroenterology. 2007;132:1261–9.
33. Northup PG, Wanamaker RC, Lee VD, et al. Model for end-stage liver disease (MELD) predicts nontransplant surgical mortality in patients with cirrhosis. Ann Surg. 2005;242:244–51.
34. Nicoll A. Surgical risk in patients with cirrhosis. J Gastroenterol Hepatol. 2012;27:1569–75.
35. Berzigotti A, Seijo S, Reverter E, et al. Assessing portal hypertension in liver diseases. Expert Rev Gastroenterol Hepatol. 2013;7:141–55.
36. Nusrat S, Khan MS, Fazili J, et al. Cirrhosis and its complications: evidence based treatment. World J Gastroenterol. 2014;20:5442–60.
37. Kim JJ, Dasika NL, Yu E, et al. Cirrhotic patients with a transjugular intrahepatic portosystemic shunt undergoing major extrahepatic surgery. J Clin Gastroenterol. 2009;43(6):574–9.
38. Hanipah ZN, Punchai S, McCullough A, et al. Bariatric surgery in patients with cirrhosis and portal hypertension. Obes Surg. 2018;28(11):3431–8.
39. Bruix J, Sherman M. Practice guidelines committee, American Association for the Study of Liver Diseases. Management of hepatocellular carcinoma. Hepatology. 2005;42:1208–36.
40. European Association for the Study of the Liver. European Organization for Research and Treatment of Cancer. EASLEORTC clinical practice guidelines: management of hepatocellular carcinoma. J Hepatol. 2012;56:908–43.

41. Mosko JD, Nguyen GC. Increased perioperative mortality following bariatric surgery among patients with cirrhosis. Clin Gastroenterol Hepatol. 2011;9:897–901.
42. Cobb WS, Heniford BT, Burns JM, et al. Cirrhosis is not a contraindication to laparoscopic surgery. Surg Endosc. 2005;19:418–23.
43. Chmielecki DK, Hagopian EJ, Kuo YH, et al. Laparoscopic cholecystectomy is the preferred approach in cirrhosis: a nationwide, population-based study. HPB (Oxford). 2012;14:848–53.
44. Borbély Y, Juilland O, Altmeier J, et al. Perioperative outcome of laparoscopic sleeve gastrectomy for high-risk patients. Surg Obes Relat Dis. 2017;13:155–60.
45. Buchwald H, Lober PH, Varco RL. Liver biopsy findings in seventy-seven consecutive patients undergoing jejunoileal bypass for morbid obesity. Am J Surg. 1974;127:48–52.
46. Hocking MP, Duerson MC, O'Leary JP, et al. Jejunoileal bypass for morbid obesity. Late follow-up in 100 cases. N Engl J Med. 1983;308:995–9.
47. Hocking MP, Davis GL, Franzini DA, et al. Long-term consequences after jejunoileal bypass for morbid obesity. Dig Dis Sci. 1998;43:2493–9.
48. Antal SC. Prevention and reversal of liver damage following biliopancreatic diversion for obesity. Obes Surg. 1994;4:285–90.
49. Castillo J, Fábrega E, Escalante CF, et al. Liver transplantation in a case of steatohepatitis and subacute hepatic failure after biliopancreatic diversion for morbid obesity. Obes Surg. 2001;11:640–2.
50. Cotler SJ, Vitello JM, Guzman G, et al. Hepatic decompensation after gastric bypass surgery for severe obesity. Dig Dis Sci. 2004;49:1563–8.
51. Eilenberg M, Langer FB, Beer A, et al. Significant liver-related morbidity after bariatric surgery and its reversal—a case series. Obes Surg. 2018;28:812–9.
52. Moize V, Geliebter A, Gluck ME, et al. Obese patients have inadequate protein intake related to protein intolerance up to 1 year following Roux- en-Y gastric bypass. Obes Surg. 2003;13:23–8.
53. Odstrcil EA, Martinez JG, Santa Ana CA, et al. The contribution of malabsorption to the reduction in net energy absorption after long-limb Roux-en-Y gastric bypass. Am J Clin Nutr. 2010;92:704–13.
54. Anand AC. Nutrition and muscle in cirrhosis. J Clin Exp Hepatol. 2017;7:340–57.
55. Barker KB, Palekar NA, Bowers SP, et al. Non-alcoholic steatohepatitis: effect of Roux-en-Y gastric bypass surgery. Am J Gastroenterol. 2006;101(2):368–73.
56. Csendes A, Smok G, Burgos AM. Histological findings in the liver before and after gastric bypass. Obes Surg. 2006;16(5):607–11.
57. Mathurin P, Hollebecque A, Arnalsteen L, et al. Prospective study of the long-term effects of bariatric surgery on liver injury in patients without advanced disease. Gastroenterology. 2009;137(2):532–40.
58. Kral JG, Thung SN, Biron S, et al. Effects of surgical treatment of the metabolic syndrome on liver fibrosis and cirrhosis. Surgery. 2004;135(1):48–58.
59. Stratopoulos C, Papakonstantinou A, Terzis I, et al. Changes in liver histology accompanying massive weight loss after gastroplasty for morbid obesity. Obes Surg. 2005;15(8):1154–60.
60. Singh T, Kochhar GS, Goh GB, et al. Safety and efficacy of bariatric surgery in patients with advanced fibrosis. Int J Obes. 2017;41:443–9.
61. Rebibo L, Gerin O, Verhaeghe P, et al. Laparoscopic sleeve gastrectomy in patients with NASH-related cirrhosis: a case-matched study. Surg Obes Relat Dis. 2014;10:405–10.
62. Jan A, Narwaria M, Mahawar KK. A systematic review of bariatric surgery in patients with liver cirrhosis. Obes Surg. 2015;25(8):1518–26.
63. Goh GB, Schauer PR, McCullough AJ. Considerations for bariatric surgery in patients with cirrhosis. World J Gastroenterol. 2018;24(28):3112–9.
64. Molodecky NA, Soon IS, Rabi DM, et al. Increasing incidence and prevalence of the inflammatory bowel diseases with time, based on systematic review. Gastroenterology. 2012;142:46–54.

65. Singh S, Dulai PS, Zarrinpar A, et al. Obesity in IBD: epidemiology, pathogenesis, disease course and treatment outcomes. Nat Rev Gastroenterol Hepatol. 2017;14:110–21.
66. Harper J, Zisman T. Interaction of obesity and inflammatory bowel disease. World J Gastroenterol. 2016;22:7868–81.
67. Steed H, Walsh S, Reynolds N. A brief report of the epidemiology of obesity in the inflammatory bowel disease population of Tayside, Scotland. Obes Facts. 2009;2:370–2.
68. Causey MW, Johnson EK, Miller S, et al. The impact of obesity on outcomes following major surgery for Crohn's disease: an American College of Surgeons National Surgical Quality Improvement Program assessment. Dis Colon Rectum. 2011;54:1488–95.
69. Ungar B, Kopylov U, Goitein D, et al. Severe and morbid obesity in Crohn's disease patients: prevalence and disease associations. Digestion. 2013;88:26–32.
70. Moran GW, Dubeau MF, Kaplan GG, et al. The increasing weight of Crohn's disease subjects in clinical trials: a hypothesis-generatings time-trend analysis. Inflamm Bowel Dis. 2013;19:2949–56.
71. Hemminki K, Li X, Sundquist J, Sundquist K. Risk of asthma and autoimmune diseases and related conditions in patients hospitalized for obesity. Ann Med. 2012;44:289–95.
72. Harpsøe MC, Basit S, Andersson M, et al. Body mass index and risk of autoimmune diseases: a study within the Danish National Birth Cohort. Int J Epidemiol. 2014;43:843–55.
73. Khalili H, Ananthakrishnan AN, Konijeti GG, et al. Measures of obesity and risk of Crohn's disease and ulcerative colitis. Inflamm Bowel Dis. 2015;21:361–8.
74. Chan SS, Luben R, Olsen A, et al. Body mass index and the risk for Crohn's disease and ulcerative colitis: data from a European prospective cohort study (the IBD in EPIC study). Am J Gastroenterol. 2013;108:575–82.
75. Bhalme M, Sharma A, Keld R, et al. Does weight-adjusted anti-tumour necrosis factor treatment favour obese patients with Crohn's disease? Eur J Gastroenterol Hepatol. 2013;25:543–9.
76. Singh S, Proudfoot J, Xu R, Sandborn WJ. Obesity and response to infliximab in patients with inflammatory bowel diseases: pooled analysis of individual participant data from clinical trials. Am J Gastroenterol. 2018;113:883–9.
77. The GBD 2015 Obesity Collaborators. Health effects of overweight and obesity in 195 countries over 25 years. N Engl J Med. 2017;377(1):13–27.
78. Braga Neto MB, Gregory M, Piovezani Ramos GP, et al. De-novo inflammatory bowel disease after bariatric surgery: a large case series. J Crohns Colitis. 2017;12:452–7.
79. Ungaro R, Fausel R, Chanq HL, et al. Bariatric surgery is associated with increased risk of new-onset inflammatory bowel disease: case series and national database study. Aliment Pharmacol Ther. 2018;47:1126–34.
80. Bastos ELS, Liberatore AMA, Tedesco RC, Koh IHJ. Gut microbiota imbalance can be associated with non-malabsorptive small bowel shortening regardless of blind loop. Obes Surg. 2018;29:369. https://doi.org/10.1007/s11695-018-3540-1.
81. Ahn LB, Huang CS, Forse RA, et al. Crohn's disease after gastric bypass surgery for morbid obesity: is there an association? Inflamm Bowel Dis. 2005;11:622–4.
82. Cañete F, Mañosa M, Clos A, et al. Review article: the relationship between obesity, bariatric surgery, and inflammatory bowel disease. Aliment Pharmacol Ther. 2018;48(8):807–16.
83. Bl K, Sonpal N, Schneider J, et al. Obesity/bariatric surgery and Crohn's disease. J Clin Gastroenterol. 2018;52:50–4.
84. Sharma P, McCarty TR, Niei B. Impact of bariatric surgery on outcomes of patients with inflammatory bowel disease: a nationwide inpatient sample analysis, 2004–2014. Obes Surg. 2018;28:1015–24.
85. Bazerbachi F, Sawas T, Vargas EJ, et al. Bariatric surgery is acceptably safe in obese inflammatory bowel disease patients: analysis of the Nationwide inpatient sample. Obes Surg. 2018;28:1007–14.
86. Keidar A, Hazan D, Sadot E, et al. The role of bariatric surgery in morbidly obese patients with inflammatory bowel disease. Surg Obes Relat Dis. 2015;11:132–6.

87. Colombo F, Rizzi A, Ferrari C, et al. Bariatric surgery in patients with inflammatory bowel disease: an accessible path? Report of a case series and review of the literature. J Crohns Colitis. 2015;9:185–90.
88. Aminian A, Andalib A, Ver MR, et al. Outcomes of bariatric surgery in patients with inflammatory bowel disease. Obes Surg. 2016;6:1189–90.
89. Lascano CA, Soto F, Carrodeguas L, et al. Management of ulcerative colitis in the morbidly obese patient: is bariatric surgery indicated. Obes Surg. 2006;16:783–6.
90. Tenorio-Jiménez C, Manzano-García G, Prior-Sánchez I, et al. Bariatric surgery in inflammatory bowel disease: case report and review of the literature. Nutr Hosp. 2013;28:958–60.
91. Cottam D, Mattar S, Barinas E. The chronic inflammatory hypothesis for the morbidity associated with morbid obesity: implications and effects of weight loss. Obes Surg. 2004;14:589–600.
92. Knoll G, Cockfield S, Blydt-Hansen T, et al. Canadian Society of Transplantation consensus guidelines on eligibility for kidney transplantation. CMAJ. 2005;173(10):1181–4.
93. Kasiske BL, Cangro CB, Hariharan S, et al. The evaluation of renal transplantation candidates: clinical practice guidelines. Am J Transplant. 2001;1(suppl 2):3–95.
94. Abramowicz D, Cochat P, Claas FH, et al. European renal best practice guideline on kidney donor and recipient evaluation and perioperative care. Nephrol Dial Transplant. 2015;30(11):1790–7.
95. Tsochatzis E, Coilly A, Nadalin S, et al. International liver transplantation consensus statement on end-stage liver disease due to nonalcoholic steatohepatitis and liver transplantation. Transplantation. 2019;103(1):45–56.
96. Khoraki J, Katz MG, Funk LM, et al. Feasibility and outcomes of laparoscopic sleeve gastrectomy after solid organ transplantation. Surg Obes Relat Dis. 2015;12:75–83.
97. Elli EF, Gonzalez-Heredia R, Sanchez-Johnsen L, et al. Sleeve gastrectomy surgery in obese patients post-organ transplantation. Surg Obes Relat Dis. 2016;12:528–34.
98. Yemini R, Nesher E, Winkler J, et al. Bariatric surgery in solid organ transplant patients: long-term follow-up results of outcome, safety, and effect on immunosuppression. Am J Transplant. 2018;18(11):2772–80.
99. Aalten J, Christiaans MH, de Fijter H, et al. The influence of obesity on short- and long-term graft and patient survival after renal transplantation. Transpl Int. 2006;19(11):901–7.
100. Cacciola RA, Pujar K, Ilham MA, et al. Effect of degree of obesity on renal transplant outcome. Transplant Proc. 2008;40(10):3408–12.
101. Lynch RJ, Ranney DN, Shijie C, et al. Obesity, surgical site infection, and outcome following renal transplantation. Ann Surg. 2009;250(6):1014–20.
102. Molnar MZ, Kovesdy CP, Mucsi I, et al. Higher recipient body mass index is associated with post-transplant delayed kidney graft function. Kidney Int. 2011;80(2):218–24.
103. Hoogeveen EK, Aalten J, Rothman KJ, et al. Effect of obesity on the outcome of kidney transplantation: a 20-year follow-up. Transplantation. 2011;91(8):869–74.
104. Cannon RM, Jones CM, Hughes MG, et al. The impact of recipient obesity on outcomes after renal transplantation. Ann Surg. 2013;257(5):978–84.
105. Nicoletto BB, Fonseca NKO, Manfro RC, et al. Effects of obesity on kidney transplantation outcomes: a systematic review and meta-analysis. Transplantation. 2014;98(2):167–76.
106. McCloskey OM, Devine PA, Courtney AE, et al. Is big bad or bearable? Long-term renal transplant outcomes in obese recipients. QJM. 2018;111(6):365–71.
107. Hill CJ, Courtney AE, Cardwell CR, et al. Recipient obesity and outcomes after kidney transplantation: a systematic review and meta-analysis. Nephrol Dial Transplant. 2015;30:1403–11.
108. Al-Bahri S, Fakhry TK, Gonzalvo JP, et al. Bariatric surgery as a bridge to renal transplantation in patients with end-stage renal disease. Obes Surg. 2017;27(11):2951–5.
109. Lin MY, Tavakol MM, Sarin A, et al. Laparoscopic sleeve gastrectomy is safe and efficacious for pretransplant candidates. Surg Obes Relat Dis. 2013;9(5):653–8.
110. Freeman CM, Woodle ES, Shi J, et al. Addressing morbid obesity as a barrier to renal transplantation with laparoscopic sleeve gastrectomy. Am J Transplant. 2015;15(5):1360–8.
111. Kienzl-Wagner K, Weissenbacher A, Gehwolf P, et al. Laparoscopic sleeve gastrectomy: gateway to kidney transplantation. Surg Obes Relat Dis. 2017;13(6):909–15.

112. Dziodzio T, Biebl M, Öllinger R, et al. The role of bariatric surgery in abdominal organ transplantation-the next big challenge? Obes Surg. 2017;27:2696–706.
113. Modanlou KA, Muthyala U, Xiao H, et al. Bariatric surgery among kidney transplant candidates and recipients: analysis of the United States renal data system and literature review. Transplantation. 2009;87(8):1167–73.
114. Szomstein S, Rojas R, Rosenthal RJ. Outcomes of laparoscopic bariatric surgery after renal transplant. Obes Surg. 2010;20(3):383–5.
115. Golomb I, Winkler J, Ben-Yakov A, et al. Laparoscopic sleeve gastrectomy as a weight reduction strategy in obese patients after kidney transplantation. Am J Transplant. 2014;14(10):2384–90.
116. Chmura A, Ziemiański P, Lisik W, et al. Improvement of graft function following Roux-en-Y gastric bypass surgery in a morbidly obese kidney recipient: a case report and literature review. Ann Transplant. 2014;19:639–42.
117. Khoraki J, Katz MG, Funk LM, et al. Feasibility and outcomes of laparoscopic sleeve gastrectomy after solid organ transplantation. Surg Obes Relat Dis. 2016;12:75–83.
118. Osseis M, Lazzati A, Salloum C, et al. Sleeve gastrectomy after liver transplantation: feasibility and outcomes. Obes Surg. 2018;28(1):242–8.
119. Viscido G, Gorodner V, Signorini FJ, et al. Sleeve gastrectomy after renal transplantation. Obes Surg. 2018;28(6):1587–94.
120. Bonner K, Heimbach JK. Obesity management in the liver transplant recipient: the role of bariatric surgery. Curr Opin Organ Transplant. 2018;23:244–9.
121. Nair S, Verma S, Thuluvath PJ. Obesity and its effect on survival in patients undergoing orthotopic liver transplantation in the United States. Hepatology. 2002;35:105–9.
122. Leonard J, Heimbach JK, Malinchoc M, et al. The impact of obesity on long-term outcomes in liver transplant recipients: results of the NIDDK liver transplant database. Am J Transplant. 2008;8:667–72.
123. Dick AA, Spitzer AL, Seifert CF, et al. Liver transplantation at the extremes of the body mass index. Liver Transpl. 2009;15:968–77.
124. Perez-Protto SE, Quintini C, Reynolds LF, et al. Comparable graft and patient survival in lean and obese liver transplant recipients. Liver Transpl. 2013;19:907–15.
125. Orci LA, Majno PE, Berney T, et al. The impact of wait list body mass index changes on the outcome after liver transplantation. Transpl Int. 2013;26:170–6.
126. Watt KD, Pedersen RA, Kremers WK, et al. Evolution of causes and risk factors for mortality post-liver transplant: results of the NIDDK long-term follow up study. Am J Transplant. 2010;10:1420–7.
127. Barone M, Viggiani MT, Avolio AW, et al. Obesity as predictor of postoperative outcomes in liver transplant candidates: review of the literature and future perspectives. Dig Liver Dis. 2017;49:957–66.
128. Adams LA, Arauz O, Angus PW, et al. Australian New Zealand liver transplant study group. Additive impact of pre-liver transplant metabolic factors on survival post-liver transplant. J Gastroenterol Hepatol. 2016;31(5):1016–24.
129. Lazzati A, Iannelli A, Schneck A-S, et al. Bariatric surgery and liver transplantation: a systematic review a new frontier for bariatric surgery. Obes Surg. 2014;25:134–42.
130. Nassif GB, Salloum C, Paolino L, et al. Laparoscopic sleeve gastrectomy after orthotopic liver transplantation, video reported. Obes Surg. 2019;29(4):1436–8.
131. Nesher E, Mor E, Shlomai A, et al. Simultaneous liver transplantation and sleeve gastrectomy: prohibitive combination or a necessity? Obes Surg. 2017;27:1387–90.
132. Heimbach JK, Watt KD, Poterucha JJ, et al. Combined liver transplantation and gastric sleeve resection for patients with medically complicated obesity and end-stage liver disease. Am J Transplant. 2013;13:363–8.
133. Tariciotti L, D’Ugo S, Manzia TM, et al. Combined liver transplantation and sleeve gastrectomy for end-stage liver disease in a bariatric patient: first European case-report. Int J Surg Case Rep. 2016;28:38–41.

Chapter 4
Preoperative Management of Candidates for Bariatric Surgery

Marianela Aguirre Ackermann, Edgardo Emilio Serra, and Guillermo Emilio Duza

4.1 Preoperative Examinations

There are a lot of publications but still no unique guidelines on which is the best preoperative evaluation should be performed before bariatric surgery. Despite that, the findings from preoperative evaluation need to be taken into consideration when planning the surgery. Each bariatric procedure has to be tailored individually according to the patient's overall health status and preexisting diseases. A complete medical evaluation should include the study of the cardiovascular, pulmonary, and gastrointestinal system as well as a metabolic status assessment.

4.2 Clinical-Nutritional

Complete clinical examination and nutritional evaluation it is necessary. Among the methods for the realization of the nutritional anamnesis can be used: 24-hour reminder, 7-day reminder (gold standard), and frequency of food consumption.

M. A. Ackermann
Nutrition and Diabetes of CIEN (Center of Obesity, Diabetes and Bariatric Surgery), Corrientes, Buenos Aires, Misiones and Formosa, Argentina

Universidad Nacional del Nordeste, Corrientes, Argentina

E. E. Serra
Bariatric Surgery and Mini-invasive Surgery of CIEN (Center of Obesity, Diabetes and Bariatric Surgery), Corrientes, Buenos Aires, Misiones and Formosa, Argentina

G. E. Duza (✉)
CIEN-Diagnomed Center (Center of Obesity, Diabetes and Bariatric Surgery), Buenos Aires, Argentina

University of Buenos Aires (UBA), Buenos Aires, Argentina

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_4

Assessment of the nutritional status will be made in every candidate to SG. Weight, height, and calculation of the body mass index (BMI) will be measured as well as the waist circumference and/or sagittal diameter and the circumference of the neck. According to the availability of other methods, evaluation of body composition can be included, being the DEXA (Absorption of dual energy of X-rays) total body the gold standard.

4.3 Medical Studies

4.3.1 Ultrasonography

Although some bariatric guidelines reserve preoperative transabdominal ultrasonography screening for symptomatic patients and those with elevated liver enzymes, there has yet to exist a general consensus regarding this issue. Still, some centers believe that it is necessary to screen all patients undergoing bariatric procedure to avoid the possible postoperative biliary disease [1].

Current guidelines for preoperative assessment of patients undergoing bariatric surgery by the American Society of Metabolic and Bariatric Surgery advise that abdominal ultrasonography be done for patients with symptoms of biliary disease and elevated liver function tests [2]. The Society of American Gastrointestinal and Endoscopic Surgeons, in their 2008 guidelines for clinical application of laparoscopic bariatric surgery, also proposed the possible advantage of preoperative transabdominal ultrasonography screening for gallstones and liver disease [3].

Even though many findings were evident on preoperative ultrasonography screening for LSG patients, it remains to be said that the findings provide little, if any, additional information needed for the preoperative workup.

Concomitant cholecystectomy during LSG is associated with slightly increased risk of adverse events, namely bleeding and pneumonia. When factoring the potential risk and cost of further hospitalization for deferred cholecystectomy, concomitant cholecystectomy might be a better option for patients with established gallbladder disease [4].

The effectiveness of ultrasonography in assessing the size and consistency of the liver in patients undergoing LSG and LRYGBP found that it was unreliable and offered very limited prognostic value [5].

This questions the need and cost-effectiveness of such screening tools and further supports the trend of performing transabdominal ultrasonography specifically on symptomatic patients as proposed in some of the current bariatric guidelines [6].

It is safe to say that we recommend that ultrasonography screening should be reserved for symptomatic patients in the preoperative workup for LSG, and its routine use seems to be not useful.

4.3.2 Pulmonary Tests

Airway management in patients with obesity can be a challenge, particularly in those with obstructive sleep apnea (OSA). Preventing major airway complications (death, brain damage, need for surgical airway, unplanned intensive care unit admission) is a central focus in this patient population [7].

The chest X-ray examination is part of any preoperative evaluation and must be done for all the patients in plan for bariatric surgery.

There are known pulmonary diseases that may increase the risk for pulmonary complications. However, the screening of asymptomatic obese patients by spirometry before bariatric surgery has not been fully supported. According to the 2013 guidelines of the American Society for Metabolic and Bariatric Surgery (ASMBS), spirometry as a preoperative test is indicated only in the presence of risk factors previously identified by other tests [8].

Given the potential dangers and complications associated with obesity, OSA, and the airway, it is important that surgeons and anesthesiologists work together to implement evidence-based protocols to minimize and address complications as they arise [9].

In general, adequate detection and treatment of OSA is important for three main reasons: reducing clinical symptoms such as sleepiness and cognitive dysfunction, reducing the long-term cardio and neurovascular risks, and reducing the occurrence of traffic, domestic, or workplace accidents. In morbidly obese patients requiring general anesthesia, a fourth important reason is reducing the preventable perioperative risks, as clinically relevant complications seem more frequent in OSA patients [10, 11].

The gold standard for diagnosis of OSA is an overnight laboratory polysomnography (PSG) [12]. Such a study determines the frequency and duration of apneas and hypopneas during a full night of accurately documented sleep and subsequently generates among other variables the apnea-hypopnea-index (AHI).

A less time-consuming and more patient-friendly sleep study than PSG is a portable study of a limited range of variables, known as type 3 portable sleep monitoring according to the definitions of the Amn Academy of Sleep Medicine [13]. This can be used for OSA in the MBS population with high pre-test probability. Its use is most reliable when moderate to severe OSA is suspected.

A commonly used and validated questionnaire is the STOP-Bang, the score of which can be used as a screening tool to stratify high-risk OSA in (morbidly) obese patients [14].

Despite these findings regarding the value of overnight measurements to determine the perioperative risk, mandatory sleep studies prior to MBS have not been accepted as the standard of care due to limited sleep laboratory capacity, costs, time management, and the unknown importance of OSA detection.

Taking these matters into consideration, mandatory OSA screening appears indicated due to the high prevalence of OSA in morbidly obese subjects and the increased risk of perioperative complications. While the gold standard to diagnose

OSA is a PSG, other tools such as the STOP-Bang questionnaire could be used to identify high-risk patients, with portable type 3 sleep studies adding information.

4.3.3 Upper Gastrointestinal Fluoroscopy

Hiatal hernia (HH) is not uncommon, with prevalence increasing with age and obesity. The association between HH, gastroesophageal reflux disease (GERD), and morbid obesity is well documented [15]. HH diagnosis is achieved by upper gastrointestinal (GI) fluoroscopy, endoscopic studies, or manometry. Unsurprisingly, evaluation of upper GI anatomy before bariatric surgery (BS) is common, with fluoroscopic and/or endoscopic examination of the gastroesophageal junction (GEJ) routinely performed in most centers [16, 17]. Some centers advocate a more selective approach, studying only patients with upper GI symptoms such as dysphagia, heartburn, etc. [18, 19].

Routine preoperative swallow studies do not seem to offer an advantage over selective intraoperative hiatal exploration, in the discovery and management of HH in patients undergoing primary LSG. Conversely, when preoperative workup yields a false-positive result, surgery is slightly but unnecessarily prolonged. If hiatal exploration is selectively performed, the barium swallow might be rendered obsolete in future bariatric preoperative assessments [20].

4.3.4 Endoscopy

There is frequent debate regarding the role of preoperative endoscopy (EGD) prior to bariatric surgery. Some centers routinely perform EGD in all patients prior to bariatric surgery, while other centers utilize EGD selectively. The 2008 guidelines of the American Society of Gastrointestinal Endoscopy (ASGE) recommended that preoperative EGD should be performed in all patients with upper gastrointestinal symptoms and should be considered in patients without symptoms in order to exclude large hiatal hernias that may alter the surgical approach [21]. More recently, the ASGE in conjunction with the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) recommended that the decision to perform preoperative EGD should be individualized in bariatric surgery patients [22]. The American Society of Metabolic and Bariatric Surgery (ASMBS) recommends that all clinically significant gastrointestinal symptoms should be evaluated prior to bariatric surgery with imaging studies, upper gastrointestinal series, or EGD [23].

Although there is no clear standard for patient symptoms requiring preoperative EGD, surgeons may consider preoperative EGD in patients with symptoms of gastroesophageal reflux disease/esophagitis (including heartburn, regurgitation, dysphagia, or any postprandial symptoms that suggest foregut pathology).

Helicobacter pylori is a class 1 carcinogen and is regarded as one of the most prevalent human pathogens affecting nearly 50% of the population [24, 25]. Diagnosis is made through invasive and noninvasive modalities.

Invasive tests are endoscopy mediated and include histology, rapid urease test, and culture. Histologic diagnosis is considered the gold standard with a high sensitivity (97–100%) and specificity (97–100%) [26–28]. So if an endoscopy is going to be made, we strongly recommend the screening for HP.

If the surgeon decides that a preoperative EGD is not necessary, noninvasive tests including the urea breath test, stool antigen test, and serological markers could be an option.

4.4 Cardiological Investigations

Morbidly obese patients have increased morbidity and mortality [29] related to a high prevalence of cardiorespiratory diseases, which may be known or unknown at the time of surgery.

The electrocardiography (ECG) should be performed for every patient in plan for sleeve gastrectomy.

In the patient with history of cardiac diseases or if the ECG shows abnormalities and in all patients with a BMI of 50 or more, a transthoracic echocardiography must be done [30].

4.4.1 Preoperative Blood Tests

Routine preoperative blood work consisting of electrolyte, renal function, complete blood count, and coagulation studies has been repeatedly shown to have a low incidence of abnormal results (0.3–6.5%, pooled results from various studies) with an even lower proportion of these results leading to an alteration in patient management (0–2.6%) [31]. Although it does seem reasonable to continue to routinely gather information on electrolyte levels, renal function, and complete blood counts, many of these patients are taking diuretics or other medications, and the operative procedure can infrequently be associated with significant postoperative bleeding. Coagulation studies, however, are likely not indicated unless a history of bleeding tendencies is elicited from the patient. These are the minimum blood tests that the patient must have for the surgery.

Patients living with obesity have a high prevalence of micronutrient deficiencies compared with healthy weight individuals of the same sex and age. Micronutrient-related abnormalities have been reported in the obese population prior to undergoing bariatric surgery [32–37]. These abnormalities are important to detect before surgery because they can worsen postsurgery as a result of a reduction in food intake

Table 4.1 Pre BS nutrient screening recommendation

Nutrient	Pre BS nutrient screening recommendation
Thiamin	Routine pre BS screening is recommended for all patients (GRADE D)
Vitamin B12 (cobalamin)	Routine pre BS screening of B12 is recommended for all patients (GRADE B) Serum MMA is the recommended assay for B12 evaluation for symptomatic or asymptomatic patients and in those with history of B12 deficiency or preexisting neuropathy (GRADE B)
Folate (folic acid)	Routine pre BS screening is recommended for all patients (GRADE B)
Iron	Routine pre BS screening is recommended for all patients (GRADE B). Screening may include ferritin levels. A combination of test (serum iron with serum transferrin saturation and total iron-binding capacity) is recommended for diagnosis of iron deficiency (GRADE B)
Vitamin D and calcium	Routine pre BS screening is recommended for all patients (GRADE A). Particularly important for pre- and postmenopausal women (GRADE D)
Zinc	Routine pre BS screening is recommended ONLY before RYGB or BPD (GRADE D)
Copper	Routine pre BS screening is recommended ONLY before RYGB or BPD (GRADE D)
Fat-soluble vitamins (A,E,K)	Routine pre BS screening is recommended for all patients (GRADE C)

and food quality, altered digestion and/or absorption, and nonadherence to diet regimens and recommended supplementation.

Optimizing postoperative patient outcomes and nutritional status begins preoperatively. Even though surgery can exacerbate preexisting nutrient deficiencies, preoperative screening for vitamin deficiencies has not been the norm for the majority of WLS practices. In 2008, the ASMBS Nutrition Committee published the Allied Health Nutritional Guidelines for the Surgical Weight Loss Patient [38]. In 2017 they published an update on Micronutrients [39]. The recommendations were formulated following grading strategy with strongest to weakest levels noted as A through D (Table 4.1).

4.4.2 Other Vitamins

It is considered dosed vitamins B2 (riboflavin), B3 (niacin), B5 (pantothenic acid), B7 (biotin), and C only in patients who will be a malabsorptive procedure, based on symptoms and risks.

Trace minerals and electrolytes: There are limited investigations regarding the needs of minerals such as selenium, chromium, manganese, sulfur, boron, iodine, and fluoride in the bariatric population, but patients may develop postoperative deficiencies. There is little documentation available in the literature on electrolyte deficiencies such as potassium, magnesium, sodium, and chloride after bariatric surgery.

Sleeve preoperative evaluation

- Blood test.
- Chest X-ray.
- ECG and cardiovascular evaluation.
- Esofagogastroduodenoscopy with gastric biopsy for HP.
- Abdominal ultrasound.
- Spirometry.
- Anesthesiologic evaluation.

4.4.3 Medical Evaluation of Comorbidities

All patients who will undergo SG should have an evaluation of the diseases related to obesity. The evaluation will include a complete medical history, psychosocial history, physical examination, and laboratory studies. It is useful to perform a detailed review by systems for the identification of undiagnosed symptoms and diseases associated with obesity.

4.5 Endocrine Evaluation

Patients at risk or suspected of primary hypothyroidism should have a screening with TSH. The screening of rare causes of obesity is indicated according to the clinical history and the physical examination of the patient. There is insufficient data to request preoperative assessment of bone mineral density by DEXA1 outside of the formal recommendation of the clinical practice guidelines of the National Osteoporosis Foundation (Grade D).

4.5.1 Evaluation and Control of the Patient with Diabetes

A complete medical evaluation should be performed to evaluate the type of diabetes, glycemic control, micro- and macrovascular complications, and other associated risk factors.

It should be considered:

- Age and characteristics of the diabetes debut.
- Review history of the disease and previous treatments.
- Review episodes of acute complications (ketoacidosis, hyperosmolar coma, hypoglycemia) and chronic complications related to diabetes.
- Current treatment: pharmacological of glycemia and comorbidities (hypertension, dyslipidemia, etc.) adherence to hygienic-dietetic measures, and self-monitoring results.

- Complete physical examination: Laboratory evaluation including: glycemia, HbA1C, C-peptide, lipid profile, hepatogram, albumin/creatinine in isolated sample of urine, serum creatinine, MDRD, and antibodies to discard LADA.

4.5.2 Gynecological Evaluation

Request β subunit in women in reproductive age. Counseling should be advised about the contraceptive choice after surgery and avoid pregnancy in the preoperative period and for 12–18 months in the postoperative period [40]. Women with infertility should be warned that this situation could improve in the postoperative period. Estrogen therapy must be discontinued before surgery (1 cycle of oral contraceptives in premenopausal women, 3 weeks of hormone replacement in postmenopausal women) to reduce the risk of thromboembolic phenomena in the postoperative period.

4.5.3 Cancer

All patients must have an appropriate screening for cancer, according to age and risk before surgery.

4.6 Preoperative Medical Preparation

A systematic team approach seems important in order to improve perioperative quality of care. Clinical care pathways (CPs) are increasingly used to face this challenge. CPs are tools that integrate evidence-based healthcare into clinical practice.

What constitutes a CP? Five criteria have been suggested [41]:

1. Is a multidisciplinary plan of care
2. Translates guidelines or evidence into local structures
3. Uses a plan, pathway, algorithm, guideline, protocol, or other inventory of actions
4. Has timeframes or criteria-based progression
5. Standardizes care for a specific clinical problem or procedure of healthcare in a specific population

Pathways are intended to improve healthcare delivery and quality, while minimizing healthcare costs. The end goal of a clinical care pathway is to provide evidence-based guidelines for routine patient care. CPs also provide a structure for patient care in situations that require different routes of usual treatment [42].

The literature currently recognizes the value of clinical care strategies in bariatric surgery, demonstrating that the implementation of good clinical practices in this field reduces the cost and length of hospital stay and perioperative complications [43–46].

A study identified considerable variations in CPs across practicing bariatric surgeons, and of 11 preoperative variables studied (duration of preoperative liquid diet, endoscopy, obstructive sleep apnea evaluation, bowel preparation, *H. pylori* testing, mandatory preoperative weight loss, cardiac evaluation, chest X-ray, nutritional evaluation, psychological evaluation, DVT screening), only 2 were concordant among CP [47]:

– Preoperative Nutritional Evaluation
– Preoperative Psychological Evaluation

4.6.1 Care Pathway for Laparoscopic Sleeve Gastrectomy

ASMBS developed an evidence-based national care pathway for sleeve gastrectomy. A task force from the QIPS (Quality Improvement and Patient Safety) committee was selected to carry out this project. The product that ensues reflects the output of this effort and represents the coalescing of over 150 manuscripts and expert consensus. The committee utilized a consensus process when there was a lack of supporting evidence. There are some recommendations based on consensus due to limited evidence. The recommendations are categorized as follows:

- Routine: indicates that the committee has confidence the evidence-based literature supports routine ordering of designated diagnostic studies, tests, and evaluations.
- Selective: indicated for patients with designated criteria to support additional practice, procedure, study, test or evaluation.
- Not recommended: practices, procedures, studies, tests, and/or evaluations that should not be routinely conducted, but may be appropriate on a case-by-case basis.

As a result, in 2017, "American Society for Metabolic and Bariatric Surgery: care pathway for laparoscopic sleeve gastrectomy" was published. Table 4.2 summarizes the preoperative recommendations for the sleeve gastrectomy care pathway from ASMBS [42]. The entire pathway, with details and rationalizations of recommendations, is available online at www.asmbs.org, in the members-only section.

4.6.2 Weight Loss Before Sleeve Gastrectomy

As we can see, ASMBS "not routinely recommended" mandatory weight loss.

We treat patients, not diseases. So, why would all obese patients who are candidates for bariatric surgery need the same time to be prepared for surgery? The effectiveness

Table 4.2 Preoperative care pathway

	Routine	Selective	Not routinely recommended
Lab work	Complete blood count Basic metabolic panel Liver function tests Albumin Glycosylated hemoglobin Coagulation profile Thyroid-stimulating hormone Vitamin D Micronutrients Urinalysis Urine pregnancy (female patents)	Vitamin B1 Vitamin B12 Helicobacter pylori Urine toxicology screen Urine nicotine	
Consultations	Nutrition Psychological evaluation	Anesthesia Cardiology Endocrinology Gastroenterology Hematology Infectious disease Nephrology Neurology Orthopedics Pain management Pulmonary Pharmacy Rheumatology Sleep medicine Urology	
Testing	Chest X-ray Electrocardiography (ECG)	Endoscopy Upper gastrointestinal series pH/esophageal manometry Dexa scan Sleep study Colonoscopy Mammography Ultrasound Gastric-emptying study	
Screening	Sleep apnea Functional status Smoking Substance abuse	Malignancy	
Preoperative preparation	Liquid diet (2–4 weeks)	Smoking cessation/ duration	Mandatory weight loss Bowel preparation Routine IVF tiller

IVF intravenous fluid

of the 6–12-month medically supervised weight loss program required by a lot of healthcare insurance companies remains controversial.

In a retrospective study in 109 patients undergoing sleeve gastrectomy from 2014 to 2015, Yin shows that during the preoperative period, 72.2% of patients achieved a net weight loss, but 34.6% had gained net weight until they started the preoperative "liver-shrinking" diet; 71.4% of the total preoperative weight loss occurred after initiating the preoperative diet, which accounted for approximately 15% of the whole preoperative period length. The interesting conclusions of the study are what we see in daily practice [48]:

- Patients with a higher percent preoperative weight loss had a *shorter* preoperative period.
- Most of the preoperative weight loss occurs *after* patients are prescribed a preoperative liver reduction diet.
- Before starting the preoperative diet, patients first lose weight and then gain weight back.

Shorter preoperative periods and earlier initiation of liver reduction diets may increase postoperative weight loss, although ultimately there may be a limit to the weight loss that patients can achieve while adhering to highly restrictive lifestyle modifications.

The most risky is not the type of surgery, but the severity of the disease and its comorbidities. Obesity increases the likelihood of complications during surgery and reduces the physiologic reserve to withstand general anesthesia and surgical stress. Fatty enlarged livers, thickened body walls, and increased intra-abdominal adiposity make even routine surgery a challenge. Excess body fat often complicates the technical aspects of surgery and can lead to longer procedure times, deviation from usual approaches and, ultimately, to poor results [49–51].

Clearly weight loss is beneficial for risk reduction prior to surgery in subjects with severe obesity.

The physiologic improvements that result from even modest weight loss have been well documented. Weight loss as modest as 10% of excess has been shown to improve obstructive sleep apnea, cardiovascular risk, inflammation, thromboembolic risk, and serum glucose concentration [52–54]. Prebariatric surgery weight loss has been associated with fewer perioperative complications, shorter operative time, less blood loss, and shorter hospital stays [55].

But not for the postoperative weight loss, most studies find that weight change during the preoperative period negligibly affects postoperative weight [56–60].

A statement was released in 2011 by the American Society of Metabolic and Bariatric Surgery (ASMBS) scientific consensus, namely, that no medical evidence supports current preoperative diet requirements [61]. The summary and recommendations from that statement concluded that there were no evidence-based reports that documented any benefit or need for a 3–18-month insurance-mandated preoperative dietary weight loss program before bariatric surgery.

In 2016 an updated position statement by ASMBS was published that concluded with these recommendations [62]:

1. There are no data from any randomized controlled trial, large prospective study, or meta-analysis to support the practice of insurance mandated preoperative weight loss. The discriminatory, arbitrary, and scientifically unfounded practice of insurance-mandated preoperative weight loss contributes to patient attrition, causes delay of life-saving treatment, leads to the progression of comorbid conditions, and should be abandoned.
2. There is no Level I data that has clearly identified any dietary regimen, duration, or type of weight loss program that is optimal for patients with clinically severe obesity.
3. Patients seeking surgical treatment for clinically severe obesity should be evaluated based on their initial BMI and comorbid conditions. The provider is best able to determine what constitutes failed weight loss efforts for their patient.

A recent published longitudinal study of 76,704 obese men and 99,791 obese women from the United Kingdom's Clinical Practice Research Datalink, followed for up to 9 years (and excluding patients who had undergone bariatric surgery), found that the annual probability of attaining normal weight was 1 in 1290 for men and 1 in 677 for women with morbid obesity. Patients seeking surgical treatment for clinically severe obesity should therefore be evaluated for eligibility based on their initial presenting BMI and not be penalized or denied care for weight lost as part of insurance-mandated preoperative weight loss [63].

The outcome of insurance-mandated preoperative weight loss requirements is patient attrition, delay in obesity treatment, progression of obesity and associated life-threatening comorbid conditions, and increased direct and indirect healthcare costs [64–67].

Modest weight loss has been shown to improve the health and wellbeing for the severely obese. Performing surgery on this population has been long recognized to be made increasingly risky by the physiologic and anatomic derangements associated with severe obesity.

Preoperative weight loss has now been shown to be achievable and beneficial, because patients who have lost weight prior to surgery are likely to suffer from fewer complications, shorter operating time, less blood loss, and a shorter hospital stay. Given all of these benefits, is it now time to suggest that preoperative weight loss be a component of the preoperative preparation process? Weight loss is important before sleeve gastrectomy, but not mandatory insurance weight loss, and not with a long nor fixed period of time.

The indication of preoperative weight loss is recommended, although the most appropriate diet and duration is still a matter of controversy, so it is the treating team who should evaluate and establish the indication in each patient individually. Although the available evidence does not allow defining a value for presurgical weight loss, it would be advisable to decrease at least 8% of the initial weight [68, 69]. In cases of very severe central obesity and superobesity, the need for a greater weight reduction prior to surgery should be evaluated.

4.7 Conclusions

Bariatric surgery is an established and integral part of the comprehensive management of a morbidly obese patient. It has been shown to be safe and remains the most effective and durable treatment for clinically severe obesity with a documented reduction in all-cause mortality and long-term survival benefit.

The selection, evaluation, and careful preparation of the patient is essential for the success of the surgical treatment of obesity. All patients who will undergo sleeve gastrectomy should have an evaluation of obesity and its related diseases. The evaluation will include a complete medical history, psychosocial history, physical examination, laboratory studies, and complementary exams. The preparation should include the improvement of obesity and its comorbidities and should be carried out by a multidisciplinary team of providers with experience with active inclusion and patient participation.

References

1. Collazo-Clavell M, Clark M, McAlpine D, et al. Assessment and preparation of patients for bariatric surgery. Mayo Clin Proc. 2006;81:S11–7.
2. Mechanick JI, Youdim A, Jones D, et al. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient—2013 update: cosponsored by American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery. Surg Obes Relat Dis. 2013;9:159–91.
3. SAGES Guidelines Committee. Guidelines for clinical application of laparoscopic bariatric surgery. Surg Endosc. 2008;22(10):2281–300.
4. Dakour-Aridi HN, El-Rayess HM, Abou-Abbass H, Abu-Gheida I, Habib RH, Safadi BY. Safety of concomitant cholecystectomy at the time of laparoscopic sleeve gastrectomy: analysis of the American College of Surgeons National Surgical Quality Improvement Program database. Surg Obes Relat Dis. 2017;13(6):934–41.
5. Jaser N, Mustonen H, Pietila J, et al. Preoperative transabdominal ultrasonography (US) prior to laparoscopic Roux-en-Y gastric bypass (LRYGBP) and laparoscopic sleeve gastrectomy (LSG) in the first 100 operations. Was it beneficial and reliable during the learning curve? Obes Surg. 2012;22(3):416–21.
6. Almazeedi S, Al-Sabah S, Alshammari D. Routine trans-abdominal ultrasonography before laparoscopic sleeve gastrectomy: the findings. Obes Surg. 2013;24(3):397–9. https://doi.org/10.1007/s11695-013-1092-y.
7. Peterson G, Domino K, Caplan RA, Posner KL, Lee LA, et al. Management of the difficult airway: a closed claims analysis. Anesthesiology. 2005;103:33–9.
8. Mechanick JI, Youdim A, Jones DB, et al. Bariatric surgery clinical practice guidelines. Endocr Pract. 2013;19:337–72.
9. Telem DA, Jones DB, Schauer PR, Brethauer SA, Rosenthal RJ, Provost D, Jones SB. Updated panel report: best practices for the surgical treatment of obesity. Surg Endosc. 2018;32:4158.
10. Cawley J, Sweeney MJ, Kurian M, Beane S. Predicting complications after bariatric surgery using obesity-related co-morbidities. Obes Surg. 2007;17(11):1451–6.
11. Shearer E, Magee CJ, Lacasia C, Raw D, Kerrigan D. Obstructive sleep apnea can be safely managed in a level 2 critical care setting after laparoscopic bariatric surgery. Surg Obes Relat Dis. 2013;9(6):845–9.

12. El SM, Topfer LA, Stafinski T, Pawluk L, Menon D. Diagnostic accuracy of level 3 portable sleep tests versus level 1 polysomnography for sleep-disordered breathing: a systematic review and meta-analysis. CMAJ. 2014;186(1):E25–51.
13. Chesson AL Jr, Berry RB, Pack A. Practice parameters for the use of portable monitoring devices in the investigation of suspected obstructive sleep apnea in adults. Sleep. 2003;7:907–13.
14. Chung F, Yang Y, Liao P. Predictive performance of the STOP-bang score for identifying obstructive sleep apnea in obese patients. Obes Surg. 2013;23(12):2050–7.
15. Menon S, Trudgill N. Risk factors in the aetiology of hiatus hernia: a meta-analysis. Eur J Gastroenterol Hepatol. 2011;23(2):133–8.
16. Daes J, Jimenez ME, Said N, Daza JC, Dennis R. Laparoscopic sleeve gastrectomy: symptoms of gastroesophageal reflux can be reduced by changes in surgical technique. Obes Surg. 2012;22(12):1874–9.
17. Praveenraj P, Gomes RM, Kumar S, et al. Diagnostic yield and clinical implications of preoperative upper gastrointestinal endoscopy in morbidly obese patients undergoing bariatric surgery. J Laparoendosc Adv Surg Tech A. 2015;25(6):465–9.
18. Korenkov M, Sauerland S, Shah S, Junginger T. Is routine preoperative upper endoscopy in gastric banding patients really necessary? Obes Surg. 2006;16(1):45–7.
19. Sharaf RN, Weinshel EH, Bini EJ, Rosenberg J, Ren CJ. Radiologic assessment of the upper gastrointestinal tract: does it play an important preoperative role in bariatric surgery? Obes Surg. 2004;14(3):313–7.
20. Goitein D, Sakran N, Rayman S, Szold A, Goitein O, Raziel A. Barium swallow for hiatal hernia detection is unnecessary prior to primary sleeve gastrectomy. Surg Obes Relat Dis. 2017;13(2):138–42.
21. ASGE Standards of Practice Committee, Anderson M, Gan S, et al. Role of endoscopy in the bariatric surgery patient. Gastrointest Endosc. 2008;68:1–10.
22. ASGE Standards of Practice Committee, Evans J, Muthusamy R, et al. The role of endoscopy in the bariatric surgery patient. Gastrointest Endosc. 2015;29:1007–17.
23. Mechanick JI, Youdim A, Jones DB, et al. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient—2013 update: cosponsored by American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery. Obesity (Silver Spring, Md). 2013;21(Suppl 1):S1–27.
24. Shanti H, Almajali N, Al-Shamaileh T, et al. Helicobacter pylori does not affect postoperative outcomes after sleeve gastrectomy. Obes Surg. 2017;27(5):1298–301.
25. Brownlee AR, Bromber E, Roslin MS. Outcomes in patients with helicobacter pylori undergoing laparoscopic sleeve gastrectomy. Obes Surg. 2015;25(12):2276–9.
26. Patel SK, Pratap CB, Jain AK, et al. Diagnosis of helicobacter pylori: what should be the gold standard? World J Gastroenterol. 2014;20(36):12847–59.
27. Wang YK, Kuo FC, Liu CJ, et al. Diagnosis of helicobacter pylori infection: current options and developments. World J Gastroenterol. 2015;21(40):11221–35.
28. Mocanu V, Dang JT, Switzer N, Skubleny D, Shi X, de Gara C, Karmali S. The effect of helicobacter pylori on postoperative outcomes in patients undergoing bariatric surgery: a systematic review and meta-analysis. Obes Surg. 2017;28(2):567–73.
29. Mokdad AH, Marks JS, Stroup DF, et al. Actual causes of death in the United States, 2000. JAMA. 2004;291:1238–45.
30. Catheline J-M, Bihan H, Le Quang T, Sadoun D, Charniot J-C, Onnen I, Cohen R. Preoperative cardiac and pulmonary assessment in bariatric surgery. Obes Surg. 2008;18(3):271–7. https://doi.org/10.1007/s11695-007-9329-2.
31. Smetana GW, Macpherson DS. The case against routine preoperative laboratory testing. Med Clin North Am. 2003;87:7–40.
32. Damms-Machado A, Friedrich A, Kramer KM, et al. Pre- and post- operative nutritional deficiencies in obese patients undergoing laparoscopic sleeve gastrectomy. Obes Surg. 2012;22:881–9.

33. Ernst B, Thumbeer M, Sharma AM, et al. Evidence for the necessity to systematically assess micronutrient status prior to bariatric surgery. Obes Surg. 2009;19:66–73.
34. Kaidar-Person O, Person B, Szomstein S, et al. Nutritional deficiencies in morbidly obese patients: a new form of malnutrition? Part A: vitamins. Obes Surg. 2008;18:870–6.
35. Kaidar-Person O, Person B, Szomstein S, et al. Nutritional deficiencies in morbidly obese patients: a new form of malnutrition? Part B: minerals. Obes Surg. 2008;18:1028–34.
36. Schweiger C, Weiss R, Berry E, et al. Nutritional deficiencies in bariatric surgery candidates. Obes Surg. 2010;20:193–7.
37. Lefebvre P, Letois F, Sultan A, et al. Nutrient deficiencies in patient with obesity considering bariatric surgery: a cross-sectional study. SOARD. 2014;10:540–6.
38. Allied Health Sciences Section Ad Hoc Nutrition Committee, Aills L, Blankenship J, Buffington C, Furtado M, Parrott J. ASMBS allied health nutritional guidelines for the surgical weight loss patient. Surg Obes Relat Dis. 2008;4(5 Suppl):S73–108.
39. Parrott J, Frank L, Rabena R, Craggs-Dino L, Isom KA, Greiman L. American Society for Metabolic and Bariatric Surgery integrated health nutritional guidelines for the surgical weight loss patient 2016 update: micronutrients. Surg Obes Relat Dis. 2017;13(5):727–41.
40. Fried M, Yumuk V, Oppert J.M, Scopinaro N, Torres A, et al. on behalf of International federation for the Surgery of Obesity and Metabolic Disorders- European Chapter (IFSO-EC) and European Association for the Study of Obesity (EASO) Interdisciplinary European guidelines on metabolic and bariatric surgery. Obes Surg. 2014;24:42–55.
41. Kinsman L, Rotter T, James E, et al. What is a clinical pathway? Development of a definition to inform the debate. BMC Med. 2010;8:31.
42. Telem DA, Gould J, Pesta C, Powers K, Majid S, Greenberg JA, Teixeira A, Brounts L, Lin H, DeMaria E, Rosenthal R. American Society for Metabolic and Bariatric Surgery: care pathway for laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2017;13:742–9.
43. Campillo-Soto A, Martín-Lorenzo JG, Lirón-Ruíz R, et al. Evaluation of the clinical pathway for laparoscopic bariatric surgery. Obes Surg. 2008;18(4):395–400.
44. Huerta S, Heber D, Sawicki MP, et al. Reduced length of stay by implementation of a clinical pathway for bariatric surgery in an academic health care center. Am Surg. 2001;67(12):1128–35.
45. Yeats M, Wedergren S, Fox N, Thompson JS. The use and modification of clinical pathways to achieve specific outcomes in bariatric surgery. Am Surg. 2005;71(2):152–4.
46. Ronellenfitsch U, Schwarzbach M, Kring A, Kienle P, Post S, Hasenberg T. The effect of clinical pathways for bariatric surgery on perioperative quality of care. Obes Surg. 2012;22(5):732–9.
47. Telem DA, Majid SF, Powers K, DeMaria E, Morton J, Jones DB. Assessing national provision of care: variability in bariatric clinical care pathways. Surg Obes Relat Dis. 2017;13(2):281–4.
48. Ying LD, et al. Impact of preoperative wait time due to insurance-mandated medically supervised diets on weight loss after sleeve gastrectomy. Are patients losing momentum? Surg Obes Relat Dis. 2017;13(9):1584–9.
49. Namba RS, Paxton L, Fithian DC, Stone ML. Obesity and perioperative morbidity in total hip and total knee arthroplasty patients. J Arthroplast. 2005;20(7 Suppl 3):46–50.
50. Raftopoulos I, Courcoulas AP. Outcome of laparoscopic ventral hernia repair in morbidly obese patients with a body mass index exceeding 35 kg/m2. Surg Endosc. 2007;21:2293–7.
51. Schwartz ML, Drew RL, Chazin-Caldie M. Factors determining conversion from laparoscopic to open Roux-en-Y gastric bypass. Obes Surg. 2004;14:1193–7.
52. Anderson JW, Brinkman-Kaplan VL, Lee H, Wood CL. Relation- ship of weight loss to cardiovascular risk factors in morbidly obese individuals. J Am Coll Nutr. 1994;13:256–61.
53. Festa A, D'Agostino R Jr, Williams K, Karter AJ, Mayer-Davis EJ, Tracy RP, et al. The relation of body fat mass and distribution to markers of chronic inflammation. Int J Obes. 2001;25:1407–15.
54. Batist G, Bothe A Jr, Bern M, Bistrian BR, Blackburn GL. Low antithrombin III in morbid obesity: return to normal with weight reduction. JPEN. 1983;7:447–9.
55. Tarnoff M, Kaplan LM, Shikora S. An evidenced-based assessment of preoperative weight loss in bariatric surgery. Obes Surg. 2008;18(9):1059–61.

56. Alami RS, Morton JM, Schuster R, et al. Is there a benefit to preoperative weight loss in gastric bypass patients? A prospective randomized trial. Surg Obes Relat Dis. 2007;3(2):141–5; discussion5–6
57. Cayci HM, Erdogdu UE, Karaman K, Budak E, Taymur I, Buyukuysal C. Does weight gain during the operation wait time have an impact on weight loss after laparoscopic sleeve gastrectomy? Obes Surg. 2016;27(2):338–42.
58. Eisenberg D, Duffy AJ, Bell RL. Does preoperative weight change predict postoperative weight loss after laparoscopic Roux-en-Y gastric bypass in the short term? J Obes. 2010; https://doi.org/10.1155/2010/907097.
59. Still CD, Benotti P, Wood GC, et al. Outcomes of preoperative weight loss in high-risk patients undergo in gastric by pass surgery. Arch Surg. 2007;142(10):994–8; discussion 9
60. Diamant A, Cleghorn MC, Milner J, et al. Patient and operational factors affecting wait times in a bariatric surgery program in Toronto: a retrospective cohort study. CMAJ Open. 2015;3(3):E331–7.
61. Brethauer S. ASMBS position statement on preoperative supervised weight loss requirements. Surg Obes Relat Dis. 2011;7(3):257–60.
62. Kim JJ, Rogers AM, Ballem N, Schirmer B, on behalf of the American Society for Metabolic and Bariatric Surgery Clinical Issues Committee. ASMBS Guidelines/Statements ASMBS updated position statement on insurance mandated preoperative weight loss requirements. Surg Obes Relat Dis. 2016;12:955–9.
63. Fildes A, Charlton J, Rudisill C, Littlejohns P, Prevost AT, Gulliford MC. Probability of an obese person attaining normal body weight: cohort study using electronic health records. Am J Public Health. 2015;105(9):e54–9.
64. Jamal MK, DeMaria EJ, Johnson JM, et al. Insurance-mandated preoperative dietary counseling does not improve outcome and increases dropout rates in patients considering gastric bypass surgery for morbid obesity. Surg Obes Relat Dis. 2006;2(2):122–7.
65. Kuwada TS, Richardson S, ElChaar M, et al. Insurance-mandated medical programs before bariatric surgery: do good things come to those whowait? Surg Obes Relat Dis. 2011;7(4):526–30.
66. Al Harakeh AB, Burkhamer KJ, Kallies KJ, Mathiason MA, Kothari SN. Natural history and metabolic consequences of morbid obesity for patients denied coverage for bariatric surgery. Surg Obes Relat Dis. 2010;6(6):591–6.
67. Jurowich C, Thalheimer A, Hartmann D, et al. Improvement of type2 diabetes mellitus (T2DM) after bariatric surgery who fails in the early postoperative course? Obes Surg. 2012;22(10):1521–6.
68. Mechanick J, Youdim A, Jones D, Garvey WT, Hurvey D, et al. AACE/TOS/ASMBS guidelines clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient 2013 update: cosponsored by American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery. Surg Obes Relat Dis. 2013;9:159–91.
69. Huerta S, Dredar S, Hayden E, Siddiqui A, Anthony T, et al. Preoperative weight loss decreases the operative time of gastric bypass at a veterans administration hospital. Obes Surg. 2008;18:508–12.

Chapter 5
Thrombo-Prophylaxis and Avoidance of Portal Vein Thrombosis

Felipe Muñoz and Alex Escalona

5.1 Introduction

Deep venous thrombosis (DVT) and pulmonary thromboembolism (PTE) are known and severe postoperative complications. These complications may develop after any surgical procedure. DVT and PET are specifically important in bariatric surgery because obesity is one of the risk factors for the development of DVT-PTE and are the major causes of morbidity and mortality up to 1 year after bariatric surgery. Indeed, the presence of pulmonary embolism within 30 days after bariatric surgery is a risk factor for 1-year mortality [1]. In spite of all the effort to prevent these complications, postoperative DVT and PE incidence may be as high as 3% and 2% in bariatric patients respectively. A recent analysis of 130,007 patients showed a 4.4% of readmission within 30 days after laparoscopic adjustable gastric banding (LAGB), laparoscopic sleeve gastrectomy (LSG), and Roux-en-Y gastric bypass (RYGB), and 3.4% of them were due to vein thrombosis requiring therapy [2].

Portomesenteric venous thrombosis (PVT) is a rare and potentially life-threatening medical condition with a nonspecific clinical presentation. Portal vein thrombosis has been described in liver cirrhosis, hypercoagulability states, neoplasms, intraabdominal sepsis, pancreatitis, and postsurgical procedures. Mesenteric vein thrombosis has been reported after liver transplantation, splenectomy, and other surgical procedures including bariatric surgery [3–6]. Different to DVT and PE, their risk factors, clinical presentation, treatment, and outcomes are still not completely understood [7].

F. Muñoz
Hospital Dr. Gustavo Fricke, Universidad de Valparaíso, Viña del Mar, Chile

A. Escalona (✉)
Department of Surgery, Faculty of Medicine, Universidad de los Andes, Santiago, Chile
e-mail: aescalona@clinicauandes.cl

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_5

Early diagnosis and management are critically important to prevent acute or chronic complications such as mesenteric ischemia with bowel infarction and sepsis, chronic cavernous transformation, and portal hypertension. PVT is not uncommon after bariatric surgery, specially following laparoscopic sleeve gastrectomy, representing in some series the most important postoperative complication [8]. In this chapter we will review the incidence of these conditions, risk factors, clinical presentation, diagnosis, treatment, and preventive strategies based on current evidence.

5.2 Etiology and Risk Factors

According to Virchow's triad, there are three factors contributing to the formation of thrombus: circulatory stasis, endothelial wall injury, and hypercoagulable state. Bariatric patients have at least a moderate risk of DVT and PE based on different risk scores [9]. These risk factors are associated with the condition of obesity, the surgical procedure, trauma, and immobilization with the different conditions of hypercoagulability. In patients with PVT after bariatric surgery, a hypercoagulable state is found in 42% [10], being the most common prothrombin 20,210 (heterozygote) in 10%, protein C deficiency (10%), and protein S deficiency (8.1%).

The incidence of PVT after LSG is higher compared to other surgical procedures such as RYGB, LAGB, or biliopancreatic diversion. Two retrospective studies evaluated the incidence of PVT after different bariatric procedures showing no events following RYGB and biliopancreatic diversion, one case after LAGB and 0.37% and 0.55% following LSG [11, 12].

There are several factors that may explain the occurrence of PVT after bariatric surgery; obesity, pneumoperitoneum, surgical trauma, liver retraction, etc. However, most of these conditions are similar in different surgical procedures and the incidence of PVT is higher in LSG compared to the other procedures. It means that the higher incidence of PVT after LSG should be explained for technical, anatomical, or physiological differences specific of LSG not present in other procedures. There are some factors that may explain the higher occurrence of PVT after LSG. These factors may be related to the use of energy devices close to the splenic vein, change on venous circulation after the surgical section of short vessels, and the inflammatory process secondary to the gastric section and stapler use or other foreign bodies in the gastric wall.

5.3 Clinical Presentation

Patients with DVT may present painful lower-extremity swelling, warmth to touch and tenderness. Dyspnea is the most common symptom of PE sometimes with pleuritic chest pain, cough, or hemoptysis. Cases of massive PE may present with syncope or cardiorespiratory arrest.

Portomesenteric venous thrombosis may be asymptomatic and diagnosed as incidental finding, may present as an unspecified abdominal pain or may be a life-threatening condition depending on the extension of the thrombosis and the number of compromised vessels. In patients with PVT after sleeve gastrectomy, the most common symptoms are abdominal pain in 83%, nausea and vomiting in 38%, and fever in 13% of the cases. Most of the cases (90%) are diagnosed during the first 30 days after the surgery [10, 13]. It highlights the importance of a high grade of suspicious in patients with abdominal pain during the first month after bariatric surgery.

5.4 Diagnosis

DVT diagnosis is normally performed using risk stratification with the Wells score, D-dimer test, and duplex ultrasound. Symptoms and signs are poor independent predictors of PE and not sufficient for DVT diagnosis. Duplex ultrasound can evaluate the proximal veins with specificity of 94% and sensitivity of 90% [14] (Fig. 5.1). Venography has a lower false-positive rate but is less available and uncomfortable and presents a higher rate of complications making this alternative less recommended.

Diagnostic strategy for pulmonary thromboembolism includes the use of pretest probability assessment to optimize the need of imaging. Ventilation perfusion scanning and computed tomography angiography are the most validated imaging tests recommended in patient with moderate and high PE risk (Figs. 5.2 and 5.3).

The diagnosis of PVT is more challenging without evidence-based algorithm. Abdominal duplex ultrasound may directly evaluate portal and mesenteric vein

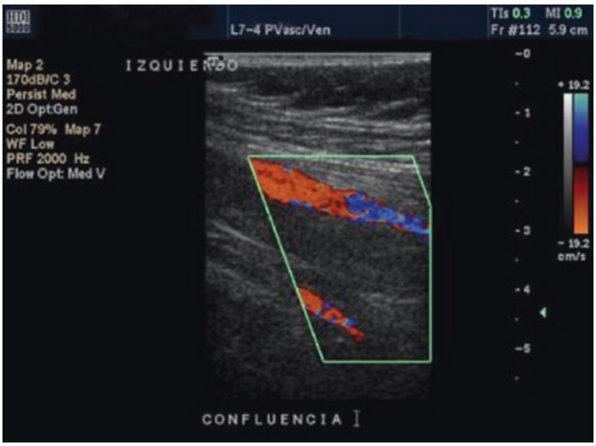


Fig. 5.1 Duplex ultrasound showing a thrombus in left femoral vein in a patient after laparoscopic RYGB

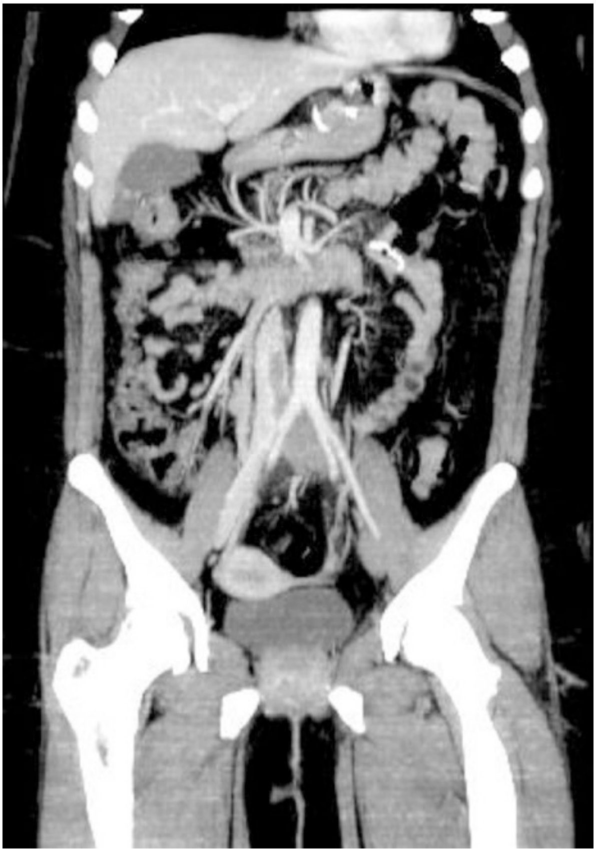


Fig. 5.2 Contrast-medium-enhanced coronal computed tomography of the abdomen shows an inferior vein cava and left iliac vein thrombus after laparoscopic RYGB

Fig. 5.3 Contrast-medium-enhanced axial computed tomography of the thorax shows a left pulmonary thrombus after laparoscopic RYGB

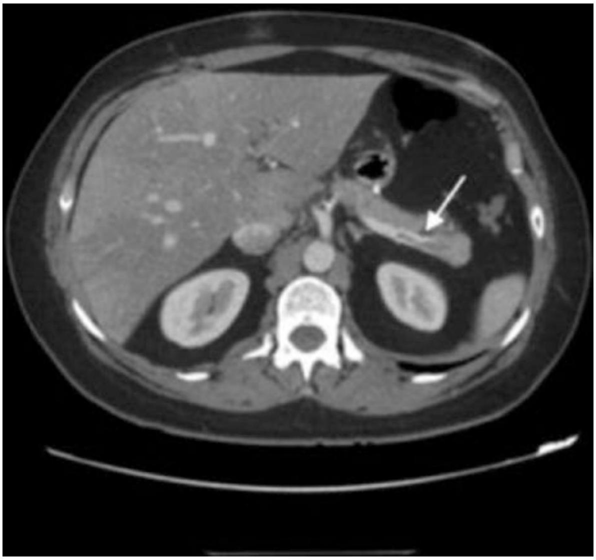


Fig. 5.4 Contrast-medium-enhanced axial computed tomography of the abdomen shows splenic vein thrombus after LSG

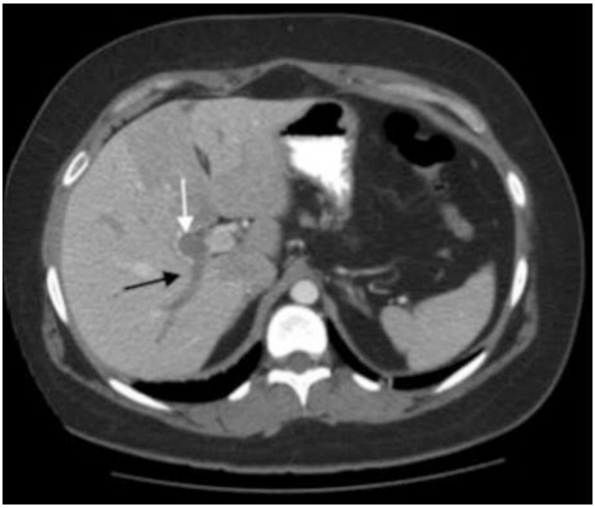


Fig. 5.5 Contrast-medium-enhanced axial computed tomography of the abdomen shows portal vein thrombus after LSG

patency to rule out thrombosis; however, its efficacy is operator dependent and in postoperative morbidly obese patients may have a reduced sensitivity and sensibility. Contrast-enhanced CT imaging is probably the most used, available, and recommended imaging test in obese patients together with magnetic resonance imaging (MRI) [15]. Both alternatives can confirm the diagnosis and show the localization and extension of the thrombosis, with the portal vein the most common location (41.5%), followed by mesenteric vein in 35.8% and splenic vein in 20.7% of the cases [10] (Figs. 5.4 and 5.5). CT and MRI may also be useful to evaluate acute or chronic ischemic bowel complications as well as to rule out other diagnosis.

5.5 Treatment

DVT and PE treatment depends on patient conditions, underlying etiology, risks for bleeding, and symptoms severity but usually consists of anticoagulation for a period of time depending on the etiology of the thrombosis and therefore on the risk of new episode [16]. Current alternatives for anticoagulation include heparin or low-molecular-weight heparin (LMWH) with transition to vitamin K antagonists, oral dabigatran, or edoxaban after 5 days of heparin or LMWH, oral apixaban, or rivaroxaban only (with loading doses) and LMWH treatment. Regarding duration of therapy, the efficacy of treatment in terms of morbidity and mortality must be weighed against the risk of bleeding. Different studies have demonstrated that short-term therapy, which means 6 weeks to 6 months, is better in terms of efficacy than an extended anticoagulation [17]. Thrombofilia should be evaluated after DVT, PE, or PVT, specially in patients with low risk to evaluate the need if long-term or life-long anticoagulation is required. Inferior cava vein filters, thrombolysis, and thrombectomy may play a limited role under specific conditions [18] (Fig. 5.6).

General management in patients with PVT follows more or less the same strategy than in patients with DVT or PE regarding anticoagulation therapy. In one of the largest systematic reviews published by Shoar et al., bowel resection was necessary in 20% of patients and splenectomy in 2% of cases. In the same study, the hospital stay ranged from 5 to 57 days, with 3.6% of mortality [10].

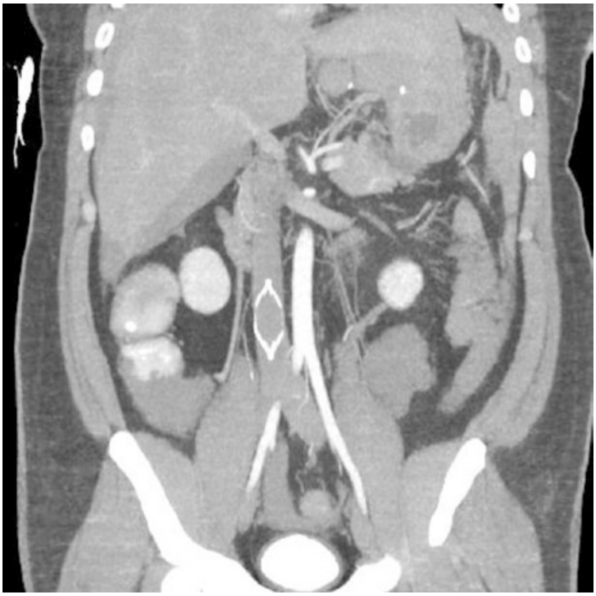


Fig. 5.6 Contrast-medium-enhanced coronal computed tomography of the abdomen shows an inferior vein cava filter in a patient with pulmonary embolism after and laparoscopic RYGB

5.6 Prevention

Obesity and general surgery are risk factors for venous thromboembolism, therefore, according to different risk scores, all patients undergoing bariatric surgery should be considered to be at least at moderate risk for DVT and PE [9, 19]. In patients with moderate risk of DVT and/or PE, pharmacologic prophylaxis is recommended in addition to sequential compression devices. Unfractionated heparin or low-molecular-weight heparin should be initiated immediately before the surgical procedure until the patient is fully mobile. Heparin administration immediately after the procedure may reduce the risk of bleeding. Preoperative placement of inferior vein cava (IVC) filters has been also considered for patients with previous DVT or PE. However, recent evidence using retrospective analysis suggests that IVC filters in high-risk patients does not reduce the incidence of postoperative PE, therefore, its use is still a matter of controversy [20].

In patients with advanced cirrhosis awaiting liver transplant and Child-Pugh score of 7–10, enoxaparin may prevent PVT. Similarly, a meta-analysis that evaluated 17 studies including 1497 patients showed that preventive anticoagulation after splenectomy because of liver cirrhosis reduces the frequency of PVT compared with no anticoagulant without serious adverse events [21].

Interestingly, in patient with sleeve gastrectomy, in most of the cases of PVT or MVT, the pharmacologic prophylaxis for DVT was inferior to 10 days [22]. It suggests that an extended use up to 4 weeks of pharmacologic prophylaxis may reduce the risk of PVT and/or MVT and has been considered as a recommendation at the expert level of evidence by different authors [22].

The effects of different bariatric procedures on drug pharmacology are still unknown. Bariatric surgery may change the pharmacokinetics of orally administered drugs by changes in gastric emptying, decrease in small intestine transit time, and reduced absorptive area [23, 24]. For this reason, there are authors that recommend unfractionated heparin or LMWH as pharmacologic prophylaxis when this is needed. A recent study analyzed pharmacokinetics of rivaroxaban 10 mg administered 1 day before and 3 days after LSG and RYGB [25]. The results of this study suggest that pharmacokinetics and pharmacodynamic effects of rivaroxaban are not significantly altered after RYGB or LSG and may be used as extended pharmacologic prophylaxis for DVT/PE and secondary also for PVT after LSG. Further research is needed to demonstrate its efficacy and evaluate an optimal pharmacologic alternative, doses, and duration of use.

5.7 Conclusions

Deep venous thrombosis and pulmonary embolism are major causes of morbidity and mortality up to 1 year after bariatric surgery. Portomesenteric vein thrombosis is a rare and potentially life-threatening postoperative complication in bariatric surgery more frequent after LSG than after other bariatric procedures. Extended postoperative pharmacologic prophylaxis reduces the incidence of DVT and PE, may also reduce the incidence of PVT, and should be considered in patients after LSG.

References

1. Inaba CS, Koh CY, Sujatha-Bhaskar S, et al. One-year mortality after contemporary laparoscopic bariatric surgery: an analysis of the bariatric outcomes longitudinal database. J Am Coll Surg. 2018;226:1166–74.
2. Berger ER, Huffman KM, Fraker T, et al. Prevalence and risk factors for bariatric surgery readmissions: findings from 130,007 admissions in the metabolic and bariatric surgery accreditation and quality improvement program. Ann Surg. 2018;267:122–31.
3. Stieber AC, Zetti G, Todo S, et al. The spectrum of portal vein thrombosis in liver transplantation. Ann Surg. 1991;213:199–206.
4. Swartz DE, Felix EL. Acute mesenteric venous thrombosis following laparoscopic Roux-en-Y gastric bypass. JSLS. 2004;8:165–9.
5. Bellanger DE, Hargroder AG, Greenway FL. Mesenteric venous thrombosis after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2010;6:109–11.
6. Hassn AM, Al-Fallouji MA, Ouf TI, Saad R. Portal vein thrombosis following splenectomy. Br J Surg. 2000;87:362–73.
7. James AW, Rabl C, Westphalen AC, Fogarty PF, Posselt AM, Campos GM. Portomesenteric venous thrombosis after laparoscopic surgery: a systematic literature review. Arch Surg. 2009;144:520–6.
8. Salinas J, Barros D, Salgado N, et al. Portomesenteric vein thrombosis after laparoscopic sleeve gastrectomy. Surg Endosc. 2014;28:1083–9.
9. Caprini JA. Thrombosis risk assessment as a guide to quality patient care. Dis Mon. 2005;51:70–8.
10. Shoar S, Saber AA, Rubenstein R, et al. Portomesentric and splenic vein thrombosis (PMSVT) after bariatric surgery: a systematic review of 110 patients. Surg Obes Relat Dis. 2018;14:47–59.
11. Rottenstreich A, Elazary R, Kalish Y. Abdominal thrombotic complications following bariatric surgery. Surg Obes Relat Dis. 2017;13:78–84.
12. Goitein D, Matter I, Raziel A, et al. Portomesenteric thrombosis following laparoscopic bariatric surgery: incidence, patterns of clinical presentation, and etiology in a bariatric patient population. JAMA Surg. 2013;148:340–6.
13. Moon RC, Ghanem M, Teixeira AF, et al. Assessing risk factors, presentation, and management of portomesenteric vein thrombosis after sleeve gastrectomy: a multicenter case-control study. Surg Obes Relat Dis. 2018;14:478–83.
14. Lim W, Le Gal G, Bates SM, et al. American Society of Hematology 2018 guidelines for management of venous thromboembolism: diagnosis of venous thromboembolism. Blood Adv. 2018;2:3226–56.
15. Bradbury MS, Kavanagh PV, Chen MY, Weber TM, Bechtold RE. Noninvasive assessment of portomesenteric venous thrombosis: current concepts and imaging strategies. J Comput Assist Tomogr. 2002;26:392–404.
16. Barritt DW, Jordan SC. Anticoagulant drugs in the treatment of pulmonary embolism. A controlled trial. Lancet. 1960;1:1309–12.
17. Prins MH, Hutten BA, Koopman MM, Buller HR. Long-term treatment of venous thromboembolic disease. Thromb Haemost. 1999;82:892–8.
18. Olaf M, Cooney R. Deep venous thrombosis. Emerg Med Clin North Am. 2017;35:743–70.

19. Geerts WH, Pineo GF, Heit JA, et al. Prevention of venous thromboembolism: the seventh ACCP conference on antithrombotic and thrombolytic therapy. Chest. 2004;126:338S–400S.
20. Haskins IN, Rivas L, Ju T, et al. The association of IVC filter placement with the incidence of postoperative pulmonary embolism following laparoscopic bariatric surgery: an analysis of the metabolic and bariatric surgery accreditation and quality improvement project. Surg Obes Relat Dis. 2019;15(1):109–15.
21. Zhang JY, Wang YB, Gong JP, Zhang F, Zhao Y. Postoperative anticoagulants in preventing portal vein thrombosis in patients undergoing splenectomy because of liver cirrhosis: a meta-analysis. Am Surg. 2016;82:1169–77.
22. Caruso F, Cesana G, Lomaglio L, et al. Is Portomesenteric vein thrombosis after laparoscopic sleeve gastrectomy related to short-course prophylaxis of thromboembolism? A monocentric retrospective analysis about an infrequent but not rare complication and review of the literature. J Laparoendosc Adv Surg Tech A. 2017;27:987–96.
23. Brocks DR, Ben-Eltriki M, Gabr RQ, Padwal RS. The effects of gastric bypass surgery on drug absorption and pharmacokinetics. Expert Opin Drug Metab Toxicol. 2012;8:1505–19.
24. Martin KA, Lee CR, Farrell TM, Moll S. Oral anticoagulant use after bariatric surgery: a literature review and clinical guidance. Am J Med. 2017;130:517–24.
25. Kubitza D, Becka M, Voith B, Zuehlsdorf M, Wensing G. Safety, pharmacodynamics, and pharmacokinetics of single doses of BAY 59-7939, an oral, direct factor Xa inhibitor. Clin Pharmacol Ther. 2005;78:412–21.

Chapter 6
How the Sleeve Gastrectomy Works: Metabolically

Vance L. Albaugh, Philip R. Schauer, and Ali Aminian

6.1 Introduction

Historically, sleeve gastrectomy (SG) was the first stage of a biliopancreatic diversion with duodenal switch (originally a two-staged procedure in high-risk operative patients). Many individuals experienced unexpected but excellent weight loss results with the SG alone, and consequently never underwent completion of the biliopancreatic diversion portion of the operation. Thus, SG as a primary procedure became an accepted bariatric operation for morbid obesity and has since become the most popular bariatric operation worldwide.

Similar to other bariatric operations (e.g., Roux-en-Y gastric bypass, duodenal switch), SG is associated with significant weight loss as well as resolution of other obesity-related medical conditions (e.g., type 2 diabetes). Even though the SG as a stand-alone operation was described in the early 2000s, our understanding of the mechanisms underlying its beneficial effects continues to evolve. Despite being a relatively straightforward operation, the mechanistic complexity driving the metabolic benefits of SG as well as other bariatric operations continues to be examined and appear far from straightforward. In the following we discuss the scientific basis of bariatric surgery and focus on preclinical and clinical studies examining the mechanisms of the SG as a metabolic and bariatric operation.

V. L. Albaugh (✉) · P. R. Schauer · A. Aminian
Bariatric and Metabolic Institute, Cleveland Clinic, Cleveland, OH, USA
e-mail: albaugv@ccf.org; schauep@ccf.org; aminiaa@ccf.org

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_6

6.2 How Does Bariatric Surgery Work?

Bariatric surgery dates to the mid-twentieth century [1] at a time when the fields of gastrointestinal physiology and endocrinology were in their infancy. Surgical operations specifically for weight loss were grounded in studies that grew out of a wartime experience with extensive gastric, small bowel, and colon resections during the second World War [2–4]. These operations, which included significant intestinal bypass and gastrointestinal resection, led to significant macronutrient and micronutrient malabsorption as well as unintended weight loss. In retrospect, these patients had the "short gut syndrome" and its classic nutritional deficiencies that we continue to see in these patients in modern day.

Even though obesity in the mid-twentieth century was not nearly as prevalent as we currently know it, obesity and its frequent associated medical conditions (e.g., type 2 diabetes mellitus, hyperlipidemia, hypertension) represented significant problems for many patients. The lessons learned from early studies of gastrointestinal resection and bypass were adapted for the specific goal of promoting weight loss in patients who were unable to achieve adequate weight loss by alternative means. The general rationale for how these operations provided weight loss was based on these early studies of extensive bowel resection. Thus, the explanation that gastric resection and alimentary diversion to the distal intestine – essentially bypassing a significant portion absorptive surface area – was blindly accepted as it seemed completely rational with our simplistic understanding of gastrointestinal physiology. It was not until larger case series [5] in the late 1990s and the early days of laparoscopic bariatric surgery [6] that unequivocally demonstrated that many of the beneficial effects previously attributed to decreased food intake and/or weight loss are indeed present sometimes just days following bariatric surgery.

6.2.1 The Myths of Restriction and Malabsorption

The simplistic explanation that the beneficial metabolic effects stem from "gastric restriction" and "malabsorption" do not hold up with our current evidence that has debunked this previously long-held belief. In fact, some investigators have posited that that restriction and malabsorption are likely not at all implicated in the weight loss and maintenance of body weight following bariatric surgery. SG in particular has been described in multiple animal studies and has several interesting physiologic effects that cannot be explained by restriction alone. In fact, data has directly challenged the notion that the SG has any intrinsic gastric restriction at all. In studies by Grayson and colleagues [7], lactating female rats who had previously received a SG or sham operation were both able to increase their food intake in response to pregnancy and lactation. In these animals there was no evidence of retarded food intake in the lactating SG rats relative to their control littermates [7]. This is one example of an elegant study that takes advantage of lactation, one of the most energy-demanding processes physiologically, that is routinely associated with marked increases in food intake [8]. Even though patients exert increased satiety or even an inability to eat as they did preoperatively, these studies suggest these effects are not related to the size of the sleeve or postoperative stomach and alternatively are modified by neurologic or other hormonal factors.

Aside from food intake and gastric restriction, other studies have examined both micro- and macro-nutrient malabsorption following bariatric surgery. Roux-en-Y gastric bypass and biliopancreatic diversion with duodenal switch have been associated with well-documented risk for development of micronutrient deficiencies [9]. Indeed, many of these patients are treated with indefinite vitamin and mineral supplementation. Regardless, several studies have aimed to identify the degree of macronutrient malabsorption associated with bariatric surgery to gauge how much that might contribute to weight loss. Surprisingly, those studies have failed to identify any measurable macronutrient malabsorption [10, 11], suggesting that macronutrient malabsorption does not contribute to weight loss long-term. Overall the field of bariatric surgery and obesity medicine has shifted away from the terms "restriction" and "malabsorption" to describe bariatric operations [12], and the data have continued to demonstrate other mechanisms that drive weight loss postoperatively.

Metabolic and bariatric surgery is the most effective treatment of obesity, though our understanding of the mechanisms driving these effects continues to evolve – far beyond the myopic explanations of restriction and malabsorption. Bariatric physiology and endocrinology [13, 14] is increasingly complex, as body weight is a highly regulated biologic variable. Dietary, lifestyle, or pharmacologic therapies that target isolated hormonal or neural pathways pharmacologically are easily overridden by a multitude of other factors contributing to weight maintenance. This physiology makes nonsurgical approaches significantly less effective, as short-term weight loss is continuously met with resistance by the natural homeostatic processes. Unlike nonsurgical interventions, however, bariatric surgery concurrently affects multiple anatomic and physiologic processes that are otherwise impossible to target collectively. These processes are numerous and include augmented gastrointestinal secretion of satiety factors [15–17], altered gut/brain neural circuitry [13, 18–21], remodeled gut microbiome [22–25], and increased gastric emptying [11, 26] with rapid nutrient delivery to the intestine [27]. The marked anatomic and physiologic changes of bariatric surgery target numerous pathways concurrently, producing powerful and sustained effects on body weight.

6.2.2 Weight-Independent and Weight-Dependent Effects

Investigation into the metabolic effects of bariatric surgery typically focuses on two broad categories, namely, those effects occurring *before* weight loss (i.e., weight-independent) and those occurring *after* weight loss (i.e., weight-dependent). Arguably the weight-independent effects are most exciting, especially the resolution of chronic medical diseases. Research into these early metabolic changes in bariatric patients attributes a substantial portion of these changes to caloric restriction [28–30], which is consistent with a previous study [31, 32]. However, there is evidence of additional metabolic changes occurring independent of caloric restriction in bariatric patients [33–35]. The mechanisms driving these additional weight-independent effects and how these might affect short- and long-term outcomes are not well understood and are the focus of intense investigation.

The second broad category of metabolic effects of bariatric surgery are those effects that are weight loss dependent. Exclusive of bariatric surgery, obesity-associated comorbid medical conditions – insulin resistance, type 2 diabetes, hypertension, and hyperlipidemia – are improved with even modest weight loss (~5–10% of body weight [36]). Many bariatric studies focus on long-term weight loss postoperatively and have demonstrated that bariatric surgery is associated with marked weight loss relative to intensive medical and/or lifestyle interventions [37–41], as well as resolution of the associated medical conditions [42–45]. A critical caveat to understand when evaluating these changes associated with marked weight loss is that many endpoints will change significantly over time solely paralleling changes in body weight and/or fat mass. It is a common misconception to attribute many of these parallel changes as driving the overall effects. This frequently leads to misinterpretation of findings and emphasis on factors that do not necessarily drive weight loss or other changes observed postoperatively. Regardless, even in the face of suboptimal weight loss, bariatric surgery is still associated with improvements or resolution of obesity-associated diseases [46].

6.3 Mechanisms of Vertical Sleeve Gastrectomy

SG may seem like a relatively straightforward operation, given that it is essentially a partial gastrectomy without additional bowel manipulation or resection. Compared to other bariatric operations, SG is by far much easier to adapt to preclinical animal models, which has led to many scientific groups exclusively studying SG and not other bariatric operations. Consequently, despite bariatric operations potentially sharing at least some fundamental mechanisms for their beneficial effects, the scientific literature is dominated by studies of SG. These studies have demonstrated a number of interesting effects and spawned new hypotheses for how SG exerts its effects, though how the results of SG-specific studies might apply to other bariatric operations is unclear. There are a number of factors that are altered by SG, though the clinically demonstrable evidence for those is still lacking. Below we describe a number of the most highly studied factors and identify the links clinically that are most promising, though a definitive mechanism driving the effects of SG remains elusive.

6.3.1 Ghrelin

Ghrelin was originally identified as a growth hormone secretagogue, but was quickly identified as an orexigenic (i.e., appetite-promoting) hormone predominately released from the stomach [47]. Circulating ghrelin spikes prior to meal times in humans and was hypothesized to be critical for meal-initiation. One of the most exciting observations, with respect to bariatric surgery, was the finding that patients post-RYGB seemed to have a complete cessation of diurnal or pre-meal variation in circulating ghrelin [48]. Anecdotally, a number of patients clinically describe the feeling of "forgetting to eat" following bariatric surgery, as well as increased satiety throughout the day. Thus, cessation of diurnal ghrelin variation was an attractive hypothesis for the perceived satiety in many patients following bariatric surgery [48]. Moreover, SG removes a majority of ghrelin-producing gastric tissue [49], and it had been posited that the absence of ghrelin secretion may be vital to the increased satiety and weight loss observed following SG. This hypothesis is supported by the observation that circulating ghrelin concentrations are decreased up to a year in SG patients [50]. Unfortunately, ghrelin is not necessary for the weight loss effects in rodent SG models [51] and the significance of ghrelin physiology overall has been questioned. Several genetic studies examining ghrelin knockout mice lack any marked clinical phenotypes [52], though do exhibit some metabolic changes when placed under long-term caloric restriction. From a metabolic perspective in rodents, ghrelin only appears important in times of starvation as a mechanism to prevent hypoglycemia and promote survival [53, 54].

Importantly, even though preclinical animal models are frequently used for mechanistic investigation, these models have their limitations. Rat and mouse stomach are exceedingly different from human stomach anatomically and potentially histologically [49, 55]; thus any findings in animal models of SG require further study in human subjects. Further clinical studies have demonstrated that ghrelin does have effects (e.g., blood pressure and glucose homeostasis) that have been shown in healthy and obese subjects [56]. Ghrelin may, in fact, act in concert with GLP-1 (and potentially other GI hormones) to affect glucose and other nutrient absorption in the prandial state [57]. Regardless, even though ghrelin may have a role in the metabolic changes associated with bariatric surgery, its role is incremental and appears disposable based on our current understanding.

6.3.2 Nutrient Delivery and Gastrointestinal Hormone Secretion

One of the earliest markers of improvement post-bariatric surgery is the improvement in glucose tolerance and the accompanying changes in gastrointestinal hormones. These hormones include glucagon-like peptide-1 (GLP-1), pancreatic polypeptide (PP), peptide YY (PYY), and glucagon-like peptide-2, among others. Current studies suggest that these postoperative elevations are driven by an increased rate of nutrient delivery after SG as well as RYGB. Even in the absence of intestinal rearrangement, SG is associated with increased secretion of the distal intestinal hormones GLP-1 and peptide YY (PYY) [58–60]. Gastric emptying and intestinal nutrient delivery are increased following SG in humans [61]. Studies using rodent models of SG have examined the contribution of these hormonal changes and other mechanisms to SG efficacy. Chambers and colleagues [62] have demonstrated in the rat that SG is associated with increased intragastric pressure and increased rate of intestinal nutrient delivery. Studies of gastric and intestinal hormones in patients have demonstrated similar changes for SG as well as RYGB, with decreases in circulating ghrelin in the fasting and prandial states relative to weight stable controls [63]. Whether these changes that are described early on, or even after significant weight loss, directly lead to weight loss or are a reaction to significant weight loss remains to be understood.

The physiology of GLP-1, previously known as enteroglucagon, is an area that has had much interest and work from early studies in gastric bypass [64]. Part of the mechanism of these changes in glucose tolerance was thought to be secondary to elevated responses of GLP-1 to oral glucose. Studies examining GLP-1 have consumed basic science research because of the marked elevations in GLP-1 post-RYGB that was described by Sugarman and colleagues [64] that was posited to be the principle mediator of the effects of bariatric surgery. However, as GLP-1 physiology and its signaling pathways have become better identified, the GLP-1 receptor has been shown to not be necessary [65] but still may contribute some beneficial effects postoperatively.

More recent studies of GLP-1/GLP-2 have begun to examine tissue-specific expression to determine whether a specific tissue can be identified that may allow for a more focused investigation for mechanism. Global GLP-2 knockout mice still lose weight following SG [66] and beta-cell-specific knockout of GLP-1 maintains its beneficial effect on glucose tolerance [67]. A clinical study examining glucose tolerance and GLP-1 secretion in subjects following SG used Ex9-39 as a GLP-1R blocker and, although insulin secretion was attenuated (presumably from GLP-1), glucose tolerance was not significantly affected [68]. Collectively these findings argue that beta-cell-specific GLP-1 is not necessary for the beneficial effects of SG in the mouse, similar to other findings by Wilson-Pérez and colleagues [65]. However, contrary findings were observed by Cummings and colleagues [69] that showed abrogation of the beneficial effects of SG on glucose-stimulated insulin secretion and glucose tolerance in a GLP-1R beta-cell-specific knockout mouse. Regardless, methodological differences or strain/species differences may explain the subtle differences in the basic science literature.

6.3.3 Bile Acid Metabolism

Perhaps one of the most unexpected advances over the last two decades has been the identification of bile acids and their receptors (e.g., farnesoid X receptor (FXR) and G protein-coupled bile acid receptor (TGR5)) as major mediators of intermediary metabolism. Once thought only to be dietary detergents that were needed for fat digestion, bile acids have been identified as bona fide hormones [70, 71] with myriad metabolic effects [14, 72]. Unlike ghrelin and GLP-1 receptor knockout mice in which SG remains effective against diet-induced obesity [51, 65], mice globally deficient in the bile acid receptor FXR (farnesoid X receptor) have completely abrogated effects of SG on body weight [73]; thus underscoring FXR as a major target of SG and potentially other bariatric operations. Consistent with this bile acid receptor dependency, SG is associated with increased plasma bile acid concentrations in the mouse [74] as well as some human studies [75, 76] that strengthen the data behind a bariatric surgery-bile acid metabolism mechanism driving weight loss postoperatively.

Unlike FXR, the other heavily studied bile acid receptor, TGR5, has previously been shown to play a role in glucose homeostasis [77] and several studies have suggested a role for TGR5 in the improvements associated with mouse models of SG [78, 79]. Cummings and colleagues demonstrated that TGR5, the G protein-coupled bile acid receptor, is necessary for at least part of the improved glucoregulatory phenotype of SG in the mouse [78]. SG in TGR5 knockout mice was associated with altered bile acid pool composition, which may have additional metabolic consequences. Interestingly, the TGR5 knockout animals following SG responded similar to wild type animals with respect to glucose-stimulated insulin secretion. Thus, this study concludes that some but clearly not all beneficial effects of SG related to glucose homeostasis are mediated through TGR5. The results of Cummings and colleagues are in contrast to similar studies carried out that showed TGR5 knockout being associated with abrogation of all of the beneficial effects of SG (e.g., body weight/composition, food intake, glucose tolerance) in the mouse [79]. The differences between these two studies may be related to differences in mouse strain, age, diet, or timing of surgery – any of which could help explain the discrepancies between the published data.

Aside from the bile acids receptors, a number of other bile acid-mediated processes may contribute to the effects of SG. It is well-recognized that bile acid composition changes after bariatric surgery and there are reported fluctuations in species of bile acids that may have differential metabolic effects [80–82]. The mechanisms of these composition changes and how SG leads to these effects is currently unknown, but is an area of great interest. Stefater and colleagues examined the effects of SG compared to diet-induced obesity, pair-fed, or chow-fed control rats. In those studies, total bile acids were increased by SG or pair-feeding by unknown mechanisms, which began to approach the higher concentrations of total bile acids reported in the chow-fed controls [83]. How FXR signaling is altered by bariatric surgery and what other pathways may be affected by SG remain unclear, though there are a number of other SG-related effects that require further study including changes to taste preference similar to RYGB as well as changes in intestinal triglyceride metabolism [84–87].

How the molecular and tissue-specific effects of FXR and TGR5 are related and potentially contribute to the phenotype of SG and/or other bariatric operations is still yet to be determined, but bile acid receptors are critically important for weight loss as well as the improvements in glucose tolerance in preclinical models. No other receptors have the profound effects as the FXR receptor in the mouse and this may represent the best therapeutic and pharmacologic target we have against obesity.

6.3.4 Debunked Mechanisms of SG Action

A discussion of mechanisms underlying SG would not be complete without a brief discussion to debunk several variables that are commonly cited as driving the metabolic improvements, but clearly do not play a role clinically. The first of these is the size of the sleeve constructed. Depending on the surgeon a bougie, gastric tube, or an endoscope may be used to "size" the sleeve for standardization. Size of the sleeve has been shown to have no effect on weight loss over time in both prospective and retrospective studies [88–91], though a smaller sleeve does appear to cause significantly more esophageal reflux [92, 93]. Similar to these studies examining sleeve size, other studies have tried to identify whether or not volume of resected stomach is associated with weight loss or other metabolic outcomes. Small, non-randomized, studies demonstrated subtle trends for marginally increased weight loss with larger volumes of stomach removed [94, 95]. As would be expected with greater gastric resection, blood concentrations of ghrelin were slightly lower, and GLP-1 was marginally increased along with subtle improvements in glucose tolerance [61, 95]. However, all of these results were of questionable clinical significance and have subsequently proven to be irreproducible by other independent groups [96, 97].

Another frequently cited but unfounded effect of bariatric surgery is that energy expenditure is increased postoperatively, despite there being little to no data to suggest this is the case and actually much data to demonstrate the contrary. A significant problem with studying energy expenditure in bariatric postoperative patients is that the "baseline" values change drastically over time. Moreover, the changes in body composition, diet, and activity, all contribute to altering the resting and total energy expenditure. None of these has a linear relationship to body composition or weight, even though most investigators use models that force linear relationships. Tam and colleagues [98] conducted a study examining SG, RYGB, and gastric banding and showed that the SG and RYGB groups were associated with a decrease in expected energy expenditure up to 2 years postoperatively. Bariatric patients are known to lose a significant amount of "fat-free mass", which includes muscle mass – a significant contributor to overall energy expenditure [99]. Metabolic adaptation is common after non-surgical weight loss as well as bariatric surgery. There is significant more adaptation of the body to return to a pre-weight loss state following non-surgical weight loss, though this adaptation is present albeit less following bariatric surgery [100]. This was shown in a cohort of individuals undergoing intensive medical weight loss and lifestyle changes compared to another cohort of patients that underwent bariatric surgery.

6.4 Conclusion

The field of bariatric surgery is at an exciting time in terms of scientific research and better understanding of the mechanisms of these operations that continues to evolve. Further research is needed to identify how these neurohormonal factors from the intestinal tract as well as the bile acids from the liver contribute to the weight-

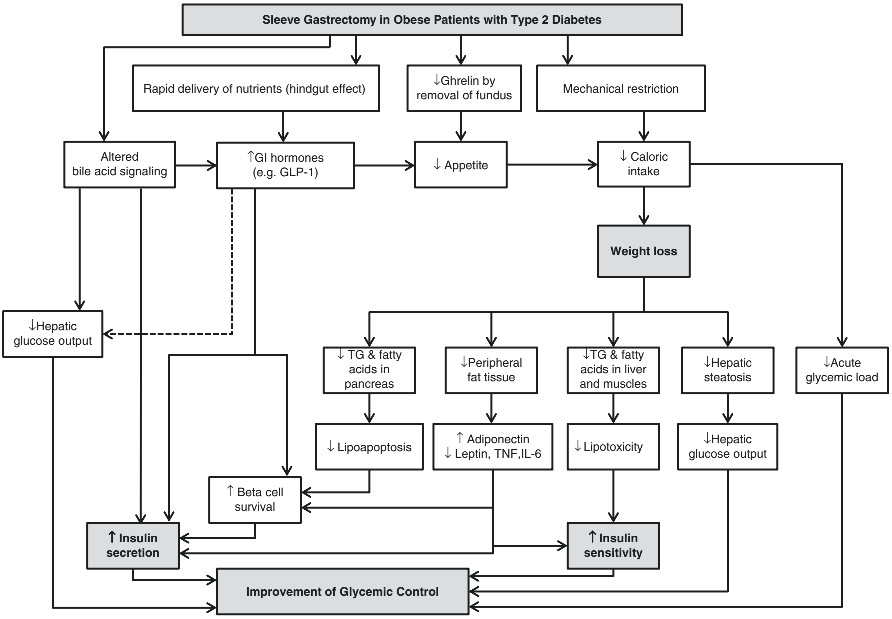


Fig. 6.1 Proposed mechanisms of action of sleeve gastrectomy in patients with obesity and type 2 diabetes: Precise antidiabetic mechanisms of sleeve gastrectomy are not well understood. Weight loss and caloric restriction improve glycemic control. Furthermore, weight-independent neurohormonal pathways involving changes in gut hormones and bile acids are contributed in metabolic changes. Abbreviations: *GI* gastrointestinal, *TG* triglyceride, *GLP-1* glucagon-like peptide-1, *TNF* tumor necrosis factor, *IL-6* interleukin-6. (Modified and adapted with permission [101])

independent and weight-dependent effects of these operations (Fig. 6.1). Better understanding of these mechanisms will lead to identification factors that can be used therapeutically as adjuvant obesity treatments, identify the cause(s) of weight regain in subjects, and potentially identify subjects with potentially surgically resistant obesity prior to intervention.

References

1. Mason EE, ITO C. Gastric bypass. Ann Surg. 1969;170:329–39.
2. Weckesser EC, Chinn AB, Scott MW Jr, Price JW. Extensive resection of the small intestine. Am J Surg. 1949;78:706–14.
3. Kremen AJ, Linner JH, Nelson CH. An experimental evaluation of the nutritional importance of proximal and distal small intestine. Ann Surg. 1954;140:439–48.
4. Payne JH, DeWind LT, Commons RR. Metabolic observations in patients with jejunocolic shunts. Am J Surg. 1963;106:273–89.
5. Pories WJ, Swanson MS, MacDonald KG, Long SB, Morris PG, Brown BM, et al. Who would have thought it? An operation proves to be the most effective therapy for adult-onset diabetes mellitus. Ann Surg. 1995;222:339–50.
6. Schauer PR, Ikramuddin S, Gourash W, Ramanathan R, Luketich J. Outcomes after laparoscopic Roux-en-Y gastric bypass for morbid obesity. Ann Surg. 2000;232:515–26.

7. Grayson BE, Schneider KM, Woods SC, Seeley RJ. Improved rodent maternal metabolism but reduced intrauterine growth after vertical sleeve gastrectomy. Sci Trans Med. 2013;5:199ra112–2.
8. National Research Council (US) Subcommittee on Laboratory Animal Nutrition. Nutrient Requirements of Laboratory Animals: Fourth Revised Edition, 1995. Washington (DC): National Academies Press (US); 1995. Available from: https://www.ncbi.nlm.nih.gov/books/NBK231927/doi:10.17226/4758.
9. Risstad H, Søvik TT, Engström M, Aasheim ET, Fagerland MW, Olsén MF, et al. Five-year outcomes after laparoscopic gastric bypass and laparoscopic duodenal switch in patients with body mass index of 50 to 60: a randomized clinical trial. JAMA Surg. 2015;150:352–61.
10. Wang G, Agenor K, Pizot J, Kotler DP, Harel Y, Van Der Schueren BJ, et al. Accelerated gastric emptying but no carbohydrate malabsorption 1 year after gastric bypass surgery (GBP). Obes Surg. 2012;22:1263–7.
11. Carswell KA, Vincent RP, Belgaumkar AP, Sherwood RA, Amiel SA, Patel AG, et al. The effect of bariatric surgery on intestinal absorption and transit time. Obes Surg. 2014;24:796–805.
12. Frikke-Schmidt H, Seeley RJ. Defending a new hypothesis of how bariatric surgery works. Obesity (Silver Spring). 2016;24:555.
13. Seeley RJ, Chambers AP, Sandoval DA. The role of gut adaptation in the potent effects of multiple bariatric surgeries on obesity and diabetes. Cell Metab. 2015;21:369–78.
14. Albaugh VL, Banan B, Ajouz H, Abumrad NN, Flynn CR. Bile acids and bariatric surgery. Mol Asp Med. 2017;56:75–89.
15. Jørgensen NB, Dirksen C, Bojsen-Møller KN, Jacobsen SH, Worm D, Hansen DL, et al. Exaggerated glucagon-like peptide 1 response is important for improved beta-cell function and glucose tolerance after Roux-en-Y gastric bypass in patients with type 2 diabetes. Diabetes. 2013;62:3044–52.
16. Salehi M, Prigeon RL, D'Alessio DA. Gastric bypass surgery enhances glucagon-like peptide 1-stimulated postprandial insulin secretion in humans. Diabetes. 2011;60:2308–14.
17. Jørgensen NB, Jacobsen SH, Dirksen C, Bojsen-Møller KN, Naver L, Hvolris L, et al. Acute and long-term effects of Roux-en-Y gastric bypass on glucose metabolism in subjects with Type 2 diabetes and normal glucose tolerance. Am J Physiol Endocrinol Metab. 2012;303:E122–31.
18. Hajnal A, Kovacs P, Ahmed T, Meirelles K, Lynch CJ, Cooney RN. Gastric bypass surgery alters behavioral and neural taste functions for sweet taste in obese rats. Am J Physiol Gastrointest Liver Physiol. 2010;299:G967–79.
19. Hajnal A, Zharikov A, Polston JE, et al. Alcohol reward is increased after Roux-en-Y gastric bypass in dietary obese rats with differential effects following ghrelin antagonism. PLoS One. 2012;7(11):e49121. https://doi.org/10.1371/journal.pone.0049121.
20. Thanos PK, Michaelides M, Subrize M, Miller ML, Bellezza R, Cooney RN, et al. Roux-en-Y gastric bypass alters brain activity in regions that underlie reward and taste perception. PLoS One. 2015;10:e0125570.
21. Browning KN, Fortna SR, Hajnal A. Roux-en-Y gastric bypass reverses the effects of diet-induced obesity to inhibit the responsiveness of central vagal motoneurones. J Physiol. 2013;591:2357–72.
22. Kong L-C, Tap J, Aron-Wisnewsky J, Pelloux V, Basdevant A, Bouillot J-L, et al. Gut microbiota after gastric bypass in human obesity: increased richness and associations of bacterial genera with adipose tissue genes. Am J Clin Nutr. 2013;98:16–24.
23. Tremaroli V, Bäckhed F. Functional interactions between the gut microbiota and host metabolism. Nature. 2012;489:242–9.
24. Flynn CR, Albaugh VL, Cai S, Cheung-Flynn J, Williams PE, Brucker RM, et al. Bile diversion to the distal small intestine has comparable metabolic benefits to bariatric surgery. Nat Commun. 2015;6:7715.
25. Palleja A, Kashani A, Allin KH, Nielsen T, Zhang C, Li Y, et al. Roux-en-Y gastric bypass surgery of morbidly obese patients induces swift and persistent changes of the individual gut microbiota. Genome Med. 2016;8:67.

26. Dirksen C, Damgaard M, Bojsen-Møller KN, Jørgensen NB, Kielgast U, Jacobsen SH, et al. Fast pouch emptying, delayed small intestinal transit, and exaggerated gut hormone responses after Roux-en-Y gastric bypass. Neurogastroenterol Motil. 2013;25:346–e255.
27. Holst JJ, Gribble F, Horowitz M, Rayner CK. Roles of the Gut in Glucose Homeostasis. Diabetes Care. 2016;39:884–92.
28. Lips MA, de Groot GH, van Klinken JB, Aarts E, Berends FJ, Janssen IM, et al. Calorie restriction is a major determinant of the short-term metabolic effects of gastric bypass surgery in obese type 2 diabetic patients. Clin Endocrinol. 2014;80:834–42.
29. Jackness C, Karmally W, Febres G, Conwell IM, Ahmed L, Bessler M, et al. Very low-calorie diet mimics the early beneficial effect of Roux-en-Y gastric bypass on insulin sensitivity and β-cell Function in type 2 diabetic patients. Diabetes. 2013;62:3027–32.
30. Isbell JM, Tamboli RA, Hansen EN, Saliba J, Dunn JP, Phillips SE, et al. The importance of caloric restriction in the early improvements in insulin sensitivity after Roux-en-Y gastric bypass surgery. Diabetes Care. 2010;33:1438–42.
31. Nuttall FQ, Almokayyad RM, Gannon MC. Comparison of a carbohydrate-free diet vs. fasting on plasma glucose, insulin and glucagon in type 2 diabetes. Metabolism. 2015;64:253–62.
32. Henry RR, Wiest-Kent TA, Schaeffer L, Kolterman OG, Olefsky JM. Metabolic consequences of very-low-calorie diet therapy in obese non-insulin-dependent diabetic and nondiabetic subjects. Diabetes. 1986;35:155–64.
33. Schmidt JB, Pedersen SD, Gregersen NT, Vestergaard L, Nielsen MS, Ritz C, et al. Effects of RYGB on energy expenditure, appetite and glycaemic control: a randomized controlled clinical trial. Int J Obes (Lond). 2016;40:281–90.
34. Lips MA, de Groot GH, Berends FJ, Wiezer R, van Wagensveld BA, Swank DJ, et al. Calorie restriction and Roux-en-Y gastric bypass have opposing effects on circulating FGF21 in morbidly obese subjects. Clin Endocrinol. 2014;81:862–70.
35. Lips MA, Van Klinken JB, van Harmelen V, Dharuri HK, PAC 't H, JFJ L, et al. Roux-en-Y gastric bypass surgery, but not calorie restriction, reduces plasma branched-chain amino acids in obese women independent of weight loss or the presence of type 2 diabetes. Diabetes Care. 2014;37:3150–6.
36. Wing RR, Lang W, Wadden TA, Safford M, Knowler WC, Bertoni AG, et al. Benefits of modest weight loss in improving cardiovascular risk factors in overweight and obese individuals with type 2 diabetes. Diabetes Care. 2011;34:1481–6.
37. Sjöström CD, Lissner L, Wedel H, Sjöström L. Reduction in incidence of diabetes, hypertension and lipid disturbances after intentional weight loss induced by bariatric surgery: the SOS Intervention Study. Obes Res. 1999;7:477–84.
38. Karlsson J, Taft C, Rydén A, Sjöström L, Sullivan M. Ten-year trends in health-related quality of life after surgical and conventional treatment for severe obesity: the SOS intervention study. Int J Obes Relat Metab Disord. 2007;31:1248–61.
39. Sjöström L. Review of the key results from the Swedish Obese Subjects (SOS) trial – a prospective controlled intervention study of bariatric surgery. J Intern Med. 2013;273:219–34.
40. Adams TD, Davidson LE, Litwin SE, Kolotkin RL, LaMonte MJ, Pendleton RC, et al. Health benefits of gastric bypass surgery after 6 years. JAMA. 2012;308:1122–31.
41. Adams TD, Gress RE, Smith SC, Halverson RC, Simper SC, Rosamond WD, et al. Long-term mortality after gastric bypass surgery. N Engl J Med. 2007;357:753–61.
42. Adams TD, Davidson LE, Litwin SE, Kim J, Kolotkin RL, Nanjee MN, et al. Weight and metabolic outcomes 12 years after gastric bypass. N Engl J Med. 2017;377:1143–55.
43. Ikramuddin S, Korner J, Lee W-J, Thomas AJ, Connett JE, Bantle JP, et al. Lifestyle intervention and medical management with vs without Roux-en-Y gastric bypass and control of hemoglobin A1c, LDL cholesterol, and systolic blood pressure at 5 years in the diabetes surgery study. JAMA. 2018;319:266–78.
44. Schauer PR, Bhatt DL, Kirwan JP, Wolski K, Brethauer SA, Navaneethan SD, et al. Bariatric surgery versus intensive medical therapy for diabetes–3-year outcomes. N Engl J Med. 2014;370:2002–13.

45. Mingrone G, Panunzi S, De Gaetano A, Guidone C, Iaconelli A, Nanni G, et al. Bariatric-metabolic surgery versus conventional medical treatment in obese patients with type 2 diabetes: 5 year follow-up of an open-label, single-centre, randomised controlled trial. Lancet. 2015;386:964–73.
46. Aminian A, Jamal M, Augustin T, Corcelles R, Kirwan JP, Schauer PR, et al. Failed surgical weight loss does not necessarily mean failed metabolic effects. Diabetes Technol Ther. 2015;17:682–4.
47. Kojima M, Hosoda H, Date Y, Nakazato M, Matsuo H, Kangawa K. Ghrelin is a growth-hormone-releasing acylated peptide from stomach. Nature. 1999;402:656–60.
48. Cummings DE, Weigle DS, Frayo RS, Breen PA, Ma MK, Dellinger EP, et al. Plasma ghrelin levels after diet-induced weight loss or gastric bypass surgery. N Engl J Med. 2002;346:1623–30.
49. Choi E, Roland JT, Barlow BJ, O'Neal R, Rich AE, Nam KT, et al. Cell lineage distribution atlas of the human stomach reveals heterogeneous gland populations in the gastric antrum. Gut. 2014;63:1711–20.
50. Karamanakos SN, Vagenas K, Kalfarentzos F, Alexandrides TK. Weight loss, appetite suppression, and changes in fasting and postprandial ghrelin and peptide-YY levels after Roux-en-Y gastric bypass and sleeve gastrectomy. Ann Surg. 2008;247:401–7.
51. Chambers AP, Kirchner H, Wilson-Perez HE, Willency JA, Hale JE, Gaylinn BD, et al. The effects of vertical sleeve gastrectomy in rodents are ghrelin independent. Gastroenterology. 2013;144:50–5.
52. Albarran-Zeckler RG, Sun Y, Smith RG. Physiological roles revealed by ghrelin and ghrelin receptor deficient mice. Peptides. 2011;32:2229–35.
53. McFarlane MR, Brown MS, Goldstein JL, Zhao T-J. Induced ablation of ghrelin cells in adult mice does not decrease food intake, body weight, or response to high-fat diet. Cell Metab. 2014;20:54–60.
54. Mani BK, Zigman JM. Ghrelin as a survival hormone. Trends Endocrinol Metab. 2017;28:843–54.
55. Kulkarni BV, LaSance K, Sorrell JE, Lemen L, Woods SC, Seeley RJ, et al. The role of proximal versus distal stomach resection in the weight loss seen after vertical sleeve gastrectomy. Am J Physiol Regul Integr Comp Physiol. 2016;311:R979–87.
56. Tong J, Prigeon RL, Davis HW, Bidlingmaier M, Kahn SE, Cummings DE, et al. Ghrelin suppresses glucose-stimulated insulin secretion and deteriorates glucose tolerance in healthy humans. Diabetes. 2010;59:2145–51.
57. Page LC, Gastaldelli A, Gray SM, D'Alessio DA, Tong J. Interaction of GLP-1 and ghrelin on glucose tolerance in healthy humans. Diabetes. 2018;67:1976–85.
58. Peterli R, Steinert RE, Woelnerhanssen B, Peters T, Christoffel-Courtin C, Gass M, et al. Metabolic and hormonal changes after laparoscopic Roux-en-Y gastric bypass and sleeve gastrectomy: a randomized, prospective trial. Obes Surg. 2012;22:740–8.
59. Papamargaritis D, le Roux CW, Sioka E, Koukoulis G, Tzovaras G, Zacharoulis D. Changes in gut hormone profile and glucose homeostasis after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2013;9:192–201.
60. Mallipedhi A, Prior SL, Barry JD, Caplin S, Baxter JN, Stephens JW. Temporal changes in glucose homeostasis and incretin hormone response at 1 and 6 months after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2014;10:860–9.
61. Sista F, Abruzzese V, Clementi M, Carandina S, Cecilia M, Amicucci G. The effect of sleeve gastrectomy on GLP-1 secretion and gastric emptying: a prospective study. Surg Obes Relat Dis. 2017;13:7–14.
62. Chambers AP, Smith EP, Begg DP, Grayson BE, Sisley S, Greer T, et al. Regulation of gastric emptying rate and its role in nutrient-induced GLP-1 secretion in rats after vertical sleeve gastrectomy. Am J Physiol Endocrinol Metab. 2014;306:E424–32.
63. Alamuddin N, Vetter ML, Ahima RS, Hesson L, Ritter S, Minnick A, et al. Changes in fasting and prandial gut and adiposity hormones following vertical sleeve gastrectomy or Roux-en-Y-gastric bypass: an 18-month prospective study. Obes Surg. 2016;27:1563–72.

64. Kellum JM, Kuemmerle JF, O'Dorisio TM, Rayford P, Martin D, Engle K, et al. Gastrointestinal hormone responses to meals before and after gastric bypass and vertical banded gastroplasty. Ann Surg. 1990;211:763–70; discussion770–1
65. Wilson-Perez HE, Chambers AP, Ryan KK, Li B, Sandoval DA, Stoffers D, et al. Vertical sleeve gastrectomy is effective in two genetic mouse models of glucagon-like Peptide 1 receptor deficiency. Diabetes. 2013;62:2380–5.
66. Patel A, Yusta B, Matthews D, Charron MJ, Seeley RJ, Drucker DJ. GLP-2 receptor signaling controls circulating bile acid levels but not glucose homeostasis in Gcgr mice and is dispensable for the metabolic benefits ensuing after vertical sleeve gastrectomy. Mol Metab. 2018;16:45–54.
67. Douros JD, Lewis AG, Smith EP, Niu J, Capozzi M, Wittmann A, et al. Enhanced glucose control following vertical sleeve gastrectomy does not require a β-cell glucagon-like peptide 1 receptor. Diabetes. 2018;67:1504–11.
68. Jiménez A, Mari A, Casamitjana R, Lacy A, Ferrannini E, Vidal J. GLP-1 and glucose tolerance after sleeve gastrectomy in morbidly obese subjects with type 2 diabetes. Diabetes. 2014;63:3372–7.
69. Garibay D, McGavigan AK, Lee SA, Ficorilli JV, Cox AL, Michael MD, et al. β-cell glucagon-like peptide-1 receptor contributes to improved glucose tolerance after vertical sleeve gastrectomy. Endocrinology. 2016;157:3405–9.
70. Makishima M, Okamoto AY, Repa JJ, Tu H, Learned RM, Luk A, et al. Identification of a nuclear receptor for bile acids. Science. 1999;284:1362–5.
71. Parks DJ, Blanchard SG, Bledsoe RK, Chandra G, Consler TG, Kliewer SA, et al. Bile acids: natural ligands for an orphan nuclear receptor. Science. 1999;284:1365–8.
72. Chiang JYL. Bile acid metabolism and signaling. Compr Physiol. 2013;3:1191–212.
73. Ryan KK, Tremaroli V, Clemmensen C, Kovatcheva-Datchary P, Myronovych A, Karns R, et al. FXR is a molecular target for the effects of vertical sleeve gastrectomy. Nature. 2014;509:183–8.
74. Myronovych A, Kirby M, Ryan KK, Zhang W, Jha P, Setchell KD, et al. Vertical sleeve gastrectomy reduces hepatic steatosis while increasing serum bile acids in a weight-loss-independent manner. Obesity (Silver Spring). 2014;22:390–400.
75. Jahansouz C, Xu H, Hertzel AV, Serrot FJ, Kvalheim N, Cole A, et al. Bile acids increase independently from hypocaloric restriction after bariatric surgery. Ann Surg. 2016;264:1022–8.
76. Steinert RE, Peterli R, Keller S, Meyer-Gerspach AC, Drewe J, Peters T, et al. Bile acids and gut peptide secretion after bariatric surgery: a 1-year prospective randomized pilot trial. Obesity (Silver Spring). 2013;21:E660–8.
77. Thomas C, Gioiello A, Noriega L, Strehle A, Oury J, Rizzo G, et al. TGR5-mediated bile acid sensing controls glucose homeostasis. Cell Metab. 2009;10:167–77.
78. McGavigan AK, Garibay D, Henseler ZM, Chen J, Bettaieb A, Haj FG, et al. TGR5 contributes to glucoregulatory improvements after vertical sleeve gastrectomy in mice. Gut. 2017;66:226–34.
79. Ding L, Sousa KM, Jin L, Dong B, Kim BW, Ramirez R, et al. Vertical sleeve gastrectomy activates GPBAR-1/TGR5 to sustain weight loss, improve fatty liver, and remit insulin resistance in mice. Hepatology. 2016;64:760–73.
80. Albaugh VL, Flynn CR, Cai S, Xiao Y, Tamboli RA, Abumrad NN. Early increases in bile acids post Roux-en-Y gastric bypass are driven by insulin-sensitizing, secondary bile acids. J Clin Endocrinol Metab. 2015;100:E1225–33.
81. Tsuchida T, Shiraishi M, Ohta T, Sakai K, Ishii S. Ursodeoxycholic acid improves insulin sensitivity and hepatic steatosis by inducing the excretion of hepatic lipids in high-fat diet–fed KK-Ay mice. Metab Clin Exp Elsevier. 2012;61:944–53.
82. Kars M, Yang L, Gregor MF, Mohammed BS, Pietka TA, Finck BN, et al. Tauroursodeoxycholic Acid may improve liver and muscle but not adipose tissue insulin sensitivity in obese men and women. Diabetes. 2010;59:1899–905.
83. Stefater MA, Wilson-Pérez HE, Chambers AP. All bariatric surgeries are not created equal: insights from mechanistic comparisons. Endocrine. 2012;33:595–622.

84. Wilson-Pérez HE, Chambers AP, Sandoval DA, Stefater MA, Woods SC, Benoit SC, et al. The effect of vertical sleeve gastrectomy on food choice in rats. Int J Obes. 2013;37:288–95.
85. le Roux CW, Bueter M, Theis N, Werling M, Ashrafian H, Löwenstein C, et al. Gastric bypass reduces fat intake and preference. Am J Physiol Regul Integr Comp Physiol. 2011;301:R1057–66.
86. Chambers AP, Wilson-Perez HE, McGrath S, Grayson BE, Ryan KK, D'Alessio DA, et al. Effect of vertical sleeve gastrectomy on food selection and satiation in rats. Am J Physiol Endocrinol Metab. 2012;303:E1076–84.
87. Stefater MA, Sandoval DA, Chambers AP, Wilson-Perez HE, Hofmann SM, Jandacek R, et al. Sleeve gastrectomy in rats improves postprandial lipid clearance by reducing intestinal triglyceride secretion. Gastroenterology. 2011;141:939–49.e1–4.
88. Cal P, Deluca L, Jakob T, Fernández E. Laparoscopic sleeve gastrectomy with 27 versus 39 Fr bougie calibration: a randomized controlled trial. Surg Endosc. 2015;30:1812–5.
89. Parikh M, Gagner M, Heacock L, Strain G, Dakin G, Pomp A. Laparoscopic sleeve gastrectomy: does bougie size affect mean %EWL? Short-term outcomes. Surg Obes Relat Dis. 2008;4:528–33.
90. Atkins ER, Preen DB, Jarman C, Cohen LD. Improved obesity reduction and co-morbidity resolution in patients treated with 40-French bougie versus 50-French bougie four years after laparoscopic sleeve gastrectomy. Analysis of 294 patients. Obes Surg. 2011;22:97–104.
91. Spivak H, Rubin M, Sadot E, Pollak E, Feygin A, Goitein D. Laparoscopic sleeve gastrectomy using 42-French versus 32-French bougie: the first-year outcome. Obes Surg. 2014;24:1090–3.
92. Patti MG, Schlottmann F. Gastroesophageal reflux after sleeve gastrectomy. JAMA Surg. 2018;153:1147–2.
93. Mandeville Y, Van Looveren R, Vancoillie P-J, Verbeke X, Vandendriessche K, Vuylsteke P, et al. Moderating the enthusiasm of sleeve gastrectomy: up to fifty percent of reflux symptoms after ten years in a consecutive series of one hundred laparoscopic sleeve gastrectomies. Obes Surg. 2017;27:1797–803.
94. Robert M, Pasquer A, Pelascini E, Valette P-J, Gouillat C, Disse E. Impact of sleeve gastrectomy volumes on weight loss results: a prospective study. Surg Obes Relat Dis. 2016;12:1286–91.
95. Sista F, Abruzzese V, Clementi M, Carandina S, Amicucci G. Effect of resected gastric volume on ghrelin and GLP-1 plasma levels: a prospective study. J Gastrointest Surg. 2016;20:1931–41.
96. Obeidat FW, Shanti HA, Mismar AA, Elmuhtaseb MS, Al-Qudah MS. Volume of resected stomach as a predictor of excess weight loss after sleeve gastrectomy. Obes Surg. 2014;24:1904–8.
97. Pawanindra L, Vindal A, Midha M, Nagpal P, Manchanda A, Chander J. Early post-operative weight loss after laparoscopic sleeve gastrectomy correlates with the volume of the excised stomach and not with that of the sleeve! Preliminary data from a multi-detector computed tomography-based study. Surg Endosc. 2015;29:2921–7.
98. Tam CS, Rigas G, Heilbronn LK, Matisan T, Probst Y, Talbot M. Energy adaptations persist 2 years after sleeve gastrectomy and gastric bypass. Obes Surg. 2016;26(2):459–63.
99. Tamboli RA, Hossain HA, Marks PA, Eckhauser AW, Rathmacher JA, Phillips SE, et al. Body composition and energy metabolism following Roux-en-Y gastric bypass surgery. Obesity (Silver Spring). 2010;18:1718–24.
100. Knuth ND, Johannsen DL, Tamboli RA, Marks-Shulman PA, Huizenga R, Chen KY, et al. Metabolic adaptation following massive weight loss is related to the degree of energy imbalance and changes in circulating leptin. Obesity (Silver Spring). 2014;22:2563–9.
101. Andalib A, Aminian A. Sleeve gastrectomy and diabetes: is cure possible? Adv Surg. 2017;51:29–40.

Part II
Technical Aspects

Chapter 7
Laparoscopic Sleeve Gastrectomy: Technical Systematization for a Safe Procedure

Mariano Palermo, Almino Ramos Cardoso, and Michel Gagner

7.1 Introduction

Laparoscopic sleeve gastrectomy (LSG) is the most commonly performed bariatric procedure in the world, accounting for more than 50% of all bariatric procedures [1]. There are several factors that have led to its rapid traction since its inception. Firstly, in comparison to the laparoscopic adjustable gastric banding a gastric-restriction based procedure, which was still popular at that time, the sleeve was a simple, yet a powerful metabolic operation, activating significant hormonal pathways that lead to changes in eating behavior, glycemic control, and gut functions; all without the need for an implant and adjustments. Secondly, in contrast to Roux-en-Y gastric bypass (RYGB), LSG is less technically complex with no anastomosis. Being limited to the stomach makes it simpler and avoids the risk of internal hernias or other complications such as severe micronutrient and protein deficiency [45–47].

In this chapter, we will describe the technical aspects of the LSG in order to perform the procedure safely and avoid simple errors that can occur.

7.2 Surgical Technique

The patient is placed in a split leg position with the surgeon in between the patient's legs, first assistant on the right, and second assistant on the left (Fig. 7.1). Special

M. Palermo (✉)
Diagnomed, University of Buenos Aires, Buenos Aires, Argentina

A. R. Cardoso
Bariatric Surgery, Gastro Obeso Center, Sao Paulo, Brazil

M. Gagner
Department of Surgery, Sacré-Coeur Hospital, Montréal, QC, Canada

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_7

Fig. 7.1 Patient's split leg position in the OR

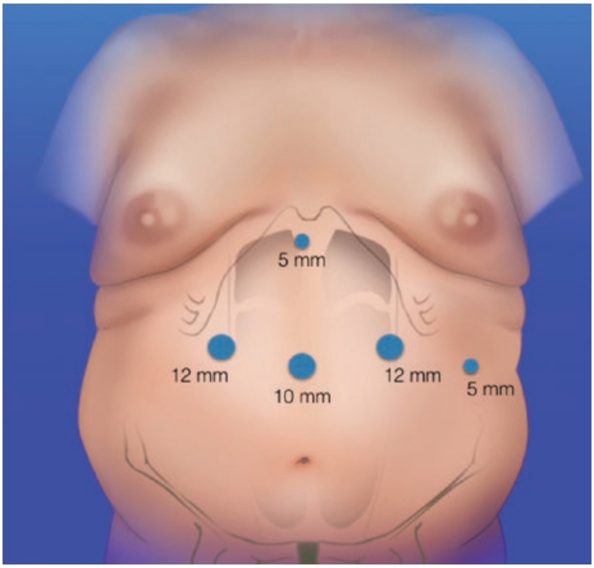


Fig. 7.2 Trocar position when using five trocars

attention is made to ensure ankle stability and prevent inward rotation. Other surgeons prefer to place the patient in a supine position with a footboard to prevent sliding during reverse-Trendelenburg maneuvering; there are other options that the surgeon locates in the right and few ones on the left [2, 47].

The best technique for pneumoperitoneum and accessing the peritoneal cavity is a controversial topic. To enter the abdomen we have different approaches, Veress needle, open technique or under direct vision with a 0° laparoscope using a bladeless optical trocar placed immediately inferior to the left subcostal margin in the midclavicular line [3–6]. CO_2 is insufflated up to 15 mmHg [7, 45].

In the majority of cases, the LSG can be performed with a total of five trocars (Fig. 7.2). There are other tentative techniques of lesser trocars numbers using five or even three trocars, but they might compromise exposure. In the most used

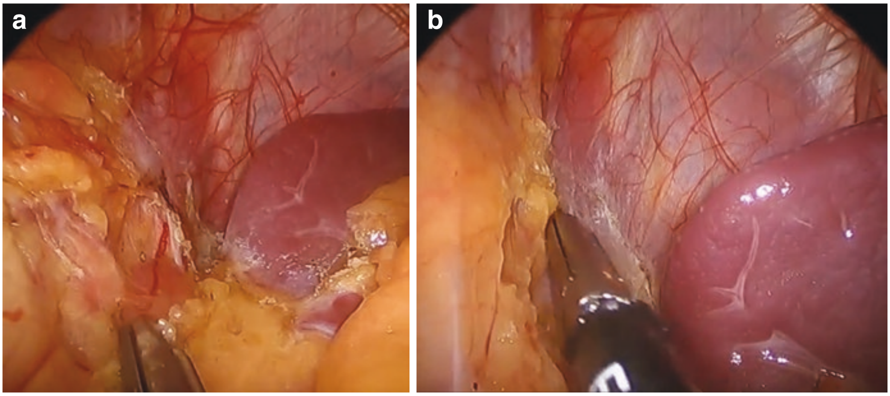


Fig. 7.3 (**a**, **b**) Exposure of the hiatus, this step is mandatory for optimal sleeve construction: inspect the hiatus for hernia and dissect the left crus to prevent retained fundus

technique, the surgeon will use two trocars for both hands and one trocar will be dedicated to the assistant. A single 12-mm trocar (for the stapler) is placed just lateral to the inferior aspect of the falciform ligament on the right [8–11, 45]. An additional 5-mm trocar is placed in the right upper quadrant for the surgeon's left hand and we use a sub-xiphoid 5 mm trocar for liver retraction with a grasper. In patients with severe visceral obesity, additional trocars can be added for the assistant on the left to retract the omentum, optimizing exposure when dissecting the left crus [12–14, 47].

An excellent exposure of the hiatus is mandatory for optimal sleeve construction in order to adequately inspect the hiatus looking for incidental hiatal hernia and completely dissect the left crus to prevent retained fundus [15–18] (Fig. 7.3a,b). It is more important in this operation than any other to clearly visualize the hiatus and dissect the left crus due to the "refluxogenic" nature of the sleeve gastrectomy [19–22, 45].

The great omentum should be opened close to the stomach wall in some part in between the fundus and the antrum in order to have the greater curvature completely detached from the stomach, preserving the gastro-epiploic vessels, beginning 3–4 cm proximal to the pylorus and continuing along the greater curvature all the way to the left crus [23–27, 46] (Fig. 7.4a–c pylorus white arrow).

Posterior adhesions are carefully divided and in this step are important to be careful with the left gastric artery, splenic vessels, spleen, and pancreas avoiding unexpected injuries [28–30]. Therefore, suboptimal exposure or excessive traction must be avoided during this part of the procedure to prevent vascular injury and massive hemorrhage [31–33]. It is important not to clear the entire posterior wall of the stomach from its attachments as some of these adhesions help to prevent the sleeve from twisting (Fig. 7.5). Some patients can present a posterior gastric artery crossing close to the fundus that should be ligated without any risk of gastric ischemia in order to allow a complete resection of the fundus avoiding inadequate weight loss or weight regain due to incomplete fundus resection. Care must be taken

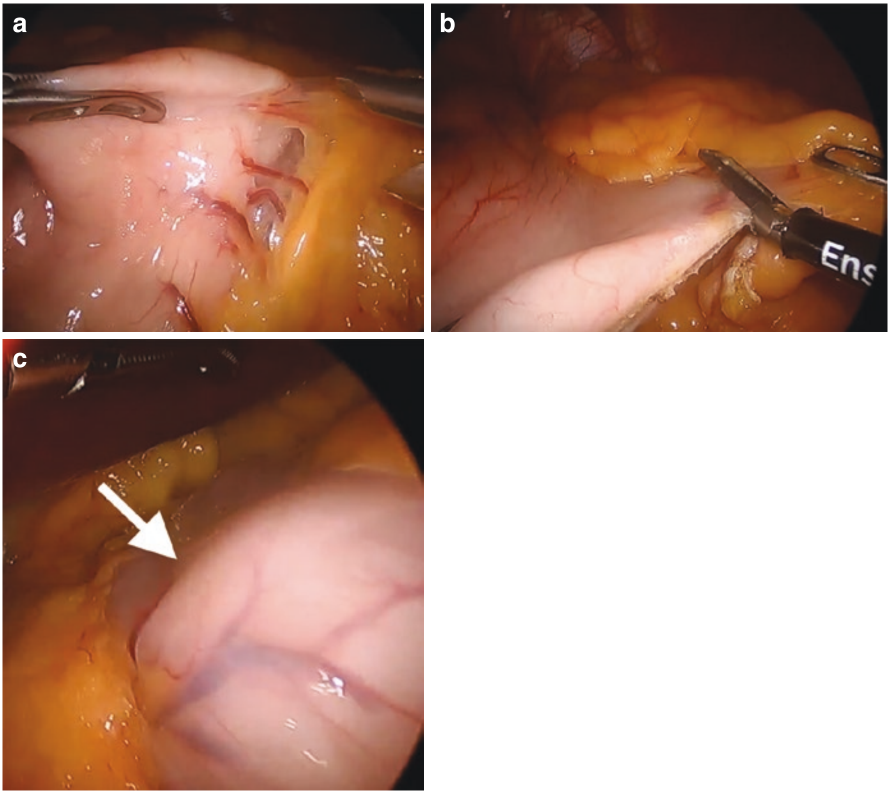
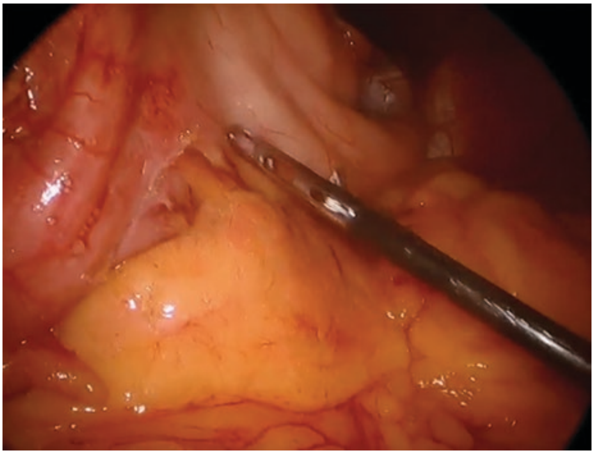


Fig. 7.4 (**a**, **b**) Omental attachments to the greater curvature are divided beginning 3–4 cm proximal to the pylorus (**c** pylorus white arrow)

Fig. 7.5 Dissection of posterior attachments and adhesions help to prevent the sleeve from twisting



when clearing the top of the fundus and angle of His, as short gastric vessels may be present and could be covered with a large amount of fat that makes it difficult at times to identify them [20, 34–36, 45]. Injury to these structures causes severe bleeding, which is particularly challenging because the stump often retracts within the fat close to the main splenic vessels, where blind use of the energy device could result in catastrophic injury [37–39]. Also the blind use of harmonic energy can lead to posterior esophageal or gastric direct or thermic lesions that could result in post-operative leakage. This is one of the most challenging steps in this surgery, also if necessaty, surgeons can use titanium clips before division avoiding any chance of bleeding.

The left gastro-phrenic ligament should be divided to expose the angle of His, because in the short term, a missed hiatal hernia or unresected fundus could lead to severe reflux and regurgitation postoperatively [13, 14, 40]. In the long term, inferior weight loss can be expected as a result of an improper fundus resection or presence of a neo-fundus [15, 16, 41].

After this key step of the surgery, attention is then turned to resection of the stomach. A bougie is mandatory. The bougie must be present before any stapler firing occurs. Before firing the staple it is important always to ask the anesthesiologist to move the bougie to be sure the tube is free and that there is a good passage through the sleeve specially at the incisura angularis level. Although blunt, non-tapered bougie size remains disputed, there is evidence to support that making a very tight sleeve will only have minimal short-term weight loss advantage, while risking significant postoperative complications [17]. In general, it is advisable not to go tighter than a 36-French bougie [42, 43, 47] (Fig. 7.6). The stapler should never be placed abutting the bougie regardless of its size; instead, the bougie should be used only for guidance. Alternatively, some surgeons elect to use the endoscope as a bougie taking care to desufflate the stomach before firing the stapler, keeping in mind the smaller diameter of the endoscopic tube.

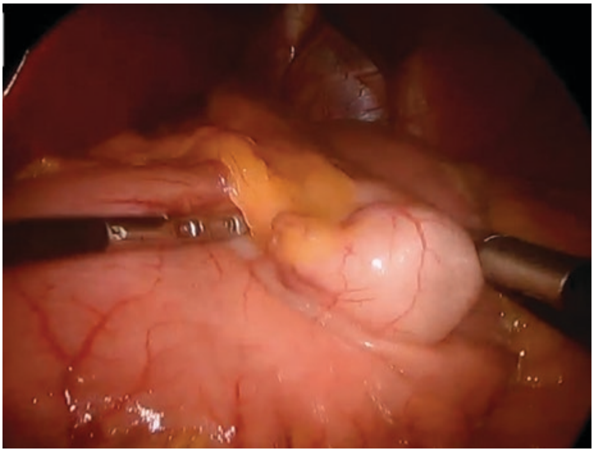


Fig. 7.6 The bougie is inserted. In this case a 36 French bougie

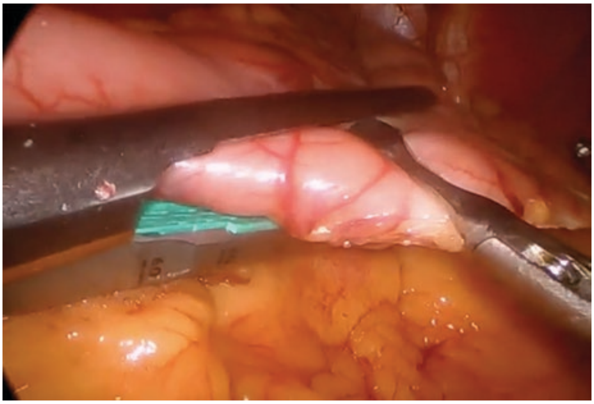


Fig. 7.7 The beginning of the gastric division starting from 2 to 5 cm from the pylorus

As for stapling, the actual, initiation point from the pylorus to begin gastric division remains controversial. Most surgeons begin antrum division 2–5 cm from the pylorus to avoid postoperative enlarged antrum [44, 45] (Fig. 7.7). Care must be taken to avoid twisting or stenosis of the sleeve at any level; however, this is particularly critical when approaching the angle made by the incisura.

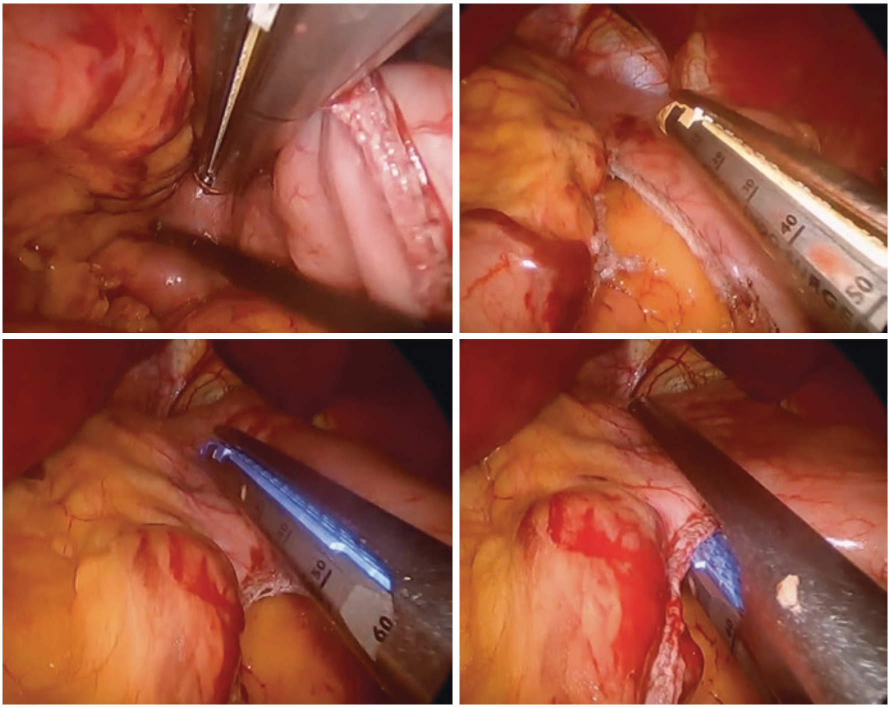
We choose the tallest stapler cartridge at the antrum level and gradually choose shorter staplers as the division continues proximally [46, 47]. The thickness of the stomach decreases from antrum to fundus and from greater curvature to the smaller one. Based on the use of Ethicon Echelon stapler, we should start with black or green and continues with golden and finishing with blue cartridge. But with Medtronic we should start with one or two black and finish with purple cartridge. In the next figures we demonstrate step by step the gastric resection. We always check the posterior wall before firing (Figs. 7.8, 7.9, 7.10, and 7.11).

The stomach is fixed medially but free laterally, so to avoid twisting during the staple, a gentle grasping only in order to have equal traction on the anterior and posterior walls should perform lateral retraction. It is crucial to elevate the tissues and inspect the posterior gastric wall before any stapling to ensure that adequate tissue resection is performed [45, 47]. This step is most critical at the fundus, where a large volume of gastric tissue can be retained posteriorly despite an adequate appearing sleeve anteriorly (Fig. 7.12). Lateral but not excessive traction allowing correct exposition by the assistant may be crucial in this surgical time.

When using buttressing material for reinforcement, we use the tallest stapler cartridges for all the staple line (Figs. 7.13, 7.14, 7.15, and 7.16).

When approaching the proximal stomach, the stapler should be positioned about one-centimeter lateral of the His angle in order to avoid inclusion of esophageal tissue [45, 47]. Fat pad dissection is often needed in large male patients although some surgeons like to preserve it as the lateral limit determining the limit for the gastric resection.

After complete division, inspection of the staple line is performed. We always reinforce the staple line. For sleeves performed without buttress staple line reinforcement, over-sewing with absorbable suture may be a better option (Figs. 7.17 and 7.18).



Figs. 7.8, 7.9, 7.10, and 7.11 Step by step the gastric resection using 60 mm loads. Tallest stapler cartridge at the antrum and gradually shorter ones as the division continues proximally

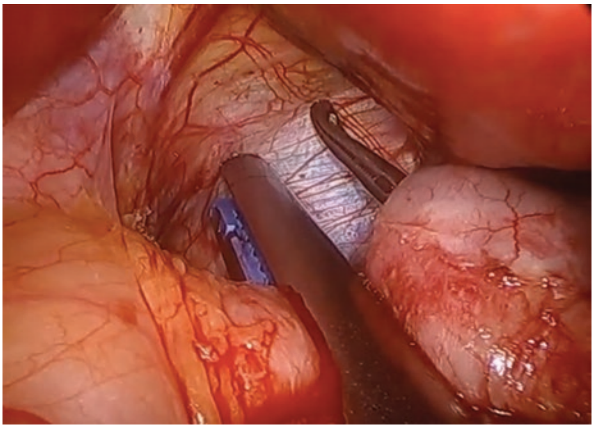
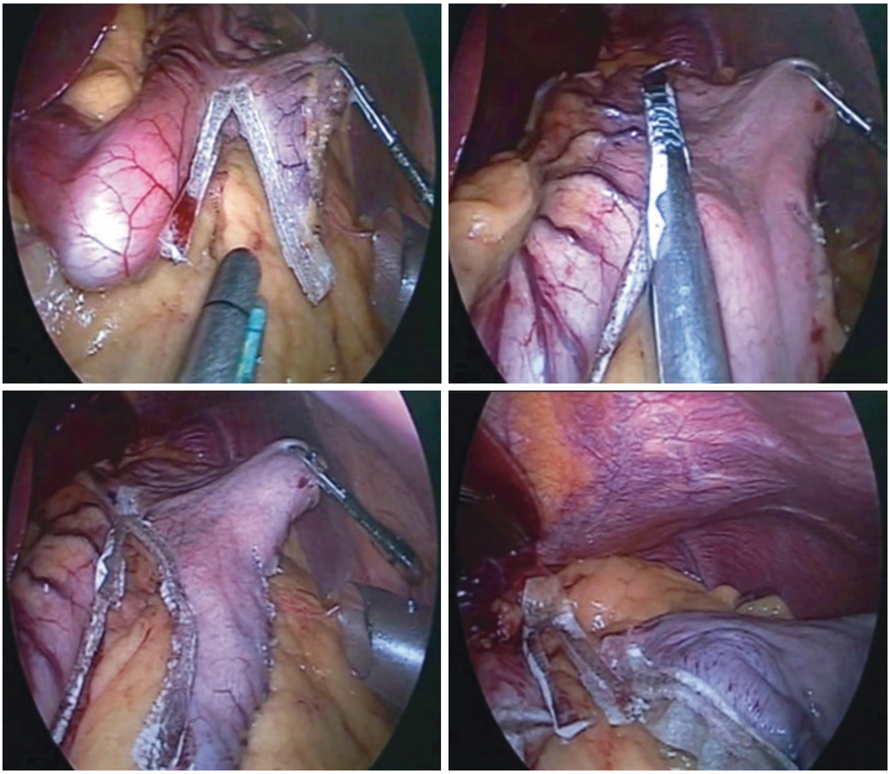
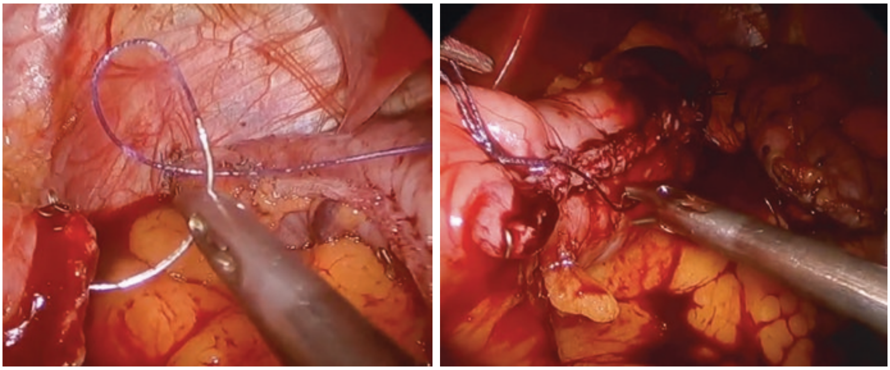


Fig. 7.12 Last stapler: this step is critical at the fundus, where a large volume of gastric tissue can be retained posteriorly

Barbed suture is currently a good choice for this kind of reinforcement. When using buttressing material, we perform a figure “8” just in the joining of the staplers (Fig. 7.19). Methylene blue test is performed routinely [45–47] (Fig. 7.20) even though very rarely surgeons reported the test result as positive.



Figs. 7.13, 7.14, 7.15, and 7.16 When using buttressing material for reinforcement, tallest stapler cartridges for all the staple line are used



Figs. 7.17 and 7.18 Reinforcement over-sewing all the staple line

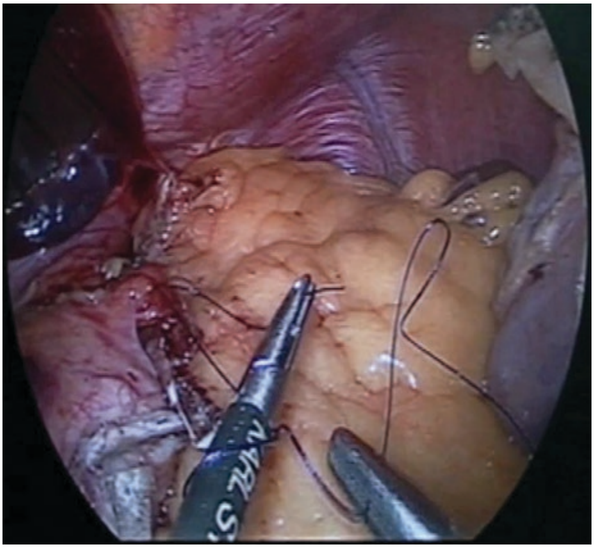


Fig. 7.19 When using buttressing material we perform Fig. 7.8

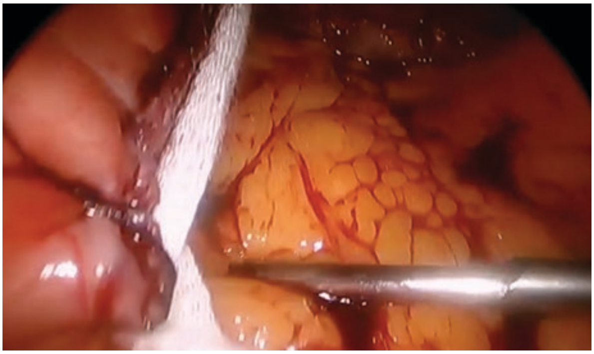


Fig. 7.20 Methylene blue test

7.3 Conclusions

LSG is a safe and effective primary bariatric procedure with durable weight loss. The simple concept of this operation, without the need to manipulate the intestine, is what made it so popular and became the most common bariatric surgery performed in the world. Nevertheless, the fine details in this operation are paramount to decrease complications. Therefore, we believe LSG, should not be called "easy" and should be performed only by surgeons trained in bariatric surgery. The highlights of a safer SG systematization are based in minimum 36Fr bougie calibration, starting 2–5 cm from the pylorus, keeping about 1 cm distance from esophagus and using some kind of staple line reinforcement.

References

1. Ponce J, DeMaria EJ, Nguyen NT, et al. American Society for Metabolic and Bariatric Surgery estimation of bariatric surgery procedures in 2015 and surgeon workforce in the United States. Surg Obes Relat Dis. 2016;12(9):1637–9.
2. Tretbar LL, Taylor TL, Sifer EC. Weight reduction. Gastric plication for morbid obesity. J Kans Med Soc. 1976;77(11):488–90.
3. Johnston D, Dachtler J, Sue-Ling HM, et al. The magenstrasse and mill operation for morbid obesity. Obes Surg. 2003;13(1):10–6.
4. Marceau P, Biron S, St Georges R, et al. Biliopancreatic diversion with gastrectomy as surgical treatment of morbid obesity. Obes Surg. 1991;1:381–7.
5. Hess DS, Hess DW. Biliopancreatic Diversion with a duodenal switch. Obes Surg. 1998;8:267–82.
6. Ren CJ, Patterson E, Gagner M. Early results of laparoscopic bilio-pancreatic diversion with duodenal switch: a case series of 40 consecutive patients. Obes Surg. 2000;10:514–23.
7. Kim WW, Gagner M, Kini S, et al. Laparoscopic vs. open biliopancreatic diversion with duodenal switch: a comparative study. J Gastrointest Surg. 2003;7:552–7.
8. Chu CA, Gagner M, Quinn T, et al. Two-stage laparoscopic bilio-pancreatic diversion with duodenal switch: an alternative approach to super-super morbid obesity. Surg Endosc. 2002;16:S069.
9. Regan JP, Inabnet WB, Gagner M, et al. Early experience with two stage laparoscopic Roux-en-Y gastric bypass as an alternative in the super-super obese patient. Obes Surg. 2003;13:861–4.
10. Alexandrou A, Felekouras E, Giannopoulos A, et al. What is the actual fate of super-morbid-obese patients who undergo laparoscopic sleeve gastrectomy as the first step of a two-stage weight-reduction operative strategy? Obes Surg. 2012;22(10):1623–8.
11. Gomberwalla A, Lutfi R. Early outcomes of helicobacter pylori and its treatment after laparoscopic sleeve gastrectomy. Bariatr Surg Pract Patient Care. 2015;10(1):12–4.
12. Berch BR, Torquati A, Lutfi RE, et al. Experience with the optical access trocar for safe and rapid entry in the performance of laparoscopic gastric bypass. Surg Endosc. 2006;20(8):1238–41.
13. Himpens J, Dobbeleir J, Peeters J. Long-term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252(2):319–24.
14. Laffin M, Chau J, Gill RS, et al. Sleeve gastrectomy and gastroesophageal reflux disease. J Obes. 2013;7:741097.
15. Silecchia G, De Angelis F, Rizzello M, et al. Residual fundus or neofundus after laparoscopic sleeve gastrectomy: is fundectomy safe and effective as revision surgery? Surg Endosc. 2015;29(19):2899–903.
16. Noel P, Nedelcu M, Nocca D, et al. Revised sleeve gastrectomy: another option for weight loss failure after sleeve gastrectomy. Surg Endosc. 2013;28(4):1096–102.
17. Parikh M, Gagner M, Heacock L, et al. Laparoscopic sleeve gastrectomy: does bougie size affect mean %EWL? Short-term outcomes. Surg Obes Relat Dis. 2008;4(4):528–33.
18. Afaneh C, Costa R, Pomp A, et al. A prospective randomized controlled trial assessing the efficacy of omentopexy during laparoscopic sleeve gastrectomy in reducing postoperative gastrointestinal symptoms. Surg Endosc. 2015;29(1):41–7.
19. Rosenthal R. International sleeve gastrectomy expert panel consensus statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8(1):8–19.
20. Parikh M, Issa R, McCrillis A, et al. Surgical strategies that may decrease leak after laparoscopic sleeve gastrectomy: a systematic review and meta-analysis of 9991 cases. Ann Surg. 2013;257(2):231–7.
21. Berger E, Clements R, Morton J, et al. The impact of different surgical techniques on outcomes in laparoscopic sleeve gastrectomies: the first report from the metabolic and bariatric surgery accreditation and quality improvement program (MBSAQIP). Ann Surg. 2016;264(3):464–73.

22. Sethi M, Zagzag J, Patel K, et al. Intraoperative leak testing has no correlation with leak after laparoscopic sleeve gastrectomy. Surg Endosc. 2016;30:883–91.
23. Bingham J, Kaufman J, Hata K, et al. A multicenter study of routine versus selective intraoperative leak testing for sleeve gastrectomy. Surg Obes Relat Dis. 2017;13(9):1469–75.
24. Alaedeen D, Madan A, Ro C, et al. Intraoperative endoscopy and leaks after laparoscopic Roux-en-Y gastric bypass. Am Surg. 2009;75(6):485–8.
25. Terterov D, Leung P, Twells L, et al. The usefulness and costs of routine contrast studies after laparoscopic sleeve gastrectomy for detecting staple line leaks. Can J Surg. 2017;60(5):335–41.
26. Caron M, Hould FS, Lescelleru O, et al. Long-term nutritional impact of sleeve gastrectomy. Surg Obes Relat Dis. 2017;13(10):1664–73.
27. Bohdjalian A, Langer FB, Shakeri-Leidenmuhler S, et al. Sleeve gastrectomy as sole and definitive bariatric procedure: 5-year results for weight loss and ghrelin. Obes Surg. 2010;20:535–40.
28. Saif T, Strain GW, Dakin G, Gagner M, Costa R, Pomp A. Evaluation of nutrient status after laparoscopic sleeve gastrectomy 1, 3 and 5 years after surgery. Surg Obes Relat Dis. 2012;8:542–7.
29. Benaiges D, Goday A, Ramon JM, et al. Laparoscopic sleeve gastrectomy and laparoscopic gastric bypass are equally effective for reduction of cardiovascular risk in severely obese patients at one year of follow-up. Surg Obes Relat Dis. 2011;7:575–80.
30. Leyba J, Aulestia S, Llopis S. Laparoscopic Roux-en-Y gastric bypass versus laparoscopic sleeve gastrectomy for the treatment of morbid obesity: a prospective study of 117 patients. Obes Surg. 2011;21:212–6.
31. Nocca D, Guillaume F, Noel P, et al. Impact of laparoscopic sleeve gastrectomy and laparoscopic gastric bypass on HbA1c blood level and pharmacological treatment of type 2 diabetes mellitus in severe or morbidly obese patients: results of a multicenter prospective study at 1 year. Updated Position Statement on Sleeve Gastrectomy. Surg Obes Relat Dis. 2012;2:21026.
32. O'Keefe K, Kemmeter P, Kemmeter K. Bariatric surgery outcomes in patients aged 65 years and older at an American Society for Metabolic and Bariatric Surgery center of excellence. Obes Surg. 2010;20:1199–205.
33. Kafri N, Valfer R, Nativ O, et al. Health behavior, food tolerance, and satisfaction after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2011;7:82–8.
34. Alley J, Fenton S, Harnisch M, et al. Quality of life after sleeve gastrectomy and adjustable gastric banding. Surg Obes Relat Dis. 2012;8:31–40.
35. Brunault P, Jacobi D, Leger J, et al. Observations regarding "quality of life" and "comfort with food" after bariatric surgery: comparison between laparoscopic adjustable gastric banding and sleeve gastrectomy. Obes Surg. 2011;21:1225–31.
36. D'Hondt M, Vanneste S, Pottel H, et al. Laparoscopic sleeve gastrectomy as a single-stage procedure for the treatment of morbid obesity and the resulting quality of life, resolution of comorbidities, food tolerance, and 6-year weight loss. Surg Endosc. 2011;25:2498–504.
37. Nedelcu M, Manos T, Cotirlet A, et al. Outcome of leaks after sleeve gastrectomy based on a new algorithm addressing leak size and gastric stenosis. Obes Surg. 2015;25(3):559–63.
38. Perez M, Brunaud L, Kedaifa S, et al. Does anatomy explain the origin of a leak after sleeve gastrectomy. Obes Surg. 2014;24(10):1717–23.
39. Warner D, Sasse K. Technical details of laparoscopic sleeve gastrectomy leading to lowered leak rate: discussion of 1070 consecutive cases. Minim Invasive Surg. 2017:4367059.
40. Aurora A, Khaitan L, Saber A. Sleeve gastrectomy and the risk of leak: a systematic analysis of 4,888 patients. Surg Endosc. 2012;26(6):1509–15.
41. Dakwar A, Assalia A, Khamaysi I, et al. Late complication of laparoscopic sleeve gastrectomy. Case Rep Gastrointest Med. 2013:13153.
42. Zundel N, Hernandez J, Galvao Neto MG, et al. Strictures after laparoscopic sleeve gastrectomy. Surg Laparosc Endosc Percut Tech. 2010;20:154–8.

43. Carter P, LeBlanc K, Hausmann M, et al. Association between gastroesophageal reflux disease and laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2011;7(5):569–72.
44. DuPree C, Blair K, Steele S, et al. Laparoscopic sleeve gastrectomy in patients with preexisting gastroesophageal reflux disease: a national analysis. JAMA Surg. 2014;149(4):328–34.
45. Lutfi R, Palermo M, Cadiere GB. Global bariatric surgery. USA: Springer; 2019.
46. Franco JV, Ruiz PA, Palermo M, Gagner M. A review of studies comparing three laparoscopic procedures in bariatric surgery: sleeve gastrectomy, Roux-en-Y gastric bypass and adjustable gastric banding. Obes Surg. 2011;21(9):1458–68.
47. Mariano P, Mariano G, Michel G. Laparoscopic gastrointestinal surgery. Novel techniques, extending the limits. Berlin, Germany: AMOLCA; 2015.

Chapter 8
Staple-Line Reinforcement and Omentopexy

Carlos Federico Davrieux, Mariano Palermo, Muhammad Shahbaz, and Michel Gagner

8.1 Introduction

Bariatric surgery is one of the most performed operations worldwide. The main techniques used are the Roux-en-Y gastric bypass (RYGB) and the laparoscopic gastric sleeve (LSG). The latter is technically simpler and requires a lower learning curve [1, 2]. It presents acceptable results, and in case of failure, it may be transformed to RYGB. It is for these reasons that it represents one of the main procedures performed in medical centers.

Although LSG is a less complex surgery than RYGB and presents fewer complications, it is still not exempt from them. The most frequent are hemorrhage, leaks, gastroesophageal reflux disease, and gastric tube stenosis [3].

Both bleeding and leakage are feared complications. While leaks originate at the level of the staple line, some hemorrhages too, but not exclusively [4]. Bleeding is associated with incorrect tissue compression/apposition during the use of stapling devices, and the experience of the surgical team. The main site of leakage is below the esophagogastric junction. This leak is difficult to resolve due to the presence of biliary and gastric contents, and high gastric pressure. Some authors consider its

C. F. Davrieux (✉)
Department of Minimally Invasive Surgery, DAICIM Foundation, City of Buenos Aires, Buenos Aires, Argentina

Department of General Surgery, Sanatorio de la Mujer, Rosario, Santa Fe, Argentina

M. Palermo
Diagnomed, University of Buenos Aires, Buenos Aires, Argentina

M. Shahbaz
Department of General Surgery, Weifang People's Hospital, Weifang, Shandong, China

M. Gagner
Department of Surgery, Sacré-Coeur Hospital, Montréal, QC, Canada

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_8

etiology under two well-defined categories: the *mechanical/tissue interaction* and *ischemic causes* [5]. Its diagnosis and early treatment are fundamental to patient safety. This motivated the development of techniques to prevent them [4] and make LSG a safer procedure.

8.2 Techniques to Reduce Postoperative Complications

The most feared complications of LSG appear at the staple line level. It has been reported an incidence of bleeding of 1.1–8.7% [6], and leaks at around 2.7% [7]. Different methods have been developed with the intention of reducing these complications. Among them are staple-line reinforcement (SLR), and omentopexy Fig. 8.1).

8.2.1 Staple-Line Reinforcement

This operative concept groups together the different methods whose objective is to reinforce the staple line of the gastric tube. It includes surgical techniques variants such as oversewing, buttressing the staple line with a specific material (e.g., bovine pericardium, absorbable polymer membrane, synthetic polyester), and glue-type hemostatic agents (thrombin matrix). Although some authors consider that the SLR does not show statistically significant advantages over "nonreinforcement" [8], different meta-analyses conclude that some reinforcement techniques were associated

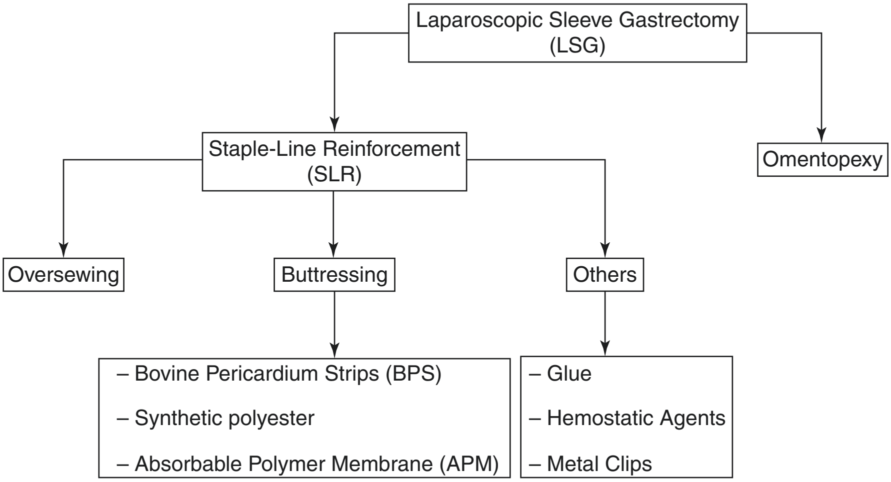


Fig. 8.1 Techniques to reduce laparoscopic sleeve gastrectomy postoperative complications in the staple line

with a lower risk of hemorrhage and general complications [9, 10], but that still more studies are needed to conclude on the other techniques. Postoperative bleeding can be reduced when the stapling line is reinforced [11]. Buttressing and oversewing present similar results. These are the most used staple-line reinforcement variants. The choice depends on the experience and preference of the surgical team [12]. Different multicenter studies, meta-analysis, and systematic reviews have studied their results. Table 8.1 provides the overall results of the use of SLR [4, 13, 14].

8.2.1.1 Oversewing

It includes one of the most used modalities. In this technique, the staple line is reinforced with a sero-serosal running suture with absorbable or nonabsorbable material. It can be applied along the entire gastric tube or in certain areas. The suture technique can be chosen by the surgeon (simple oversewing, imbricating, and baseball stitch, others). Although it is an economical option, it requires an experienced operator in laparoscopic manual suture so as not to excessively prolong the operative time [4, 13, 15, 16]. Some surgeons decide to oversee the entire line of staples, while others oversee only selected regions of the staple line. A study reported that the combination of oversewing and buttress reduces the overall complication rate [17].

8.2.1.2 Buttressing

In this technical option, surgeons can use several materials and techniques.

Bovine Pericardium Strips (BPS) This is a semiabsorbable material made from a biological matrix of collagen developed from bovine pericardium. It is treated with sodium hydroxide to reduce or inactivate transmissible bovine spongiform encephalopathies [18]. It is a reinforcement material that adds thickness (approximately

Table 8.1 Results of the application of SLR

Technique	Leaks rate %[a–c]	Bleeding rate %[b,c]	Overall complication rate %[a]
Nonreinforcement	2.60–4.8	13.7–4.94	8.9
Oversewing	2.04–3.0	1.4–2.41	6.3
Buttressing			
Bovine pericardium	0.3–3.3	0–1.16	7.8
APM	1.09–3.25	1.6–2.09	5.5
Synthetic polyester	7.8	1.3	ND
Glue/Hemostatic agents	2.2	0	ND

SLR staple-line reinforcement, *APM* absorbable polymer membrane
[a]Gagner and Buchwald [13]
[b]D'Ugo et al [4]
[c]Shikora and Mahoney [14]

1 mm) and resistance to the staple line. They are manufactured to fit the stapler device. A plastic assembly ensures dehydrated BPS. A gel is used to create a temporary bond between the BPS buttress and the stapler until it is placed and fired, promoting its rehydration. It remains "stapled" in the tissue when the device is activated. It is easy to use but needs some training from surgeons. It is necessary to choose the correct cartridge size to match the thickness of the tissue, because if the staple height is too small or if the BPS is loaded incorrectly, the stapler may fail. If the BPS is moistened with blood or liquid, they may float out of the staple cartridge. The time required for its use is not excessive, and the cost-benefit ratio is acceptable [4, 13, 14, 15]. Sometimes, to reduce costs, some teams only use BPS applications in the last two stapler firings, in the high-pressure area at the angle of His.

Nonabsorbable synthetic polyester It is a tissue reinforcement material, made of a synthetic polymer preloaded in staplers, with a single use. This product is made of expanded polytetrafluoroethylene (ePTFE). After operating the stapler, this material is fixed in the staple line, reinforcing it, using mechanical strength [16]. The material is released from the stapler arms by pulling an extraction cord [19]. Although this technique has been shown to be better than none, some studies reported that it has a higher leak rate when compared to other methods [4].

Absorbable polymer membrane (APM) This absorbable polymer membrane reinforces the stapling line. It is developed based on the synthetic biocompatible copolymer. There are two types available: PGA:TMC (polyglycolic acid: trimethylene carbonate) and PGA alone. The most used is the PGA:TMC. It consists of synthetic material (67%) and trimethylene carbonate (33%). It is degraded through a combination of hydrolytic and enzymatic pathways, within 6 months. The device is used together with the linear cut, designed for single use; it is prepared before the gastric transection and is used during stapling. It is composed of preformed porous bioabsorbable sheets that are maintained by the use of a nonabsorbable polyester suture. An insertion device facilitates its placement, which is then discarded. After activation of the stapler, the nonabsorbable suture component is removed and discarded. We must bear in mind that this reinforcing material increases the thickness of the stapling area by 0.5 mm. Its use requires some training by the surgeon [20]. Currently, it is presented as a buttress with a high effectivity rate. In a systematic review, Gagner et al. reported that it showed better results than other techniques of reinforcing the suture line [13].

8.2.1.3 Other Procedures

Glue or hemostatic agents Thrombin matrix consists of a bovine-derived gelatin matrix and a human-derived thrombin component. The gelatin matrix consists of cross-linked gelatin granules, while thrombin is a nonpyrogenic sterile material.

The combination of these components forms a biocompatible substance with hemostatic effect, that is reabsorbed in 6–8 weeks. The thrombin matrix is applied over the whole stretch of the staple line. It is a simple procedure, which has a low complication rate [21]. Other products have also been developed, such as tranexamic acid (TXA). It is a synthetic analog of lysine. It works as an antifibrinolytic agent, blocking the binding of lysine with plasminogen molecules. In this way, it inhibits the formation of plasmin and fibrinolysis [22]: 1 g is administered intravenously during induction. It has been proven in cardiac and orthopedic procedures, with satisfactory results.

Metal clips: many centers use metal clips to reduce hemorrhagic complications. They are applied selectively at specific bleeding sites on the staple line intraoperatively. It is an economical way to solve this problem. It is a recommended practice to maintain systolic blood pressure below 120 mmHg during the stapling phase, since it reduces the risk of bleeding and the need for clips. [23].

8.2.2 Omentopexy

Omentopexy is a controversial technique, used by some groups of surgeons. It consists of the fixation of the greater omentum to the staple line. It is carried out after performing LSG according to standard technique, using the greater omentum, which is sutured to the staple line by a nonabsorbable material. Certain studies maintain that the probability of torsion, volvulus, and obstruction of the gastric tube decreases. On the other hand, although it could improve postoperative nausea and vomiting, some authors question this statement [24]. It is considered that this technique does not present a notable decrease in the rate of leak and hemorrhage [25].

8.3 Procedures Without Staple-Line Reinforcement

Some surgical teams decide not to use any reinforcement. The fundamentals are based on the waste of operating time, it is more expensive, and a longer learning curve is needed. Proponents of the reinforcement technique argue that, in case of bleeding or leakage in the staple line, the treatment of the complication will require more time, will be more expensive, and will require the collaboration of other medical teams.

Although it can be considered that the current recommendation is the reinforcement of the stapling lines, finally, the application of this technique depends on the surgical criteria of the performance team. The respect for the stapling technique is very important. It should be noted that stapling with several staple heights can reduce bleeding but increase leakage.

8.4 Conclusion

There are several techniques to reduce bleeding and leakage complications at the level of the stapling line in the LSG. Several studies have shown that the application of SRL reduced the rate of postoperative complications. Although their different techniques show slight advantages among them, none of them stands out above the others.

More prospective randomized clinical trials are needed to determine the best technique. The experience and technology available at the time of surgery should be considered. For this reason, we think that the operating surgical team should opt for the type of treatment that is most effective.

References

1. Carandina S, Montana L, Danan M, et al. Laparoscopic sleeve gastrectomy learning curve: clinical and economical impact. Obes Surg. 2018; https://doi.org/10.1007/s11695-018-3486-3. [Epub ahead of print]
2. Doumouras AG, Saleh F, Gmora S, et al. The value of surgical experience: excess costs associated with the Roux-en-Y gastric bypass learning curve. Surg Endosc. 2018; https://doi.org/10.1007/s00464-018-6472-x. [Epub ahead of print].
3. Trastulli S, Desiderio J, Guarino S, et al. Laparoscopic sleeve gastrectomy compared with other bariatric surgical procedures: a systematic review of randomized trials. Surg Obes Relat Dis. 2013;9(5):816–29.
4. D'Ugo S, Gentileschi P, Benavoli D, et al. Comparative use of different techniques for leak and bleeding prevention during laparoscopic sleeve gastrectomy: a multicenter study. Surg Obes Relat Dis. 2014;10(3):450–4.
5. Baker RS, Foote J, Kemmeter P, et al. The science of stapling and leaks. Obes Surg. 2004;14(10):1290–8.
6. Gagner M, Deitel M, Kalberer TL, et al. The second international consensus summit for sleeve gastrectomy, March 19 – 21, 2009. Surg Obes Relat Dis. 2009;5:476–85.
7. Clinical Issues Committee of American Society for Metabolic and Bariatric Surgery. Updated position statement on sleeve gastrectomy as a bariatric procedure. Surg Obes Relat Dis. 2010;6:1–5.
8. Glaysher M, Khan OA, Mabvuure NT, et al. Staple line reinforcement during laparoscopic sleeve gastrectomy: does it affect clinical outcomes? Int J Surg. 2013;11(4):286–9.
9. Choi YY, Bae J, Hur KY, et al. Reinforcing the staple line during laparoscopic sleeve gastrectomy: does it have advantages? A meta-analysis. Obes Surg. 2012;22(8):1206–13.
10. Wang Z, Dai X, Xie H, et al. The efficacy of staple line reinforcement during laparoscopic sleeve gastrectomy: a meta-analysis of randomized controlled trials. Int J Surg. 2016;25:145–52.
11. Zafar SN, Felton J, Miller K, et al. Staple line treatment and bleeding after laparoscopic sleeve gastrectomy. JSLS. 2018;22(4)
12. Demeusy A, Sill A, Averbach A. Current role of staple line reinforcement in 30-day outcomes of primary laparoscopic sleeve gastrectomy: an analysis of MBSAQIP data, 2015-2016 PUF. Surg Obes Relat Dis. 2018;14(10):1454–61.
13. Gagner M, Buchwald JN. Comparison of laparoscopic sleeve gastrectomy leak rates in four staple-line reinforcement options: a systematic review. Surg Obes Relat Dis. 2014;10(4):713–23.

14. Shikora SA, Mahoney CB. Clinical benefit of gastric staple line reinforcement (SLR) in gastrointestinal surgery: a meta-analysis. Obes Surg. 2015;25(7):1133–41.
15. Al Hajj GN, Haddad J. Preventing staple-line leak in sleeve gastrectomy: reinforcement with bovine pericardium vs. oversewing. Obes Surg. 2013;23(11):1915–21.
16. Serra E, Jacob CE. Optimizing the staple line. In: Lutfi R, Palermo M, Cadière G-B, editors. Global bariatric surgery. 1st ed. Switzerland: Springer; 2018. p. 341–8.
17. El Chaar M, Stoltzfus J. Assessment of sleeve gastrectomy surgical technique: first look at 30-day outcomes based on the MBSAQIP database. J Am Coll Surg. 2018;227(6):564–72.
18. Shah SS, Todkar JS, Shah PS. Buttressing the staple line: a randomized comparison between staple-line reinforcement versus no reinforcement during sleeve gastrectomy. Obes Surg. 2014;24(12):2014–20.
19. Yo LS, Consten EC, Quarles van Ufford HM, et al. Buttressing of the staple line in gastrointestinal anastomoses: overview of new technology designed to reduce perioperative complications. Dig Surg. 2006;23(5–6):283–91.
20. Consten EC, Gagner M, Pomp A, et al. Decreased bleeding after laparoscopic sleeve gastrectomy with or without duodenal switch for morbid obesity using a stapled buttressed absorbable polymer membrane. Obes Surg. 2004;14(10):1360–6.
21. Gentileschi P, D'Ugo S, Benavoli D, et al. Staple-line reinforcement with a thrombin matrix during laparoscopic sleeve gastrectomy for morbid obesity: a case series. J Laparoendosc Adv Surg Tech A. 2012;22(3):249–53.
22. Chakravartty S, Sarma DR, Chang A, et al. Staple line bleeding in sleeve gastrectomy-a simple and cost-effective solution. Obes Surg. 2016;26(7):1422–8.
23. Karaman K, Aziret M, Ercan M, et al. A preventive strategy for staple line bleeding in morbidly obese patients undergoing sleeve gastrectomy. J Laparoendosc Adv Surg Tech A. 2017;27(10):1015–21.
24. Afaneh C, Costa R, Pomp A, et al. A prospective randomized controlled trial assessing the efficacy of omentopexy during laparoscopic sleeve gastrectomy in reducing postoperative gastrointestinal symptoms. Surg Endosc. 2015;29(1):41–7.
25. Arslan E, Banli O, Sipahi M, et al. Effects and results of omentopexy during laparoscopic sleeve gastrectomy. Surg Laparosc Endosc Percutan Tech. 2018;28(3):174–7.

Chapter 9
Upper Endoscopy in Sleeve Gastrectomy

Joshua P. Landreneau and Matthew D. Kroh

9.1 Introduction

The effectiveness of sleeve gastrectomy (SG) at producing weight loss and resolution of weight-related comorbidities with relatively low risk of complications makes SG an attractive bariatric procedure for both the patient and surgeon. As such, in recent years, SG has become the most popular bariatric operation performed in the United States [1]. In addition to its relative technical simplicity, SG also obviates some of the risks inherent to other bariatric procedures such as anastomotic complications, internal hernia, and risks associated with implanted foreign bodies.

However, like all bariatric procedures, SG does not come without risks to the patient. The potential causes of significant morbidity following SG include staple line leaks, postoperative hemorrhage, and stenosis or stricture of the sleeve leading to obstructive symptoms [2]. While these adverse events are relatively rare, their risk can be further decreased with appropriate operative planning and adherence to the principles discussed elsewhere throughout this text. In addition, the judicious use of endoscopy plays an important role in achieving favorable outcomes following SG.

Herein, we discuss the various roles of endoscopy in patients undergoing SG. These include its utility in preoperative evaluation, intraoperative planning and evaluation of the sleeve, as well as its applications for managing complications in the postoperative setting.

J. P. Landreneau
General surgeon in Cleveland, Cleveland Clinic and Cleveland Clinic Fairview Hospital, Cleveland, OH, USA

M. D. Kroh (✉)
Chief of the Digestive Disease Institute at Cleveland Clinic Abu Dhabi, Abu Dhabi, United Arab Emirates
e-mail: KROHM@ccf.org

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_9

9.2 Preoperative Endoscopy

Diagnostic upper endoscopy can play an important role in the preoperative workup of patients considering SG, although there is no consensus as to its absolute necessity in all patients preparing for this operation. Obesity is an independent risk factor for the development of gastroesophageal reflux disease as well as its potential manifestations such as erosive esophagitis and esophageal adenocarcinoma [3]. In addition to allowing for the identification of GERD-associated pathology, preoperative endoscopy may also reveal important anatomical considerations such as the presence of hiatal hernia which may alter surgical planning or cause one to consider other surgical options such as roux-en-Y gastric bypass. As such, the American Society of Gastrointestinal Endoscopy (ASGE) has advised that all patients with preoperative symptoms of GERD such as dysphagia, heartburn, or regurgitation undergo routine upper endoscopy prior to bariatric surgery [4]. The European Association for Endoscopic Surgery (EAES) has taken a more broad approach, recommending preoperative endoscopy in all bariatric patients regardless of symptoms, although this may be substituted with an upper gastrointestinal barium study [5].

There is strong evidence to suggest that patients with symptoms suggestive of GERD should undergo preoperative endoscopic evaluation. However, many patients with GERD may have atypical symptoms or be completely asymptomatic [6]. Further, several studies have noted a relatively high prevalence of clinically significant pathology even among patients who did not report GERD symptoms, including esophagitis and Barrett's esophagus with intestinal metaplasia [7–9]. However, it should be noted that changes in operative approach or a delay in surgery was rare despite such findings; and it has been argued that the number needed to screen in order to identify abnormalities that would affect clinical management is prohibitively high and that routine endoscopy not be performed prior to SG [10].

Given the controversial nature of this topic and inconclusive data, it is difficult to definitively recommend mandatory endoscopic evaluation prior to SG. Indeed, the major bariatric surgical societies have yet to take a consistent position on the subject, based on existing evidence. However, it is reasonable to suggest that, at minimum, preoperative EGD be performed in all patients with preoperative upper gastrointestinal symptoms. There should be a low threshold to additionally pursue this preoperative evaluation even in asymptomatic patients, although this may be left at the discretion of the surgeon and the bariatric treatment team.

9.3 Intraoperative Endoscopy

While likely not essential to the safety and efficacy of SG, intraoperative endoscopy can play an important role in maximizing the success of this procedure. This is typically performed using a standard, front-viewing endoscope using carbon dioxide (CO_2) for insufflation, as the rapid absorption of CO_2 compared to room air can minimize prolonged bowel distension due to insufflation. The use of intraoperative endoscopy to evaluate the sleeve anatomy in real-time can be accomplished with little to no increase in cost or operative time [11, 12], while helping to avoid several of the significant complications associated with this procedure.

9.3.1 Preventing Sleeve Stenosis

Stenosis following SG may lead to significant postoperative morbidity and may necessitate repeat interventions or revisional surgery. This complication is estimated to occur in 0.7–4.0% of cases and can be caused by unintentional narrowing of the stomach, most commonly occurring at the incisura [13, 14].

A common cause for stricture or stenosis following SG is insufficient tubular diameter caused by inadvertent narrowing of the sleeve (Fig. 9.1). There are multiple methods of preventing this complication, such as the use of bougies to guide the staple line to a predetermined size with the goal of preventing inadvertent narrowing of the sleeve, especially at the incisura of the stomach. While this is traditionally accomplished with the use of Maloney bougie dilators or equivalents, an endoscope can serve as a functional equivalent to a Maloney dilator, with a standard gastroscope having a diameter equivalent to 28–30 French and a colonoscope to 38 French. While both methods are acceptable for the luminal sizing of the gastric pouch, it has been suggested that the use of an endoscope for this purpose may result in a decreased rate of complications as well as provide superior long-term weight loss [15, 16]. Narrowing of the tubularized sleeve is most likely to occur at the incisura and may not often be appreciated during laparoscopy but become immediately

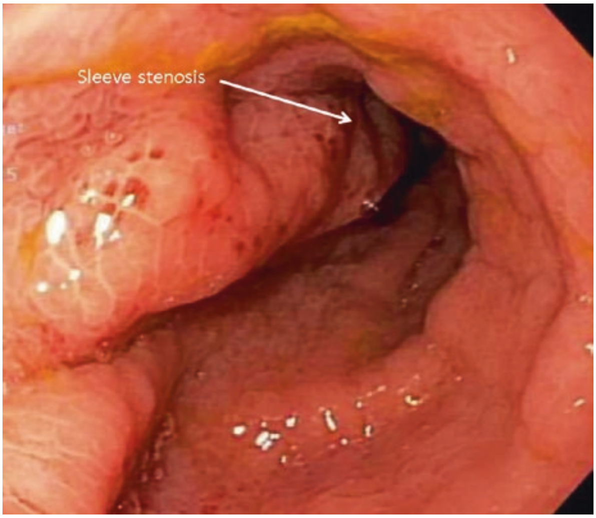


Fig. 9.1 Sleeve stenosis

apparent with endoscopic examination. Further, the use of an endoscope as opposed to bougie dilator may have particular utility when oversewing of the staple line is planned, as subsequent endoscopic examination of the oversewed staple line can identify segments that were inadvertently narrowed and allow for selective removal of invaginating sutures, decreasing the risk of postoperative stenosis [12].

Other causes of postoperative sleeve stenosis include a helical twist of the tubularized stomach (Fig. 9.2). This twisting of the sleeve is caused by errant rotation of the stapler line in the anterior-posterior plane, leading to a functional narrowing despite adequate diameter of the tubularized stomach. Intraoperative endoscopy is of particular value in evaluating intraluminal contour and can reveal subtleties such as twisting or spiraling far greater than a laparoscopic view. A torsion of the gastric sleeve is usually easily traversed with the endoscope by advancing the scope while twisting in the same direction of the helical twist; however, the functional obstruction returns when the scope is withdrawn. Recognition of this technical error either intraoperatively or in the immediate postoperative period can sometimes allow for endoscopic modalities to correct the obstruction, such as the temporary placement of a stent [17]. However, severe torsion may require treatment with gastropexy or conversion to Roux-en-Y anatomy [18, 19].

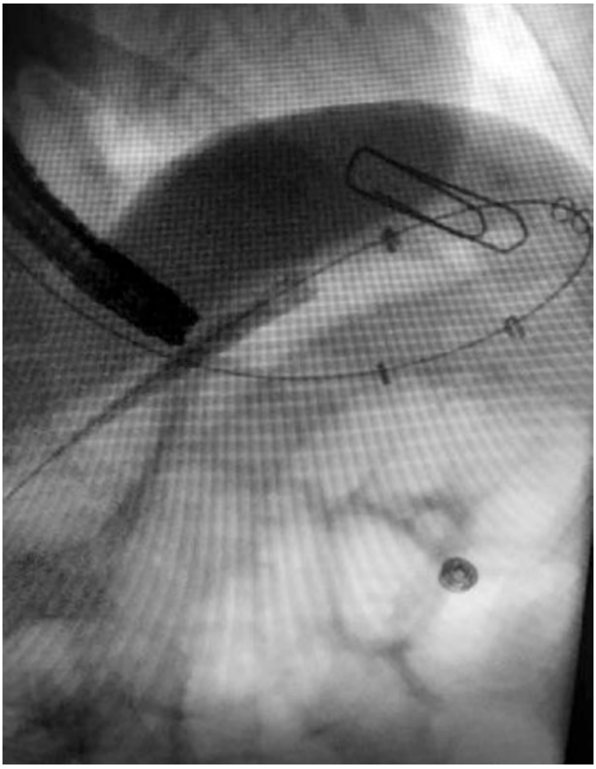


Fig. 9.2 Helical twist of SG, prior to pneumatic dilation

9.3.2 Diagnosing Intraluminal Hemorrhage

Acute gastrointestinal hemorrhage following SG is a rare but significant complication, occurring in approximately 2% of patients [20]. Bleeding events following SG occur most commonly at the staple line, the short gastric vessels, or the gastroepiploic arcade. While external bleeding can be appreciated laparoscopically, endoscopic evaluation can allow for diagnosis of intraluminal bleeding. There is some evidence suggesting that certain methods of staple line reinforcement decrease the rate of staple line bleeding events, although there is no consensus on the ideal reinforcement technique; and no reinforcement method eliminates the risk of this complication [21].

While most cases of intraluminal bleeding following SG are self-limited and respond to nonoperative measures, severe intraluminal hemorrhage may require urgent return to the operating room for endoscopic or surgical control of bleeding. Endoscopic evaluation of the staple line intraoperatively can avoid this morbid situation and allow for interventions to control bleeding. This typically involves the use of endoscopic clips, with or without injection with epinephrine. While thermal coagulation techniques may be of utility in certain situations, it is generally suggested to avoid using these methods on a new staple line [22]. Alternatively, focused laparoscopic oversewing of an identified site of intraluminal bleeding can be accomplished with endoscopic guidance.

The rates of intraoperative bleeding during SG are not often reported, so the incidence of these events is not well described. In a large retrospective series of nearly 1400 patients undergoing SG, Abd Ellatif et al. reported intraoperative bleeding in 2.5% of cases that required oversewing or endoscopic placement of endoclips, suggesting that the rate of this complication is not negligible [23]. That endoscopy can simultaneously diagnose and delivery therapy for these intraluminal bleeding events further adds to the value of routine intraoperative endoscopy during SG.

9.3.3 Evaluating Gastric Leak

Staple line leaks are potentially the most devastating complication following SG. While most leaks do not occur until several days following surgery, stapler equipment failure or technical errors during gastric transection can compromise the staple line leading to leak. Several methods for testing the integrity of the gastric staple line exist, including air or dye insufflation through an orogastric (OG) tube or through the use of intraoperative endoscopy.

Endoscopic testing for gastric leak typically involves the instillation of normal saline into the abdomen to submerge the tubularized stomach. The distal stomach is then occluded with a laparoscopic instrument at the level of the pylorus, and the stomach is insufflated with carbon dioxide using the endoscope. Gas bubbles escaping the stomach can be appreciated laparoscopically and are suggestive of a staple line leak.

The current literature is wanting for high-quality studies exploring the efficacy of endoscopic leak testing during SG compared to other methods of leak testing. However, one can look to evidence from utilizing this technique during Roux-en-Y gastric bypass (RYGB) to demonstrate its advantages over traditional methods of leak testing. When comparing leak testing during RYGB using either intraoperative endoscopy or OG tube air insufflation, Alaedeen et al. found a decreased incidence of postoperative leaks when endoscopic methods were employed, suggesting better efficacy with endoscopic examination [24].

The routine use of any type of intraoperative leak testing remains controversial. In a retrospective study of 1550 consecutive cases of SG, Sethi and colleagues found that there was no correlation between intraoperative leak testing and postoperative leak. In their case series, over 1300 patients underwent intraoperative testing through either endoscopic or OG tube methods, and there were no observed "positive" leak tests in any patient. In a 2015 ASMBS position statement that included commentary on this topic, they concluded that intraoperative leak testing did not reduce the incidence of postoperative leak following SG, although they did not argue for or against its practice [25]. In contrast, a study of 712 by Wahby et al. focusing on intraoperative methylene blue during SG found a positive leak in 28 cases that were able to be repaired by oversewing [26].

The inconsistent data regarding the utility of intraoperative endoscopy to identify or prevent postoperative leaks is likely related to the multiple etiologies of leak following SG. These include stapler misfiring, hematoma, tissue ischemia, distal obstruction, and relatively high intraluminal pressures associated with the gastric sleeve anatomy, and not all of these scenarios can be appreciated with an intraoperative leak test [27, 28]. However, it is clear that in certain cases, staple line leaks are readily apparent and identifiable with intraoperative leak testing, allowing for early recognition and repair [26]. For this reason, intraoperative endoscopy to evaluate the staple line can be encouraged, and performing an endoscopic leak test should be considered routine when intraoperative endoscopy is already planned.

9.4 Perioperative/Postoperative Endoscopy

In addition to its utility in the preoperative and intraoperative setting, endoscopy plays an essential role in the postoperative period following SG. While a complete discussion on the role of endoscopy in the postoperative SG patient is beyond the scope of this chapter, a brief discussion of endoscopy in the perioperative period is warranted.

Early complications following SG include hemorrhage, leak, and functional obstruction of the gastric sleeve secondary to torsion or stricture. These potential complications can be diagnosed with varying degrees of sensitivity and specificity with computerized topography, contrast-enhanced upper gastrointestinal radiography, and endoscopy [29]. In contrast to radiographical studies, upper endoscopy has additional value in that it can play both a diagnostic and therapeutic role.

Gastrointestinal hemorrhage in the early postoperative period may manifest as hematemesis, either as fresh blood or "coffee ground" emesis, melanotic stools, a drop in hemoglobin/hematocrit, or with an acute change in a patient's vital signs. When this complication occurs, it usually presents early, occurring within the first few postoperative days. General principles of initial management are similar to other etiologies of acute gastrointestinal bleeding, including volume and potential blood product resuscitation, with the urgency of intervention dictated by the volume and duration of bleeding and overall clinical state [30]. In patients with severe or ongoing bleeding, there should be a low threshold to perform upper endoscopy. This is ideally performed in the operating room under general anesthesia with orotracheal intubation, as this allows for concomitant diagnostic laparoscopy to identify other causes of bleeding if needed. If a source of intraluminal bleeding is identified, endoscopic management predominantly relies on endoscopic clips and injection therapy for staple line bleeding, but other modalities such as thermal therapies can be considered for bleeding lesions not associated with the staple line [22].

Staple line leak is a rare but potentially devastating complication following SG and is estimated to occur in approximately 1% of patients [31]. Suspicion for gastric leak must be raised with new tachycardia, worsening abdominal or chest pain, nausea and vomiting, or pyrexia in the postoperative setting. Without early intervention these leaks can lead to fistulas, abscesses, sepsis and even death, so early diagnosis and management is critical following this complication. In addition to surgical and percutaneous interventions, endoscopic modalities play an important role in the management of this complication. The clinical state of the patient is paramount when deciding on an appropriate approach, with unstable patients generally requiring more aggressive surgical interventions. However, in an otherwise clinically stable patient in a facility with appropriate resources, multiple endoscopic therapies can be employed to manage staple line leaks with less morbidity than open or laparoscopic surgical approaches. An increasingly preferred method involves the use of self-expanding metal stents (SEMS) to close the defect causing leak. Reported rates of complete closure after SEMS placement range from 65% to 95%, with a median period of stent therapy being 3–10 weeks [32]. As an alternative to stent placement, smaller leaks may be amenable to closure with other approaches such as the use of endoclips, internal drainage of intraabdominal abscesses, or endoscopic suturing platforms, although evidence for the efficacy of these techniques is limited [33].

Obstruction following SF is most often attributable to stenosis or stricture of the tubularized gastric sleeve and does not present in the immediate postoperative setting. However, as previously discussed, technical complications such as a helical twist can produce a functional obstruction of the tubularized stomach. Presentation consists of persistent nausea, vomiting, and intolerance to oral intake. Several authors have reported resolution of obstruction with the placement of endoscopic stents across the twisted portion of the gastric sleeve [17, 34]. In these several reported cases of treatment of early postoperative obstruction due to a helical twist, these patients were reportedly free from symptoms even after removal of the stents. Evidence regarding this application is limited, and further studies are needed, but this endoscopic technique could potentially avoid the morbidity of reoperation in select patients with this complication. Additionally, pneumatic balloon dilation of stenosis has been shown to be effective at diameters of 30 and 35 mm, though efficacy may be diminished with concomitant helical twist [35, 36].

9.5 Conclusion

The use of upper endoscopy in the SG patient has both diagnostic and therapeutic applications. For these indications, the authors recommend its routine use both in the preoperative and intraoperative setting. Additionally, multiple early complications can be effectively managed through endoscopic techniques while potentially avoiding surgical intervention. The lack of equipment or qualified personnel to perform routine endoscopy should not necessarily preclude bariatric surgeons from offering this important weight loss procedure; but the proven benefits to treat and prevent both early and late complications make endoscopy an important adjunct to effectively performing SG.

References

1. Sullivan S, Kumar N, Edmundowicz SA, Abu Dayyeh BK, Jonnalagadda SS, Larsen M, et al. ASGE position statement on endoscopic bariatric therapies in clinical practice. Gastrointest Endosc. 2015;82(5):767–72.
2. Cai JX, Schweitzer MA, Kumbhari V. Endoscopic Management of Bariatric Surgery Complications. Surg Laparosc Endosc Percutan Tech. 2016;26(2):93–101.
3. Campos JM, Mello FS, Ferraz AA, Brito JN, Nassif PA, Galvao-Neto Mdos P. Endoscopic dilation of gastrojejunal anastomosis after gastric bypass. Arq Bras Cir Dig. 2012;25(4):283–9.
4. de Moura EG, Orso IR, Aurelio EF, de Moura ET, de Moura DT, Santo MA. Factors associated with complications or failure of endoscopic balloon dilation of anastomotic stricture secondary to Roux-en-Y gastric bypass surgery. Surg Obes Relat Dis. 2016;12(3):582–6.
5. Escalona A, Devaud N, Boza C, Perez G, Fernandez J, Ibanez L, et al. Gastrojejunal anastomotic stricture after Roux-en-Y gastric bypass: ambulatory management with the Savary-Gilliard dilator. Surg Endosc. 2007;21(5):765–8.
6. Sapala JA, Wood MH, Sapala MA, Flake TM, Jr. Marginal ulcer after gastric bypass: a prospective 3-year study of 173 patients. Obes Surg. 1998;8(5):505–16.
7. Huang CS, Forse RA, Jacobson BC, Farraye FA. Endoscopic findings and their clinical correlations in patients with symptoms after gastric bypass surgery. Gastrointest Endosc. 2003;58(6):859–66.
8. Garrido Jr. AB, Rossi M, Lima Jr. SE, Brenner AS, Gomes Jr CAR. Early marginal ulcer following Roux-en-Y gastric bypass under proton pump inhibitor treatment: prospective multicentric study. Arquivos de Gastroenterologia. 2010;47:130–4.
9. Huang CS, Farraye FA. Endoscopy in the bariatric surgical patient. Gastroenterol Clin North Am. 2005;34(1):151–66.
10. Fobi M, Lee H, Igwe D, Felahy B, James E, Stanczyk M, et al. Band erosion: incidence, etiology, management and outcome after banded vertical gastric bypass. Obes Surg. 2001;11(6):699–707.

11. Campos JM, Evangelista LF, Ferraz AA, Galvao Neto MP, De Moura EG, Sakai P, et al. Treatment of ring slippage after gastric bypass: long-term results after endoscopic dilation with an achalasia balloon (with videos). Gastrointest Endosc. 2010;72(1):44–9.
12. Espinel J, Pinedo E. Stenosis in gastric bypass: Endoscopic management. World J Gastrointest Endosc. 2012;4(7):290–5.
13. Marins Campos J, Moon RC, Magalhaes Neto GE, Teixeira AF, Jawad MA, Bezerra Silva L, et al. Endoscopic treatment of food intolerance after a banded gastric bypass: inducing band erosion for removal using a plastic stent. Endoscopy. 2016;48(6):516–20.
14. Blero D, Eisendrath P, Vandermeeren A, Closset J, Mehdi A, Le Moine O, et al. Endoscopic removal of dysfunctioning bands or rings after restrictive bariatric procedures. Gastrointest Endosc. 2010;71(3):468–74.
15. Wilson TD, Miller N, Brown N, Snyder BE, Wilson EB. Stent induced gastric wall erosion and endoscopic retrieval of nonadjustable gastric band: a new technique. Surg Endosc. 2013;27(5):1617–21.
16. Ferraz A, Campos J, Dib V, Silva LB, de Paula PS, Gordejuela A, et al. Food intolerance after banded gastric bypass without stenosis: aggressive endoscopic dilation avoids reoperation. Obes Surg. 2013;23(7):959–64.
17. Shnell M, Fishman S, Eldar S, Goitein D, Santo E. Balloon dilatation for symptomatic gastric sleeve stricture. Gastrointest Endosc. 2014;79(3):521–4.
18. Zundel N, Hernandez JD, Galvao Neto M, Campos J. Strictures after laparoscopic sleeve gastrectomy. Surg Laparosc Endosc Percutan Tech. 2010;20(3):154–8.
19. Rosenthal RJ, Diaz AA, Arvidsson D, Baker RS, Basso N, Bellanger D, et al. International Sleeve Gastrectomy Expert Panel Consensus Statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8(1):8–19.
20. Vix M, Diana M, Marx L, Callari C, Wu HS, Perretta S, et al. Management of staple line leaks after sleeve gastrectomy in a consecutive series of 378 patients. Surg Laparosc Endosc Percutan Tech. 2015;25(1):89–93.
21. Bhayani NH, Swanstrom LL. Endoscopic therapies for leaks and fistulas after bariatric surgery. Surg Innov. 2014;21(1):90–7.
22. Baretta G, Campos J, Correia S, Alhinho H, Marchesini JB, Lima JH, et al. Bariatric postoperative fistula: a life-saving endoscopic procedure. Surg Endosc. 2015;29(7):1714–20.
23. Campos JM, Pereira EF, Evangelista LF, Siqueira L, Neto MG, Dib V, et al. Gastrobronchial fistula after sleeve gastrectomy and gastric bypass: endoscopic management and prevention. Obes Surg. 2011;21(10):1520–9.
24. Silva LB, Moon RC, Teixeira AF, Jawad MA, Ferraz AA, Neto MG, et al. Gastrobronchial Fistula in Sleeve Gastrectomy and Roux-en-Y Gastric Bypass-A Systematic Review. Obes Surg. 2015;25(10):1959–65.
25. Puli SR, Spofford IS, Thompson CC. Use of self-expandable stents in the treatment of bariatric surgery leaks: a systematic review and meta-analysis. Gastrointest Endosc. 2012;75(2):287–93.
26. Basha J, Appasani S, Sinha SK, Siddappa P, Dhaliwal HS, Verma GR, et al. Mega stents: a new option for management of leaks following laparoscopic sleeve gastrectomy. Endoscopy. 2014;46 Suppl 1 UCTN:E49–50.
27. Shehab HM, Hakky SM, Gawdat KA. An Endoscopic Strategy Combining Mega Stents and Over-The-Scope Clips for the Management of Post-Bariatric Surgery Leaks and Fistulas (with video). Obes Surg. 2015.
28. Fischer A, Bausch D, Richter-Schrag HJ. Use of a specially designed partially covered self-expandable metal stent (PSEMS) with a 40-mm diameter for the treatment of upper gastrointestinal suture or staple line leaks in 11 cases. Surg Endosc. 2013;27(2):642–7.
29. Nedelcu M, Manos T, Cotirlet A, Noel P, Gagner M. Outcome of leaks after sleeve gastrectomy based on a new algorithm adressing leak size and gastric stenosis. Obes Surg. 2015;25(3):559–63.
30. van Wezenbeek MR, de Milliano MM, Nienhuijs SW, Friederich P, Gilissen LP. A Specifically Designed Stent for Anastomotic Leaks after Bariatric Surgery: Experiences in a Tertiary Referral Hospital. Obes Surg. 2015.

31. Fishman MB, Sedov VM, Lantsberg L. [Laparoscopic adjustable gastric banding in treatment of patients with obesity]. Vestn Khir Im I I Grek. 2008;167(1):29–32.
32. Galloro G, Magno L, Musella M, Manta R, Zullo A, Forestieri P. A novel dedicated endoscopic stent for staple-line leaks after laparoscopic sleeve gastrectomy: a case series. Surg Obes Relat Dis. 2014;10(4):607–11.
33. Bezerra Silva L, Galvao Neto M, Marchesini JC, E SNG, Campos J. Sleeve gastrectomy leak: endoscopic management through a customized long bariatric stent. Gastrointest Endosc. 2017;85(4):865–6.
34. Pequignot A, Fuks D, Verhaeghe P, Dhahri A, Brehant O, Bartoli E, et al. Is there a place for pigtail drains in the management of gastric leaks after laparoscopic sleeve gastrectomy? Obesity surgery. 2012;22(5):712–20.
35. Lutfi, R., Palermo, M., Cadière, G.B. (Eds.) Global Bariatric Surgery. The Art of Weight Loss Across the Borders. Springer. 2018.
36. Palermo M., Gimenez M., Gagner M. Laparoscopic Gastrointestinal Surgery. AMOLCA Barranquilla, Colombia. 2015.

Chapter 10
Staplers, Cartridges, and Energy Devices

Mojdeh S. Kappus and Daniel B. Jones

10.1 Energy Devices

The adaptation of electrosurgical devices to be used for robotic and laparoscopic surgery has pushed the boundaries and complexity of that which surgeons can perform using minimally invasive techniques [1]. Energy devices can be used to ligate vessels, fulgurate bleeding surfaces, and divide and dissect tissues. In performing the perfect sleeve gastrectomy, electrosurgical devices are paramount to dividing the gastroepiploic and short gastric vessels, dissecting the diaphragmatic hiatus, and ensuring hemostasis throughout the procedure. The most commonly used electrosurgical devices for laparoscopic sleeve gastrectomies are bipolar devices and ultrasonic shears; however, in certain circumstances, monopolar devices including the argon beam may be utilized.

10.1.1 Bipolar Devices

The basic electrosurgical circuit is composed of an electrosurgical unit, connecting wires, two electrodes, and the patient. When using a monopolar device, one electrode known as the dispersive electrode is placed on the patient. This electrode is also commonly and incorrectly referred to as a "grounding pad." The other electrode, which is known as the active electrode, is the monopolar instrument itself. This electrode may take the form of a hook, spatula, or "Bovie" pencil. Each electrode is connected by individual wire to the electrosurgical unit. When the monopolar instrument is activated, current passes from the electrosurgical unit to the

M. S. Kappus (✉) · D. B. Jones
Department of Surgery, Beth Israel Deaconess Medical Center, Boston, MA, USA
e-mail: mkappus@bidmc.harvard.edu; djones1@bidmc.harvard.edu

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_10

monopolar instrument, through the patient, to the dispersive electrode and back to the electrosurgical unit, thus creating a complete circuit (Fig. 10.1). In contrast, bipolar devices contain two active electrodes within the instrument itself, typically on either jaw of a bipolar forceps. Only one wire connects the bipolar device to the electrosurgical unit. Current only passes through the tissue held within the grasp of the bipolar forceps to create a complete circuit [2]. This allows for a more targeted approach to energy delivery allowing for utilization of a lower voltage and decrease in inadvertent injury or spread of current to adjacent tissues.

Bipolar devices are primarily used for the coaptation of tissues and blood vessels. The target tissue or vessel is first compressed by the jaws of the bipolar forceps, thus impeding blood flow. The bipolar device is then activated allowing for radiofrequency current to pass through the electrodes and tissue where it is converted to intracellular heat (approximately 60 °C) and allows for coagulation, desiccation, or vaporization depending on tissue temperature [3]. Bipolar devices may be used to seal vessels up to 7 mm in diameter. Most commercially available bipolar devices contain feedback mechanisms that monitor tissue impedance and temperature to automatically adjust the delivery of radiofrequency energy. Additionally, many

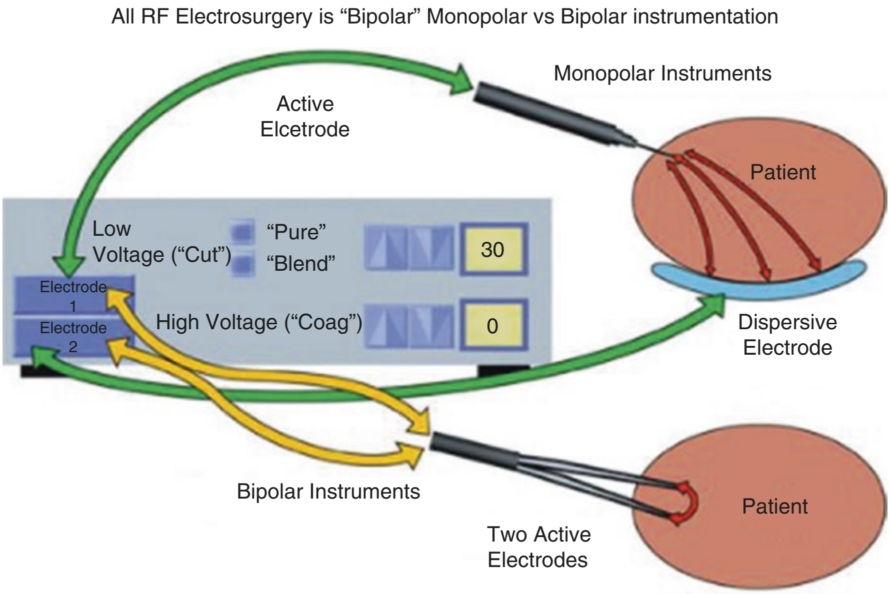


Fig. 10.1 All radiofrequency (RF) electrosurgery is essentially bipolar in nature in that two electrodes are used to complete the circuit. When so-called monopolar energy is used, the handheld electrosurgical device is considered the active electrode and what is often incorrectly referred to as the "grounding pad" is considered the dispersive electrode. When bipolar energy is used, the handheld electrosurgical device contains two active electrodes across which current flows. (Modified from: Munro [2])

bipolar devices also contain a sliding blade that can be activated to cut tissue after it has been desiccated.

Various commercial bipolar devices are available which differ in the size of grasping jaws. When using the bipolar device for sleeve gastrectomy, if too much tissue is brought into the jaws of the device, proper seal formation will be impeded, causing subsequent bleeding. It is also important to note that there may be lateral thermal spread up to 7 mm, which may cause inadvertent injury to adjacent structures. This is particularly important when dividing the gastroepiploic and short gastric vessels along the border of the stomach and dissecting the diaphragmatic hiatus. Although the majority of the fundus will be removed after stapling, thus removing any inadvertently damaged stomach tissue, it is important to remain at least 7 mm away from the distal stomach and diaphragmatic hiatus, where injury from lateral thermal spread may contribute to leaks.

In addition to taking an appropriate amount of tissue into the jaws of the bipolar device at an appropriate distance from important structures, it is also important to avoid other materials such as metallic clips or staples as these can cause an unpredictable diversion of current, which may result in injury. Patients with comorbid conditions that change the size and consistency of blood vessels may change the efficacy of the bipolar device. Additionally, char build-up in the jaws of the instrument must be cleaned so as not to increase impedance, which may interfere with appropriate tissue or vessel sealing. If in the process of using the bipolar device the tissue becomes adherent to the jaws, mechanical force should not be used to separate it as this may cause tissue destruction or bleeding. Instead, tissue dislodgement may be achieved by reactivating the device under irrigation.

10.1.2 Ultrasonic Energy Devices

Ultrasonic energy devices convert electrical current to mechanical energy via the excitation of piezoelectrodes contained between metal cylinders within the handle of the ultrasonic device (Fig. 10.2). The vibrations of these piezoelectrodes create an ultrahigh-frequency (23–55 kHz) oscillation that is transmitted over the fixed active blade of the ultrasonic energy device. When tissue is compressed between the fixed active blade and articulating passive blade of the ultrasonic energy device, mechanical friction from the ultrahigh ultrasonic frequency oscillation causes protein bonds to break. Additionally, frictional forces cause an elevation of the intracellular temperature. At 60 °C, protein denaturation and bond reformation allow for the coaptation or coagulation of blood vessels, similar to the bipolar device (Fig. 10.3). When the temperature reaches 100 °C, vaporization of intracellular water occurs leading to cell rupture, and the "cutting" effect of the ultrasonic energy device is demonstrated [4]. The surgeon may also control the amount of mechanical energy delivered per unit time by adjusting blade excursion. Typically, a minimum and

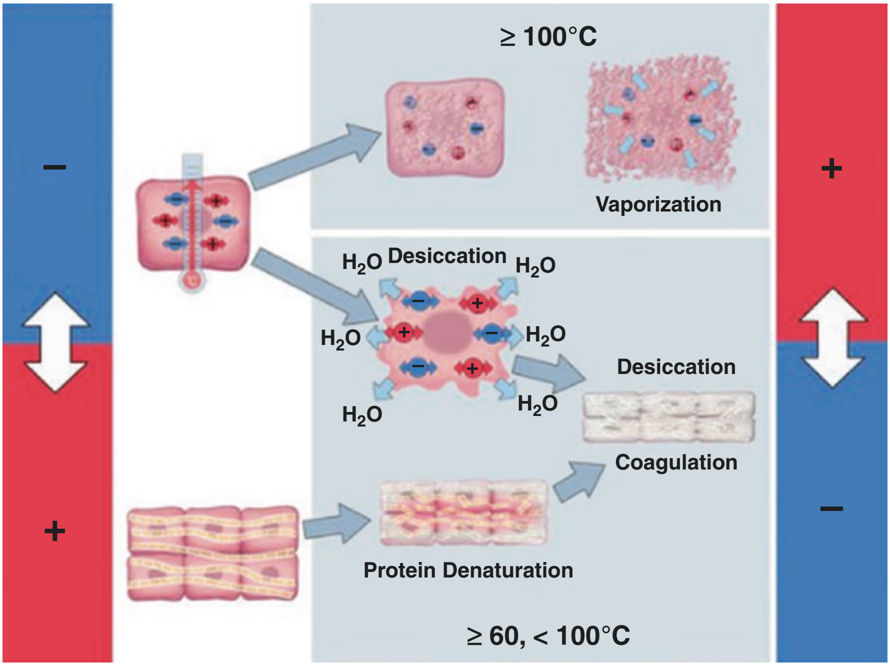


Fig. 10.2 Ultrasonic shears contain piezoelectric ceramic discs that convert electric energy into mechanical motion. When tissue is compressed between the fixed active blade and articulating passive blade of the ultrasonic energy device, mechanical friction from the ultrahigh ultrasonic frequency oscillation causes protein bonds to break. Additionally, frictional forces cause an elevation of the intracellular temperature. (Modified from: Bittner et al. [4]. With permissions from Springer Nature)

maximum blade excursion are utilized commercially. The minimum setting allows for less energy to be delivered over a longer period of time, thus allowing coagulation to occur for vessels up to 5 mm in diameter. The maximum setting allows for greater energy to be delivered over a shorter period of time, thus allowing for cutting to occur. In addition to adjusting blade excursion, the surgeon may also affect tissue cutting and coagulation by adjusting tissue tension. Increased tension against the active blade allows for more rapid cutting but decreases coagulation of vessels, which may lead to bleeding.

In comparison to bipolar devices, the active blade of the ultrasonic shears may reach high temperatures of up to 105 °C with a thermal spread of 3 mm. The active blade may retain these high temperatures for 20–45 seconds depending upon the target tissue; thus, great care must be taken not to inadvertently allow contact between the active blade and adjacent tissue until it has fully cooled. The active blade should be kept under direct visualization at all times to prevent inadvertent injury [5].

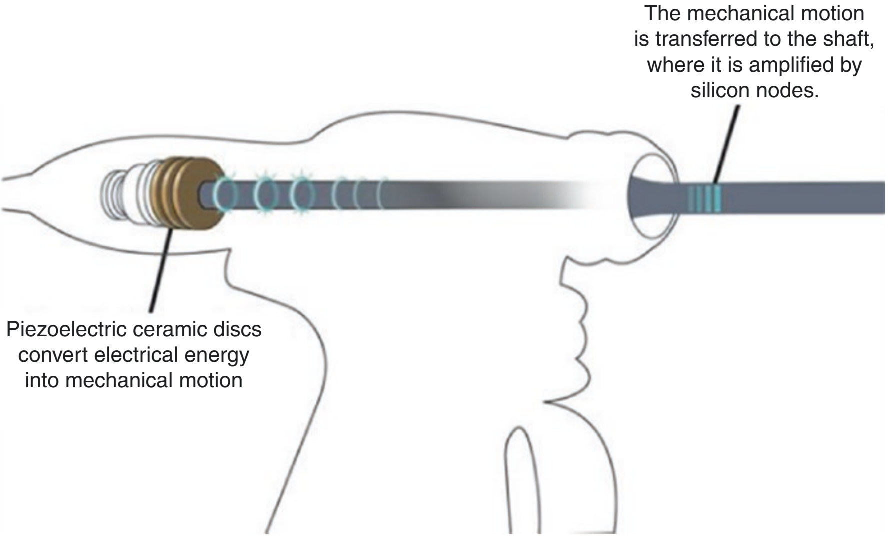


Fig. 10.3 Impact of elevated temperature on tissue. Tissue desiccation results from cellular dehydration and allows for a cutting effect through the tissue. Protein denaturation occurs with the rupture of hydrothermal bonds with crosslinks and reformation of these in a random fashion that includes bridging the gap between two opposing tissue surfaces. Provided these tissues are somewhat similar in protein content, the result will be a strong seal, otherwise referred to as vessel coaptation. (Modified from: Munro [2])

10.1.3 Bipolar Versus Ultrasonic

Multiple studies have been conducted comparing various commercially available bipolar and ultrasonic devices. Comparisons of such factors as vessel sealing and cutting time, burst pressure, lateral thermal spread, particulate/smoke production, and seal histology have been made between devices with no clear consensus as to which device is superior in terms of safety and efficacy [3, 6].

In some cases, ultrasonic devices may be preferred over bipolar/monopolar devices in order to avoid electromagnetic interference since ultrasonic devices utilize mechanical rather than electrical energy (Table 10.1). Electromagnetic energy may cause damage or inappropriately trigger/inhibit implantable devices such as pacemakers, implantable defibrillators, nerve stimulators, and cochlear implants. Bipolar energy is typically considered to be safer than monopolar energy in that when used correctly, current should only pass through the small amount of tissue held within the jaws of the instrument. However, a bipolar instrument may still cause damage or injury if used in close proximity to the implantable device. If monopolar energy must be used, it should be used as far from the implantable device as possible at a low-voltage setting ("cut" mode) to avoid injury. The electrosurgical device being used should not be activated until direct contact with the tissue is made.

Table 10.1 Differences between electrosurgery devices and ultrasonic shears

Category	Electrosurgery	Ultrasonic shears
Grounding electrode	Yes	No
Smoke generation	Yes	No
Electrocardiogram, pacemaker interference	Yes	No
Current travels through patient	Yes	No
Heat generation	Constant	Time dependent
Thermal spread	Moderate	Minimal
Cost	Low/intermediate	Intermediate/high
Complications	Current concentration Direct coupling Capacitive coupling Tissue sticking	Thermal injury

Modified from Bittner et al. [4]. With permissions from Springer Nature

When implantable cardiac defibrillators (ICDs) or pacemakers are in place, consultation with a cardiologist or cardiac electrophysiologist to determine the appropriate intraoperative management of the device may be wise. Pacemakers may often be converted to asynchronous mode, and ICDs' anti-tachyarrhythmia functions may be suspended, typically by placing a magnet over the device. Conversion to asynchronous mode should be avoided in patients prone to ventricular tachyarrhythmias. External defibrillators and pacing equipment should be readily available in these cases. Electromagnetic energy may also interfere with EKG monitoring; thus, consideration must be given to using other methods of monitoring perfusion [7].

10.1.4 Monopolar Energy

Monopolar energy devices may be used in sleeve gastrectomy for dissection of the hiatus in the case of a hiatal hernia or in the removal of a gastric band prior to conversion to sleeve gastrectomy. Monopolar energy may also be used for hemostasis at the port sites. Monopolar energy devices used in the operating room involve the creation of a circuit system through which current can pass to create the desired effect. Generally, alternating current from a wall outlet (60 Hz) passes into an electrosurgical unit where it is converted to radiofrequency output (300–500 kHz). Different waveforms can then be created by the surgeon by changing the settings on the electrosurgical unit. Typically, a surgeon may choose between a continuous low-voltage waveform, commonly called "cut" or an intermittent, dampened high-voltage waveform, commonly called "coag." An additional option known as "blend" may also be used which typically offers an intermittent version of the "cut" waveform; however, this may vary between devices and manufacturers. After passing through the electrosurgical unit, current then travels via connecting wires to a handheld device known as the active electrode. Handheld devices may include a "Bovie" pencil, laparoscopic hook, or spatula. The handheld device may contain buttons to control the waveform emitted, or it may be controlled with a foot pedal. Current then passes through the tissue with which the device is making contact, travels through the patient's body, and then makes its way to a dispersive electrode often incorrectly referred to as a "grounding pad." Next, current passes from the dispersive electrode via connecting wires to the electrosurgical unit to complete the circuit (Fig. 10.1). Although the same current passes throughout the circuit, the current density at the active electrode is much greater than that at the dispersive electrode. This is due to the surface area of each electrode. Thus, at the active electrode, current has its desired effect on the tissue, but this same effect is not seen at the site of the dispersive electrode where current dissipates across a larger surface area [8].

Electrosurgical energy may cause various tissue effects that are dependent upon a multitude of factors including voltage, waveform, tissue impedance, current density, distance from the target tissue, and time. Depending on these factors, cells or tissues may be vaporized, desiccated, coagulated, or fulgurated. Vaporization occurs at a temperature of 100 °C. When low-voltage continuous energy is used at a quick pace, with minimal tissue contact, at a high current density, this vaporization results in what appears to be a "cutting" of the tissue. Desiccation and coagulation occur at temperatures of 60–90 °C as a result of protein denaturation and cell dehydration. Coagulation is best accomplished by compression or apposition of the vessel walls and application of a low-voltage continuous waveform. Fulguration occurs at temperatures greater than 100 °C, which results in breakdown of organic molecules into carbon (Fig. 10.3). This is best accomplished with a high-voltage modulated waveform using an arcing technique in which the electrode does not directly contact the tissue.

10.1.5 Argon

Although rarely used in sleeve gastrectomy, argon beam fulguration is an important tool for addressing potential injuries to the liver or spleen. A steady stream of argon gas particles conducts electricity remarkably well, allowing for the rapid, uniform application of electric current to an area that does not penetrate more than 2–5 mm into underlying tissue, more superficial than other monopolar instruments [9]. The emitted gas flow also pushes blood away from the target, making it well suited for quickly staunching capillary oozing when encountered in large areas of irregular tissue. Care must be taken, and the intra-abdominal pressure closely monitored because the influx of gas accompanying use may increase the risk of emboli and compartment syndrome. Leaving a laparoscopic port open during use is a well-established preventative measure [10]. The distance of the electrode from the tissue must also be carefully calibrated to provide effective fulguration without inadvertently pushing gas into an open vessel, provoking embolism. Several case studies noted direct contact between the electrode and bleeding tissue immediately prior to patient decompensation due to gas emboli [11]. These reports also note that the hypotension accompanying hemorrhagic hypovolemia may mask early signs of gas embolus.

10.1.6 Electrosurgical Safety

Electrosurgical devices have allowed for great advances in the breadth of surgical procedures that can now be performed using minimally invasive surgery; however, these devices can also result in catastrophic harm to the patient, surgeon, and operating room staff if used incorrectly [12]. For example, care must be taken to ensure that electrosurgical devices, especially monopolar instruments, are not inadvertently activated, or activated in contact with other conduction materials or tissues other than the target tissue as this may lead to direct or capacitive coupling. For this reason, surgeons performing single-port laparoscopy must take special care to avoid the contact of activated electrosurgical devices with other instruments in close proximity. Additionally, electrosurgical devices may serve as ignition sources in operating room fires and explosions. Thus, it is of paramount importance that all operating room personnel be appropriately trained in the use and principles of electrosurgical devices [13]. To that end, the Society of American Gastrointestinal and Endoscopic Surgeons offers a web-based didactic course entitled Fundamental Use of Surgical Energy (FUSE) from which most of the information in this chapter was derived. A comprehensive review of the FUSE didactic material should be completed before the use of electrosurgical energy devices [14, 15].

10.2 Staplers and Cartridges

Perhaps the most dreaded complication of sleeve gastrectomy is staple line leakage. There are multiple factors that may contribute to staple line leaks including bougie size, staple height, appropriate stapler usage, use of buttressing or fibrin glue, body mass index (BMI), and patient comorbidities amongst others [16]. Staple line leaks likely mainly occur secondary to a combination of tissue ischemia and poor staple apposition; thus, education on the appropriate use of stapling devices is vital in performing the perfect sleeve gastrectomy. Various commercial stapling devices and cartridges are available; thus, it is important to review the instructions for use for each product. Nevertheless, general basic principles apply to proper surgical staple use.

10.2.1 Staple Height

Staple cartridges come in various staple heights designed for varying tissue thicknesses. For the ease of further discussing appropriate staple use in sleeve gastrectomy, the commonly used color schematics and staple heights are as follows: gray (0.75 mm), white (1.0 mm), blue (1.5 mm), gold (1.8 mm), green (2.0 mm), black (2.3 mm), gray tri-staple (0.75, 0.75, 0.75 mm), tan tri-staple (0.75, 1.0, 1.25 mm),

Table 10.2 Published closed staple height and assumed appropriate range. Cartridge colors and staple heights refer to Ethicon Endosurgery (Blueash, CN) products

Color	Min closed height range (mm)	Published closed height (mm)	Max closed height range (mm)
Gray	0.5	0.75	0.875
White	0.875	1.0	1.25
Blue	1.25	1.5	1.65
Gold	1.65	1.8	1.9
Green	1.9	2.0	2.15
Black	2.15	2.3	2.5

Modified from: Huang and Gagner [17]. https://doi.org/10.1007/s11695-015-1705-8. With permissions from Springer Nature

Table 10.3 Published closed staple height and assumed appropriate range. Cartridge colors and staple heights refer to Covidien (Norwalk, CT) products

Color	Min closed height range (mm)	Published closed height (mm)	Max closed height range (mm)
Gray	0.5	0.75, 0.75, 0.75	1.0
Tan	0.5	0.75, 1.0, 1.25	1.5
Purple	1.0	1.25, 1.5, 1.75	2.0
Black	1.5	1.75, 2.0, 2.25	2.5

Modified from: Huang and Gagner [17]. https://doi.org/10.1007/s11695-015-1705-8. With permissions from Springer Nature

purple tri-staple (1.25, 1.5, 1.75 mm), and black tri-staple (1.75, 2.0, 2.25 mm) [17]. Cartridge colors and staple heights refer to Covidien (Norwalk, CT) and Ethicon Endosurgery (Blueash, CN) products (Tables 10.2 and 10.3).

In choosing the appropriate staple height, one must carefully consider the thickness of the tissue. If the tissue is too thin, the staple approximation will be loose, and leakage or bleeding may result. If the tissue is too thick, overcompression by the stapling device may cause tissue ischemia, which may also result in leakage or bleeding. According to Baker et al., leaks occur when intraluminal pressure is greater than the strength of the tissue and staple line [18]. Thus, it is also important to avoid narrowing at areas such as the angle of His and gastroesophageal junction where increased intraluminal pressure may increase the risk of leak formation.

In March 2011, an international expert panel was convened to provide consensus best practice guidelines on sleeve gastrectomy. Twenty-four centers representing 11 countries with a collective experience of over 12,000 sleeve gastrectomies performed were gathered. Regarding stapling, 81% agreed that it is not appropriate to use staples with closed height less than that of a blue load (1.5 mm) on any part of sleeve gastrectomy, 79% agreed that when using buttressing materials, the surgeon should never use any staple with closed height less than that of a green load (2.0 mm), 87% agreed that when resecting the antrum, the surgeon should never use any staple with closed height less than that of a green load (2.0 mm), and 100% agreed that staple line reinforcement will reduce bleeding along the staple line [19].

Multiple studies have been conducted to determine the appropriate staple height for the stapling of the gastric antrum, midbody, and fundus during sleeve gastrectomy. In 2015, Huang et al. found that the wide range of gastric thicknesses across different regions of the stomach and between different patients was so variable that a “thickness calibration device” would be needed to properly choose a staple height [17]. In a study conducted by Boeker et al., 141 patients underwent laparoscopic sleeve gastrectomy using Ethicon staple cartridges starting at 4–6 cm proximal to the pylorus. First, two green 4.1 mm loads were used followed by either gold 3.8 mm loads or blue 3.5 mm loads according to the judgement of the surgeon. The removed fundus of the stomach was fixed in formalin and sent to pathology for evaluation of stomach thickness. They found the wall thickness of the proximal sleeve to range from 1439 to 6345 μm with a median value of 3242 μm. The median male stomach thickness was 3590 μm compared to the female stomach thickness which was 3198 μm. Of three patients who developed a postoperative leak, all were female and the median wall thickness was 2810 μm compared to 3249 μm. No difference in leak rate was noted between patients who received gold vs. blue cartridge staple loads [20]. Thus, in this case, it was not a stomach that was too thick that led to a staple line leak, but rather it may have been a stomach that was too thin for the staples used that led to a staple line leak.

10.2.2 Buttressing

In addition to choosing a proper staple height, a decision about whether or not to use staple line reinforcement must also be made [21]. Some studies have shown benefits of staple line reinforcement with buttressing material, including a decrease in bleeding and a decrease in intraoperative time [22]. Other studies have noted no difference in leak rates with or without the use of buttressing material in patients undergoing sleeve gastrectomy.

By conducting leak tests on ex vivo porcine and cadaveric gastric pouches, Baker et al. found that staple lines reinforced with polytetrafluoroethylene were significantly able to withstand greater intraluminal pressures without leakage, full-thickness oversewing of the staple line weakened the staple line, and there was no difference in leakage thresholds between three- and two-row staple lines [18]. Shah et al. conducted a randomized study of 100 patients undergoing sleeve gastrectomy with or without staple line reinforcement with Peri-Strips Dry® with Veritas®. A 34 or 36 French bougie was used on patients with either BMI > 32.5 kg/m^2 with one comorbidity or BMI > 37.5 kg/m^2. No staple line leaks were noted in either group; however, there were fewer staple line bleeds and significantly shorter operating time in the staple line reinforcement group [23]. Debs et al. found that in a series of 434 consecutive patients undergoing laparoscopic sleeve gastrectomy, uniformly using black staple loads with Gore Seamgaurd reinforcement resulted in a 0% leak rate [24]. In a retrospective review of 204 patients undergoing laparoscopic sleeve gastrectomy with Gore® Seamgaurd®, two patients (0.9%) suffered major bleeding requiring return to the OR and 0 patients suffered a leak [25]. In 2014, Gagner and Buchwald conducted a systematic review comparing various means of staple line reinforcement including oversewing, nonabsorbable bovie pericardial strips, and absorbable polymer membrane. They included 88 papers in their analysis and found 191 leaks amongst 8920 patients, giving an overall leak rate of 2.1%. Amongst these, they found that patients with bovine pericardium buttressing had the highest leak rate (3.3%), followed by no reinforcement (2.6%), then oversewing (2.04%). The lowest leak rate was found in patients who had received absorbable membrane buttressing (1.09%) [26].

Perhaps the most important thing to remember when using buttressing material is that the thickness of the material being used must be factored into the choice of staple height used to avoid incomplete staple formation. For example, bovine pericardial strips (Peri-Strips Dry®) add 0.8 mm thickness (when used on both stapler prongs) and absorbable synthetic polyglycolide (Gore® Seamguard®) add 0.5 mm thickness (when used on both stapler prongs) [27]. If buttress reinforced staple lines are then overlapped, the factoring in of this additional thickness becomes even more complex. As stated by Peri-Strips Dry® with Veritas® (Baxter), "final tissue compression, including PSDV Reinforcement, must meet the range specified by the stapler manufacturer; this is especially important if staple firings are overlapped. PSDV Reinforcement increases the total thickness of the area stapled by 0.4 mm–12 mm" [28].

10.2.3 Powered and Manual Staplers

Although the use of powered vs. manual staplers has largely been influenced by cost and surgeon preference, some have reasoned that powered staplers provide a less traumatic, more consistent approach to stapling the stomach; however, the implications of this on patient outcomes have not been well studied. At this time, there is no clear evidence that powered staplers get better results. Kimura et al. found that there were fewer staple malformations, or failure to create the complete "B" shape of a correctly fired staple, with the powered stapler as compared to a manual stapler when firing across the porcine small bowel. The implications of this finding on bleeding or leak rates, however, are unclear [29].

10.3 Conclusions

Without the advent of laparoscopic electrosurgical and stapling devices, complex procedures such as sleeve gastrectomy would be impossible. Proper knowledge of the safe use of these devices is critical to providing patients with the best possible outcomes. As the medical device industry continues to change and perfect these commonly used tools of laparoscopic surgery, surgeons must continue to evaluate the safety and efficacy of these instruments [30]. Even as surgeon scientists work to closely study these tools and compare them to our current standards, it can be difficult to keep up with the fast pace of surgical innovation [31]. Thus, the surgeon must keep in mind the basic guiding principles of performing the perfect sleeve gastrectomy. Ultimately, staples must be well-formed and well-fitting with careful attention paid to the quality of the tissue being stapled. The magnificent power, flow of current, and high degree of heat generated by electrosurgical instruments must be carefully understood and never underestimated.

References

1. Madani A, Jones DB, Fuchshuber P, Robinson TN, Feldman LS. Fundamental use of surgical energy™ (FUSE): a curriculum on surgical energy-based devices. Surg Endosc. 2014;28:2509–12. https://doi.org/10.1007/s00464-014-3623-6.
2. Munro MG. Fundamentals of Electrosurgery part I: principles of radiofrequency energy for surgery. In: The SAGES manual on the fundamental use of surgical energy (FUSE). New York: Springer; 2012. p. 15–59.
3. Park CW, Portenier DD. Bipolar electrosurgical devices. In: The SAGES manual on the fundamental use of surgical energy (FUSE). New York: Springer; 2012. p. 93–106.
4. Bittner JG, Varela JE, Herron D. Ultrasonic energy systems. In: The SAGES manual on the fundamental use of surgical energy (FUSE). New York: Springer; 2012. p. 123–32.
5. Sankaranarayanan G, Resapu RR, Jones DB, Schwaitzberg S, De S. Common uses and cited complications of energy in surgery. Surg Endosc. 2013;27:3056–72. https://doi.org/10.1007/s00464-013-2823-9.
6. Tsamis D, Natoudi M, Aggeliki A, Flessas I, Papailiou I, Bramis K, et al. Using Ligasure™ or harmonic ace® in laparoscopic sleeve Gastrectomies? A prospective randomized study. Obes Surg. 2015;25:1454–7. https://doi.org/10.1007/s11695-014-1551-0.
7. Jones SB, Rozner MA. Integration of energy systems with other medical devices. In: The SAGES manual on the fundamental use of surgical energy (FUSE). New York: Springer; 2012. p. 181–94.
8. Jones DB, Mikami DJ, Brunt ML, Robinson TN, Feldman LS, Jones SB. Safe energy use in the operating room. Curr Probl Surg. 2015;52:443–68. https://doi.org/10.1067/j.cpsurg.2015.09.001.
9. Gale P, Adeyimi B, Ferrer K, Al B, Scoccia B. Histologic characteristics of laparoscopic argon beam coagulation. J Am Assoc Gynecol Laparosc. 1998;5(1):19–22.
10. Voyles CR. The art and science of monopolar electrosurgery. In: The SAGES manual on the fundamental use of surgical energy (FUSE). New York: Springer; 2012. p. 81–91.
11. Cornejo A, Liao L, Kenneth W. Argon gas embolism with the use of argon beam coagulation during open hepatic resection. Inter J Surg. 2009;22(2):1–4.
12. Schwaitzberg SD, Jones DB. Don't get burned from lack of knowledge. Ann Surg. 2012;256:219–2. https://doi.org/10.1097/SLA.0b013e318260260c.
13. Jones SB, Munro MG, Feldman LS, Robinson TN, Brunt LM, Schwaitzberg SD, et al. Fundamental use of surgical energy (FUSE): an essential educational program for operating room safety. Perm J. 2017;21:34–45. https://doi.org/10.7812/TPP/16-050.
14. Fuchshuber PR, Robinson TN, Feldman LS, Brunt LM, Madani A, Jones SB, et al. Fundamental use of surgical energy (FUSE): closing a gap in medical education. Ann Surg. 2015;262:20–2. https://doi.org/10.1097/SLA.0000000000001256.

15. Feldman LS, Fuchshuber P, Jones DB, Mischna J, Schwaitzberg SD. FUSE (fundamental use of surgical energy™) task force. Surgeons don't know what they don't know about the safe use of energy in surgery. Surg Endosc. 2012;26:2735–9. https://doi.org/10.1007/s00464-012-2263-y.
16. Aurora AR, Khaitan L, Saber AA. Sleeve gastrectomy and the risk of leak: a systematic analysis of 4,888 patients. Surg Endosc. 2012;26:1509–15. https://doi.org/10.1007/s00464-011-2085-3.
17. Huang R, Gagner M. A thickness calibration device is needed to determine staple height and avoid leaks in laparoscopic sleeve gastrectomy. Obes Surg. 2015;25:2360–7. https://doi.org/10.1007/s11695-015-1705-8.
18. Baker RS, Foote J, Kemmeter P, Brady R, Vroegop T, Serveld M. The science of stapling and leaks. Obes Surg. 2004;14:1290–8. https://doi.org/10.1381/0960892042583888.
19. Rosenthal RJ. International sleeve gastrectomy expert panel, Diaz AA, Arvidsson D, Baker RS, basso N, et al. International sleeve gastrectomy expert panel consensus statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8:8–19. https://doi.org/10.1016/j.soard.2011.10.019.
20. Boeker C, Mall J, Reetz C, Yamac K, Wilkens L, Stroh C, et al. Laparoscopic sleeve gastrectomy: investigation of Fundus Wall thickness and staple height—an observational cohort study. Obes Surg. 2017;27:3209–14. https://doi.org/10.1007/s11695-017-2755-x.
21. Lee MGM, Jones DB. Staple-line buttressing material in gastric bypass surgery. Expert Rev Med Devices. 2005;2:599–603. https://doi.org/10.1586/17434440.2.5.599.
22. Schneider BE, Jones DB. Editorial comment. Surg Obes Relat Dis. 2007;3:422. https://doi.org/10.1016/j.soard.2007.03.242.
23. Shah SS, Todkar JS, Shah PS. Buttressing the staple line: a randomized comparison between staple-line reinforcement versus no reinforcement during sleeve gastrectomy. Obes Surg. 2014;24:2014–20. https://doi.org/10.1007/s11695-014-1374-z.
24. Debs T, Petrucciani N, Kassir R, Sejor E, Karam S, Amor IB, et al. Complications after laparoscopic sleeve gastrectomy: can we approach a 0% rate using the largest staple height with reinforcement all along the staple line? Short-term results and technical considerations. Surg Obes Relat Dis. 2018;14:1804–10. https://doi.org/10.1016/j.soard.2018.08.028.
25. Saleh M, Cheruvu MS, Moorthy K, Ahmed AR. Laparoscopic sleeve gastrectomy using a synthetic bioabsorbable staple line reinforcement material: post-operative complications and 6 year outcomes. Ann Med Surg (Lond). 2016;10:83–7. https://doi.org/10.1016/j.amsu.2016.08.005.
26. Gagner M, Buchwald JN. Comparison of laparoscopic sleeve gastrectomy leak rates in four staple-line reinforcement options: a systemic review. Surg Obes Relat Dis. 2014;10:713–23. https://doi.org/10.1016/j.soard.2014.01.016.
27. Important Risk Information – Peri-Strips Dry. 2015. http://www.peristripsdry.com/us/important-risk-information.html. Accessed 7 Feb 2019.
28. Spencer AU, Manguson TH, Nguyen H, Steele KE, Lidor AO, Schweitzer MA. The evidence for staple line buttress material. In: Bariatric Times. 2009. http://bariatrictimes.com/the-evidence-for-staple-line-buttress-material/. Accessed 7 Feb 2019.
29. Kimura M, Terashita Y. Superior staple formation with powered stapling devices. Surg Obes Relat Dis. 2016;12:668–72. https://doi.org/10.1016/j.soard.2015.11.023.
30. Madani A, Watanabe Y, Townsend N, Pucher PH, Robinson TN, Egerszegi PE, et al. Structured simulation improves learning of the fundamental use of surgical energy™ curriculum: a multicenter randomized controlled trial. Surg Endosc. 2016;30:684–91. https://doi.org/10.1007/s00464-015-4260-4.
31. Madani A, Watanabe Y, Vassiliou MC, Fuchshuber P, Jones DB, Schwaitzberg SD, et al. Long-term knowledge retention following simulation-based training for electrosurgical safety: 1-year follow-up of a randomized controlled trial. Surg Endosc. 2016;30:1156–63. https://doi.org/10.1007/s00464-015-4320-9.

Chapter 11
Surgical and Medical Follow-Up

Luciana J. El-Kadre, Silvia Leite Faria, and Almino Ramos Cardoso

Nutritional deficiencies may occur before and after all types of bariatric surgery. On the other hand, the ideal bariatric operation should be safe and effective in terms of weight loss and control of comorbidities, with a minimum or no adverse events, including nutritional problems.

Vertical sleeve gastrectomy (SG) has become the most popular bariatric operation worldwide, even in countries with decades of preference for Roux-en-Y Gastric Bypass (RYGB) [1] with the supposed idea of a less complex operation, with maintenance of bowel arrangement.

Pylorus preserving would allow normal grinding and food bolus formation for duodenal entry [2]. For both surgeons and patients, there was a belief of a less intense need for mineral and vitamin supplementation, as the path of digestion and absorption was kept, as opposed to RYGB and biliopancreatic diversion with duodenal switch (BPD-DS), both requiring lifetime supplementation.

SG was first published in 1993, as a surgical step inside the BPD-DS. At that time, it was named parietal gastrectomy and involved a 60% resection of the stomach [3]. The first laparoscopic report of SG was done in 2000, again as a part of BPD-DS [4].

The newly now named laparoscopic sleeve gastrectomy was proposed in 2003, as the first step of a staged procedure for high-risk super-obese patients [5]. After this initial step, used in very selectively indications, as staged bariatric surgery,

L. J. El-Kadre (✉)
Gávea Metabolic Center for Diabetes and Obesity, Sao Lucas Copacabana Hospital, Rio de Janeiro, RJ, Brazil

S. L. Faria
Brasília Gastrosurgery, Brasília, DF, Brazil

A. R. Cardoso
Bariatric Surgery, Gastro Obeso Center, São Paulo, Brazil

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_11

before and after transplant surgery, intestinal multiple adhesions, small bowel inflammatory diseases, and others, SG began to be recommended as a stand-alone bariatric procedure [6, 7].

SG was considered mainly as a restrictive procedure due to anatomic alterations in the upper gastrointestinal tract. On the other hand, intestinal hormonal changes, and gut microbiome shifts, launched SG to more than a purely restrictive classification [8]. Weight loss would be related to changes in gastric emptying, reduced acyl ghrelin levels, increased glucagon-like peptide-1 levels, cholecystokinin, and peptide YY, all contributing to reduced hunger and increased satiety [9].

The understanding of the consequences of rapid weight loss, coupled with the established effects of gastric resections, is sufficient to assert that patients submitted to SG are at risk for long-term nutritional deficiencies.

Reduced food intake, decreased hydrochloric acid, reduced intrinsic factor secretion, possible vomiting, and poor eating habits are among the reasons [10] as well as signs of food intolerance, low adherence to prescribed nutritional supplements, and the possibility of nutritional deficiencies preoperatively [11].

Table 11.1 shows the most frequent nutritional deficiencies relative to the SG procedure.

Likewise, the gastric environment can be modified, with speculative effects on gastric microbiota diversity [12] and the possibility of chronic dysmotility as a result of the resection of the normal gastric pacemaker [13].

Nutritional deficiencies can lead to health risks such as neuropathy, anemia, bone loss disease, cognitive dysfunction, and more [14].

The main focus of postoperative follow-up would be to prevent micronutrient deficiency and the loss of body fat-free mass (FFM), as a consequence of reduced protein and caloric intake.

On the other hand, the decreased levels of ghrelin production may have an impact on its function to limit muscle catabolism [15]. The goal is to reduce excessive fat mass excess without affecting FFM [16]. Despite that, FFM loss is systematically observed after SG leading to reduced resting energy expenditure, diet-induced thermogenesis and even sarcopenia, with a decline in functional capacity [17]. The possibility of sarcopenia after SG can be as high as 32% of the cases, being strongly associated with a low initial skeletal muscle mass and the amount of weight loss [18].

Table 11.1 Prevalence of nutritional deficiencies following sleeve gastrectomy

Nutrient	Prevalence of deficiency (%)
Vitamin D	30–70
Vitamin B_{12}	10–20
Thiamin	5–25
Iron	15–45
Zinc	7–15
Folate	10–20
Calcium	0–12
Copper	10

Bariatric surgery is intended to facilitate safe and sustained weight loss, supporting body homeostasis and preserving lean muscle mass. Based on this cornerstone for a patient's quality of life, this chapter will highlight the main causes, prevention, and treatment of possible nutritional deficiencies after SG.

11.1 Vitamin B1 or Thiamine

Vitamin B1, also known as thiamine, is an essential water-soluble vitamin, not produced by the human body, that plays a role in cellular production of energy from ingested food, enhancing normal neuronal activities and reducing cellular oxidative stress [19].

Thiamine deficiency, or beriberi, can occur in all bariatric procedures. Dry beriberi, which predominantly shows neurological involvement, is the preferred form. Wet beriberi, characterized by cardiac symptoms, has not yet been described after bariatric surgery. Thiamine deficiency is also common among bariatric candidates with a prevalence as high as 29% [20, 21].

Thiamine absorption is maximal in the duodenum, decreasing caudally along the small intestine with the support of a dual system, saturable at low concentrations and diffusive at higher. Thiamine reserves in the body amount to only 30 mg and are depleted in 18–20 days. Its deficiency leads to a variety of clinical abnormalities such as cardiovascular and neurological disorders, including the devastating mitochondria dysfunction manifesting as Wernicke encephalopathy (WE) and Korsakoff psychosis [22, 23].

Among patients submitted to SG, causes for thiamin deficiency are related to low caloric intake and limited consumption of animal proteins due to poor tolerance, as the SG procedure decreases gastric capacity and vomiting [24].

There is no consensus as to whether compliance with prescribed vitamins affects thiamine deficiency. The literature has shown an incidence that ranges from 5% to 26%. Patients with thiamine deficiency are more likely to be African American, have a larger preoperative body mass index (BMI), and to present nausea and vomiting [25].

The American Society for Metabolic and Bariatric Surgery (ASMBS) guidelines recommend that postoperative SG patients take at least 12 mg of thiamine daily to prevent deficiency. The maximum preventive dose is 50 mg daily [11].

Thiamine deficiency is diagnosed based on signs and symptoms. Thiamine status can be evaluated assessing the degree of thiamine diphosphate saturation of a thiamine-dependent enzyme (erythrocyte transketolase assay) or measuring thiamine metabolites in accessible tissues [23].

Any suspicion of this deficiency should be quickly treated, as its consequences can be irreversible. It is better to overdose than to allow consequences to appear. Any vomiting bariatric patient should be given thiamine before or concomitantly with intravenous administration of glucose so as not to precipitate WE. Glucose loading precipitates brain lactate resulting in an acid brain pH with thalamic neuronal damage and cerebral dysfunction [26].

The early symptoms are neuritis, neuropathy—especially in the lower extremities—and muscle pain with atrophy and paraplegia. If not quickly recognized, it attacks the central nervous system and the spinal cord. Ataxia and oculomotor problems are further symptoms. If treated early, the prognosis of beriberi is positive, but mortality still ranges between 10% and 20%. Persistent residual neurologic symptoms, such as gait abnormalities, are common [27].

Early symptoms of neuropathy can be treated with 100 mg two to three times oral doses of thiamine, until symptoms disappear. For more advanced symptoms, and for patients with protractile vomiting, 100 mg of thiamine parenterally for 5–7 days is recommended, followed by oral doses of 100 mg daily until complete recovery. During thiamine supplementation treatment, additional supplementation with specifically the B group or other vitamins is important [28].

11.2 Vitamin B12

Vitamin B12 is absorbed in the terminal ileum. This absorption is almost entirely dependent upon the intrinsic factor (IF), secreted by parietal cells situated in the stomach mucosa. High doses of oral vitamin B12 (>1000 μm daily) can be absorbed without IF [29]. The incidence of vitamin B12 deficiency may range from 4% to 30% among patients seeking bariatric surgery. Vitamin B12 assays, currently used to diagnose clinical vitamin deficiency, may reach a failure rate of 22–35%, and clinicians may not recognize this deficiency. The concentration of total vitamin B12 in serum is not a reliable indicator of vitamin B12 deficiency, and holoTC, the active vitamin B12, could more accurately reflect intracellular B12 levels. Laboratory screening for B12 may also include serum methylmalonic acid (MMA) and homocysteine [30].

Anatomical rearrangement, induced by the resection of the gastric fundus, decreases hydrochloric acid and pepsin secretion, and causes poor release of B12 from food and loss of food exposure to IF-secreting cells, resulting in B12 malabsorption. Vitamin B12 deficiency right after the operation may lead to stem cell differentiation into parietal cells, a compensatory mechanism for decreased gastric volume [31].

The literature recommends a daily prophylactic dose of 350–500 mcg orally or sublingually to prevent nutritional deficiencies. Intramuscular monthly doses of 1000 mcg can also be used to prevent B12 deficiency. In case of deficiency, 1000 mcg daily should be prescribed. B12 blood levels below 400 pg/dL are accepted as indicators of possible deficiency of this vitamin. Levels below 100 pg/dL represent a severe deficiency and should be treated with IM or IV supplementations.

Clinical manifestations of severe and persistent vitamin B12 deficiency may include reversible hematological changes and irreversible loss of neurological function. Megaloblastic anemia is the most often found chronic B12 deficiency. Prior to the hematologic problems, patients may present neurologic ones, such as ataxia, optic atrophy, memory loss, changes in their mental status, myeloneuropathy, megaloblastic anemia, thrombocytopenia, and blindness. Paresthesias are ascending and may involve the trunk. Untreated patients may develop limb weakness and ataxia [32].

Most of the cases are asymptomatic, while hematologic and neurologic manifestations are occasionally dissociated. More serious neurological sequelae may be represented by spinal cord degeneration, leading to permanent neurological deficit. High oral doses of B12 (>1000 mcg) can be as effective as intramuscular, bypassing the need of the itrinsic factor.

11.3 Anemia

Anemia, defined as low blood hemoglobin concentration, is a serious worldwide public health problem, and the most frequent nutritional complication of bariatric surgery. Screening for anemia should be one of the priorities in pre- and postoperative care.

According to the World Health Organization (WHO), hemoglobin (Hb) levels <12 g/dL in women (<11 g/dL in pregnant women) and <13 g/dL in men are cutoff values for the diagnosis of anemia [33].

11.4 Iron

Although iron deficiency is the most common cause of anemia among bariatric patients, relevant nutritional causes involve folic acid and B12 deficiencies [34].

Hepcidin production, the main iron-regulatory protein, is regulated by the liver, the major site of iron deposition. Hepcidin is a negative regulator of release from iron stores and intestinal absorption. It can be elevated in obesity, resulting in iron depletion, preventing the release of dietary iron and limiting the replenishment of body iron losses [35]. Transferrin saturation and serum ferritin should be used together for the identification of the iron status, considering that increased BMI may lead to hyperferritinemia with no relation to body iron stores [36].

Among bariatric patients, depleted iron stores, with the absence of inflammation, are indicated by serum ferritin levels below 20 μg/L. Additionally, low transferrin saturation is indicative of iron deficiency. These conditions need to be treated adequately in order to minimize patient morbidity and optimize postoperative quality of life. Iron deficit seems to be one of the most common nutritional deficiencies among SG patients. At 1 year postoperatively, 4.5–43% of patients presented low levels of serum iron. At 5 years, the prevalence increased to 40–56% [37].

Iron deficiency may occur as a result from limited exposure of food to gastric acid and reduction of meat intake, with a significant decrease in the absorption of both heme iron (coming primarily from meat) and nonheme iron. SG reduces the stomach size and the gastric juice, necessary to the release of heme from dietary hemoglobin and myoglobin. On the other hand, intraluminal inhibiting and enhancing factors are more relevant to nonheme-iron absorption. The decreased acid production, inherent to SG surgery, can interfere in the oxidization from the ingested iron. Iron needs an acid environment to be converted into ferric (3+) state for its solubility [38].

Regular annual checkups over extended periods of time are necessary because deficiencies were reported in patients even 5 years after surgery.

Routine oral multivitamin/mineral supplementation of post-bariatric patients is necessary, although it may not be sufficient to prevent iron deficiency in menstruating women, adolescents, and pregnant women.

Patients submitted to SG should receive at least 18 mg of iron from their multivitamin. Indefinite long-term daily oral iron supplementation is necessary to prevent the development of iron deficiency in the majority of menstruating women. Iron deficiency should be treated daily with oral ferrous sulfate, ferrous fumarate, or ferrous gluconate to provide at least 45–60 mg of elemental iron. Vitamin C may be added to improve iron absorption [39].

Iron deficiency can be treated with 150–300 mg of elemental iron daily. Ferrous sulphates tend to present gastrointestinal effects (constipation), whereas other formulations seem to be better tolerated. In cases of anemia where there is oral iron intolerance, noncompliance or severe deficiency, intravenous infusion, with ferric gluconate or sucrose, may be necessary.

11.5 Bone

Bone mineral metabolism is adversely affected by bariatric procedures, and it is largely related to physiological and hormonal changes, reduced production of acid from the stomach, low intake of calcium-rich foods, low intake and absorption of vitamin D, and weight loss itself. These factors may lead the patient to an onset of secondary hyperparathyroidism with osteopenia and osteoporosis [40].

Calcium is absorbed within the duodenum, jejunum, and ileum with a length-dependent absorption. Intestinal barrier transfer of calcium occurs through both saturable (duodenum and jejunum) and nonsaturable pathway. Even without a duodenal bypass, SG can predispose to bone loss, considering that fluctuations in body weight play an important role in bone health, while weight loss by caloric restriction can result in bone loss [41].

Vitamin D deficiency is one of the most frequent nutritional deficiencies among patients with severe obesity. In a recent systematic review, mean serum 25 OH vitamin D3 concentration before surgery was <20 ng/mL, and ranged from 20 to 30 ng/mL in 33–42% [42]. Obese individuals may be predisposed to vitamin D deficiency due to sequestration or volumetric dilution of the fat-soluble vitamin in fat stores and inadequate sunlight exposure [43].

After SG, studies have shown that the rate of deficiency declines to near 38% after 5 years. The improvement in vitamin D status can be attributed to the intense supplementation and monitoring of vitamin D. Despite the significant increase in vitamin D level post-SG, mean values did not reach normal levels [44].

Secondary hyperparathyroidism may be presented in 20.8% of SG patients 5 years after surgery. Hypocalcemia is rare in the literature. Serum calcium tends to be preserved in the normal range, even in the presence of hyperparathyroidism, by bone resorption [45].

Overall, current indicators of nutritional status concerning bone mineral density among SG patients are 25-hydroxy D vitamin, parathyroid hormone (PTH), also a marker of the metabolic syndrome, which can be elevated before surgery with a positive correlation to BMI, bone reabsorption markers, and bone density (DXA) [40].

At present, calcium and vitamin D supplements are recommended to all post-SG patients, with daily intake of 1200–1500 mg of elemental calcium in the form of calcium citrate and 3000 International Units (IU) of vitamin D for patients who underwent SG [11].

Although vitamin K may have an anabolic effect on the bone turnover, promoting osteoblast differentiation, there is not enough evidence to recommend combined vitamin D and K supplementation.

11.6 Lean Mass—Protein

The loss of lean tissue mass (LTM) during rapid postoperative weight loss and the risks it poses to the patient's health have been recognized as serious nutrition problems of bariatric patients [46].

Although the focus of weight loss after bariatric surgery is the reduction of excess fat mass, FFM is also inevitably lost in the process. The loss of body weight following surgery is not only due to loss of fat mass, but also loss of FFM, composed of bone and LTM. FFM is important for maintenance of body temperature, the skeletal integrity, and the functionality of the body throughout life.

Factors that contribute to FFM loss in the post-bariatric period include the type of the undergone surgery, caloric restriction, low protein intake, inactivity, and volume of weight loss. Excessive loss of LTM is an adverse effect of weight loss because it has been associated with higher risk of post-bariatric surgery mortality and morbidity [47].

In addition, the resting energy expenditure and diet-induced energy expenditure seem to be directly associated with the amount of LTM, and therefore, its excessive loss may be one of the factors associated with late weight regain among post-BS patients.

Following SG, protein deficiency can occur due to decreased volume of dietary intake. Indeed, adequate protein intake is difficult to accomplish due to a common intolerance to protein-rich food such as meat, which may lead to net protein loss [48].

A prospective study has evaluated patients submitted to different bariatric procedures [49]. It was found that SG patients lost an average of 17% of FFM in 5 years. The main loss of FFM occurred in the first year after surgery.

The general understanding was that 25% of weight loss after BS would be in the form of FFM, but this rule has been criticized, due to a lack of evidence. A prospective study compared RYGB and SG patients and found no difference in LTM loss [50].

The 2013 nutritional support guidelines for perioperative care of bariatric surgery patients stated that protein intake should be individualized, assessed, and defined based on gender, age, and weight of the patient. The guidelines also recommend a minimal daily protein intake of 60 g and up to 1.5 g/kg ideal body weight per day (Grade D level of evidence) [51].

The main objective of sufficient protein intake is to avoid excessive loss of LTM. Despite these recommendations, post-surgery patients tend to ingest low amounts of food, especially protein foods, as a consequence of their reduced stomach capacity and changes in gut hormone that induce early satiety.

Of special note is the intolerance to certain foods, especially red meat and other fibrous protein sources, which contributes to low protein intake. Blood albumin and prealbumin levels have been used to monitor protein deficiencies, but as negative acute-phase reactants, they may not be reliable markers for long-term protein status in this group of patients. Low serum prealbumin levels shortly after surgery have been reported to be consistent only with recent dietary energy and protein intake [52].

Careful evaluation of body composition and daily protein ingestion is necessary to monitor protein status. For those with low intake, supplementation may be necessary to avoid protein depletion states. Supplements such as whey protein, soy isolate, and essential amino acids have been used for this purpose.

Sarcopenia is defined as the presence of both low muscle mass and low muscle strength or performance, and it has been applied to studies of frailty in the elderly population. Evidence indicates that avoiding the loss of LTM after bariatric surgery is important for the long-term success. To maintain sufficient LTM and muscle strength, an adequate protein intake, with or without the use of supplements, is recommended.

11.7 Zinc

Zinc is an essential trace metal which functions in DNA synthesis, wound healing, and protein synthesis. Zinc deficiency can be present among 30% of individuals with obesity. Zinc is absorbed in the small intestine by a carrier-mediated mechanism, and with high intakes, it can be absorbed through a passive paracellular route. About 70% of the zinc is bound to albumin, and altering serum albumin will affect serum zinc levels [53].

11.8 Folate

Folate deficiency may occur due to noncompliance to multivitamin recommendations and poor dietary intake. In patients with folate deficiency, the mean corpuscular volume tends to increase before the hemoglobin level decreases. Red blood cell (RBC) folate is a better indicator of body folate stores than serum folate, which is affected by recent folate intake. Serum folate measurement is nonspecific as folate concentrations within erythrocytes are higher than in serum [54].

11.9 Vitamins A, E, and K

Digestion of lipids begins in the mouth and continues in the stomach. In adult humans, most fat arrives in the duodenum intact. On the other hand, fat malabsorption may be found after partial gastrectomies [55]. The increased transit time would prevent sufficient mixing of food with digestive enzymes, and the loss of the antrum might allow larger than normal food particles to empty into the jejunum. Evidence that serum fat-soluble vitamin levels may decrease after gastrectomy has not been established, and even low levels found after partial resections did not produce symptoms [56].

Therefore, fat-soluble vitamins should be monitored and supplemented as needed, guided by the degree of weight loss, laboratory analysis, and clinical presentation of symptoms. The exception would be for vitamin D that has its own metabolism in obesity (Table 11.2).

11.10 Copper

Copper is a dietary trace metal, a zinc competitor and antagonist. Patients with copper deficiency may experience painful neuropathy, anemia, neutropenia, optic neuropathy, and ataxia, mimicking vitamin B12 deficiency. Lower rates of copper deficiency can be noted after SG, and hypocupremia was described after partial gastric [57]. Measurement of serum copper and ceruloplasmin levels can identify individuals with copper deficiency.

The routine of supplementation among SG patients should include a multivitamin-multimineral daily that covers from 100% to 200% of the Recommended Daily Allowance daily (Table 11.3).

Besides the adult multivitamin-multimineral, patients may take separate doses of calcium, B12, and protein. Calcium supplement should be taken into divided doses, maximum of 500 mg each, to improve the absorption rate. Carbonate needs acid and is one of the least bioavailable forms. Calcium citrate-malate is more easily dissolved in the stomach than citrate and is well absorbed taken with or without food.

Table 11.2 Preoperative and postoperative suggested nutritional evaluation

	Preop	1 Month	3 Month	6 Month	9 Month	1 Year	1 ½ Year	2 Year	2 ½ Year	3 Year	4 Year	5 Year
DXA	X							X		X		X
Hemogram	X	X	X	X	X	X	X	X	X	X	X	X
INR	X	X		X		X	X	X	X	X	X	X
Calcium	X					X		x		X		X
Iron	X					X		X		X		X
Transferrin	X	X	X	X	X	X	X	X	X	X	X	X
Ferritin+TS	X		X	X	X	X	X	X	X	X	X	X
Zinc/copper	X					X		X		X	X	X
Glucose	X		X	X		X	X	X	X	X	X	X
Creatinine	X	X	X	X	X	X		X		X		X
Transferrin	X		X	X		X		X		X	X	X
Vit A/Vit E	X			X		X		X		X		X
25 OH D3	X		X	X		X		X		X		X
CTX	X	X		X		X		X		X		x
Vitamin B12	X			X		X		X		X		X
Folic acid (?)	X			X		X		X		X		X
Parathormone	X			X		X		X		X		X
MMA	X			X		X		X		X		X
Body composition	X		X	X		X		X		X		X

DXA dual-energy X-ray absorptiometry, *CTX* C-telopeptides of type I collagen, *TS* transferrin saturation, *MMA* methylmalonic acid

Table 11.3 Nutritional recommendation for patients submitted to SG

Vitamins and minerals	Routine supplementation prevention	Deficiency treatment
Thiamine	12 mg daily	100 mg daily IV or IM at least 3 days followed by 100 mg daily oral dose until disappearance of symptoms
Vitamin B_{12}	350–500 mcg/day or 1000 mcg IM monthly	1000 mcg/day IM until disappearance of symptoms
Folic acid	400–800 mcg/day (women) 400 mcg (men)	1000 mcg/day
Iron	18 mg/day Woman at a fertile age: 45–60 mg/day	150–300 mg (2–3 times)/day IV supplementation should be used
Vitamin D	3000 UI/day To maintain 25 OH vit D > 30 ng/mL	6000 UI/day or 50,000 UI 1–3 times/week
Calcium (citrate malate)	500–1000 mg/day	1500 mg/day
Vitamin A (if necessary)	5000–10,000 UI/day	10,000–25,000 UI/day
Vitamin E (if necessary)	15 m/day	100–400 UI/day
Vitamin K (if necessary)	90–120 µg/day	10 mg parenterally
Zinc	8–11 mg/day	Upper level: 40 mg/day
Copper	1 mg/day	3–8 mg/day
Protein	Diet + supplement = 80 g	Diet + supplement = 120 g

Table 11.4 Nutritional supplementation (daily doses)

Supplement	SG
Multivitamin-multimineral	200% DRI/day
Additional B_{12}	350–500 mcg/day
Calcium + vitamin D	1500 mg (+800 UI)/day
Iron (elemental)	>18 mg/day (check)
Protein	Diet + supplement = 80 a 120 g/day

SG requires supplementation in all cases. There is no universal supplementation and every case should be analyzed. The main focus is the prevention and treatment of anemia, thiamine deficiency, and protein supplementation. Patients must be aware of the costs and future expenses with supplementation (Table 11.4).

References

1. Welbourn R, Hollyman M, Kinsman R, et al. Bariatric surgery worldwide: baseline demographic description and one-year outcomes from the fourth IFSO global registry report. Obes Surg. 2018;28:313.
2. Lim R, Blackburn G, Jones D. Benchmarking best practices in weight loss surgery. Curr Probl Surg. 2010;47:79–174.
3. Marceau P, Biron S, Bourque RA, et al. Biliopancreatic diversion with a new type of gastrectomy. Obes Surg. 1993;3:29–35.
4. Ren CJ, Patterson E, Gagner M. Early results of laparoscopic biliopancreatic diversion with duodenal switch: a case series of 40 consecutive patients. Obes Surg. 2000;10:514–23.
5. Regan JP, Inabnet WB, Gagner M, et al. Early experience with two-staged laparoscopic Roux-en-y gastric bypass as an alternative in the super-super obese patient. Obes Surg. 2003;13:861–4.
6. Moon Han SM, Kim WW, Oh JH. Results of laparoscopic sleeve gastrectomy at 1 year in morbidly obese Korean patients. Obes Surg. 2015;15:1469–75.
7. Silecchia G, Boru C, Pecchia A, et al. Effectiveness of laparoscopic sleeve gastrectomy (first stage of biliopancreatic diversion with duodenal switch) on co-morbidities in super-obese high-risk patients. Obes Surg. 2006;16(9):1138–44.
8. Jahansouz C, Staley C, Bernlohr DA, et al. Sleeve gastrectomy drives persistent shifts in the gut microbiome. Surg Obes Relat Dis. 2017;13(6):916–24.
9. Dimitriadis GK, Randeva MS, Miras AD. Potential hormone mechanisms of bariatric surgery. Curr Obes Rep. 2017;6(3):253–65.
10. Rogers C. Postgastrectomy nutrition. Nutr Clin Pract. 2011;26(2):126–36.
11. Parrott J, Frank L, Rabena R, et al. American Society for Metabolic and Bariatric Surgery Integrated Health Nutritional Guidelines for the surgical weight loss patient 2016 update: micronutrients. Surg Obes Relat Dis. 2017;13(5):727–41.
12. Lin XH, Huang KH, Chuang WH, et al. The long term effect of metabolic profile and microbiota status in early gastric cancer patients after subtotal gastrectomy. PLoS One. 2018;13(11):e0206930.
13. Sioka E, Tzovaras G, Perivoliotis K, et al. Impact of laparoscopic sleeve gastrectomy on gastrointestinal motility. Gastroenterol Res Pract. 2018:4135813.
14. Stein J, Stier C, Raab H, Weiner R. The nutritional and pharmacological consequences of obesity surgery. Aliment Pharmacol Ther. 2014;40(6):582–609.
15. Hill NE, Murphy KG, Saeed S, et al. Impact of ghrelin on body composition and muscle function in a long-term rodent model of critical illness. PLoS One. 2017;12(8):e0182659.
16. Thibault R, Makhlouf AM, Mulliez A, et al. Fat-free mass at admission predicts 28-day mortality in intensive care unit patients: the international prospective observational study phase angle project. Intensive Care Med. 2016;42(9):1445–53.
17. Guida B, Cataldi M, Busetto L, et al. Predictors of fat-free mass loss 1 year after laparoscopic sleeve gastrectomy. J Endocrinol Investig. 2018;41(11):1307–15.
18. Voican CS, Lebrun A, Maitre S, et al. Predictive score of sarcopenia occurrence one year after bariatric surgery in severely obese patients. PLoS One. 2018;13(5):e0197248.
19. Abdou E, Hazell AS. Thiamine deficiency: an update of pathophysiologic mechanisms and future therapeutic considerations. Neurochem Res. 2015;40(2):353–61.
20. Matrana MR, Vasireddy S, Davis WE. The skinny on a growing problem: dry beriberi after bariatric surgery. Ann Intern Med. 2008;149(11):842–4.
21. Kerns JC, Arundel C, Chawla LS. Thiamin deficiency in people with obesity. Adv Nutr. 2015;6(2):147–53.
22. Hoyumpa AM Jr, Strickland R, Sheehan JJ, et al. Dual system of intestinal thiamine transport in humans. J Lab Clin Med. 1982;99(5):701–8.
23. Warnock LG, Prudhomme CR, Wagner C. The determination of thiamin pyrophosphate in blood and other tissues, and its correlation with erythrocyte transketolase activity. J Nutr. 1978;108(3):421–7.

24. Pardo-Aranda F, Perez-Romero N, Osorio J, et al. Wernicke's encephalopathy after sleeve gastrectomy: literature review. Int J Surg Case Rep. 2016;20:92–5.
25. Tang L, Alsulaim HA, Canner JK, et al. Prevalence and predictors of postoperative thiamine deficiency after vertical sleeve gastrectomy. Surg Obes Relat Dis. 2018;14(7):943–50.
26. Navarro D, Zwingmann C, Chatauret N, Butterworth RF. Glucose loading precipitates focal lactic acidosis in the vulnerable medial thalamus of thiamine-deficient rats. Metab Brain Dis. 2008;23(1):115–22.
27. Wijnia JW, Oudman E, Bresser EL, et al. Need for early diagnosis of mental and mobility changes in Wernicke encephalopathy. Cogn Behav Neurol. 2014;27(4):215–21.
28. Nishimoto A, Usery J, Winton JC, Twilla J. High-dose parenteral thiamine in treatment of Wernicke's encephalopathy: case series and review of the literature. In Vivo. 2017;31(1):121–4.
29. Chan CQ, Low LL, Lee KH. Oral vitamin B12 replacement for the treatment of pernicious anemia. Front Med (Lausanne). 2016;3:38.
30. Nexo E, Hoffmann-Lücke E. Holotranscobalamin, a marker of vitamin B-12 status: analytical aspects and clinical utility. Am J Clin Nutr. 2011;94(1):359S–65S.
31. Muhuri D, Nagy G, Rawlins V, et al. Exploring vitamin B12 deficiency in sleeve gastrectomy from a histological study of a cadaveric stomach and ileum. J Nutr Disorders Ther. 2016;6:193.
32. Punchai S, Hanipah ZN, Meister KM, et al. Neurologic manifestations of vitamin B deficiency after bariatric surgery. Obes Surg. 2017;27(8):2079–82.
33. Cappellini MD, Motta I. Anemia in clinical practice-definition and classification: does hemoglobin change with aging? Semin Hematol. 2015;52(4):261–9.
34. Jáuregui-Lobera I. Iron deficiency and bariatric surgery. Nutrients. 2013;5(5):1595–608.
35. Cepeda-Lopez AC, Allende-Labastida J, Melse-Boonstra A, et al. The effects of fat loss after bariatric surgery on inflammation, serum hepcidin, and iron absorption: a prospective 6-mo iron stable isotope study. Am J Clin Nutr. 2016;104(4):1030–8.
36. Alam F, Memon AS, Fatima SS. Increased body mass index may lead to Hyperferritinemia irrespective of body Iron stores. Pak J Med Sci. 2015;31(6):1521–6.
37. Kwon Y, Kim HJ, Lo Menzo E, et al. Anemia, iron and vitamin B12 deficiencies after sleeve gastrectomy compared to Roux-en-Y gastric bypass: a meta-analysis. Surg Obes Relat Dis. 2014;10(4):589–97.
38. Ruz M, Carrasco F, Rojas P, et al. Heme- and nonheme-iron absorption and iron status 12 mo after sleeve gastrectomy and Roux-en-Y gastric bypass in morbidly obese women. Am J Clin Nutr. 2012;96(4):810–7.
39. Steenackers N, Van der Schueren B, Mertens A, et al. Iron deficiency after bariatric surgery: what is the real problem? Proc Nutr Soc. 2018;77(4):445–55.
40. El-Kadre LJ, Rocha PR, de Almeida Tinoco AC, Tinoco RC. Calcium metabolism in pre- and postmenopausal morbidly obese women at baseline and after laparoscopic Roux-en-Y gastric bypass. Obes Surg. 2004;14(8):1062–6.
41. Shapses SA, Sukumar D. Bone metabolism in obesity and weight loss. Annu Rev Nutr. 2012;32:287–309.
42. Gagnon C, Schafer AL. Bone health after bariatric surgery. JBMR Plus. 2018;2:121–33.
43. Walsh JS, Bowles S, Evans AL. Vitamin D in obesity. Curr Opin Endocrinol Diabetes Obes. 2017;24(6):389–94.
44. Moore CE, Sherman V. Vitamin D supplementation efficacy: sleeve gastrectomy versus gastric bypass surgery. Obes Surg. 2014;24(12):2055–60.
45. Alexandrou A, Tsoka E, Armeni E, et al. Determinants of secondary hyperparathyroidism in bariatric patients after Roux-en-Y gastric bypass or sleeve gastrectomy: a pilot study. Int J Endocrinol. 2015:984935.
46. Faria SL, Faria OP, Buffington C, et al. Dietary protein intake and bariatric surgery patients: a review. Obes Surg. 2011;21(11):1798–805.
47. Dulloo AG, Jacquet J, Miles-Chan JL, Schutz Y. Passive and active roles of fat-free mass in the control of energy intake and body composition regulation. Eur J Clin Nutr. 2017;71(3):353–7.
48. Friedrich AE, Damms-Machado A, Meile T, et al. Laparoscopic sleeve gastrectomy compared to a multidisciplinary weight loss program for obesity--effects on body composition and protein status. Obes Surg. 2013;23(12):1957–65.

49. Davidson LE, Yu W, Goodpaster BH, et al. Fat-free mass and skeletal muscle mass five years after bariatric surgery. Obesity (Silver Spring). 2018;26(7):1130–6.
50. Moizé V, Andreu A, Flores L, et al. Long-term dietary intake and nutritional deficiencies following sleeve gastrectomy or Roux-En-Y gastric bypass in a mediterranean population. J Acad Nutr Diet. 2013;113(3):400–10.
51. Mechanick JI, Youdim A, Jones DB, et al. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient–2013 update: cosponsored by American Association of Clinical Endocrinologists, the Obesity Society, and American Society for Metabolic & Bariatric Surgery. Endocr Pract. 2013;19(2):337–72.
52. Lee JL, Oh ES, Lee RW, Finucane TE. Serum albumin and Prealbumin in calorically restricted, nondiseased individuals: a systematic review. Am J Med. 2015;128(9):1023.e1–1023.e22.
53. Sallé A, Demarsy D, Poirier AL, et al. Zinc deficiency: a frequent and underestimated complication after bariatric surgery. Obes Surg. 2010;20(12):1660–70.
54. Snow CF. Laboratory diagnosis of vitamin B12 and folate deficiency: a guide for the primary care physician. Arch Intern Med. 1999;159(12):1289–98.
55. Borgstrom B, Dahlovist A, Lundh G, Sjovall J. Studies of intestinal digestion and absorption in the human. J Clin Invest. 1957;36:1521.
56. Rino Y, Oshima T, Yoshikawa T. Changes in fat-soluble vitamin levels after gastrectomy for gastric cancer. Surg Today. 2017;47(2):145–50.
57. Prodan CI, Bottomley SS, Vincent AS, et al. Copper deficiency after gastric surgery: a reason for caution. Am J Med Sci. 2009;337(4):256–8.

Chapter 12
Results in Weight Loss and Improvement of Comorbidities

Eduardo Lemos De Souza Bastos and Almino Ramos Cardoso

12.1 Introduction

The sleeve gastrectomy was first described as an effort to improve the results of the classic biliopancreatic diversion (BPD) [1] and some years later was reported by laparoscopy [2], as a part of the BPD as well. At first, laparoscopic sleeve gastrectomy (LSG) was mostly performed as a first stage in high-risk morbidly obese patients [3], but subsequently it began to be studied as a stand-alone bariatric procedure [4, 5]. Currently, LSG is recognized both as a primary bariatric procedure and as first-step practice in high-risk patients as part of a planned staged surgical strategy [6].

In the past few years, several studies addressing the LSG results have shown adequate weight loss, control of comorbidities, and pretty satisfactory quality of life, even in the long-term postoperatively. In the surgeons' point of view, LSG is a faster, technically less demanding procedure that usually does not require high skills in endosuture. For all these reasons, recent data have exhibited LSG at the top of the list of the most accomplished bariatric and metabolic procedures worldwide, accounting for about 50–60% of them [7, 8].

However, because LSG is a relatively young procedure, there are still some doubts about the long-term maintenance of results widely demonstrated in the short term. In addition, LSG is still regarded as a metabolically weaker procedure, which may offer poorer obesity-related comorbidity control. Thus, the purpose of this chapter is to discuss the impact of LSG on sustained weight loss and on the control of obesity-related diseases.

E. L. D. S. Bastos (✉)
Division of Gastrointestinal Surgery, Marilia Medical School, Marilia, Brazil

Gastro Obeso Center, Advanced Institute for Metabolic Optimization, Sao Paulo, Brazil

A. R. Cardoso
Bariatric Surgery, Gastro Obeso Center, Sao Paulo, Brazil

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_12

12.2 Sleeve and Weight Loss

Based on the preference of surgeons and patients, LSG has become the most common bariatric procedure, with numbers close to 60% of all bariatric operations performed worldwide [8]. However, long-term weight loss outcomes are a bit scarce and generally do not exceed 5-year follow-up, with the vast majority of the studies presenting results of less than 2-year follow-up. Recent systematic review with meta-analysis performed to retrieve data on weight loss after bariatric surgery with more than 10 years of follow-up identified 57 studies that met the inclusion criteria, but only 2 of these referred to sleeve [9]. This might be likely related to its official recognition as a primary time bariatric operation only in more recent years [10]. Nevertheless, available data have already suggested that LSG generates substantial sustained weight loss and improvement of comorbidities in the mid- and long-term follow-up.

The highest amount of weight loss (Nadir) appears to be reached within 1–2 years after the procedure, and thereafter temporary weight stabilization is expected followed by small, but gradual weight gain, leading to a mean % excess weight loss (%EWL) of 50–60% and mean body mass index (BMI) of 30–35 kg/m^2 in the long term postoperatively [11–14]. However, a significant number of patients can reach the final BMI between 20 and 25 kg/m^2, and the final outcome regarding long-term weight evolution seems to be related to several factors, mainly preoperative BMI. Indeed, postoperative weight and BMI loss after LSG tend to change significantly according to body weight and BMI at baseline. The reported %EWL is usually greater in morbidly obese patients with "low BMI" (up to 50 kg/m^2) compared with those who are super-obese, or even greater in comparison with the super-super-obese patients [15, 16]. In this group of patients, a two-stage surgery seems to be the most effective option.

The long-term report of %EWL after LSG appears to be between 50% and 60%. A systematic review based on 16 studies and 492 patients, with a minimum of 5 years of follow-up, reported %EWL of 62.3%, 53.8%, 43%, and 54.8% at 5, 6, 7, and 8 years, respectively [17]. Similarly, a more recent systematic review including 20 studies and 1626 patients analyzing long-term outcomes also reported satisfactory weight control, with %EWL of 58.4%, 59.5%, 56.6%, 56.4%, and 62.5% at 5, 6, 7, 8, and 11 years, respectively [18], suggesting that LSG can lead to substantial and lasting excess weight loss. Lastly, a single-center cohort study enrolling patients who underwent LSG as a primary procedure with a minimum of 10 years of follow-up was proved to be successful in generating and maintaining significant %EWL, with an overall mean %EWL of 52.5%, which was considered a very satisfactory result [19]. Significantly, all weight loss results reported in these studies were accompanied by a satisfactory percentage of improvement/resolution of obesity-related comorbidities, meaning that these %EWL seem to be enough to change the patients' life expectancy, and certainly the overall quality of life.

Some correlation with the results of weight loss should be done with surgical systematization such as the gastric sleeve calibration. The bougie size used for this purpose seems to be a relevant predictor determining the evolution of weight loss. The smallest bougie size usually means the greatest weight loss, especially sizes below 36-Fr [20]. However, it is worth noting that the risk of staple-line leak and strictures also correlates directly with a smaller bougie size. An electronic literature search that analyzed 29 publications involving 4888 patients who underwent LSG observed a leak rate of 0.6% when a bougie size of 40-Fr or greater was used. This rate increased to 2.8% in groups who used a bougie size below 40-Fr [21]. Similarly, a systematic review and meta-analysis analyzing surgical strategies to decrease post-Sleeve leakage rate enrolled almost 10,000 patients and revealed lower risk of developing a leak after LSG by using a bougie size ≥40-Fr [22].

Although relevant, the bougie size is not the only determining factor in weight loss, since even relatively large bougie (48-Fr) can provide satisfactory results. A case series of 114 morbidly obese patients with a minimum 10-year follow-up after LSG calibrated with bougie 48-Fr showed a mean %EWL of 52.5%. The success rate, defined by %EWL > 50, was present in 50.9% of these consecutive patients [19]. Better results were reported in a retrospective analysis of prospectively collected data from 148 patients who underwent LSG with 6 years of follow-up and gastric sleeve also calibrated with a bougie size of 48-Fr. A %EWL greater than 50% was registered in 123 patients (83.1%), and the mean BMI and the mean EWL were respectively 30.2 kg/m^2 and 67.3%. Interestingly, this case series revealed that preoperative BMI (> or <50 kg/m^2) did not influence significantly the postoperative EWL (67.4% vs 67.3%, respectively) [13]. Finally, a comparative 1-year follow-up study involving patients who underwent LSG (n = 120) with two sizes of calibration (32 Fr vs 42 Fr) showed that both groups experienced significant %EWL and BMI reductions as well as a similar rate of resolution of comorbidities [23], although these similar outcomes were observed in short-term follow-up.

Beyond gastric sleeve calibration, some other technical aspects of the surgical technique can contribute to the effort of adequate weight loss outcomes with similar significance. The first include the extensive and careful exposition of the gastric fundus involving total dissection of the left crus, allowing complete fundus resection attaining an optimal stomach shape tubulization, decreasing the chance of occurrence of the phenomenon known as fundus regeneration or neo-fundus formation observed on the late postoperative period of LSG, which may be closely related to significant weight recidivism [24]. Besides the incomplete fundus removal, inadequate antrum resection has also been blamed as a factor associated with inadequate weight loss or weight recidivism. A retrospective multicenter study enrolling 1395 patients (307 with 8 years of follow-up) noted that the beginning of stapling a shorter distance from the pylorus maintained weight loss in the long term [20].

Although tighter gastric sleeves (bougie size of 32–36 Fr) and stapling from 2 to 6 cm of the pylorus have achieved a high percentage of consensus in an Expert Panel Statement [25], the optimal gastric sleeve calibration and the ideal amount of antrum resection are technical aspects that remain undetermined, and should be weighed with the risks of higher rate of complications and impairment of food tolerance, and subsequently quality of life. In addition to the surgical technique, other factors of selection and management of criteria can make a difference in weight loss, although these factors are more difficult to quantify. For instance, large-volume eaters are theoretically more likely to have greater weight loss with a primarily restrictive procedure, such as LSG. On the other hand, sweet eaters may have more difficulty losing weight after LSG.

Revisional procedures due to long-term poor weight loss or weight recovery after LSG have also been a major source of concern, and several studies are now addressing this issue. After a mean follow-up period of 3 years, a retrospective case series observed the need to perform 26 revisional procedures [Roux-en-Y Gastric Bypass (RYGB) and re-Sleeve] after primary LSG, totaling a revisional rate of 5.2% [26]. Another case series encompassing morbidly obese patients who underwent LSG (n = 101) prospectively studied and followed up for 2 years reported weight recidivism in 10.1%, directly correlated with preoperative body weight and BMI [27]. A report based on MBSAQIP Data Registry identified 98,292 sleeve patients (69% of total cohort). Among these, 92,666 (94%) had a primary procedure, and the remaining 5626 (6%) had revisional one, mainly performed to address inadequate weight loss and weight recidivism [28]. Finally, a large case series of 1300 patients who underwent LSG identified 36 patients submitted to a revisional procedure due to insufficient weight loss and weight regain (laparoscopic RYGB = 12; re-Sleeve = 24), giving a rate of 2.8%. The mean %EWL after the index procedure was 40.5 [29]. However, these percentages can be higher. A multicenter study with very long-term follow-up (10 years) after LSG (n = 53) reported a revisional rate due to weight regain of 20.7% (11/53), most converted to the RYGB. In this study, a 42–48-Fr bougie size was used for calibration during the index procedure, and 36% of the patients were super-obese (BMI over 50 kg/m^2) [30].

It is important to note that the reported rate of failure in body weight control after LSG, as well as the percentage of indications of revisional procedures, varies widely in the literature, and this large variation is closely related to the nonconsensual definition of inadequate weight loss and weight recidivism adopted by the various studies. In addition, revision after LSG is a broad term that encompasses re-Sleeve, RYGB, One Anastomosis Gastric Bypass, Duodenal Switch, and even hiatal hernia repair [31, 32]. Databases such as the MBSAQIP can contribute a lot to better record these data, allowing the follow-up of individual patients and highlighting the actual failure rates as well as the expected percentage of revisional procedures throughout the time [33].

In summary, LSG appears to be an effective bariatric procedure to provide sustained results regarding weight loss in morbidly obese patients, with a high percentage of adequate excess weight loss, though long-term reports are still scarce and weight recidivism may be a concern in the near future.

12.3 Sleeve and Diabetes

Type 2 diabetes mellitus (T2DM) is a very common obesity-related comorbidity that may worsen the quality of life and life expectancy of morbidly obese subjects. Bariatric surgery is nowadays the most effective and durable approach for severe obesity and its comorbidities with better outcomes than medical treatment alone [34]. LSG has been increasingly accepted as a stand-alone procedure with the goal of both weight control and resolution of comorbidities, and is currently the most widely performed bariatric procedure worldwide [8].

Regarding T2DM control, the sustained and satisfactory weight loss seems to be the best strategy to achieve the desired effect. However, in recent decades, theories about the beneficial effects on T2DM of gastrointestinal hormones have created the paradigm of metabolic surgery, which is sometimes mistaken for diabetes surgery. Despite recent impressive advances in regard to knowledge about changes in gut hormone signaling, particularly in the incretins such as glucagon-like peptide 1 (GLP-1), the complete underlying mechanism for T2DM remission after bariatric surgery remains full of gaps.

Beyond surgery-induced weight loss, the duodeno-jejunal exclusion and precocious ileal stimulus have supported the current understanding of the role of metabolic surgery in the amelioration of glycemic control. These two mechanisms are mainly provided by bariatric surgical techniques that address the small bowel, such as RYGB. As LSG is an exclusive "gastric-technique," keeping the small bowel intact, several concerns have arisen regarding the power of LSG in T2DM improvement or resolution. This has led many surgeons to categorize LSG as the metabolic weaker procedure, whose effects on T2DM are solely dependent on weight loss.

However, large trials have shown similar outcomes between LSG and RYGB regarding long-term diabetes control. The STAMPEDE study, a 5-year randomized trial primarily designed to compare the effects of intensive medical therapy alone with those of intensive medical therapy plus bariatric surgery (RYGB or LSG) in T2DM, revealed a sustained reduction from baseline in the mean glycated hemoglobin level (−2.1%), median fasting plasma glucose (RYGB: −72 mg/dL; LSG: −49 mg/dL; nonsignificant), and mean requirement of insulin therapy (−35%) similarly in both surgical groups [34]. The SLEEVEPASS Randomized Clinical Trial, a multicenter, randomized clinical equivalence trial, showed a nonsignificant difference in complete or partial remission of T2DM between morbidly obese patients who underwent LSG (37%; 15/41) or RYGB (45%; 18/40) after 5 years. Interestingly, RYGB resulted in statistically greater weight loss than LSG at 5 years (57% and 49%, respectively), although this difference was borderline and considered not clinically significant [35]. The SM-BOSS Randomized Clinical Trial, a 2-group (LSG vs. RYGB) randomized trial, found that, at baseline, 25.7% (26/101) and 26.9% (28/104) of the patients had diabetes in the LSG and RYGB group, respectively. Of these, 23.1% (LSG; 6/26) and 21.4% (RYGB; 6/24) were under insulin therapy. After 5 years of the bariatric procedures, percentage of complete remission of T2DM was similarly observed in both groups (LSG = 61.5%; RYGB = 67.9%), and nonsignificant differences in marked amelioration of glycemic control expressed by mean fasting glucose (LSG = 114.1 mg/dL; RYGB = 101.1 mg/dL) and mean glycated hemoglobin level (LSG = 6.2%; RYGB = 5.9%) were also reported [36]. The Longitudinal Assessment of Bariatric Surgery (LABS-2) study, a long-term comparative study, encompassed morbidly obese individuals submitted to LSG ($n = 57$) or matched RYGB counterparts. However, during the time of recruitment, LSG was recommended only in high-risk or super-obese patients who would significantly benefit from the 2-stage approach, and 10 patients were submitted to the second-stage procedure (BPD/DS) because of weight loss failure. Diabetes was seen in 67.9% (36/53) of LSG patients at baseline. For both surgical groups, the prevalence of diabetes was similarly and significantly lower for 5 years [37].

Finally, comparative equivalence of LSG vs RYGB can also be tested through systematic review methodology. Among 29 studies included in a systematic review with meta-analysis, a slight but nonsignificant difference in favor of RYGB regarding diabetes control was noted [38]. Considering the greater mean percentage of excess weight loss observed in the patients who underwent RYGB, it is reasonable to infer that the cutoff level of decreasing body weight to provide a satisfactory control of diabetes may be inferior to what is usually achieved by LSG.

In addition to comparative studies, large case series have shown encouraging results. From the prospectively collected data of the German Bariatric Surgery Registry, which enrolled obese patients who underwent LSG as a primary operation (n = 435) between 2005 and 2011 and with at least 5 years of follow-up, a 64% remission rate for T2DM was observed. The overall prevalence of T2DM with insulin therapy was reduced postoperatively from 10.8% (47/435) to 5.8% (25/435), and without insulin therapy from 23.6% (102/435) to 6.4% (28/435). The global mortality of the whole series (n = 21,525) was 0.11% [39]. A long-term single-surgeon case series analyzing patients who underwent LSG (n = 116) observed 19.8% (23/116) of T2DM prevalence at baseline. After long-term follow-up (8 years), T2DM was considered completely resolved in 43.4% (10/23) of the patients [40].

Although some direct metabolic effects of LSG have been studied, a cohort study using a retrospective analysis of a prospectively collected data to investigate the long-term (5 years) effects of LSG (n = 39) revealed a 20% complete remission in T2DM. This percentage was lower than that observed at 1 year of follow-up (50.7%), and this worsening could be associated with significant weight regain, suggesting that diabetes control may be dependent on sustained weight loss [41].

The reported experience in case series addressing LSG effects on T2DM can support systematic review regard this. A systematic review that aimed to investigate the effect of LSG on T2DM encompassed a total of 27 studies and 673 patients who underwent LSG, and it was noted that diabetes status had resolved in 66.2% of the patients, improved in 26.9%, and remained stable in 13.1%, with a mean decrease in glycated hemoglobin level of 1.7%. However, the maximum follow-up period was 36 months, with most studies reporting a follow-up of only 1 year [42]. Likewise, a retrospective review of a prospectively maintained database analyzing the short-term glycemic control in 30 patients with T2DM who had undergone LSG observed resolution of the disease, defined as a fasting blood glucose level of less than 126 mg/dL and an glycosylated hemoglobin (HbA1c) level in the normal range in the absence of any hypoglycemic medication, in 63% (19/30) of the patients at 6 months of follow-up. In addition, it was also noted that patients with a shorter duration of T2DM (less than 5 years) and better weight loss after surgery achieved greater resolution rates [43].

Recently, a systematic review including only randomized controlled trials was undertaken to investigate the postoperative impact on diabetes resolution following LVSG versus LRYGB, and seven studies involving a total of 732 patients (LSG; n = 365) were retrieved. Combining several parameters of diabetes control (glycated hemoglobin level, fasting blood glucose, glucose tolerance, measures of insulin secretion and resistance, and reduction in antidiabetic medication), the review concluded for similarly effects in both procedures from 12 months postoperatively [44].

In addition to effectively contributing to the glycemic control in obese diabetic patients, LSG can provide a significant reduction in the risk of developing diabetes in the postoperative follow-up. A retrospective review of a prospectively collected database analyzed the risk reduction of developing T2DM in severely obese nondiabetic patients who underwent LSG ($n = 86$). After 1 year, a significant reduction in the risk of developing diabetes was observed, with a mean relative risk reduction of 74.2% (male and female), nearly achieving ideal risk values observed in nonobese general population [45].

In summary, LSG appears to be a very satisfactory procedure for T2DM control, showing similar long-term results to RYGB. However, unlike RYGB, the effectivity of LSG on diabetes resolution or improvement seems to be more dependent on a sustained weight loss.

12.4 Sleeve and Sleep Apnea

According to the American Academy of Sleep Medicine, obstructive sleep apnea (OSA) is defined as apnea-hypopnea index (AHI) greater than 5 events/h with typical symptoms (daytime sleepiness, loud snoring, witnessed breathing interruptions, or awakenings due to gasping or choking) [46]. OSA is the most common type of sleep-disordered breathing affecting up to 10% of the adult population [47–49], requiring continuous nighttime use of positive airway pressure (CPAP) in severe cases.

Currently, obesity seems to be the strongest risk factor for the development of OSA [50]. Therefore, it is highly recommended that all morbidly obese individuals undergoing bariatric surgery (BS) be previously screened for OSA, mainly through overnight polysomnogram, since percentages of OSA found in morbidly obese are generally much higher than in general population. Roughly 60% of patients scheduled for BS are diagnosed with some degree of OSA, and nearly 90% of these patients were not aware prior to testing [51, 52]. Indeed, obesity and OSA are probably linked in a vicious cycle, in which OSA can contribute to weight gain and obesity worsens OSA, though mechanisms underlying this reciprocal relationship have not been completely elucidated yet [53].

The obesity management has been considered as the prime therapeutic strategy for OSA, and a weight loss as low as from about 10% of total body weight seems to be enough to lead to a significant improvement in OSA [54]. Nowadays, bariatric surgery is the most effective option for sustained weight loss and control of comorbidities in morbidly obese subjects, and LSG indications have been growing exponentially in the past few years for this purpose, being the most accomplished bariatric procedure worldwide [8].

The reports of LSG's role in improvement or resolution of OSA appear to be somewhat heterogeneous, but generally very expressive. A comparative study involving 476 patients who underwent LSG impressively observed that all (100%) patients were off CPAP and showed improvement in symptoms of OSA after 2 years of follow-up [55]. Likewise, the collected data of 156 patients who underwent LSG with a mean follow-up of 32 months found that the use of CPAP could be withdrawn in all patients with OSA (13% – 21/156) [56]. Additionally, a longitudinal study with 36 OSA patients followed for 5 years after LSG observed a significant improvement in AHI (80.6% – 29/36) and an even more expressive improvement in the Modified Epworth Sleepiness Scale (91.6%), a scale which evaluates patients' level of habitual sleepiness during the day [57]. However, other studies have found still encouraging results, but not as expressive as those aforementioned. Case series of 168 patients who underwent LSG observed a resolution percentage of 73% at 8 years postoperatively [40], and prospectively collected data from 456 patients who underwent LSG with a minimum of 5 years of follow-up observed an overall remission rate of 50%; about 11% of patients (baseline = 22%) still remained with some degree of OSA, despite satisfactory and sustained weight loss [39].

Although it has been admitted that the results are probably more dependent on sustained weight loss than on the surgical technique itself, a comprehensive database analysis searching to understand the role of several bariatric procedures on OSA revealed that 86% of patients who underwent LSG ($n = 543$) experienced resolution or improvement, a percentage higher than those submitted to RYGB [58]. Similarly, a 6-year follow-up comparative study enrolling 221 super-super-obese patients (BMI over 60 kg/m^2) showed that LSG was inferior to RYGB regarding weight loss and all studied comorbidities, except for OSA [59]. However, this apparent superiority of LSG over RYGB is not unanimity. The SM-BOSS Randomized Clinical Trial, a two-group randomized, multicenter study that is following patients undergoing LSG or RYGB, observed more than 90% of improvement or remission regarding OSA after 5 years, regardless of the technique [36].

Notwithstanding, the effective control of obesity provided by LSG seems to impact more strongly on OSA than in other related comorbidities. This is an important clinical endpoint, since OSA seems to be not only a sleep disorder but also an independent risk factor for metabolic syndrome. A cohort study encompassing 1040 obese morbid individuals found OSA in almost half of the patients (47.1%) at baseline. With a mean of 38-month follow-up, 98% and 85% of patients had this comorbidity improved or resolved after LSG, respectively, and these percentages were much higher compared with the results of other comorbidities, such as T2DM and hypertension [60]. Similarly, a review of literature evaluating patients who underwent LSG with a follow-up of at least 5 years found a high rate of OSA resolution (87%). Once again, this percentage was greater than that observed for other obesity-related comorbidities, such as T2DM and dyslipemia [17]. These data suggest that OSA can be more closely associated with obesity than other obesity-related comorbidities.

Despite the high percentage of satisfactory results, some patients remain with some degree of residual disease, or even develop a "de novo" OSA postoperatively. Despite effective BMI reduction, around 20% of patients persisted with some degree of OSA, probably due to persistent nasal obstruction [57]. Thus, obesity plays a relevant role in the management of OSA, but may not be the sole cause. In addition, a published review has noted that BS does not always lead to a resolution of OSA, and pointed age, gender, and severity of OSA as predictor factors of residual disease after satisfactory weight loss [50]. The percentage of improvement or resolution seems to be paler if measured in the short term after surgery, especially when more accurate methods of diagnosis are applied. A prospective multicenter study observed that the prevalence of OSA decreased from 71% at baseline to 44% in overnight polygraphy at 12 months after the bariatric procedure, and about 20% of the patients still persisted with moderate or severe OSA. Interestingly, this study also reported the development of a "de novo" OSA in about 6% of the patients [61].

In summary, OSA seems to be the one of obesity comorbidities most positively impacted by the LSG weight loss, even in the long term. The exact mechanism to explain these expressive results on OSA demonstrated by several studies is not completely elucidated, but seems to be related to weight control rather than the procedure itself.

12.5 Sleeve and Hypertension

Hypertension is a chronic disease with increasing prevalence in recent decades. Currently, it is among the main causes of general health risk, especially for cardiovascular events, such as ischemic heart disease. Projections suggest that an estimated almost 900 million adults have high systolic blood pressure nowadays around the world [62]. Obesity has been recognized as the prime risk factor for hypertension and the excess adiposity can induce hypertension or worsen the preexisting essential hypertension.

Regarding the obesity-related hypertension, there might be a specific and somewhat different mechanism of essential hypertension observed in the lean population. Although the pathophysiology remains to be better elucidated, sympathetic nervous system activation, primary renal sodium retention, hyperleptinemia, hyperinsulinemia, increased intra-adipose glucocorticoid action, and endothelial dysfunction are relevant factors in the pathogenesis [63, 64], most likely a combination of them. The pivotal trigger (or source) of obesity-related hypertension appears to be high adiposity with the release of adipokines, since significant weight loss generally positively affects pressure levels.

The sustained control of body weight provided by bariatric surgery in morbidly obese subjects is also generally reflected in a high rate of blood pressure control after surgery. However, hypertension is usually a secondary endpoint in studies involving metabolic outcomes after bariatric surgery, unlike T2DM and dyslipemia. Therefore, there is a paucity of direct data (primary endpoint) about hypertension control after bariatric surgery.

One of the most important studies addressing hypertension as a primary endpoint is the GATEWAY Randomized Trial, a randomized, single-center, nonblinded trial encompassing obese individuals undergoing bariatric surgery (RYGB) plus medical therapy or medical therapy alone. In this trial, improvement in blood pressure levels was found in 83.7% of surgical patients compared with only 12.8% of those submitted to drug therapy. In addition, remission of hypertension was present in around 50% of patients who underwent bariatric surgery. Considering the SPRINT (Systolic Blood Pressure Intervention Trial) levels [65], 22.4% of the patients from the bariatric group reached the target (office systolic blood pressure < 120 mmHg) without antihypertensive, whereas none in the medical group at 1 year of follow-up [66]. It is worth mentioning that this high rate of remission/improvement observed in the bariatric group ran along with a significantly greater weight loss. This side-by-side outcome (weight loss and hypertension control) is similarly reported in most studies published so far.

Blood pressure control after the bariatric procedure seems to be dependent on weight loss rather than the technique. A comparative study involving obese patients who underwent LSG or RYGB observed that hypertension significantly improved in both groups (95.6% and 92%, respectively), although weight loss after 2 years was slightly higher in RYGB [55]. This finding does not suggest that hypertension control involves enhanced stimulation of gut hormones (as usually seen in RYGB), but rather a lower cutoff point in the percentage weight loss to allow blood pressure control. Similarly, the SM-BOSS Randomized Clinical Trial, a 2-group randomized (LSG × RYGB) multicenter study, also observed a high rate of improvement or remission in hypertension, irrespective of the procedure performed. In the LSG group, this study also revealed a prevalence of 63% (64/101) of hypertension in the LSG group at baseline and a significant amelioration after 5 years, with 63% of remission and 25% of improvement, gathering 88% of satisfactory outcome. Interestingly, two cases of "de novo" hypertension were also found [36].

Regarding the effectiveness of LSG on hypertension control, a recent systematic review carried out specifically to evaluate the efficacy of LSG on hypertension included 14 studies and found a mean of 37% preoperative diagnosis of arterial hypertension among morbidly obese patients. Five years after the surgical procedure, mean percentage of hypertension dropped to around 15%, with 62% of remission and 35% of improvement, supporting the conclusion favored to LSG as an effective intervention for bariatric patients with arterial hypertension [67].

As widely pointed by several published studies, the rate of improvement or remission of hypertension has been expressive after bariatric surgery, but about 10–20% of the patients remain diseased, irrespective of the procedure. The reasons are not yet fully clarified, but an individual who develops hypertension after obesity (obesity-related hypertension) is likely to be more susceptible to the beneficial effects of weight loss and will unlikely get into complete remission state following weight loss provided by bariatric surgery than a lean subject who was already a carrier of essential hypertension before gaining excessive weight.

Although the long-term results of improvement or remission in hypertension appear to depend on satisfactory weight loss after bariatric surgery, a prospective 12-month study encompassing 60 morbidly obese patients submitted to LSG interestingly revealed a significant reduction in mean blood pressure as early as 10 days in 23 patients (74% – 23/31), suggesting a likely short-term effect on hypertension following bariatric surgery, since the decrease of blood pressure occurs prior to a significant reduction of weight. Although a clear explanation cannot be offered to date, some mechanisms may explain this early effect of LSG on blood pressure. Reduced food and salt intake along with expressive changes in signaling in gastrointestinal hormones and adipokines may be implicated. Moreover, this cohort approached patients with a relatively shorter disease course, with only 12 patients using antihypertensive drugs and 19 patients who were previously unaware of their hypertension before operation [68].

In summary, LSG has been shown to be a highly effective bariatric procedure in the management of obesity-related hypertension, with a high rate of improvement or resolution, notably after satisfactory weight loss.

12.6 Sleeve and Dyslipidemia

Obesity is a high-prevalence disease characterized by excessive accumulation of adipose tissue. Beyond increasing amount of adipocytes, fat tissue dysfunction ("adiposopathy") caused by obesity-induced metabolic stress could be involved in pathogenic mechanisms underlying dyslipidemia. Dyslipidemia is an abnormality in the lipid blood profile, such as elevated low-density lipoprotein cholesterol (LDL-C) and triglyceride levels and/or decreased high-density lipoprotein cholesterol (HDL-C) levels, commonly associated with overweight and obesity [69, 70]. The association between obesity and dyslipidemia is very harmful to health and exponentially increases the risk of cardiovascular disease [69, 71, 72]. The single dyslipidemia more often associated with this increased cardiovascular risk seems to be an elevation in LDL-C levels [73].

One of the most striking beneficial effects of bariatric surgery is the resolution of dyslipidemia, with expected normalization of the lipid profile in the blood, significantly reducing the risk of a cardiovascular event and ultimately affecting the mortality rate. However, the detailed mechanism underlying lipid improvement and bariatric weight loss is still under discussion.

In-depth reviews addressing the relationship between bariatric surgery and lipid metabolism disturbances have demonstrated favorable effects of bariatric surgery on adipose tissue dysfunction, strongly contributing to improvement in dyslipidemia, probably through the change in endocrine and inflammatory homeostasis, as well as beneficial effects on bile acid metabolism and gut microbiome [74]. Furthermore, there seems to be a close relationship between the amount of loss in total fat mass and resolution/improvement in dyslipidemia, allowing a significant withdrawn/reduction in drug therapy. Among bariatric procedures, LSG seemed to be so effective as the others, demonstrated by the amelioration in lipid profile parameters such as blood levels of triglycerides, total cholesterol, LDL-C, and HDL-C [75].

Notwithstanding, studies specifically addressing the impact of LSG on dyslipidemia are uncommon. A retrospective descriptive study enrolled 107 morbidly obese patients submitted to LSG and found encouraging results regarding the global control of dyslipidemia after 1 year of the bariatric procedure. The remission and improvement of hypercholesterolemia was achieved in 45% and 19% of the patients, respectively. Moreover, better results were observed in relation to hypertriglyceridemia, with remission in 86% of patients and improvement in another 4%. Medication was discontinued in about 44% of the patients, and the overall result was strongly related to weight loss [76]. Likewise, a retrospective analysis of a prospective cohort of obese subjects who underwent LSG ($n = 443$) revealed highly favorable changes in lipid profiles at 5 years of follow-up. Again, hypertriglyceridemia had partial or complete remission rate (around 80%) much higher than that observed for hypercholesterolemia (around 50%), although an increase in HDL-C and a decrease in LDL-Cl level have been consistently noted. Based on this result, hypertriglyceridemia was the only dyslipidemia whose remission rate could be correlated with percentage of excess weight loss [41]. On the other hand, an observational study enrolling patients submitted to LSG ($n = 86$) reported a very low remission rate after 5 years (27.4% – 17/86), with three “de novo” cases in the postoperative follow-up. Although there was a statistically significant amelioration in HDL-C, LDL-C and triglycerides levels, the mean total cholesterol level did not show a significant improvement, which may explain the reported low percentage of resolution, given the definition of dyslipidemia adopted [77].

Considering the paucity of studies that include dyslipidemia as the primary endpoint after LSG, the impact of LSG on resolution/improvement of dyslipidemia can also be obtained in studies comparing the metabolic outcomes of LSG and BGYR, usually as a secondary endpoint. However, despite the close and dangerous relationship between obesity and dyslipidemia, this relevant metabolic outcome is not always reported. A recent systematic review with meta-analysis aiming to compare the results of laparoscopic BGYR and LSG retrieved 62 studies with a total of 18,449 patients (LSG group; $n = 7951$), but only 14 studies were eligible to evaluate the postoperative results on dyslipidemia (LSG group; $n = 580$) [38]. Similarly, a previous review aimed at addressing long-term results of LSG retrieved 16 studies that met the inclusion criteria. Of these, only four studies contained data about the long-term effect of LSG on dyslipidemia, and the mean percentage of complete or near-complete dyslipidemia resolution reported in those papers was 61.5% [17]. Finally, a retrospective analysis of a prospective, nonrandomized cohort to compare laparoscopic RYGB vs. LSG ($n = 48$) outcomes with respect to the evolution of lipid disturbances observed a lower remission rate, a percentage of remission in hypertriglyceridemia (66.7% – 10/15) and total hypercholesterolemia (23.1% – 6/26), in patients submitted to LSG after 5 years. In addition, normal LDL-C was achieved in 26.1% (6/23) of the patients, also lower than RYGB. However, the percentage of patients achieving normal HDL-C 5 years after LSG was similar to RYGB [78.3% (18/23) and 83% (39/47), respectively], which can be considered a significant metabolic outcome. Furthermore, differences in results may have been affected by percentage total body weight loss at 5 years, slightly higher in the RYGB group [78].

Looking at the patients belonging to the LSG group in some comparative studies with RYGB, dyslipidemia has shown a significant overall improvement, even in long-term follow-up, despite some variations in results of the lipid subfractions. The STAMPEDE study, a randomized trial primarily designed to compare the effects of intensive medical therapy alone with those of intensive medical therapy plus bariatric surgery (RYGB or LSG) in T2DM, revealed an increase in HDL-C levels from baseline, while triglyceride levels dropped at 5 years after LSG, both significantly. Although no significant differences were observed in LDL-C levels compared with the medical group, the number of medications required to treat hyperlipidemia was significantly lower in the LSG group ($n = 47$) [34]. The SLEEVEPASS Randomized Clinical Trial, a multicenter, multisurgeon, open-label, randomized clinical equivalence trial, showed that medication for dyslipidemia was discontinued in 47% (14/30), reduced in 20% (6/30), and remained unchanged in 33% (10/30) of the patients after 5 years in the LSG group (n = 98). With the exception of LDL-C levels, the overall dyslipidemia remission rate was similar to that of the RYGB group [35]. The SM-BOSS Randomized Clinical Trial, a 2-group (LSG vs. RYGB) randomized trial, found that dyslipidemia was present at baseline in 67.3% of the patients randomized to receive LSG (n = 101). After 5 years, complete remission was observed in 42.6% (29/68) and improvement in 41.2% (28/68), while the remaining patients lasted unchanged (16.2% – 11/68), without worsening. Regarding lipid subfractions, significant amelioration was seen in levels of triglycerides, total cholesterol, LDL-C, and HDL-C, results very similar to those observed in the RYGB group [36].

In summary, dyslipidemia is a high-risk and high-prevalence obesity comorbidity, which appears to be significantly ameliorated by weight loss provided by LSG, even in the long term.

12.7 Conclusion

LSG is a young bariatric procedure that has shown excellent results regarding weight loss and improvement/resolution of obesity-related comorbidities. However, long-term data regarding weight recidivism and comorbidities rebound remain incomplete.

References

1. Marceau P, Biron S, Bourque RA, et al. Biliopancreatic diversion with a new type of gastrectomy. Obes Surg. 1993;3:29–35.
2. Ren CJ, Patterson E, Gagner M. Early results of laparoscopic biliopancreatic diversion with duodenal switch: a case series of 40 consecutive patients. Obes Surg. 2000;10:514–23.
3. Regan JP, Inabnet WB, Gagner M, et al. Early experience with two-stage laparoscopic Roux-en-Y gastric bypass as an alternative in the super-superobese patient. Obes Surg. 2003;13:861–4.
4. Han S, Kim W, Oh J. Results of laparoscopic sleeve gastrectomy (LSG) at 1 year in morbidly obese Korean patients. Obes Surg. 2005;15(10):1469–75.
5. Silecchia G, Boru C, Pecchia A, et al. Effectiveness of laparoscopic sleeve gastrectomy (first stage of biliopancreatic diversion with duodenal switch) on co-morbidities in super-obese high-risk patients. Obes Surg. 2006;16(9):1138–44.
6. ASMBS Clinical Issues Committee. Updated position statement on sleeve gastrectomy as a bariatric procedure. Surg Obes Relat Dis. 2012;8:e21–6.
7. English WJ, DeMaria EJ, Brethauer SA, et al. American Society for Metabolic and Bariatric Surgery estimation of metabolic and bariatric procedures performed in the United States in 2016. Surg Obes Relat Dis. 2018;14(3):259–63.
8. Angrisani L, Santonicola A, Iovino P, et al. IFSO worldwide survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28(12):3783–94.
9. O'Brien PE, Hindle A, Brennan L, et al. Long-term outcomes after bariatric surgery: a systematic review and meta-analysis of weight loss at 10 or more years for all bariatric procedures and a single-centre review of 20-year outcomes after adjustable gastric banding. Obes Surg. 2019;29(1):3–14.

10. ASMBS Clinical Issues Committee of the American Society for Metabolic and Bariatric Surgery. Updated position statement on sleeve gastrectomy as a bariatric procedure. Surg Obes Relat Dis. 2010;6(1):1–5.
11. D'Hondt M, Vanneste S, Pottel H, et al. Laparoscopic sleeve gastrectomy as a single-stage procedure for the treatment of morbid obesity and the resulting quality of life, resolution of comorbidities, food tolerance, and 6-year weight loss. Surg Endosc. 2011;25:2498–504.
12. Sarela AI, Dexter SP, O'Kane M, et al. Long term follow-up after laparoscopic sleeve gastrectomy: 8–9 -year results. Surg Obes Relat Dis. 2012;8:679–84.
13. Casella G, Soricelli E, Giannotti D, et al. Long-term results after laparoscopic sleeve gastrectomy in a large monocentric series. Surg Obes Relat Dis. 2016;12:757–62.
14. Gagner M, Hutchinson C, Rosenthal R. Fifth international consensus conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6.
15. Lemanu DP, Srinivasa S, Singh PP, et al. Single-stage laparoscopic sleeve gastrectomy: safety and efficacy in the super-obese. J Surg Res. 2012;177:49–54.
16. Lemanu DP, Singh PP, Rahman H, et al. Five-year results after laparoscopic sleeve gastrectomy: a prospective study. Surg Obes Relat Dis. 2015;11:518–2.
17. Diamantis T, Apostolou KG, Alexandrou A, et al. Review of long-term weight loss results after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2014;10:177–83.
18. Juodeikis Ž, Brimas G. Long-term results after sleeve gastrectomy: a systematic review. Surg Obes Relat Dis. 2017;13(4):693–9.
19. Castagneto-Gissey L, Casella Mariolo JR, et al. 10-year follow-up after laparoscopic sleeve gastrectomy: outcomes in a monocentric series. Surg Obes Relat Dis. 2018;14(10):1480–7.
20. Abd-Ellatif ME, Abdallah E, Askar W, et al. Long term predictors of success after laparoscopic sleeve gastrectomy. Int J Surg. 2014;12:504–8.
21. Aurora AR, Khaitan L, Saber AA. Sleeve gastrectomy and the risk of leak: a systematic analysis of 4,888 patients. Surg Endosc. 2012;26:1509–15.
22. Parikh M, Isa R, McCrillis A, et al. Surgical strategies that may decrease leak after laparoscopic sleeve gastrectomy. Ann Surg. 2013;257(2):231–7.
23. Spivak H, Rubin M, Sadot E, et al. Laparoscopic sleeve gastrectomy using 42-French versus 32-French bougie: the first-year outcome. Obes Surg. 2014;24(7):1090–3.
24. Himpens J, Dobbeleir J, Peeters G. Long term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252:319–234.
25. Rosenthal RJ. International Sleeve Gastrectomy Expert Panel. International Sleeve Gastrectomy Expert Panel Consensus Statement: best practice guidelines based on experience of 412,000 cases. Surg Obes Relat Dis. 2012;8:8–19.
26. Yilmaz H, Ece I, Sahin M. Revisional surgery after failed laparoscopic sleeve gastrectomy: retrospective analysis of causes, results, and technical considerations. Obes Surg. 2017;27(11):2855–60.
27. Fahmy MH, Sarhan MD, Osman AM, et al. Early weight recidivism following laparoscopic sleeve gastrectomy: a prospective observational study. Obes Surg. 2016;26(11):2654–60.
28. El-Chaar M, Stoltzfus J, Melitics M, et al. 30-day outcomes of revisional bariatric stapling procedures: first report based on MBSAQIP data registry. Obes Surg. 2018;28(8):2233–40.
29. Al-Sabah S, Alsharqawi N, Almulla A, et al. Approach to poor weight loss after laparoscopic sleeve gastrectomy: re-sleeve vs. gastric bypass. Obes Surg. 2016;26:2302–7.
30. Felsenreich DM, Langer FB, Kefurt R, et al. Weight loss, weight regain, and conversions to Roux-en-Y gastric bypass: 10-year results of laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(9):1655–62.
31. Silecchia G, De Angelis F, Rizzello M, et al. Residual fundus or neofundus after laparoscopic sleeve gastrectomy: is fundectomy safe and effective as revision surgery? Surg Endosc. 2015;29:2899–903.
32. Casillas RA, Um SS, Zelada-Getty JL, et al. Revision of primary sleeve gastrectomy to Roux-en-Y gastric bypass: indications and outcomes from a high-volume center. Surg Obes Relat Dis. 2016;12(10):1817–25.
33. Clapp B, Wynn M, Martyn C, et al. Long term (7 or more years) outcomes of the sleeve gastrectomy: a meta-analysis. Surg Obes Relat Dis. 2018;14(6):741–7.

34. Schauer PR, Bhatt DL, Kirwan JP, et al. STAMPEDE Investigators. Bariatric surgery versus intensive medical therapy for diabetes – 5-year outcomes. N Engl J Med. 2017;376(7):641–51.
35. Salminen P, Helmiö M, Ovaska J, et al. Effect of laparoscopic sleeve gastrectomy vs laparoscopic Roux-en-Y gastric bypass on weight loss at 5 years among patients with morbid obesity: the SLEEVEPASS randomized clinical trial. JAMA. 2018;319(3):241–54.
36. Peterli R, Wölnerhanssen BK, Peters T, et al. Effect of laparoscopic sleeve gastrectomy vs laparoscopic Roux-en-Y gastric bypass on weight loss in patients with morbid obesity: the SM-BOSS randomized clinical trial. JAMA. 2018;319(3):255–65.
37. Ahmed B, King WC, Gourash W, et al. Long-term weight change and health outcomes for sleeve gastrectomy (SG) and matched Roux-en-Y gastric bypass (RYGB) participants in the Longitudinal Assessment of Bariatric Surgery (LABS) study. Surgery. 2018;164(4):774–83.
38. Li J, Lai D, Wu D. Laparoscopic Roux-en-Y gastric bypass versus laparoscopic sleeve gastrectomy to treat morbid obesity-related comorbidities: a systematic review and meta-analysis. Obes Surg. 2016;26(2):429–42.
39. Gärtner D, Stroh C, Hukauf M, et al. Obesity Surgery Working Group. Sleeve gastrectomy in the German Bariatric Surgery Registry from 2005 to 2016: perioperative and 5-year results. Surg Obes Relat Dis. 2019;15(2):187–93.
40. Noel P, Nedelcu M, Eddbali I, et al. What are the long-term results 8 years after sleeve gastrectomy? Surg Obes Relat Dis. 2017;13(7):1110–5.
41. Golomb I, Ben David M, Glass A, et al. Long-term metabolic effects of laparoscopic sleeve gastrectomy. JAMA Surg. 2015;150(11):1051–7.
42. Gill RS, Birch DW, Shi X, et al. Sleeve gastrectomy and type 2 diabetes mellitus: a systematic review. Surg Obes Relat Dis. 2010;6(6):707–13.
43. Rosenthal R, Li X, Samuel S, et al. Effect of sleeve gastrectomy on patients with diabetes mellitus. Surg Obes Relat Dis. 2009;5(4):429–34.
44. Osland E, Yunus RM, Khan S, et al. Diabetes improvement and resolution following laparoscopic vertical sleeve gastrectomy (LVSG) versus laparoscopic Roux-en-Y gastric bypass (LRYGB) procedures: a systematic review of randomized controlled trials. Surg Endosc. 2017;31(4):1952–63.
45. Gutierrez-Blanco D, Romero Funes D, Castillo M, et al. Bariatric surgery reduces the risk of developing type 2 diabetes in severe obese subjects undergoing sleeve gastrectomy. Surg Obes Relat Dis. 2019;15(2):168–72.
46. Epstein LJ, Kristo D, Strollo PJ, et al. Clinical guideline for the evaluation, management and long-term care of obstructive sleep apnea in adults. J Clin Sleep Med. 2009;5:263–76.
47. Young T, Palta M, Dempsey J, et al. The occurrence of sleep-disordered breathing among middle-aged adults. N Engl J Med. 1993;328(17):1230–5.
48. Ashrafian H, le Roux CW, Rowland SP, et al. Metabolic surgery and obstructive sleep apnoea: the protective effects of bariatric procedures. Thorax. 2012;67:442–9.
49. Maspero C, Giannini L, Galbiati G, et al. Obstructive sleep apnea syndrome: a literature review. Minerva Stomatol. 2015;64:97–109.
50. Pannain S, Mokhlesi B. Bariatric surgery and its impact on sleep architecture, sleep-disordered breathing, and metabolism. Best Pract Res Clin Endocrinol Metab. 2010;24(5):745–61.
51. Ravesloot MJ, van Maanen JP, Hilgevoord AA, et al. Obstructive sleep apnea is underrecognized and underdiagnosed in patients undergoing bariatric surgery. Eur Arch Otorhinolaryngol. 2012;269:1865–71.
52. de Raaff CA, Gorter-Stam MA, de Vries N, et al. Perioperative management of obstructive sleep apnea in bariatric surgery: a consensus guideline. Surg Obes Relat Dis. 2017;13:1095–109.
53. Hamilton GS, Joosten SA. Obstructive sleep apnoea and obesity. Aust Fam Physician. 2017;46(7):460–3.
54. Tham KW, Lee PC, Lim CH. Weight management in obstructive sleep apnea: medical and surgical options. Sleep Med Clin. 2019;14(1):143–53.
55. Garg H, Priyadarshini P, Aggarwal S, et al. Comparative study of outcomes following laparoscopic Roux-en-Y gastric bypass and sleeve gastrectomy in morbidly obese patients: a case control study. World J Gastrointest Endosc. 2017;9:162–70.

56. Hoyuela C. Five-year outcomes of laparoscopic sleeve gastrectomy as a primary procedure for morbid obesity: a prospective study. World J Gastrointest Surg. 2017;9(4):109–17.
57. Del Genio G, Limongelli P, Del Genio F, et al. Sleeve gastrectomy improves obstructive sleep apnea syndrome (OSAS): 5 year longitudinal study. Surg Obes Relat Dis. 2015;12:70–4.
58. Sarkhosh K, Switzer NJ, El-Hadi M, et al. The impact of bariatric surgery on obstructive sleep apnea: a systematic review. Obes Surg. 2013;23(3):414–23.
59. Arapis K, Macrina N, Kadouch D, et al. Outcomes of Roux-en-Y gastric bypass versus sleeve gastrectomy in super-super-obese patients (BMI ≥60 kg/m2): 6-year follow-up at a single university. Surg Obes Relat Dis. 2019;15(1):23–33.
60. Nocca D, Loureiro M, Skalli EM, et al. Five-year results of laparoscopic sleeve gastrectomy for the treatment of severe obesity. Surg Endosc. 2017;31(8):3251–7.
61. Peromaa-Haavisto P, Tuomilehto H, Kössi J, et al. Obstructive sleep apnea: the effect of bariatric surgery after 12 months – a prospective multicenter trial. Sleep Med. 2017;35:85–90.
62. Forouzanfar MH, Liu P, Roth GA, et al. Global burden of hypertension and systolic blood pressure of at least 110 to 115 mm Hg, 1990–2015. JAMA. 2017;317:165–82.
63. Kotsis V, Stabouli S, Papakatsika S, et al. Mechanisms of obesity-induced hypertension. Hypertens Res. 2010;33:386–93.
64. do Carmo JM, da Silva AA, Wang Z, et al. Obesity-induced hypertension: brain signaling pathways. Curr Hypertens Rep. 2016;18(7):58.
65. The SPRINT Research Group. A randomized trial of intensive versus standard blood-pressure control. N Engl J Med. 2015;373(22):2103–16.
66. Schiavon CA, Bersch-Ferreira AC, Santucci EV, et al. Effects of bariatric surgery in obese patients with hypertension: the GATEWAY randomized trial (gastric bypass to treat obese patients with steady hypertension). Circulation. 2018;137(11):1132–42.
67. Graham C, Switzer N, Reso A, et al. Sleeve gastrectomy and hypertension: a systematic review of long-term outcomes. Surg Endosc. 2019;33(9):3001–7.
68. Yin X, Qian J, Wang Y, et al. Short-term outcome and early effect on blood pressure of laparoscopic sleeve gastrectomy in morbidly obese patients. Clin Exp Hypertens. 2018;29:1–5.
69. Bays HE. "Sick fat," metabolic disease, and atherosclerosis. Am J Med. 2009;122(1 Suppl):S26–37.
70. Catapano AL, Graham I, De Backer G, et al. ESC scientific document group. 2016 ESC/EAS guidelines for the management of dyslipidaemias. Eur Heart J. 2016 Oct 14;37(39):2999–3058.
71. Bays HE. Adiposopathy is "sick fat" a cardiovascular disease? J Am Coll Cardiol. 2011;57(25):2461–73.
72. Bays HE, Toth PP, Kris-Etherton PM, et al. Obesity, adiposity, and dyslipidemia: a consensus statement from the National Lipid Association. J Clin Lipidol. 2013;7(4):304–83.
73. Third report of the National Cholesterol Education Program (NCEP). Expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III): final report. Circulation. 2002;106:3143–421.
74. Bays HE, Jones PH, Jacobson TA, et al. Lipids and bariatric procedures part 1 of 2: scientific statement from the National Lipid Association, American Society for Metabolic and Bariatric Surgery, and Obesity Medicine. Association J Clin Lipidol. 2016;10(1):33–57.
75. Bays H, Kothari SN, Azagury DE, et al. Lipids and bariatric procedures part 2 of 2: scientific statement from the American Society for Metabolic and Bariatric Surgery (ASMBS), the National Lipid Association (NLA), and Obesity Medicine Association (OMA). Surg Obes Relat Dis. 2016;12(3):468–95.
76. Vigilante A, Signorini F, Marani M, et al. Impact on dyslipidemia after laparoscopic sleeve gastrectomy. Obes Surg. 2018;28(10):3111–5.
77. Kikkas EM, Sillakivi T, Suumann J, et al. Five-year outcome of laparoscopic sleeve gastrectomy, resolution of comorbidities, and risk for cumulative nutritional deficiencies. Scand J Surg. 2019;108(1):10–6.
78. Climent E, Benaiges D, Flores-Le Roux JA, et al. Changes in the lipid profile 5 years after bariatric surgery: laparoscopic Roux-en-Y gastric bypass versus laparoscopic sleeve gastrectomy. Surg Obes Rel Dis. 2018;14(8):1099–105.

Chapter 13
Intraoperative Anesthesia Management

Jan Paul Mulier and Luiz Fernando dos Reis Falcão

13.1 Introduction

The prevalence of obesity has increased globally during the past few decades [1], affecting more than 700 million people. Since the 1980s, the prevalence of obesity has doubled in more than 70 countries and continues to increase in most regions of the world [2]. If current trends continue, by 2025, approximately 2.7 billion adults will be overweight (BMI ranging from 25 to 29.9 kg/m^2), with an additional 1 billion affected by obesity (BMI ≥ 30 kg/m^2), and 177 million severely affected by obesity [3] (BMI ≥ 40 kg/m^2). The financial cost of obesity was 2 trillion US dollars in 2014, or 2.8% of global gross domestic product (GDP) [4]. The obesity epidemic and the development of laparoscopy have resulted in an exponential increase in bariatric procedures during the past decade, making them one of the more commonly performed gastrointestinal operations [5]. Bariatric surgery is the most effective treatment for morbid obesity, resulting in sustained weight loss and reduced obesity-related comorbidities.

Sleeve gastrectomy (SG) is the most common bariatric procedure performed worldwide. SG is usually performed laparoscopically, although endoscopic methods have recently been developed. Low-impact laparoscopy is performed with 3-mm-sized trocars, instead of 5-mm trocars, and micro-instruments, including a 3-mm camera, to minimize surgical injury. One or two 12-mm trocars are required for the stapler and clipper to remove the resected stomach from the abdomen.

J. P. Mulier
Department of Anaesthesiology & Intensive care AZ Sint-Jan Brugge KULeuven & UGent Brugge, Flanders, Belgium

L. F. d. R. Falcão (✉)
Department of Anaesthesiology, Professor of Anaesthesiology,
Universidade Federal de São Paulo, Sao Paulo, Brazil

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_13

Procedures are performed at the lowest intra-abdominal pressure possible by measuring the pressure required to reach a 3-liter workspace. Low pressure minimizes peritoneal inflammation and subsequent shoulder pain and adhesions. The use of small trocars and low pressure ultimately reduce surgical injury and inflammation.

Anesthesiologists play important roles in the success of these procedures, especially considering enhanced recovery protocols to improve outcomes. The goal of the enhanced recovery after bariatric surgery (ERABS) pathway is to maintain physiological function, enhance mobilization, reduce pain through a multimodal analgesic approach, and reduce perioperative surgical stress [6]. The ERABS pathway improves outcomes, including reduced morbidity, faster recovery, and reduced hospital stay [7]. Małczak et al. [8] demonstrated that ERABS reduces the length of hospital stay without increase in morbidity. The ERABS protocol is safe and feasible [9]. A recent retrospective study [10] from the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program database, which included 85,321 SG cases, showed that same-day discharge after SG was associated with increased complications, readmissions, and reoperations compared with discharge after postoperative day 1. However, laparoscopic SG in an ambulatory setting is feasible with a dedicated anesthesiology approach and an expert surgical team [11–13]. Therefore, anesthesiologists must possess deep knowledge of specialized anesthetic measures and common acute and chronic complications after SG to improve outcomes.

In this chapter, we summarize different anesthetic aspects that all anesthesiologists should achieve to improve surgical outcomes after SG and decrease acute and chronic complications.

13.2 Common Anesthetic-Related Problems

The most common anesthetic-related problems after SG are postoperative nausea and vomiting [14] (PONV) and post-discharge nausea and vomiting (PDNV), followed by abdominal pain [15], shoulder pain after laparoscopy, and esophageal spastic pain.

13.2.1 PONV and PDNV

PONV is the most common preventable cause of delayed hospital discharge or emergency department return following bariatric surgery [15–17]. Intra-abdominal and intra-gastric pressure can reach up to 290 ± 123 mmHg during vomiting [18], but transmural pressure remains low. However, avoiding vomiting after SG may reduce leaks from the site of the last staple close to the esophagus in the fundus. During high intra-abdominal pressure, the upper esophageal sphincter herniates through the diaphragm to break the stomach content. This is achieved by a downward movement of the diaphragm followed by an inspiration and abdominal muscle contraction. The fundus of the stomach might also herniate and be exposed to much higher transmural pressures [18]. Aydin [19] reported a mean bursting pressure of 32 mmHg to rupture the excised human stomach after SG, with 35 mmHg pressure needed for reinforcements and 75 mmHg (30–170) when over-sewing. This is never enough to cope with the pressures reached during vomiting if the staple line herniates through the diaphragm. Rogula [20] noted that excised sleeves burst at much higher pressures of 329 ± 123 mmHg, which is close to the pressures achieved during vomiting.

PONV remains common after SG, affecting up to 77.8% of patients compared with 63.1% of patients who receive gastric bypass [14]. The vagal nerves are one of the main peripheral afferent pathways triggering PONV [21]. Laparoscopic gastric bypass and SG involve incisions through branches of the vagus nerve. Due to the high incidence of PONV and its consequences, it is important to stratify high-risk patients. Major risk factors include female gender, non-smoking status, history of motion sickness or PONV, and the use of postoperative opioids [22]. Roberts described a logarithmic opioid dose-related increase in PONV [23]. On halving the opioid dose, the incidence of nausea is reduced by 20% and vomiting by 10%.

There are two main approaches for reducing PONV: (1) reduce baseline factors, and (2) administer PONV prophylaxis [24]; however, the latter is difficult to achieve. Strategies for reducing baseline risk include: (1) avoiding general anesthesia by using regional anesthesia, which is not possible for laparoscopic SG; (2) preferential use of propofol infusion; (3) avoiding nitrous oxide and volatile anesthetics; (4) minimizing or avoiding perioperative opioids; and (5) adequate hydration. Regarding prophylaxis, the recommended pharmacologic anti-emetics include the 5-hydroxytryptamine (5-HT_3) receptor antagonists (ondansetron, dolasetron, granisetron, tropisetron, ramosetron, and palonosetron), neurokinin-1 (NK-1) receptor antagonists (aprepitant, casopitant, and rolapitant), corticosteroids (dexamethasone and methylprednisolone), butyrophenones (droperidol and haloperidol), antihistamines (dimenhydrinate and meclizine), and anticholinergics (transdermal scopolamine). Prophylactic anti-emetic drugs are not effective [25] even when combined with rescue drugs [26]. Total intravenous anesthesia was assumed to be an effective method, as propofol is a strong anti-emetic, but this approach is difficult to continue postoperatively. Therefore, although most patients wake up without nausea, the frequency of PDV on the ward or at home is not effectively reduced. The impact of opioids is more important than all other factors combined. Opioid-free anesthesia (OFA) is the most effective treatment, although not completely effective, for reducing nausea and vomiting [27]. OFA requires multimodal anesthesia to avoid postoperative pain [28].

13.2.2 Postoperative Pain

Postoperative pain is the second most common preventable reason for emergency department return following bariatric surgery [15]. Pain is related to surgical injury with large variability among patients depending on individual pain thresholds.

Maximal pain occurs within the first 24 hours after laparoscopic surgery and diminishes progressively after the second or third postoperative day [29]. Postoperative pain after laparoscopic SG can present in the chest, shoulder, or abdominal region and is frequently spastic. Shoulder pain of unknown etiology is common after laparoscopy; however, effective preventive and treatment approaches remain unestablished. Shoulder pain is most likely an indication of peritoneal ischemia, which is more painful in the densely innervated diaphragmatic peritoneum. Reducing pressure in the pneumoperitoneum during surgery can reduce shoulder pain. Therefore, the anesthetist should maintain deep-muscle relaxation at the peripheral thumb. In addition, pulmonary recruitment maneuvers and infusion of intraperitoneal normal saline at the end of surgery can effectively reduce postoperative pain [30]. Parietal pain represents 50–70% of total pain after laparoscopic surgery. Visceral pain accounts for 10–20%, and pneumoperitoneal pain for 20–30% [31, 32].

Postoperative pain control is especially important for morbidly obese patients, given that atelectasis and other lung complications are more frequent in these subjects and might affect sleep apnea and hypopnea [33]. The need for postoperative opioids varies among different centers, ranging from 80 mg morphine to almost zero, where no opioids are used intraoperatively (OFA). Multimodal analgesia, or the use of many drugs with different mechanisms of action, has been defended by many authors as an approach to reduce the incidence and severity of post-surgical pain [28, 34, 35]. The use of diverse therapeutic agents enables the reduction of individual dosing, resulting in optimal therapeutic potential with fewer side effects [36, 37]. This approach is particularly useful when designing an analgesic plan where opioid-based analgesia should be minimized. The following pharmacological agents are the most frequently used in a multimodal analgesic approach after bariatric surgery.

Nonsteroidal anti-inflammatory drugs (NSAIDs) are classical anti-inflammatory analgesic agents that could be administered prior to surgical incision. The safety profile of these drugs has improved with the introduction of COX-2-specific inhibitors. Patients undergoing bariatric surgery show a marked opioid-sparing effect with the appropriate use of NSAIDs. The limitation of most NSAIDs is that they are low-ceiling analgesics, and dose-response curves flatten after specific dose increments. The pharmacological profile of NSAIDs makes it a preferable analgesic during the perioperative period, when opioids need to be avoided. In contrast to NSAIDs, steroidal anti-inflammatory agents should be given as soon as surgical injury begins. For example, 10 mg dexamethasone reduces laparoscopic inflammation if given before insufflation.

Paracetamol has fewer anti-inflammatory effects and may be the only agent that can be reserved for the end of surgery, as the autonomic system is easily blocked by other non-opioid drugs. Paracetamol does not cause the bleeding, gastric, or renal side effects that limit the use of NSAIDs. Conventional use dictates that the dose of paracetamol in obese patients should be based on ideal body weight. Paracetamol is often supplemented with additional analgesics during the first few days after surgery to achieve optimal pain relief.

Ketamine is an N-methyl-D-aspartate (NMDA) receptor antagonist and has a well-established role in the management of chronic pain [38, 39]. Low-dose ketamine decreases pain without significant sedation or airway-related complications, which is a desired property in obese patients. Ketamine is loaded as a 50-mg bolus before incision and continued at a low rate of 0.05 mg/kg LBW/h.

Lidocaine, which is safe at serum concentrations from 1.5 to 5 mcg/ml, reduces opioid and hypnotic consumption and the duration of postoperative ileus during laparoscopic abdominal surgeries [40, 41]. Lidocaine based on adjusted body weight during bariatric surgery improves postoperative recovery with no reported adverse effects [40]. Carabalona et al. [42] demonstrated that patients receiving an intravenous 1.5 mg/kg lidocaine bolus for 10 minutes after induction (with a maximal dose of 100 mg) followed by a continuous infusion of 2 mg/kg/h did not show concentrations of lidocaine outside the accepted range (1.5–5 mcg/ml). Lidocaine, dexmedetomidine, ketamine, and magnesium have better anti-inflammatory effects than classical opioid anesthesia and are preferable for OFA [43]. Lidocaine is administered as a supplementary IV bolus of 1 mg/kg and continued at 1 mg/kg LBW/h, whereas dexmedetomidine is loaded as a bolus of 0.25 mcg/kg LBW/h and continued at 0.1 mcg/kg LBW/h.

Gabapentinoids (gabapentin and pregabalin) were originally introduced as antiepileptics but have additional analgesic, anticonvulsant, and anxiolytic effects. During the past decade, gabapentinoids emerged as an increasingly used alternative for postoperative acute pain despite the lack of approval by health authorities for this indication. The American Pain Society supports the use of gabapentinoids as a component of multimodal analgesia [44]. A single preoperative oral dose of 150 mg pregabalin promotes effective and safe analgesia with a low incidence of sedation or airway-related side effects and may be useful for reducing morphine consumption after SG. However, Martins et al. [45] demonstrated that a single preoperative oral dose of 75 mg pregabalin did not improve pain relief, quality of postoperative recovery, or reduce opioid consumption after bariatric surgery. There is no recent systematic review or meta-analysis evaluating the efficacy and safety of gabapentinoids in different surgical settings [46].

Satisfaction scores with regional anesthesia are high among morbidly obese patients according to retrospective analysis [47]. Regional anesthetic techniques are highly efficient in reducing opioid requirements and airway- or obstructive sleep apnea (OSA)-related complications. Postoperative epidural analgesia is effective but not required if other methods are used to reduce opioid use. Local wound infiltration with long-acting local anesthetics is simple and effective. Ideally, infiltration should be performed before surgery to reduce local inflammation when analgesia is not yet needed. In case of longer procedures, such as revision surgery, local infiltration with 20 ml 1% lidocaine before incision can be followed by infiltration with 20 ml 1% ropivacaine (max 3 mg/kg) to prolong postoperative analgesia. The second infiltration should be done by laparoscopic view to infiltrate deep into the abdominal muscles without traumatizing abdominal organs. Boerboom et al. demonstrated that 0.5% bupivacaine before incision reduces opioid consumption, postoperative pain, and possibly the incidence rate of chronic post-surgical pain after laparoscopic bariatric surgery [48]. Another promising strategy is erector spinal plane block, which provides adequate visceral abdominal analgesia during bariatric surgery [49].

After sleeve gastrectomy some patients complain of chest pain due to diffuse spasm of the esophagus. Differential diagnosis is required with cardiac ischemic pain. Theophylline use is not practical after sleeve gastrectomy, but a nitroglycerine patch (Nitroderm 10 mg) seems to be effective [50] and can be given prophylactic to all sleeve procedures.

13.3 Less Common Acute Complications After SG

Postoperative bleeding and leak are less common acute complications with potentially dangerous outcomes. These are surgical complications, but the incidence can be reduced if the anesthesiologist and surgeon cooperate.

13.3.1 Postoperative Hemorrhage

Postoperative hemorrhage can occur from any surgical incision, including trocar placement. The long stapler line represents the most frequent source of bleeding, ranging between 0 and 20% [51]. Other possible sources are the omentum, trocar sites, and iatrogenic injury of the liver or spleen. Intraluminal bleeding is uncommon once all staple lines are closed on the exterior of the lumen. If intraluminal bleeding does occur, it is unlikely to be related to the staples but rather to internal mucosal damage. Extraluminal staple-line bleedings are more problematic, as those do not stop spontaneously in contrast to manual sutured lines. The arteries cannot retract when fixed between staples without being occluded. There should be space between each staple to allow perfusion up to the edge, or ischemia and late leaking are risks.

Many surgical studies describe the value of staple reinforcement, over-sewing, and other technical methods to reduce postoperative bleeding. Special attention should be given to patients with type 2 diabetes, because they have increased risk for postoperative hemorrhage [52].

Based on the Mulier & Dillemans protocol of 2009 [53] and recent clinical observations in the literature [54, 55], a standard protocol should be followed and should include routine elevation of systolic blood pressure (SAP) to 140 mmHg at the end of surgery with clipping of bleeding spots. Some consider reinforcement and over-suturing of the staple line [54, 55]. Increased blood pressure can be achieved with a bolus dose of 2.5–10 mg ephedrine or 0.1–0.4 mg phenylephrine depending on heart rate. In addition, decreasing pneumoperitoneal pressure to 10 mmHg is recommended to identify possible silent bleeding during surgery. Bleeding may be caused by hypotension (SAP below 100 mmHg) and high pneumoperitoneal pressure in obese patients. The protocol takes about 5 minutes, which does not significantly increase the mean operative time [54].

13.3.2 Postoperative Leak

Postoperative leak is currently considered the most dangerous complication after SG, with reported rates ranging between 0 and 8% [51, 56, 57]. Postoperative leak is the second cause of death after bariatric surgery with an overall mortality rate ranging from 0 to 1.4% [58]. The localization of the leak is at the proximal third of the staple line in 89.9% of patients [56]. Patients with BMI > 50 kg/m^2 and boogie size <40-Fr during the procedure are at high risk of postoperative leak [59]. Mechanical and ischemic factors are believed to contribute to the development of leaks [60, 61].

Mechanical factors are linked to the intrinsic characteristics of the long staple line during SG and thickness of the gastric wall. The correct choice of cartridge for stapling is important, as stomach thickness varies by location, with the antrum being the thickest (2.70 mm), and the fundus having an average of 1.97 mm. Both super-obesity and male gender are associated with increased tissue thickness but only in the antrum [62].

In addition, postoperative leaking might be induced during vomiting as previously explained. Rached et al. found that the most frequent site of leakage after SG is the last staple close to the esophagus [63]. Furthermore, the ischemic aspects are related to the most common location of leakage, which is the esophagogastric junction. Gastric wall perfusion is significantly decreased at the angle of His and the gastric fundus, as opposed to other gastric areas. This is particularly evident for obese patients in contrast to non-obese patients. Yehoshua et al. [64] showed that the mean intra-sleeve pressure filled with saline was 43 mmHg (range: 32–58 mmHg) in SG performed on a 50-Fr bougie and reinforced with absorbable running suture. Additional small fluid volumes (150 cm^3) significantly elevate intraluminal pressure (58 mmHg before fluid refluxed into the esophagus). Thus, as patients swallow saliva, the gastric mucosa secretes mucus, and the volume/burst/leak pressure ratio of the gastric sleeve staple line may become clinically significant, necessitating a liquid diet during the first 2 weeks.

In an effort to detect and correct any staple-line deficiencies, many surgeons elect to test the newly constructed sleeve with an intraoperative leak test, which is typically performed by anesthesiologists with injection of air or methylene blue. This test is not without its own risk. There is a theoretical concern that stress caused by the leak test on the newly formed staple line may weaken the perioperative staple line, contributing to a postoperative staple-line leak [65]. The international SG expert panel failed to reach a consensus (48% consensus) about whether routine intraoperative leak tests should be performed [66] compared with gastric bypass surgery, where an intraoperative leak test with a rapidly injected large volume

(150 ml) might be useful [53]. Different authors reported that intraoperative leak testing is not correlated with leaking due to SG and is not predictive of later development of a staple-line leak [67, 68].

13.4 The Most Common Chronic Complications After SG

The most common chronic complications after SG are abbess, stricture, and chronic postoperative pain syndrome. Nutrient deficiency is less frequent after SG compared with gastric bypass, whereas GERD is more problematic and requires long-term therapy. Nutrient deficiency is less of an issue for anesthesia and is not discussed here.

13.4.1 Surgical Site Infections and Abscesses

Obesity is known to increase infectious morbidity and mortality and is an independent risk factor for surgical site infections (SSIs) [69]. SSIs and abscesses can be prevented by adhering to basic principles of sterility and using prophylactic antibiotics. Sterile manipulation of the gastric bougies is not possible, as gastric content is not sterile. Fasting before surgery is important to empty the stomach of all food remnants. Cases in which stapling through residual food increases subsequent risk for leaks or infections have occurred.

Cefazolin, a first-generation cephalosporin, was one of the first antimicrobial prophylactic agents effective during bariatric procedures [70]. Cefazolin is the most commonly used agent because of its broad spectrum, safety, and experience of use [71, 72]. Cefazolin should be given by the anesthesiologist before incision. The usual dosing strategy (2000 mg administered before surgery) may fail to provide adequate perioperative prophylaxis in different bariatric surgeries. The American Society of Health-System Pharmacists, the Infectious Diseases Society of America, the Surgical Infections Society, and the Society for Healthcare Epidemiology of America currently recommend 2000 mg cefazolin before surgery followed by a second dose 4 hours later for patients weighing more than 80 kg, or 3000 mg before surgery followed by a second dose 4 hours after the first for patients weighing more than 120 kg. The French Society of Anesthesia and Reanimation (SFAR) recommends 4000 mg cefazolin before surgery followed by a second dose of 2000 mg 4 hours after the first [71]. On the basis of duration of surgery and minimum inhibitory concentrations, Grégoire et al. showed that an initial administration of 4000 mg should be sufficient; however, for extended surgeries longer than 4 hours, continuous infusion of 1000 mg/h may be considered [73].

Despite recommendations to use cefazolin, other drugs and regimens are also employed. In a large observational study, 37 different antibiotic regimens were found to prevent SSIs in bariatric surgery [74], indicating that other options are widely used, although cefazolin is the most highly recommended drug.

13.4.2 Stricture

Acute postoperative stricture is due to tissue edema combined with tight stapling close to the gastric tube. Delayed stricture might be due to kinking if an uneven part of the anterior and posterior walls are removed, or staples are not following in line. The most common site of stenosis is the incisura angularis [75], where the staples should stay away from the guiding boogie tube, even when a size larger than 40 French is used. These patients present with food intolerance, dysphagia, or vomiting. The role of the anesthesiologist is to position the bougie correctly and help the surgeon to accurately place the staples. Depending on the required weight reduction, some bariatric surgeons try to be brave and make the smallest sleeve possible by stapling as close as possible to the tube. When following Dilleman's approach of sleeving and maintaining a safe distance from the tube at the incisura angularis, no obstruction or leak is possible. The tube is positioned through the pylorus during the first staple, redrawn to reduce angulation, and laid straight to the first staple when stapling the second one. Each time the staple is closed, the bougie is moved slightly up and down to ensure that the sleeve is not too tight and waiting 15 seconds for compression before firing. Stapling close to the bougie might stress the tissue and create tears and leaking.

13.4.3 Chronic Pain Syndromes

The development of chronic pain after surgery, also called persistent postoperative pain, is recognized as a significant health problem affecting postoperative outcome, rehabilitation, and quality of life with important legal and medico-economic consequences. Chronic abdominal pain and discomfort have not been adequately studied. Persistent postoperative pain is defined by the International Association for the Study of Pain as clinical discomfort lasting more than 2 months after surgery without other causes of pain, such as chronic infection or previously diagnosed chronic conditions. The International Classification of Diseases defines duration for persistent postoperative pain as 3 months after surgery, because healing times from different procedures vary. Hogestol et al. reported an incidence of 33.8% for chronic abdominal pain after gastric bypass in morbid obese patients [76]. Pathologic features that contribute to unexplained abdominal pain after bariatric surgery can be divided into surgical, nonsurgical, and psychological or behavioral factors. Chronic pain syndromes occur more often after laparotomy than laparoscopy and are frequently related to hyperalgesia, which is defined as increased pain sensitivity outside the area of injury.

Although controversial, multiple clinical trials demonstrate that opioid-induced hyperalgesia is common after surgery [77, 78]. Opioid administration during surgery may activate NMDA receptors and/or glial cells, resulting in higher acute postoperative hyperalgesia. An increased understanding of opioid-induced hyperalgesia will improve postoperative management and reduce the risk of chronic postoperative pain.

Therefore, the anesthesiologist plays an import role in avoiding or decreasing opioid use during general anesthesia and management of postoperative pain. Pharmacological prevention of persistent postoperative pain can be achieved with anti-inflammatory drugs, such as cyclooxygenase inhibitors [79] and corticosteroids [80, 81]; regional anesthesia [82, 83]; continuous wound infiltration [83]; intravenous lidocaine [84]; NMDA receptor antagonists [85] (ketamine); anticonvulsants, such as pregabalin [86]; alpha-2 agonists, such as clonidine [87]; and dexmedetomidine [88].

13.5 Conclusion

Anesthesiologists can impact outcomes after laparoscopic SG by adapting perioperative anesthesia management.

References

1. Piche ME, et al. Overview of epidemiology and contribution of obesity and body fat distribution to cardiovascular disease: an update. Prog Cardiovasc Dis. 2018;61(2):103–13.
2. Ng M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2014;384(9945):766–81.
3. About obesity. World Obesity Federation, 2017. 2017 [cited 2018 Sep 23th, 2018]; Available from: http://www.worldobesity.org/what-we-do/aboutobesity/.
4. Tremmel M, et al. Economic burden of obesity: a systematic literature review. Int J Environ Res Public Health. 2017;14(4):435–453.
5. Smith BR, Schauer P, Nguyen NT. Surgical approaches to the treatment of obesity: bariatric surgery. Endocrinol Metab Clin North Am. 2008;37(4):943–64.
6. Thorell A, et al. Guidelines for perioperative care in bariatric surgery: Enhanced Recovery After Surgery (ERAS) Society recommendations. World J Surg. 2016;40(9):2065–83.
7. Ahmed OS, et al. Meta-analysis of enhanced recovery protocols in bariatric surgery. J Gastrointest Surg. 2018;22(6):964–72.
8. Malczak P, et al. Enhanced recovery after bariatric surgery: systematic review and meta-analysis. Obes Surg. 2017;27(1):226–35.
9. Wang W, Yang C, Wang B. Meta-analysis on safety of application of enhanced recovery after surgery to laparoscopic bariatric surgery. Zhonghua Wei Chang Wai Ke Za Zhi. 2018;21(10):1167–74.
10. Inaba CS, et al. How safe is same-day discharge after laparoscopic sleeve gastrectomy? Surg Obes Relat Dis. 2018;14(10):1448–53.
11. Badaoui R, et al. Outpatient laparoscopic sleeve gastrectomy: first 100 cases. J Clin Anesth. 2016;34:85–90.
12. Lalezari S, et al. Laparoscopic sleeve gastrectomy as a viable option for an ambulatory surgical procedure: our 52-month experience. Surg Obes Relat Dis. 2018;14(6):748–50.
13. Surve A, et al. Does the future of laparoscopic sleeve gastrectomy lie in the outpatient surgery center? A retrospective study of the safety of 3162 outpatient sleeve gastrectomies. Surg Obes Relat Dis. 2018;14(10):1442–7.
14. Halliday TA, et al. Post-operative nausea and vomiting in bariatric surgery patients: an observational study. Acta Anaesthesiol Scand. 2017;61(5):471–9.

15. Chen J, et al. Preventing returns to the emergency department followingbariatric surgery. Obes Surg. 2017;27(8):1986–92.
16. Decker GA, et al. Gastrointestinal and nutritional complications after bariatric surgery. Am J Gastroenterol. 2007;102(11):2571–80; quiz 2581.
17. Macht R, et al. Factors associated with bariatric postoperative emergency department visits. Surg Obes Relat Dis. 2016;12(10):1826–31.
18. Iqbal A, et al. A study of intragastric and intravesicular pressure changes during rest, coughing, weight lifting, retching, and vomiting. Surg Endosc. 2008;22(12):2571–5.
19. Aydin MT, Aras O, Karip B, Memisoglu K. Staple line reinforcement methods in laparoscopic sleeve gastrectomy: comparison of burst pressures and leaks. JSLS. 2015;19(3).
20. Rogula T, et al. Comparison of reinforcement techniques using suture on staple-line in sleeve gastrectomy. Obes Surg. 2015;25(11):2219–24.
21. Horn CC, et al. Pathophysiological and neurochemical mechanisms of postoperative nausea and vomiting. Eur J Pharmacol. 2014;722:55–66.
22. Sherif L, Hegde R, Mariswami M, Ollapally A. Validation of the Apfel scoring system for identification of High-risk patients for PONV. Karnataka Anaesth J. 2015;1:3.
23. Roberts GW, et al. Postoperative nausea and vomiting are strongly influenced by postoperative opioid use in a dose-related manner. Anesth Analg. 2005;101(5):1343–8.
24. Gan TJ, et al. Consensus guidelines for the management of postoperative nausea and vomiting. Anesth Analg. 2014;118(1):85–113.
25. Bataille A, et al. Impact of a prophylactic combination of dexamethasone-ondansetron on postoperative nausea and vomiting in obese adult patients undergoing laparoscopic sleeve gastrectomy during closed-loop propofol-remifentanil anaesthesia: a randomised double-blind placebo-controlled study. Eur J Anaesthesiol. 2016;33(12):898–905.
26. Kovac AL, et al. Efficacy of repeat intravenous dosing of ondansetron in controlling postoperative nausea and vomiting: a randomized, double-blind, placebo-controlled multicenter trial. J Clin Anesth. 1999;11(6):453–9.
27. Ziemann-Gimmel P, et al. Opioid-free total intravenous anaesthesia reduces postoperative nausea and vomiting in bariatric surgery beyond triple prophylaxis. Br J Anaesth. 2014;112(5):906–11.
28. Brown EN, Pavone KJ, Naranjo M. Multimodal general anesthesia: theory and practice. Anesth Analg. 2018;127(5):1246–58.
29. Inan A, Sen M, Dener C. Local anesthesia use for laparoscopic cholecystectomy. World J Surg. 2004;28(8):741–4.
30. Tsai HW, et al. Maneuvers to decrease laparoscopy-induced shoulder and upper abdominal pain: a randomized controlled study. Arch Surg. 2011;146(12):1360–6.
31. Joris J, et al. Pain after laparoscopic cholecystectomy: characteristics and effect of intraperitoneal bupivacaine. Anesth Analg. 1995;81(2):379–84.
32. Mouton WG, et al. Pain after laparoscopy. Surg Endosc. 1999;13(5):445–8.
33. Ahmad S, et al. Postoperative hypoxemia in morbidly obese patients with and without obstructive sleep apnea undergoing laparoscopic bariatric surgery. Anesth Analg. 2008; 107(1):138–43.
34. Falcão LFR, Cardoso Filho FA, Silva BD. Anestesia livre de opioides. In: Bagatini A, Nunes RR, LTD D, editors. PROANESTESIA Programa de Atualização em Anestesiologia. Porto Alegre: Artmed Panamericana; 2018. p. 141–72.
35. Mulier J. Opioid free general anesthesia: a paradigm shift? Rev Esp Anestesiol Reanim. 2017;64(8):427–30.
36. Alvarez A, Goudra BG, Singh PM. Enhanced recovery after bariatric surgery. Curr Opin Anaesthesiol. 2017;30(1):133–9.
37. Alvarez A, Singh PM, Sinha AC. Postoperative analgesia in morbid obesity. Obes Surg. 2014;24(4):652–9.
38. Kurdi MS, Theerth KA, Deva RS. Ketamine: current applications in anesthesia, pain, and critical care. Anesth Essays Res. 2014;8(3):283–90.

39. Niesters M, Martini C, Dahan A. Ketamine for chronic pain: risks and benefits. Br J Clin Pharmacol. 2014;77(2):357–67.
40. De Oliveira GS Jr, et al. Systemic lidocaine to improve quality of recovery after laparoscopic bariatric surgery: a randomized double-blinded placebo-controlled trial. Obes Surg. 2014;24(2):212–8.
41. Vigneault L, et al. Perioperative intravenous lidocaine infusion for postoperative pain control: a meta-analysis of randomized controlled trials. Can J Anaesth. 2011;58(1):22–37.
42. Carabalona JF, et al. Serum concentrations of lidocaine during bariatric surgery. Anesth Analg. 2020;130(1):e5–e8. https://doi.org/10.1213/ANE.0000000000003905. [Epub ahead of print].
43. Mulier JP, Dillemans B. A prospective randomized controlled trial comparing a multitarget opioid free anaesthesia (OFA) and a 3-liter volume calculated airseal carbon dioxide insufflator with a balanced anaesthesia using sufentanil-sevoflurane and a standard 15 mmhg carbon dioxide pressure pneumoperitoneum insufflator in a 2x2 factorial design. J Clin Anesth Pain Med. 2018;2(2):6.
44. Chou R, et al. Management of Postoperative Pain: A Clinical Practice Guideline From the American Pain Society, the American Society of Regional Anesthesia and Pain Medicine, and the American Society of Anesthesiologists' Committee on Regional Anesthesia, Executive Committee, and Administrative Council. J Pain. 2016;17(2):131–57.
45. Martins MJ, et al. Pregabalin to improve postoperative recovery in bariatric surgery: a parallel, randomized, double-blinded, placebo-controlled study. J Pain Res. 2018;11:2407–15.
46. Verret M, et al. Perioperative use of gabapentinoids for the management of postoperative acute pain: protocol of a systematic review and meta-analysis. Syst Rev. 2019;8(1):24.
47. Davies KE, Houghton K, Montgomery JE. Obesity and day-case surgery. Anaesthesia. 2001;56(11):1112–5.
48. Boerboom SL, et al. Preperitoneal bupivacaine infiltration reduces postoperative opioid consumption, acute pain, and chronic postsurgical pain after bariatric surgery: a randomized controlled trial. Obes Surg. 2018;28(10):3102–10. https://doi.org/10.1007/s11695-018-3341-6.
49. Chin KJ, Malhas L, Perlas A. The erector spinae plane block provides visceral abdominal analgesia in bariatric surgery: a report of 3 cases. Reg Anesth Pain Med. 2017;42(3):372–6.
50. Konturek JW, Gillessen A, Domschke W. Diffuse esophageal spasm: a malfunction that involves nitric oxide? Scan J Gastroenterol. 1995;30:1041–5.
51. Gagner M, et al. Survey on laparoscopic sleeve gastrectomy (LSG) at the Fourth International Consensus Summit on Sleeve Gastrectomy. Obes Surg. 2013;23(12):2013–7.
52. Spivak H, et al. Sleeve gastrectomy postoperative hemorrhage is linked to type-2 diabetes and not to surgical technique. Obes Surg. 2017;27(11):2927–32.
53. Mulier JP, Dillemans B. Anesthetic factors affecting outcome after bariatric surgery, a retrospective leveled regression analysis. Obes Surg. 2019;29(6):1841.
54. De Angelis F, et al. Perioperative hemorrhagic complications after laparoscopic sleeve gastrectomy: four-year experience of a bariatric center of excellence. Surg Endosc. 2017;31(9):3547–51.
55. Sroka G, et al. Minimizing hemorrhagic complications in laparoscopic sleeve gastrectomy – a randomized controlled trial. Obes Surg. 2015;25(9):1577–83.
56. Berger ER, et al. The impact of different surgical techniques on outcomes in laparoscopic sleeve gastrectomies: the first report from the Metabolic and Bariatric Surgery Accreditation and Quality Improvement Program (MBSAQIP). Ann Surg. 2016;264(3):464–73.
57. Gagner M, Buchwald JN. Comparison of laparoscopic sleeve gastrectomy leak rates in four staple-line reinforcement options: a systematic review. Surg Obes Relat Dis. 2014;10(4):713–23.
58. Jurowich C, et al. Gastric leakage after sleeve gastrectomy-clinical presentation and therapeutic options. Langenbecks Arch Surg. 2011;396(7):981–7.
59. Aurora AR, Khaitan L, Saber AA. Sleeve gastrectomy and the risk of leak: a systematic analysis of 4,888 patients. Surg Endosc. 2012;26(6):1509–15.
60. Baker RS, et al. The science of stapling and leaks. Obes Surg. 2004;14(10):1290–8.

61. Iossa A, et al. Leaks after laparoscopic sleeve gastrectomy: overview of pathogenesis and risk factors. Langenbecks Arch Surg. 2016;401(6):757–66.
62. Rawlins L, Rawlins MP, Teel D 2nd. Human tissue thickness measurements from excised sleeve gastrectomy specimens. Surg Endosc. 2014;28(3):811–4.
63. Abou Rached A, Basile M, El Masri H. Gastric leaks post sleeve gastrectomy: review of its prevention and management. World J Gastroenterol. 2014;20(38):13904–10.
64. Yehoshua RT, et al. Laparoscopic sleeve gastrectomy--volume and pressure assessment. Obes Surg. 2008;18(9):1083–8.
65. Causey MW, Fitzpatrick E, Carter P. Pressure tolerance of newly constructed staple lines in sleeve gastrectomy and duodenal switch. Am J Surg. 2013;205(5):571–4; discussion 574–5.
66. Rosenthal RJ, et al. International Sleeve Gastrectomy Expert Panel Consensus Statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8(1):8–19.
67. Bingham J, et al. Routine intraoperative leak testing for sleeve gastrectomy: is the leak test full of hot air? Am J Surg. 2016;211(5):943–7.
68. Sethi M, et al. Intraoperative leak testing has no correlation with leak after laparoscopic sleeve gastrectomy. Surg Endosc. 2016;30(3):883–91.
69. Falagas ME, Kompoti M. Obesity and infection. Lancet Infect Dis. 2006;6(7):438–46.
70. Pories WJ, et al. Prophylactic cefazolin in gastric bypass surgery. Surgery. 1981;90(2):426–32.
71. Bratzler DW, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Am J Health Syst Pharm. 2013;70(3):195–283.
72. Mangram AJ, et al. Guideline for Prevention of Surgical Site Infection, 1999. Centers for Disease Control and Prevention (CDC) Hospital Infection Control Practices Advisory Committee. Am J Infect Control. 1999;27(2):97–132; quiz 133–4; discussion 96.
73. Gregoire M, et al. Prophylactic cefazolin concentrations in morbidly obese patients undergoing sleeve gastrectomy: do we achieve targets? Int J Antimicrob Agents. 2018;52(1):28–34.
74. Freeman JT, et al. Surgical site infections following bariatric surgery in community hospitals: a weighty concern? Obes Surg. 2011;21(7):836–40.
75. Parikh A, et al. Management options for symptomatic stenosis after laparoscopic vertical sleeve gastrectomy in the morbidly obese. Surg Endosc. 2012;26(3):738–46.
76. Hogestol IK, et al. Chronic abdominal pain and symptoms 5 years after gastric bypass for morbid obesity. Obes Surg. 2017;27(6):1438–45.
77. Angst MS, Clark JD. Opioid-induced hyperalgesia: a qualitative systematic review. Anesthesiology. 2006;104(3):570–87.
78. Fletcher D, Martinez V. Opioid-induced hyperalgesia in patients after surgery: a systematic review and a meta-analysis. Br J Anaesth. 2014;112(6):991–1004.
79. Botting RM. Inhibitors of cyclooxygenases: mechanisms, selectivity and uses. J Physiol Pharmacol. 2006;57(Suppl 5):113–24.
80. De Oliveira GS Jr, et al. Perioperative single dose systemic dexamethasone for postoperative pain: a meta-analysis of randomized controlled trials. Anesthesiology. 2011;115(3):575–88.
81. Waldron NH, et al. Impact of perioperative dexamethasone on postoperative analgesia and side-effects: systematic review and meta-analysis. Br J Anaesth. 2013;110(2):191–200.
82. Andreae MH, Andreae DA. Regional anaesthesia to prevent chronic pain after surgery: a Cochrane systematic review and meta-analysis. Br J Anaesth. 2013;111(5):711–20.
83. Capdevila X, et al. Effectiveness of epidural analgesia, continuous surgical site analgesia, and patient-controlled analgesic morphine for postoperative pain management and hyperalgesia, rehabilitation, and health-related quality of life after open nephrectomy: a prospective, randomized. Controlled Study. Anesth Analg. 2017;124(1):336–45.
84. Tabone LE. Comment on perioperative analgesic profile of dexmedetomidine infusions in morbidly obese undergoing bariatric surgery: a meta-analysis and trial sequential analysis. Surg Obes Relat Dis. 2017;13(8):1447–8.
85. Laskowski K, et al. A systematic review of intravenous ketamine for postoperative analgesia. Can J Anaesth. 2011;58(10):911–23.

86. Clarke H, et al. The prevention of chronic postsurgical pain using gabapentin and pregabalin: a combined systematic review and meta-analysis. Anesth Analg. 2012;115(2):428–42.
87. Blaudszun G, et al. Effect of perioperative systemic alpha2 agonists on postoperative morphine consumption and pain intensity: systematic review and meta-analysis of randomized controlled trials. Anesthesiology. 2012;116(6):1312–22.
88. Singh PM, et al. Perioperative analgesic profile of dexmedetomidine infusions in morbidly obese undergoing bariatric surgery: a meta-analysis and trial sequential analysis. Surg Obes Relat Dis. 2017;13(8):1434–46.

Part III
Sleeve Gastrectomy GERD and Hiatal Hernia

Chapter 14
Pathophysiology of Gastroesophageal Reflux Disease in Obese Patients

Marco G. Patti, Francisco Schlottmann, and Timothy M. Farrell

14.1 Introduction

Gastroesophageal reflux disease (GERD) is a multifactorial disease with a prevalence of 15–20% in the Western adult population [1]. Obesity has also become an epidemic in this century, affecting one-third of the world population [2].

GERD is undoubtedly a disease directly related to obesity. Overweight doubles the chance of GERD, and the prevalence of GERD symptoms in patients with morbid obesity reaches 50% [3]. Moreover, the prevalence of GERD is proportional to the severity of obesity: GERD affects 23% of individuals with body mass index (BMI) less than 25 kg/m^2, 27% when the BMI is between 25 and 30 kg/m^2, and 50% if the BMI is greater than 30 kg/m^2 [4].

It is not only the frequency of GERD symptoms in the obese population that is of concern, but also the severity of the disease, with a higher incidence of erosive esophagitis and Barrett's esophagus (BE). A direct correlation between erosive esophagitis degree and BMI has been reported by different studies as summarized by a recent meta-analysis [5]. The association of BE and obesity was well demonstrated by Stein et al., who showed that for every 5 units of increase in BMI the

M. G. Patti (✉)
Department of Medicine, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Department of Surgery, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA
e-mail: marco_patti@med.unc.edu

F. Schlottmann
Department of Surgery, Hospital Aleman, Buenos Aires, Argentina

T. M. Farrell
Department of Surgery, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_14

incidence of BE increases 35% [6]. The risk of developing BE is higher when visceral obesity is present, as compared to peripheral obesity [7]. Obesity also increases the risk of esophageal and cardia cancer [8]. The chance of developing esophageal carcinoma is, in fact, four times higher in overweight patients as compared to individuals with normal BMI [9].

It is necessary to understand the pathophysiology of GERD in obese individuals to adequately treat both GERD and obesity.

14.2 Pathophysiology

14.2.1 Defective Gastroesophageal Barrier

While a defective lower esophageal sphincter (LES) is the most common cause of GERD in the general population, it is not always observed in the obese. Some studies found similar LES basal pressures when lean and obese individuals with GERD were compared [10]. Moreover, other studies showed an increased basal pressure in the obese, probably linked to compensatory mechanisms due to the increased intra-abdominal pressure [11, 12]. Transient LES relaxations (TLESR), however, seem to be more frequent in the obese, and this might explain GERD in the setting of a normal LES basal pressure. The number of episodes of TLESR is higher in the obese [13, 14], and there is a correlation between the number of TLESR with BMI and abdominal circumference [15, 16].

The angle of His is an important antireflux mechanism. The more acute this angle, the more the gastric fundus will be projected toward the esophagus as gastric distension occurs during a meal. The deposition of fat in the gastroesophageal junction, common and excessive in obese individuals, can make this angle obtuse [17].

Hiatal hernia (HH) is more frequent in the obese [18]. Obese women are two and a half times more likely to have HH than non-obese women [19]. Pandolfino et al. using high-resolution manometry showed progressive disruption of the esophago-gastric junction anatomy with obesity [20].

14.2.2 Defective Esophageal Clearance

Esophageal clearance is affected by production of saliva, gravity, and esophageal peristalsis. Obese patients have decreased salivation [21], and esophageal peristalsis may be impaired in as much as a quarter of obese individuals [18, 22]. Data regarding the gastric emptying time in obese individuals are conflicting, as it has been found to be both normal and delayed [23–25].

14.2.3 Trans-diaphragmatic Pressure Gradient

Abdominal pressure is increased in obese individuals due to deposition of abdominal fat and its effect on gastric pressure. For each point of increase in BMI there is a 10% increase in intragastric pressure [26].

Obese patients may also have a more negative intrathoracic pressure due to a diaphragm elevation secondary to abdominal fat and a consequent decrease in pulmonary expansion. Negative intrathoracic pressure may also be increased by the frequent occurrence of obstructive apnea. Apnea itself may be a cause for GERD due to increase of TLESR [27].

14.2.4 Altered Hormonal Profile

Abdominal fat accumulation decreases adiponectin (anti-inflammatory cytokine) and causes an increase in inflammatory agents such as leptin. These altered cytokines may contribute to the higher incidence of erosive esophagitis and Barrett's esophagus in the obese population compared to non-obese individuals [28]. Increased secretion of estrogens by adipose tissue contributes to the increase of reflux symptoms in obese women. Women of reproductive age and those who are in menopause but receiving estrogen therapy have a higher incidence of GERD than menopausal women without hormone replacement [3].

14.2.5 Diet

Consumption of high-fat diet (more common in obese individuals) increases the occurrence of GERD symptoms as compared to a high-fiber diet, regardless of caloric intake, due to decrease in gastric emptying, decrease in LES pressure, and increase in the number of TLESR [29].

Some foods such as eggs, chocolate, soft drinks, and fat, consumed more frequently by obese individual, can induce reflux.

14.2.6 Visceral Sensitivity

There are several putative factors for an increased visceral sensitivity in the obese. First, overweight leads to a permanent inflammatory state releasing inflammatory molecules that decrease the perception threshold to refluxate stimuli [30]. Chronic stress to which the obese are exposed by physical limitation or psychological aggression favors the occurrence of GERD symptoms by increasing visceral sensitivity [31]. Sleep deprivation, which occurs more frequently in the obese population due to sleep apnea, also may induce a chronic state of stress [32, 33].

14.3 Treatment of GERD in Obese Subjects

14.3.1 Clinical Treatment

Treatment of obese patients with GERD may be aimed towards GERD, obesity, or both.

Weight loss may alleviate symptoms due to a decrease in intra-abdominal pressure, and perhaps a change in hormonal status. It has been shown that a decrease of 3.5 kg/m^2 in BMI reduces the risk of GER symptoms by 40% [8]. Many studies using pH-monitoring have shown a decrease in acid exposure of the esophagus after weight loss [34, 35]. Weight loss has a positive impact on GERD symptoms by reducing intra-abdominal pressure [36–38]. The loss of 14 kg reduces the incidence of GERD from 37 to 15%, and 75% of the population evaluated showed improvement in DeMeester score [39].

It is not clear if obese people respond differently from the lean ones regarding the use of proton pump inhibitors (PPI) [40]. There is no evidence that obese subjects should be treated differently, such as with increased dosage from lean individuals with GERD [41].

14.3.2 Surgical Treatment

Antireflux surgery in the obese is highly controversial [26]. GERD pathophysiology is, in fact, different in obese and lean individuals. A fundoplication acts at the level of the gastroesophageal barrier only, which is not the only factor causing GERD in the obese. Furthermore, a fundoplication may be technically more demanding in the overweight, and the raised intra-abdominal pressure is a challenge to the long-term integrity of the fundoplication and the hiatoplasty. The procedure is, however, feasible in the obese. A meta-analysis analyzing 3772 obese patients who underwent a fundoplication did not find any significant difference in the conversion rate, reoperation due to recurrence or migration of the fundoplication among the obese group compared to procedures performed in lean patients [42]. There was a significant difference, however, in the operative and hospitalization time, which was higher in the obese group. The authors concluded that anti-reflux surgery in obese patients is safe and the results are comparable to those of patients with normal BMI.

14.3.3 Gastroesophageal Reflux Disease and Bariatric Procedures

The Roux-en-Y gastric bypass (RYGB) is the ideal operation for morbidly obese patients with GERD because of its antireflux properties. Acid production is highly reduced as the small proximal pouch has very few parietal cells, while a long Roux limb prevents the reflux of bile. On the other hand, there is today a growing concern that the sleeve gastrectomy (SG) may worsen GERD if present pre-operatively, or might lead to the development of *de novo* GERD [43]. In a large study from Italy with a 5-year follow-up, the mean BMI decreased from 46 to 29 kg/m^2, but postoperatively erosive esophagitis (Los Angeles [LA] grades C and D) developed in 21% of patients, and Barrett's metaplasia in 17%. Interestingly, GERD symptoms were experienced only by 33% of patients with LA grade C esophagitis, and by 57% of patients with LA grade D esophagitis [44]. Others have shown different results. For instance, in a prospective study, Rebecchi et al. showed that the SG improved reflux symptoms in most morbidly obese patients with pre-operative GERD, while *de novo* reflux was uncommon [45]. The validity of their conclusions is, however, tempered by the loss to follow-up of about 40% of patients and by the short follow-up of only two years. Furthermore, the authors arbitrarily excluded some patients with abnormal pH monitoring as they stated that it was caused by retention of food in the proximal portion of the sleeve. These patients were not considered as having pathologic reflux.

Most experts feel that the high incidence of pathologic reflux and esophagitis after SG is probably caused by the development of a hypotensive LES secondary to (1) alteration of the angle of His and damage of the sling fibers, (2) decreased gastric compliance, (3) increased intragastric pressure secondary to creation of a narrow gastric tube, and (4) the herniation of part of the gastric sleeve into the posterior mediastinum.

On the basis of the above considerations, we feel that the choice of the bariatric operation should not be left to the surgeon's preference, but rather it should be based on a thorough preoperative work-up. Because many studies have shown that the symptomatic evaluation has limited value for the diagnosis of GERD, as symptoms such as heartburn have low sensitivity and specificity [43], endoscopy should always be performed, and if erosive esophagitis is present, a RYGB should be chosen. In the absence of esophagitis on endoscopy, esophageal manometry followed by pH monitoring should be performed. If pathologic reflux is present, a RYGB should be chosen.

Finally, surgeons must be aware that a large number of patients will develop pathologic GERD after SG. In patients in whom symptoms are due to reflux (confirmed by endoscopy or pH monitoring), medical treatment should be initiated. If symptoms do not resolve, or esophagitis does not heal, conversion to a RYGB should be entertained regardless of the weight loss.

14.4 Conclusions

The pathophysiology of GERD is different in lean and obese individuals. Visceral adipose tissue secretes hormones, which increase the risk of GERD. Obesity increases esophageal motor disorders and the number of TLESR. Central obesity increases the trans-diaphragmatic pressure gradient, disrupts the integrity of the gastroesophageal junction, and induces HH formation. Treatment must be tailored to the individual patients based on their pre-operative work-up.

Conflict of Interest The authors have no conflict of interest.

References

1. El-Serag HB, Sweet S, Winchester CC, et al. Update on the epidemiology of gastro-oesophageal reflux disease: a systematic review. Gut. 2014;63:871–80.
2. Zvenyach T, Pickering MK. Health care quality: measuring obesity in performance frameworks. Obesity. 2017;25:1305–12.
3. Chang P, Friedenberg F. Obesity and GERD. Gastroenterol Clin N Am. 2014;43:161–73.
4. Jacobson BC, Somers SC, Fuchs CS, Kelly CP, Camargo CA Jr. Body-mass index and symptoms of gastroesophageal reflux in women. N Engl J Med. 2006;354:2340–8.
5. Hampel H, Abraham NS, El-Serag HB. Meta-analysis: obesity and the risk for gastroesophageal reflux disease and its complications. Ann Intern Med. 2005;143:199–211.
6. Stein DJ, El-Serag HB, Kuczynski J, et al. The association of body mass index with Barrett's oesophagus. Aliment Pharmacol Ther. 2005;22:1005–10.
7. Corley DA, Kubo A, Levin TR. Abdominal obesity and body mass index as risk factors for Barrett's esophagus. Gastroenterology. 2007;133:34–41.
8. Pohl H, Wrobel K, Bojarski C, et al. Risk factors in the development of esophageal adenocarcinoma. Am J Gastroenterol. 2013;108:200–7.
9. Hoyo C, Cook MB, Kamangar F, et al. Body mass index in relation to oesophageal and oesophagogastric junction adenocarcinomas: a pooled analysis from the International BEACON Consortium. Int J Epidemiol. 2012;41:1706–18.
10. Quiroga E, Cuenca-Abente F, Flum D. Impaired esophageal function in morbidly obese patients with gastroesophageal reflux disease: evaluation with multichannel intraluminal impedance. Surg Endosc. 2006;20:739–43.
11. Herbella FA, Sweet MP, Tedesco P, Nipomnick I, Patti MG. Gastroesophageal reflux disease and obesity. Pathophysiology and implications for treatment. J Gastrointest Surg. 2007;11:286–90.
12. Valezi AC, Herbella FA, Junior JM, de Almeida Menezes M. Esophageal motility after laparoscopic Roux-en-Y gastric bypass: the manometry should be preoperative examination routine? Obes Surg. 2012;22:1050–4.
13. Wu JC, Mui LM, Cheung CM, Chan Y, Sung JJ. Obesity is associated with increased transient lower esophageal sphincter relaxation. Gastroenterology. 2007;132:883–9.
14. Schneider JH, Keuper M, Keonigsrainer A, Breucher B. Transient lower esophageal sphincter relaxation in morbid obesity. Obes Surg. 2009;19:595–600.
15. Lee YY, McColl KEL. Pathophysiology of gastroesophageal reflux disease. Best Pract Res Clin Gastroenterol. 2013;27:339–51.
16. Richter JE, Rubenstein JH. Gstroesophageal reflux disease – presentation and epidemiology of gastroesophageal reflux disease. Gastroenterology. 2018;154:267–76.

17. Valezi AC, Herbella FA, Mali J Jr. Gastroesophageal reflux disease: pathophysiology. In: Fisichella PM, Allaix ME, Morino M, Patti MG, editors. Esophageal diseases. Evaluation and treatment. New York: Springer; 2014. p. 41–51.
18. Suter M, Dorta G, Giusti V, et al. Gastro-esophageal reflux and esophageal motility disorders in morbidly obese patients. Obes Surg. 2004;14:959–66.
19. Herbella FA, Patti MG. Gastroesophageal reflux disease: from pathophysiology to treatment. World J Gastroenterol. 2010;16:3745–9.
20. Pandolfino JE, El-Serag HB, Zhang Q, Shah N, Ghosh SK, Kahrilas PJ. Obesity: a challenge to esophagogastric junction integrity. Gastroenterology. 2006;130:639–49.
21. Cote-Daigneault J, Leclerc P, Joubert J, Bouin M. High prevalence of esophageal dysmotility in asymptomatic obese patients. Can J Gastroenterol Hepatol. 2014;28:311–4.
22. Koppman JS, Poggi L, Szomstein S, et al. Esophageal motility disorders in the morbidly obese population. Surg Endosc. 2007;21:761–4.
23. Gourcerol G, Benanni Y, Boueyre E, Leroi AM, Ducrotte P. Influence of gastric emptying on gastroesophageal reflux: a combined pH-impedance study. Neurogastroenterol Motil. 2013;25:800–4.
24. Buchholz V, Berkenstadt H, Goitein D, Dickman R, Bernstine H, Rubin M. Gastric emptying is not prolonged in obese patients. Surg Obes Relat Dis. 2013;9:714–7.
25. Mushref MA, Srinivasan S. Effect of high fat-diet and obesity on gastrointestinal motility. Ann Transl Med. 2013;1:14–7.
26. Nadaleto BF, Herbella FAM, Patti MG. Gastroesophageal reflux disease in the obese: pathophysiology and treatment. Surgery. 2016;159:475–86.
27. Shepherd K, Hillman D, Holloway R, Eastwood P. Mechanisms of nocturnal gastroesophageal reflux events in obstructive sleep apnea. Sleep Breath. 2011;15:561–70.
28. Tilg H, Moschen AR. Adipocytokines: mediators linking adipose tissue, inflammation and immunity. Nat Rev Immunol. 2006;6:772–83.
29. Mion F, Dargent J. Gastro-oesophageal reflux disease and obesity: pathogenesis and response to treatment. Best Pract Res Clin Gastroenterol. 2014;28:611–22.
30. Knowles CH, Aziz Q. Visceral hypersensitivity in non-erosive reflux disease. Gut. 2008;57:674–83.
31. Velden vd A, de Wit NJ, Quartero AO. Maintenance treatment for GERD: residual symptoms are associated with psychological distress. Digestion. 2008;77:207–13.
32. Schey R, Dickman R, Parthasarathy S. Sleep deprivation is hyperalgesic in patients with gastroesophageal reflux disease. Gastroenterology. 2007;133:1787–95.
33. Fass R, Naliboff BD, Fass SS. The effect of auditory stress on perception of intraesophageal acid in patients with gastroesophageal reflux disease. Gastroenterology. 2008;134:696–705.
34. De Groot NL, Burgerhart JS, Van De Meeberg PC, de Vries DR, Smout AJ, Siersema PD. Systematic review: the effects of conservative and surgical treatment for obesity on gastro-oesophageal reflux disease. Aliment Pharmacol Ther. 2009;30:1091–102.
35. Kaltenbach T, Crockett S, Gerson LB. Are lifestyle measures effective in patients with gastroesophageal reflux disease? An evidence-based approach. Arch Intern Med. 2006;166:965–71.
36. Rosenthal RJ, International Sleeve Gastrectomy Expert Panel, Diaz AA, Arvidsson D, Baker RS, Basso N. International sleeve gastrectomy expert panel consensus statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis 2012;8:8–19.
37. Soricelli E, Iossa A, Casella G, Abbatini F, Cali B, Basso N. Sleeve gastrectomy and crural repair in obese patients with gastroesophageal reflux disease and/or hiatal hernia. Surg Obes Relat Dis. 2013;9:356–61.
38. Braghetto I, Csendes A, Korn O, Valladares H, Gonzalez P, Henriquez A. Gastroesophageal reflux disease after sleevebgastrectomy. Surg Laparosc Endosc Percutan Tech. 2010;20:148–53.
39. Fraser-Moodie CA, Norton B, Gornall C. Weight loss has an independent beneficial effect on symptoms of gastro-oesophageal reflux in patients who are overweight. Scand J Gastroenterol. 1999;34:337–40.

40. Burton PR, Brown WA, Laurie C, Korin A, Yap K, Richards M. Pathophysiology of laparoscopic adjustable gastric bands: analysis and classification using high-resolution video manometry and a stress barium protocol. Obes Surg. 2010;20:19–29.
41. Cruiziat C, Roman S, Robert M, Espalieu P, Laville M, Poncet G. High resolution esophageal manometry evaluation in symptomatic patients after gastric banding for morbid obesity. Dig Liver Dis. 2011;43:116–20.
42. Tandon A, Rao R, Hotouras A, Nunes QM, Hartley M, Gunasekera R, Howes N. Safety and effectiveness of antireflux surgery in obese patients. Ann R Coll Surg Engl. 2017;99:515–23.
43. Mandeville Y, Looveren R, Vancoillie PJ, et al. Moderating the enthusiasm of sleeve gastrectomy: up to fifty percent of reflux symptoms after ten years in a consecutive series of one hundred laparoscopic sleeve gastrectomy. Obes Surg. 2017;27:1797–803.
44. Genco A, Soricelli E, Casella G, et al. Gastroesophageal reflux disease and Barrett's esophagus after laparoscopic sleeve gastrectomy: a possible, underestimated long-term complication. Surg Obes Relat Dis. 2017;13:568–74.
45. Rebecchi F, Allaix ME, Giaccone C, Ugliono E, Scozzari G, Morino M. Gastroesophageal reflux disease and laparoscopic sleeve gastrectomy. A physiopathologic evaluation. Ann Surg. 2014;260:909–15.

Chapter 15
Sleeve in Patients with GERD

David Nocca and Marius Nedelcu

15.1 Obesity and Gastroesophageal Reflux Disease

Overweight and obesity represent a growing threat to health of the people in an increasing number of countries. In 2016, 1.9 billion adults were overweight. Of these, over 650 million were obese. Globally, obesity rates have tripled since 1975. Over 340 million children and adolescents aged 5–19 were overweight or obese in 2016. Nearly 41 million children under the age of 5 were overweight in 2016, worldwide [1]. According to data from the National Health and Nutrition Examination Survey, during 2015–2016, the prevalence of obesity was 39.8% in adults and 18.5% in youth in the United States [2]. Over the most recent decade between 2007–2008 and 2015–2016, increases in obesity and severe obesity prevalence persisted among adults, whereas there were no overall significant trends among youth [3].

15.1.1 Gastroesophageal Reflux Disease (GERD)

The Montreal conference defines GERD as a disorder related to reflux of stomach contents leading to discomfort or complications affecting the quality of life of an individual with the following symptoms:

- Typical symptoms: Heartburn (upstream esophageal burning) and regurgitation.
- Atypical symptoms: Epigastric burns, chest pain, respiratory symptoms (chronic cough and asthma), and dental erosions [4].

D. Nocca
CHU Montpellier, Département de Chirurgie Digestive, Hôpital St Eloi, Montpellier, France

M. Nedelcu (✉)
Centre de Chirurgie de l'Obesite (CCO), Clinique Saint Michel, Toulon, France

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_15

It is a common pathology with a prevalence of 9–25% in Europe [5] in constant increase (Fig. 15.1). The GERD is a complex diagnosis, especially in the era of bariatric surgery. There are teams that are considering the diagnosis only a clinical one, but GERD can also be asymptomatic and can be measured by pH-metrics. This additional examination makes it possible to measure the number of acid reflux per 24 hours and it is extremely useful in morbid obese patients with clinical symptomatology of GERD and negative signs on upper endoscopy (not always relevant).

GERD can lead to the development of acute or chronic esophageal lesions with more or less severe esophagitis that can be classified by upper endoscopy from A to D with the Los Angeles classification (Table 15.1) [6]. A chronic inflammation can induce more serious lesions since up to 10–15% of patients develop dysplasia (Barrett's esophagus or endobrachyesophagus) that can lead to esophageal cancer (1 in 170 patient years) [7, 8].

Five variables are associated with an increased risk of progression of BE in dysplasia and/or adenocarcinoma [9]:

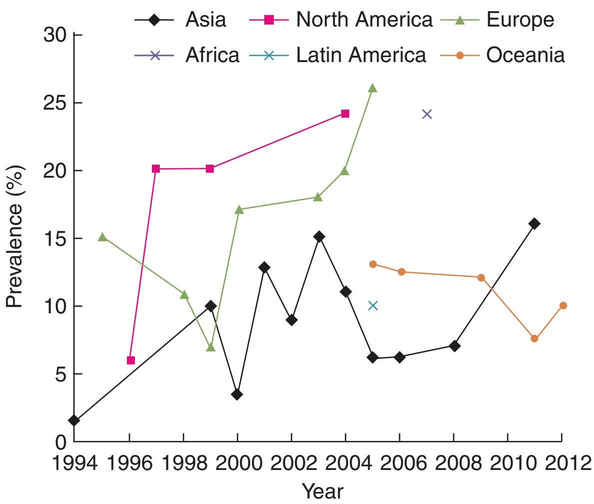


Fig. 15.1 GERD worldwide

Table 15.1 Los Angeles classification for GERD disease

Grade A	One (or more) mucosal break no longer than 5 mm that does not extend between the tops of two mucosal folds
Grade B	One (or more) mucosal break more than 5 mm long that does not extend between the tops of two mucosal folds
Grade C	One (or more) mucosal break that is continuous between the tops of two or more mucosal folds but which involve less than 75% of the circumference
Grade D	One (or more) mucosal break that involves at least 75% of the esophageal circumference

1. Age > 70 years old.
2. Gender: Male.
3. Absence of treatment with proton pump inhibitor (PPI).
4. Barrett's esophagus longer than 3 cm.
5. Esophageal candidiasis.

However, reflux control (by PPI medical treatment or antireflux surgery) is associated with regression of Barrett's mucosa [10], an important reason to combine an antireflux mechanism to a bariatric procedure.

Some studies also find that GERD may be an independent factor of pharyngeal and laryngeal cancer in nonsmoking patients [11, 12].

The association between obesity and GERD is very well known. Obese patients have 2–2.5 more chances to develop reflux symptoms in comparison to the general population [13, 14]. GERD is present in more than 50% of obese patients and up to 70% among morbidly obese patients who seek bariatric surgery [15, 16].

The pathophysiology of GERD is not completely understood but is likely to have a multifactorial nature. Obesity, one of the main factors, is reported to increase the intragastric pressure with impaired gastric emptying, the frequency of transient lower esophageal sphincter (LES) relaxation episode, and the gastroesophageal pressure gradient, potentially leading to GERD. The findings of manometric studies, however, have been inconsistent, indicating both decreased and normal lower esophageal sphincter pressures in obese patients. Studies have also suggested that rather than obesity, the amount and the type of dietary intake, notably fat, associated with hormonal changes (e.g., cholecystokinin, ghrelin) are responsible for GERD [13, 17].

Hormonal factors have also been considered as the pathogenic agents of obesity for GERD. A statistically significant association between obesity and esophagitis in women has been reported. Compared with obese men, obese postmenopausal women receiving estrogen therapy and premenopausal obese women have an increased risk for GERD symptoms [18].

The mechanism of developing the obesity-related esophageal adenocarcinoma is unclear. Obesity increases the risk of GERD by increasing the distal esophageal acid exposure and the number of reflux episodes. On the other hand, the severity of GERD is not directly related to the stage of obesity [13]. Many studies have shown that symptomatic evaluation has limited value for the diagnosis of GERD because symptoms such as heartburn have low sensitivity and specificity.

The role of preoperative and postoperative endoscopy is crucial, especially in asymptomatic patients to identify erosive esophagitis or intestinal metaplasia, defined as the presence of columnar epithelium with goblets cells at histological examination, located distal to the squamocolumnar junction (short segment BE: 10–30 mm length of columnar epithelium; long segment BE: 31–99 mm) [19]. Since the endoscopic absence of esophagitis does not necessarily rule out GERD, especially in symptomatic patients, some authors have proposed a routine preoperative measurement of acid reflux with PH monitoring as an additional tool for a better evaluation of preoperative reflux for bariatric surgery [20].

15.2 Bariatric Surgery and GERD

Surgery is the only effective treatment for morbid obesity and obtains the best long-term outcomes. It is indicated when BMI is greater than 40, or BMI is greater than 35 with significant associated comorbidities. Bariatric procedures were classified into following categories: malabsorptive, combined malabsorptive/restrictive, and restrictive procedures. The prototype of malabsorptive procedures and the first operation performed specifically to induce weight loss was the jejunoileal bypass. The problems associated with this operation caused its demise. Today's most popular malabsorptive procedures is the duodenal switch or its form single-anastomosis duodeno-ileal bypass. Malabsorptive/restrictive surgery is currently predicated on the Roux-en-Y gastric bypass (RYGBP), both the traditional short-limb and the long-limb for the super obese and its variation, the mini bypass. Restrictive procedures are represented by the banded vertical gastroplasty, the gastric banding, and the sleeve gastrectomy. All of these procedures were performed initially by an open approach, but nowadays the standard of care is represented by the laparoscopic surgery [21]. Each procedure is associated with a different balance of risks and benefits, in terms of surgical complications, excess weight loss (EWL), and resolution of comorbidities. The mortality rate in specialized centers is less than 0.3% [22]. Since specific procedure guidelines are missing, surgical treatment for morbid obese patients must be selected according to the clinical characteristics of the patient, his eating habits, and patient willingness. It should be based on a preoperative work-up with shared decision making, with the double purpose of treating both GERD and obesity [23]. The effect of bariatric surgery on preexisting GERD, or newly developed GERD, is still controversial. Little is known about the evolution of pre-existing BE after bariatric surgery and the incidence of esophageal adenocarcinoma. To the best of our knowledge, only a few cases of esophageal cancer after laparoscopic sleeve gastrectomy (LSG) have been reported; however, physicians should be aware of the increased prevalence of GERD, given that the young age of patients could represent a risk [24–26].

Although bariatric surgery has been successfully performed for several decades, the mechanism of action of each type of procedure is not completely understood both for the weight loss and GERD remission or *de novo* GERD.

15.2.1 Laparoscopic Adjustable Gastric Banding (LAGB)

After the initial description of laparoscopic adjustable gastric band in 1993, it soon acquired popularity among patients and surgeons, which led at the beginning of 2000, together with the rising prevalence of morbid obesity, to a yearly increase in the number of band implantations. The LAGB can be implanted with low morbidity and mortality. On average, good EWL is achieved as well as a decrease in comorbidities in the short term. The skepticism among some bariatric surgeons about the long-term weight loss results, complications rates, and patient satisfaction has been confirmed by many bariatric centers. For some years now, there has been a decline in the number of LAGB procedures in both Europe and, later, the United States. In the majority of the national registers, the numbers of gastric band removal and revisions following LAGB have surpassed the implants [27].

LAGB is reported to briefly delay semisolid transit of food into the infraband stomach without physically restricting meal size, with no effect on the overall rate of gastric emptying [28]. This obstruction to flow allows content to remain in the stomach section above the band and below the LES, favoring gastroesophageal reflux if the gastric pouch fills rapidly [13]. On the other hand, some cases of suppression of preoperative GERD following LAGB were described. It is currently unclear if GERD resolution depends on the weight loss, thereby reducing the previously described phenomena of higher intragastric pressure (IGP), or essentially it is an anatomical augmentation of gastroesophageal sphincter; most likely, it is a combination of both factors. The possible good antireflux properties of LAGB appear when the band is placed and fixed correctly as high as possible, and a very small pouch is constructed. Still, it seems to be a higher incidence of large pouches with time, leading to increasing symptoms and findings of GERD. LAGB could reduce the gastroesophageal reflux in the short term in some cases, but overeating will inevitably lead to enlargement of the pouch with loss of its antireflux properties [29].

15.2.2 Vertical Banded Gastroplasty (VBG)

Described by Mason, the VBG consists of a vertical pouch of about 50 mL created with an EEA stapler used to perform a window and linear stapler to partition the stomach. The stoma is calibrated with a size 32-Fr tube internally and reinforced externally with a polypropylene mesh or with a band. VBG has been the choice of bariatric surgeons since the 1980s. Although it is not a difficult procedure since it does not involve any anastomosis, the reoperation rate for failure/complications reported in long-term studies is approximately 50% [30]. The mechanism of action for weight loss and GERD resolution are similar to LAGB and not very enthusiastic. Nowadays, the majority of centers specialized for VBG have aborted this procedure. Conversion to RYGBP is effective in terms of weight loss and treatment of complications after VBG and it remains the only valid option [31].

15.2.3 Laparoscopic Roux-en-Y Gastric Bypass (LRYGB)

LRYGB was considered the gold standard for treatment of both obesity and GERD, and it consists in creating a small gastric pouch connected to the alimentary limb. For a long time, many authors have considered that the alimentary limb should be longer than the biliary one. With weight recidivism following LRYGB, many centers have advocated longer biliary loops. LRYGB has a higher complication rate (marginal ulcers, internal hernia) compared to LSG but improved results on GERD. Its mechanisms of diverting the bile away from the esophagus, decreasing acid production in the gastric pouch, and reducing the volume of acid reflux are well known. For morbid obese patients with refractory reflux disease and/or BE following LSG, LRYGB has been suggested by many reports as an excellent antireflux procedure, proven by the disappearance of symptoms and the healing of endoscopic esophagitis or peptic ulcer in all patients, and important regression of intestinal metaplasia to cardiac mucosa. Still, there are some cases with recurrence of reflux following LRYGB explained probably by neglected hiatal hernia, large gastric pouch, or multiple revisional procedures.

Although the LRYGB was considered the gold standard procedure for obese patients with reflux disease, more than 35% of patients who underwent LRYGB had at least one complication within the 10-year follow-up period [32]. In another study, Sandler et al. [33] reported on 129,432 LRYGB patients amounting to an overall mortality rate at 1, 5, and 10 years of 2.2%, 4.4%, and 8.1%, respectively. The number of patients hesitating or refusing the choice for RYGBP because of long-term complications cannot be neglected.

15.2.4 One Anastomosis Gastric Bypass (OAGB)

OAGB has been promoted as a quick and effective alternative to the standard LRYGB procedure. In some reports, it seems more efficient on weight loss (70–80% at 2 years) and comorbidities with immediate improvement of diabetes [34]. It consists of a unique gastrojejunal anastomosis between a gastric pouch and a jejunal loop of 150–200 cm. It also has the advantage of being less technically difficult (only one anastomosis and no closure of peritoneal spaces) and less morbid, especially for multicomplicated obese and/or the super obese. However, this procedure is at risk of biliary reflux and anastomotic ulcers with dysplastic changes of the gastric and esophageal mucosa [35]. Many authors propose OAGB as a revisional procedure for weight regain following LSG. This option must be carefully evaluated in terms of GERD as the esophagus has already had a potential acid exposure with LSG and with the OAGB will be exposed to the alkaline reflux. These modifications in terms of pH could be the trigger of dysplastic modifications of the mucosa at the level of the lower esophagus. As a result, OAGB remains a controversial procedure.

15.2.5 Single Anastomosis Duodeno-Ileostomy (SADI) and Duodenal Switch (DS)

SADI with sleeve gastrectomy is an easier and quicker version of the DS. Given its effectiveness as a primary surgery, it is hypothesized as a successful second-step operation for patients with a suboptimal result following bypass or sleeve surgery.

For DS, the extra weight loss is offset by a significant risk of protein or vitamin deficiency and a poorer quality of life from diarrhea. In SADI, the anastomosis between the duodenum and the small bowel is performed with a "common limb" measuring 3 m long, with the reduction of bowel frequency compared to DS and similar EWL [36]. As revisional surgery, either SADI or DS has little or no impact on GERD, and in our experience, the indication for SADI/DS is a valid option in case of absence of any symptoms of reflux.

15.3 Sleeve Gastrectomy, GERD, and Barrett Esophagus

Laparoscopic sleeve gastrectomy (LSG) has evolved into a primary surgical treatment modality for morbid obesity. It has gained wide popularity as a sole bariatric procedure, now established as the most frequent bariatric procedure in France since 2011 and in the United States since 2013 [37, 38]. This growth can be explained by several advantages that LSG carries over more complex bariatric procedures, such as RYGBP or DS, including the absence of most side effects of bypass procedures like dumping syndrome, marginal ulcers, malabsorption, small bowel obstruction and internal hernia, and a better quality of life over gastric banding [39].

The effect of gastric resection for GERD could be contradictory. LSG induces alteration of the angle of Hiss due to surgery itself, hypotony of the LES after division of muscular sling fibers, decrease of the gastric volume and consequent increased intragastric pressure, decrease of a ghrelin, and hence dysmotility. All these factors contribute to exposing the patient to the risk of increasing GERD and PPI dependency or developing new onset GERD. On the other hand, weight loss after surgery together with accelerated gastric emptying, decreased acid production, and restoration of Hiss angle over time is supposed to improve reflux symptoms. However, the presence of preoperative GERD should be considered a relative contraindication to LSG and patients should be properly counseled, while follow-up after LSG should focus not only on weight loss and comorbidities resolution but also on detection and treatment of GERD.

Measuring GERD is a difficult measure. Chan et al. [40] showed the difficulty between self-reported reflux symptoms and their correlation with objectified reflux: of 336 patients who completed a GERD questionnaire, only half of the patients who claimed to have GERD were confirmed positively by tests like the 24 hour pH-metry. Some studies evaluate GERD on the evolution of the patient's prescriptions of PPIs or antacids. This measure is not always representative since some patients have GERD but are untreated and others are not symptomatic of GERD but consume PPIs systematically as a preventive or by habitude.

Studies are also discordant about the effect of LSG on GERD. These are difficult to compare because monitoring is not equivalent and the technique may differ, particularly in terms of calibration of the sleeve and/or the length of the antrum preserved. A systematic review analyzed 15 papers on the effect of LSG on GERD. Seven of these studies were in favor of positive effects of LSG over GERD, whereas four of them were against it [41].

The explanations for improving symptoms of GERD postoperatively were as follows:

- Acceleration of gastric emptying at 6 months and 2 years after sleeve gastrectomy [42].
- Decrease in intra-abdominal pressure and therefore in intragastric pressure by weight loss.
- Decrease in acid secretion by reducing the volume of the gastric mucosa.

The reasons for worsening of GERD symptoms after LSG were as follows:

- Braghetto et al. [43] demonstrated that lower esophageal sphincter pressure was decreased after sleeve gastrectomy, which caused GERD and postoperative esophagitis.
- The hypothesis of Himpens et al. [44] was that the modification of the anatomy at the angle of Hiss and the lack of compliance of the stomach were responsible for the immediate postoperative GERD, before the organism does not fit.

Mion et al. [45] performed high-resolution impedance manometry in 53 patients:

- Intragastric pressure was increased in more than two-thirds of patients (77%) but was not associated with GERD symptoms.
- Reflux impedance was measured in half of patients and was significantly associated with GERD symptoms and esophageal motility dysfunction.
- The volume and diameter of the gastric sleeve were significantly associated in patients with reflux impedance.

Another meta-analysis published in 2016, bringing together 33 articles published between 2005 and 2014, studies the link between LSG and GERD: the combined risk of developing *de novo* GERD was estimated at 20% [46]. A consensus conference was held in 2012 bringing together experts on sleeve gastrectomy working on a panel with more than 12,000 patients [47]. In this study, the prevalence of postoperative GERD was 12% (±9%). Furthermore, recommendations were issued such as:

- Endobrachyesophagus (EBO) is an absolute contraindication to sleeve gastrectomy (81%).
- The intraoperative identification of a hiatal hernia must be identified and a diaphragmatic defect must be repaired if present. No recommendation for the indication or contraindication of sleeve gastrectomy was made for the existence of preoperative GERD.

The experts present at the fifth consensus conference on sleeve gastrectomy in Montreal in 2016 cited as contraindications to sleeve gastrectomy: GERD for 23% of them, the presence of hiatal hernia for 12% of them, and the presence of Barrett's esophagus for 80% of them. There was a conversion rate for GERD of sleeve gastrectomy to another bariatric surgery technique of 2.9% [48].

15.3.1 Sleeve Gastrectomy and Hiatal Hernia Repair

Some studies have been published on the realization of LSG with concomitant repair of hiatal hernia. A review of the literature by Mahawar et al. [49] on the hiatal repair associated with sleeve gastrectomy involving more than 700 patients was performed. Of the 17 studies analyzed, only one did not show a satisfactory result on GERD. Soricelli et al. [50] evaluated in 97 patients the repair of a concomitant hiatal hernia of a sleeve gastrectomy with a median follow-up of 18 months. A total of 80.4% of these patients had remission of reflux, 12.1% had improved symptoms, 7.5% had persistent symptoms, and no *de novo* reflux. Samakar et al. [51] followed 58 patients over 2 years who underwent LSG with hiatal hernia repair. In their study, only one-third of the patients who were symptomatic had resolution of their GERD and there had been 15.6% *de novo* GERD.

15.3.2 Sleeve Gastrectomy and Barrett's Esophagus

There is increasing evidence of an existing relationship between sleeve gastrectomy and the development of Barrett's esophagus in patients with no preoperative history of the disease. Although data are yet limited, there are several published studies that have shown the development of Barrett's esophagus at mid-term follow-up upper GI endoscopy.

Braghetto et al. [14] recently reported a 1.2% incidence of Barrett's esophagus (3 patients) in a cohort of 231 sleeve gastrectomy patients who did not have reflux symptoms, hiatal hernia, or Barrett's prior to surgery. Braghetto reported that BE was diagnosed between five and six years after surgery. All those three patients were later converted to RYGBP.

In another study, Genco et al. [52] reported a new diagnosis of Barrett's esophagus in 19 of 110 patients (17.2%) at a mean of 58 months' follow-up postgastric sleeve. In the same study, they reported only 14 of 19 patients (73.6%) with GERD symptoms, indicating that the presence of symptoms did not correlate with the severity of esophageal disease.

In a multicenter study, Sebastianelli et al. [53] observed a prevalence of 18.8% for Barrett's esophagus postsleeve gastrectomy in patients with normal esophagus preoperatively. All patients but one complained of GERD symptoms and 35% required PPIs. No dysplasia was noted and no significant difference was observed among centers. They also noticed a correlation between weight loss failure (defined as EWL < 50%) and the presence of BE. Although the link between the degree of weight loss and the presence of BE is still unclear, the authors of this study proposed the hypothesis of a dilated sleeve leading to weight regain and increased GERD and, secondly, the possibility of the modification of eating habits by patients suffering GERD symptoms in order to buffer acid.

There is still little follow-up on the long-term complications of GERD in postoperative sleeve gastrectomy: Felsenreich et al. [54] carried out a full paraclinical evaluation of GERD 10 years following LSG, including upper endoscopy and pH-metric studies for 20 patients. The results showed *de novo* hiatus hernia in 45% of patients ($n = 9/20$) and the development of Barrett's esophagus without dysplasia in 15% of patients ($n = 3/20$).

Given the slow nature of development of dysplasia and then to adenocarcinoma in the setting of BE, most authors found that there will be a room for a long and close endoscopic follow-up prior to attempting a conversion to a new bariatric procedure (most probably RYGB).

15.4 Prevention of GERD After Sleeve: The Concept – Nissen Sleeve

Although the LRYGB was considered the gold standard procedure for obese patients with reflux disease, more than one-third of patients who underwent LRYGB had at least 1 complication within the 10-year follow-up period [30]. The number of patients hesitating or refusing the choice for RYGBP because of long-term complications cannot be neglected. The most dreaded complication after LSG is represented by the gastric leak, but recent reports [55] showed a decreased incidence to 1%. Within the six years that followed LSG, Himpens et al. [56] reported new gastroesophageal reflux complaints in 21% of patients. Considering all these findings and encouraged by the good results of LSG and concomitant hiatal hernia repair [49–51], we have developed a modification to the usual surgical technique of LSG by adding a Nissen fundoplication (N-sleeve) in order to minimize both leaks and GERD. (Fig. 15.2).

Some modifications have been proposed in the literature to the standard LSG in order to control postoperative GERD; for instance, Silva et al. [57] proposed a similar Collis–Nissen procedure or others a cardiopexy with ligamentous teres [58]. Furthermore, Le Page et al. [59] conducted a pilot study of four patients describing a sleeve gastrectomy associated with a fundoplication. This intervention was not performed for the purpose of weight loss but in nonobese patients with severe gastric emptying associated with hiatal hernia for the dual purpose of improving gastric emptying and GERD symptoms. The four patients were able to stop their PPI treatment.

In 2016, Hawasli et al. [60] described in 40 patients a similar technique combining sleeve gastrectomy and anterior fundoplication. The results in terms of postoperative GERD and loss of excess weight were satisfactory with 95% immediate improvement in reflux and EWL at 69% ± 27 at 2 years. In contrast, 15% of patients had to be readmitted to this period.

In the early experience, our main question was: "Is the Nissen sleeve a feasible technique, with a reasonable rate of short-term complications and a good

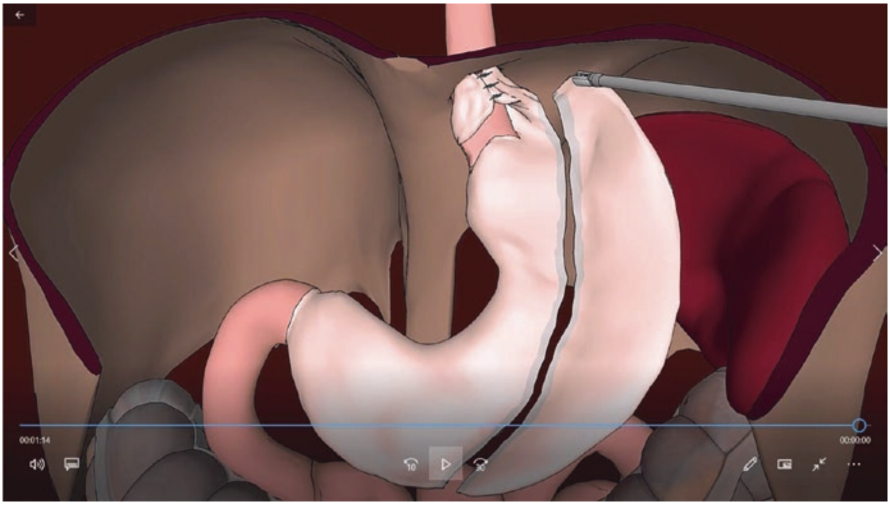


Fig. 15.2 Nissen sleeve

result on the loss of excess weight and gastroesophageal reflux in the medium term?" Our initial results regarding the Nissen sleeve were previously published [61]. The recent analysis includes 99 patients and the percentages of excess weight loss at 1 year, 2 years, and 3 years were respectively 69.8%, 71.4%, and 69.8% with a 3-year success rate according to Reinhold's 66.7% (% PEP > 50%).

For the evaluation of GERD, the score GerdQ was used with the following results:

- The proportion of GERD (GerdQ score > 8) increased from 72.4% preoperatively to 6.9% after 1 year.
- Impairment of quality of life due to GERD (simplified GerdQ score > 4) increased from 51.7% preoperatively to 1.1% after 1 year.
- There was a decline in the consumption of PPIs and antacids from 70% to 16.1% and from 35.6% to 3.4%.
- There was no onset of reflux *de novo* during our follow-ups at 1, 2, 3, and 4 years (GerdQ score > 8).

There were 7% serious complications in our analysis (Dindo–Clavien classification> IIIa) and 6% early surgical revisions (in the first postoperative month). However, there were no reported deaths, no intraoperative complications, and no conversion to laparotomy. We find in our study the classic complications of sleeve gastrectomy (bleeding, leak, stenosis, and venous thromboembolic disease) to which are added new specific complications of the Nissen sleeve (high occlusion, perforation of the valve, and release of the valve). The technique evolved during the course of the study according to the complications.

15.4.1 Current Surgical Technique

All operations were performed under general anesthesia and by laparoscopic approach using the French technique (the surgeon standing between the patient's legs). Each procedure required five trocars. Pneumoperitoneum was induced through the first trocar inserted at the umbilicus by open technique (Hasson technique). The trocar placement is the same as a standard LSG.

The first step of the N-sleeve technique was the dissection and reduction of a hiatal hernia, if present. An extension of at least 5 cm of abdominal esophagus was mobilized and all the anterior and posterior esophageal hiatal space were clearly dissected.

The greater curvature of the stomach was dissected from the short gastric vessels and gastrocolic ligament, starting 6 cm from the pylorus using an impedance coagulator Ultracision® (Ethicon Endo-surgery, Johnson-Johnson Inc., 2010, USA). A careful dissection was performed at the level of the gastric fundus so that an appropriate distance from the gastric wall could be kept and also to avoid any possible thermal injury to this important part of the gastric wall, which would be used later to perform the fundoplication.

The hiatal orifice was closed by two or three nonabsorbable sutures of Ethibond® 2.0 suture (Johnson-Johnson Inc., USA), and a 37F calibration tube (Midsleeve®, Medical Innovation Development, Dardilly, France) was introduced in the stomach. A short Nissen valve of 3 cm was created using Ethibond® 3.0 suture (Johnson-Johnson Inc., USA). This valve was created to maintain a gastric fundus as smaller as possible. We have to emphasize that the fundus is grasped at its upper anterior part (3 cm from the Hiss angle) in order to create the wrap. Two sutures will fix the valve at the anterior lower part of the esophagus. A gastrogastric suture will complete the closure of the fundoplication.

Dissection of the rest of the greater curvature continued. Then, 50 cc of saline was inserted in the distal balloon of the Midsleeve® (MID Company) to define accurately the beginning of the staple line. A laparoscopic linear stapler (Echelon green cartridges® Ethicon Endosurgery reinforced by Bioseamguard® WL Gore) was introduced in the peritoneal cavity and was positioned so that it divided the stomach parallel to the Midsleeve® (MID Company) tube along the lesser curvature. The instrument was fired and reloaded, and the procedure was repeated. At the level of the new valve created, special consideration must be taken and attention paid in order to maintain its natural position. The final aspect is an appropriate Nissen valve over a sleeved stomach (video).

All patients received perioperative deep vein thrombosis prophylaxis using low-molecular-weight heparin and intermittent pneumatic leg compression during the operation.

Contrary to standard LSG, for the N-sleeve, some technical details are extremely important, which are as follows:

1. Avoid ischemia of the gastric wall during short gastric vessel dissection.
2. Delicate handling of the gastric fundus during fundoplication.
3. Avoid double stapling of the gastric fundus, maybe the worse injury, which can create a blind pouch.

4. To check at the end of the procedure the good way for food intake, by pushing the gastric tube from the esophagus to the stomach. If the tube is going through the posterior pouch of the fundoplication and not through the sleeve, you have to redo the valve or convert to a toupet sleeve.

The standard LSG is a restrictive procedure, and very often, the results are correlated to the amount of the gastric resection. The Nissen sleeve was incriminated for not achieving similar results in terms of weight loss due to the nonresected used for the valve. The fundoplication is no longer functional for storing the bolus and it acts like standard valve of a Nissen procedure (containing only air). The gastric volume is also calibrated on a probe that is in place during the realization of the valve and during stapling. The realization of a Nissen sleeve thus does not modify the "restriction" properties of the surgery compared to a standard LSG.

In the early experience Nissen sleeve was proposed only for patients with the presence of Barrett esophagus. Recent studies report increased rates of BE [52–54] following LSG, and the prophylactic character to prevent GERD, could become another indication for Nissen sleeve.

15.5 Treatment of GERD After Sleeve

The identification of some form of GERD preoperatively (clinical, endoscopy, or pH-metry) is still a matter of debate about the choice of bariatric procedure. Postoperatively, for patients with refractory reflux disease and/or BE following LSG, LRYGB is, with no doubt, the procedure of choice with an excellent antireflux effect as it has been reported by many teams. This has been proven by the disappearance of symptoms and the healing of endoscopic esophagitis or peptic ulcer in all patients, and important regression of intestinal metaplasia to cardiac mucosa. A technical detail must be discussed for this type of revision otherwise with no degree of complexity. Following LSG almost always the gastric tube is migrated intrathoracical and the esophagus must be well mobilized before any gastric section, in order to well appreciate the volume of the gastric pouch. Contrarily, the risk of persistent reflux exists, especially in patients with multiple revisional surgeries (multiple LAGB or LSG).

Different alternatives to LRYGB for severe reflux following LSG have been proposed, but different clinical trials must confirmed their utility.

15.5.1 Linx Procedure

The Linx system was approved by the Food and Drug administration in 2012 for the treatment of refractory esophageal reflux by using magnetic beads to augment the lower esophageal sphincter. The existing literature supports the use of this device as a safe and effective treatment option in the general population and may be offered as an alternative to the conversion to RYGB for the treatment of severe refractory reflux after sleeve gastrectomy; however, the use has not been widely reported [62, 63] and some concerns about migration of the device exist.

15.5.2 Lower Esophageal Sphincter Electrical Stimulation

Electrical stimulation of the LES is a novel surgical option that has been shown to normalize LES pressure and esophageal acid exposure in GERD patients without altering the anatomy. It is a procedure with minimal morbidity with a positive impact on LES pressure and length and may improve esophageal motility and reduce the frequency of transient LES relaxations. In an international multicentric study [64], 17 patients who underwent LES-electrical stimulation were analyzed. The study showed that the procedure is safe and technically feasible. It offers a significant improvement of esophageal acid exposure, with normalization in almost half of patients. Symptomatic control, in terms of PPI use and standardized questionnaires, was excellent and comparable to RYGB. Even more, the patient population included was nonresponsive to PPI and had a rather high esophageal acid exposure.

15.5.3 Endoscopic Radiofrequency – Stretta

Endoscopic radiofrequency (Stretta) is another minimally invasive tool to treat GERD. In the first report [65] where 15 patients were analyzed, the results were not very encouraging. One case (6.7%) was complicated by hematemesis. At 6 months, 66.7% of patients were not satisfied, though the PPI medications were ceased in 20%. Two patients (13.3%) underwent RYGBP at 8 months post-Stretta to relieve symptoms.

Evolution of surgical techniques for morbid obesity disease – some surgeons prefer to perform LSG in opposition to LRYGB, but despite this, a large number of experts advise against performing a LSG in case of preoperative GERD or EBO identified in the preoperative work-up. Still, the bariatric surgery remains a functional surgery with the main purpose to improve the quality of life of the patient. Accordingly, the patients' willingness should be adapted to the procedural choice more than the surgeons' concern about too complex LRYGB or the surgeons' "beliefs" about GERD and LSG.

References

1. World Health Organ Tech Rep Ser. 2000;894:i–xii, 1–253 https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.

2. Hales C, M, Carroll MD, Fryar CD, Ogden CL. Prevalence of obesity among adults and youth: United States, 2015–2016. NCHS Data Brief. 2017;(288):1–8.
3. Hales CM, Fryar CD, Carroll MD, Freedman DS, Ogden CL. Trends in Obesity and Severe Obesity Prevalence in US Youth and Adults by Sex and Age, 2007–2008 to 2015–2016. JAMA. 2018;319(16):1723–5.
4. Vakil N, van Zanten SV, Kahrilas P, Dent J, Jones R. Globale Konsensusgruppe. [The Montreal definition and classification of gastroesophageal reflux disease: a global, evidence-based consensus paper]. Z Gastroenterol. 2007;45(11):1125–40.
5. El-Serag HB, Sweet S, Winchester CC, Dent J. Update on the epidemiology of gastro-oesophageal reflux disease: a systematic review. Gut. 2014;63(6):871–80.
6. Lundell L, Dent J, Bennett J, Blum A, Armstrong D, Galmiche J, et al. Endoscopic assessment of oesophagitis: clinical and functional correlates and further validation of the Los Angeles classification. Gut. 1999;45(2):172–80.
7. Oh DS, Demeester SR. Pathophysiology and treatment of Barrett's esophagus. World J Gastroenterol. 2010;16(30):3762–72.
8. Spechler SJ, Robbins AH, Rubins HB, Vincent ME, Heeren T, Doos WG, et al. Adenocarcinoma and Barrett's esophagus. An overrated risk? Gastroenterology. 1984;87(4):927–33.
9. Brown CS, Lapin B, Goldstein JL, Linn JG, Talamonti MS, Carbray J, et al. Predicting progression in Barrett's esophagus: development and validation of the Barrett's Esophagus Assessment of Risk Score (BEAR Score). Ann Surg. 2017.
10. Brown CS, Lapin B, Wang C, Goldstein JL, Linn JG, Denham W, et al. Reflux control is important in the management of Barrett's Esophagus: results from a retrospective 1,830 patient cohort. Surg Endosc. 2015;29(12):3528–34.
11. Langevin SM, Michaud DS, Marsit CJ, Nelson HH, Birnbaum AE, Eliot M, et al. Gastric reflux is an independent risk factor for laryngopharyngeal carcinoma. Cancer Epidemiol Biomark Prev Publ Am Assoc Cancer Res Cosponsored Am Soc Prev Oncol. 2013;22(6):1061–8.
12. Bacciu A, Mercante G, Ingegnoli A, Ferri T, Muzzetto P, Leandro G, et al. Effects of gastroesophageal reflux disease in laryngeal carcinoma. Clin Otolaryngol Allied Sci. 2004;29(5):545–8.
13. Tutuian R. Obesity and GERD: Pathophysiology and effect of bariatric surgery. Curr Gastroenterol Rep. 2011;13:205–12.
14. Braghetto I, Csendes A. Prevalence of Barret's esophagus in bariatric patients undergoing sleeve gastrectomy. Obes Surg. 2016;26(4):710–4.
15. Anand G, Katz PO. Gastroesophageal reflux disease and obesity. Rev Gastroenterol Disorder. 2008;8(4):233–9.
16. Mejía-Rivas MA, Herrera-Lopez A, Hernández-Calleros J, et al. Gastroesophageal reflux disease in morbid obesity: the effect of Roux-en-Y gastric bypass. Obes Surg. 2008;18:1217–24.
17. Hampel H, Abraham NS, El-Serag HB. Meta-analysis: obesity and the risk for gastroesophageal reflux disease and its complications. Ann Intern Med. 2005;143(3):199–211.
18. Nilsson M, Lundegårdh G, Carling L, Ye W, Lagergren J. Body mass and reflux oesophagitis: an oestrogen-dependent association? Scand J Gastroenterol. 2002;37(6):626–30.
19. Mandeville Y, Van Looveren R, Vancoillie PJ, Verbeke X, Vandendriessche K, Vuylsteke P, Pattyn P, Smet B. Moderating the enthusiasm of sleeve gastrectomy: up to fifty percent of reflux symptoms after ten years in a consecutive series of one hundred laparoscopic sleeve gastrectomies. Obes Surg. 2017;27(7):1797–803.
20. Melendez-Rosado J, Gutierrez-Blanco D, Schneider A, Menzo EL, Szomstein S, Rosenthal RJ. Impact of preoperative wireless pH monitoring in the evaluation of esophageal conditions prior to bariatric surgery in a severely obese patient population. Surg Obes Relat Dis. 2018. pii: S1550-7289(18)30462-3. doi: https://doi.org/10.1016/j.soard.2018.11.014. [Epub ahead of print].
21. Buchwald H, Buchwald JN. Evolution of operative procedures for the management of morbid obesity 1950–2000. Obes Surg. 2002;12(5):705–17.
22. Miller K. Obesity: surgical options. Best Pract Res Clin Gastroenterol. 2004;18(6):1147–65.

23. Braghetto I, Korn O, Csendes A, Gutiérrez L, Valladares H, Chacon M. Laparoscopic treatment of obese patients with gastroesophageal reflux disease and Barrett's esophagus: a prospective study. Obes Surg. 2012;22(5):764–72.
24. El Khoury L, Benvenga R, Romero R, Cohen R, Roussel J, Catheline JM. Esophageal adenocarcinoma in Barrett's esophagus after sleeve gastrectomy: Case report and literature review. Int J Surg Case Rep. 2018;52:132–6.
25. Scheepers AF, Schoon EJ, Nienhuijs SW. Esophageal carcinoma after sleeve gastrectomy. Surg Obes Relat Dis. 2011;7(4):e11–2.
26. Sohn S, Fischer J, Booth M. Adenocarcinoma of the gastro-oesophageal junction after sleeve gastrectomy: a case report. ANZ J Surg. 2017;87(10):E163–4.
27. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J, Buchwald H, Scopinaro N. IFSO worldwide survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28(12):3783–94.
28. Woodman G, Cywes R, Billy H, Montgomery K, Cornell C, Okerson T. Effect of adjustable gastric banding on changes in gastroesophageal reflux disease (GERD) and quality of life. APEX Study Group. Curr Med Res Opin. 2012;28(4):581–9.
29. Tolonen P, Victorzon M, Niemi R, Mäkelä J. Does gastric banding for morbid obesity reduce or increase gastroesophageal reflux? Obes Surg. 2006;16(11):1469–74.
30. David MB, Abu-Gazala S, Sadot E, Wasserberg N, Kashtan H, Keidar A. Laparoscopic conversion of failed vertical banded gastroplasty to Roux-en-Y gastric bypass or biliopancreatic diversion. Surg Obes Relat Dis. 2015;11(5):1085–91.
31. Mognol P, Chosidow D, Marmuse JP. Roux-en-Y gastric bypass after failed vertical banded gastroplasty. Obes Surg. 2007;17(11):1431–4.
32. Higa K, Ho T, Tercero F, Yunus T, Boone KB. Laparoscopic Roux-en-Y gastric bypass: 10-year follow-up. Surg Obes Relat Dis. 2011;7(4):516–25.
33. Weiss AC, Parina R, Horgan S, Talamini M, Chang DC, Sandler B. Quality and safety in obesity surgery-15 years of Roux-en-Y gastric bypass outcomes from a longitudinal database. Surg Obes Relat Dis. 2016;12(1):33–40.
34. Disse E, Pasquer A, Espalieu P, Poncet G, Gouillat C, Robert M. Greater weight loss with the omega loop bypass compared to the Roux-en-Y gastric bypass: a comparative study. Obes Surg. 2014 Jun;24(6):841–6.
35. Saarinen T, Räsänen J, Salo J, Loimaala A, Pitkonen M, Leivonen M, Juuti A. Bile reflux scintigraphy after mini-gastric bypass. Obes Surg. 2017;27(8):2083–9.
36. Sanchez-Pernaute A, Rubio MA, Conde M, Arrue E, Perez-Aguirre E, Torres A. Single-anastomosis duodenoileal bypass as a second step after sleeve gastrectomy. Surg Obes Relat Dis. 2015;11(2):351–5.
37. Lazzati A, Guy-Lachuer R, Delaunay V, Szwarcensztein K, Azoulay D. Bariatric surgery trends in France: 2005–2011. Surg Obes Relat Dis. 2014;10(2):328–34.
38. Ponce J, DeMaria EJ, Nguyen NT, Hutter M, Sudan R, Morton JM. American Society for Metabolic and Bariatric Surgery estimation of bariatric surgery procedures in 2015 and surgeon workforce in the United States. Surg Obes Relat Dis. 2016.
39. Fezzi M, Kolotkin RL, Nedelcu M, et al. Improvement in quality of life after laparoscopic sleeve gastrectomy. Obes Surg. 2011;21(8):1161–7.
40. Chan K, Liu G, Miller L, Ma C, Xu W, Schlachta CM, et al. Lack of correlation between a self-administered subjective GERD questionnaire and pathologic GERD diagnosed by 24-h esophageal pH monitoring. J Gastrointest Surg Off J Soc Surg Aliment Tract. 2010;14(3):427–36.
41. Chiu S, Birch DW, Shi X, et al. Effect of sleeve gastrectomy on gastroesophageal reflux disease: a systematic review. Surg Obes Relat Dis. 2011;7:510–5.
42. Melissas J, Daskalakis M, Koukouraki S, Askoxylakis I, Metaxari M, Dimitriadis E, et al. Sleeve gastrectomy-a "food limiting" operation. Obes Surg. 2008;18(10):1251–6.
43. Braghetto I, Lanzarini E, Korn O, Valladares H, Molina JC, Henriquez A. Manometric changes of the lower esophageal sphincter after sleeve gastrectomy in obese patients. Obes Surg. 2010;20(3):357–62.

44. Himpens J, Dapri G, Cadière GB. A prospective randomized study between laparoscopic gastric banding and laparoscopic isolated sleeve gastrectomy: results after 1 and 3 years. Obes Surg. 2006;16(11):1450–6.
45. Mion F, Tolone S, Garros A, Savarino E, Pelascini E, Robert M, et al. High-resolution impedance manometry after sleeve gastrectomy: increased intragastric pressure and reflux are frequent events. Obes Surg. 2016;26(10):2449–56.
46. Oor JE, Roks DJ, Ünlü Ç, Hazebroek EJ. Laparoscopic sleeve gastrectomy and gastroesophageal reflux disease: a systematic review and meta-analysis. Am J Surg. 2016;211(1):250–67.
47. Rosenthal RJ, International Sleeve Gastrectomy Expert Panel, Diaz AA, Arvidsson D, Baker RS, Basso N, et al. International Sleeve Gastrectomy Expert Panel Consensus Statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis Off J Am Soc Bariatr Surg 2012;8(1):8–19.
48. Gagner M, Hutchinson C, Rosenthal R. Fifth International Consensus Conference: current status of sleeve gastrectomy. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2016;12(4):750–6.
49. Mahawar KK, Carr WRJ, Jennings N, Balupuri S, Small PK. Simultaneous sleeve gastrectomy and hiatus hernia repair: a systematic review. Obes Surg. 2015;25(1):159–66.
50. Soricelli E, Iossa A, Casella G, Abbatini F, Calì B, Basso N. Sleeve gastrectomy and crural repair in obese patients with gastroesophageal reflux disease and/or hiatal hernia. Surg Obes Relat Dis Off J Am Soc Bariatr Surg. 2013;9(3):356–61.
51. Samakar K, McKenzie TJ, Tavakkoli A, Vernon AH, Robinson MK, Shikora SA. The effect of laparoscopic sleeve gastrectomy with concomitant hiatal hernia repair on gastroesophageal reflux disease in the morbidly obese. Obes Surg. 2016;26(1):61–6.
52. Genco A, Soricelli E, Casella G, Maselli R, Castagneto-Gissey L, Di Lorenzo N, Basso N. Gastroesophageal reflux disease and Barrett's esophagus after laparoscopic sleeve gastrectomy: a possible, underestimated long-term complication. Surg Obes Relat Dis. 2017;13(4):568–74.
53. Sebastianelli L, Benois M, Vanbiervliet G, Bailly L, Robert M, Turrin N, Gizard E, Foletto M, Bisello M, Albanese A, Santonicola A, Iovino P, Piche T, Angrisani L, Turchi L, Schiavo L, Iannelli A. Systematic endoscopy 5 years after sleeve gastrectomy results in a high rate of Barrett's esophagus: results of a multicenter study. Obes Surg. 2019; https://doi.org/10.1007/s11695-019-03704-.
54. Felsenreich DM, Kefurt R, Schermann M, Beckerhinn P, Kristo I, Krebs M, et al. Reflux, sleeve dilation, and barrett's esophagus after laparoscopic sleeve gastrectomy: long-term follow-up. Obes Surg. 2017.
55. Gagner M. Decreased incidence of leaks after sleeve gastrectomy and improved treatments. Surg Obes Relat Dis. 2014;10(4):611–2.
56. Himpens J, Dobbeleir J, Peeters G. Long-term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252(2):319–24.
57. Da Silva LE, Alves MM, El-Ajouz TK, et al. Laparoscopic Sleeve-Collis-Nissen gastroplasty: a safe alternative for morbidly obese patients with gastroesophageal reflux disease. Obes Surg. 2015;25(7):1217–22.
58. Gálvez-Valdovino R, Cruz Vigo JL, Marín Santillán E, et al. Cardiopexy with ligament teres in patients with hiatal hernia and previous sleeve gastrectomy: an alternative treatment for gastroesophageal reflux disease. Obes Surg. 2015;25(8):1539–43.
59. Le Page PA, Martin D. Laparoscopic partial sleeve gastrectomy with fundoplication for gastroesophageal reflux and delayed gastric emptying. World J Surg. 2015;39(6):1460–4.
60. Hawasli A, Reyes M, Hare B, Meguid A, Harriott A, Almahmeed T, et al. Can morbidly obese patients with reflux be offered laparoscopic sleeve gastrectomy? A case report of 40 patients. Am J Surg. 2016;211(3):571–6.
61. Nocca D, Skalli EM, Boulay E, Nedelcu M, Michel Fabre J, Loureiro M. Nissen Sleeve (N-Sleeve) operation: preliminary results of a pilot study. Surg Obes Relat Dis. 2016;12(10):1832–7.

62. Hawasli A, Sadoun M, Meguid A, Dean M, Sahly M, Hawasli B. Laparoscopic placement of the LINX® system in management of severe reflux after sleeve gastrectomy. Am J Surg. 2018. pii: S0002-9610(18)30976-0. doi: https://doi.org/10.1016/j.amjsurg.2018.10.040. [Epub ahead of print].
63. Desart K, Rossidis G, Michel M, Lux T, Ben-David K. Gastroesophageal reflux management with the LINX® system for gastroesophageal reflux disease following laparoscopic sleeve gastrectomy. J Gastrointest Surg. 2015;19(10):1782–6.
64. Borbély Y, Bouvy N, Schulz HG, Rodriguez LA, Ortiz C, Nieponice A. Electrical stimulation of the lower esophageal sphincter to address gastroesophageal reflux disease after sleeve gastrectomy. Surg Obes Relat Dis. 2018;14(5):611–5.
65. Khidir N, Angrisani L, Al-Qahtani J, Abayazeed S, Bashah M. Initial experience of endoscopic radiofrequency waves delivery to the lower esophageal sphincter (Stretta procedure) on symptomatic gastroesophageal reflux disease post-sleeve gastrectomy. Obes Surg. 2018;28(10):3125–30.

Chapter 16
Hiatal Hernia Repair During Sleeve Gastrectomy

Jorge Daes and Andres Hanssen

16.1 The Difficulty of Diagnosing Hiatal Hernia

Hiatal hernia (HH) is a condition in which elements of the abdominal cavity, most commonly the stomach, herniate through the esophageal hiatus into the mediastinum. HH is defined by the distance between the esophagogastric junction (EGJ) and the diaphragm.

Under normal conditions, the esophagus is anchored to the diaphragm, which precludes the displacement of the stomach into the mediastinum. The main restraining structures are the phrenoesophageal ligaments that insert circumferentially into the esophageal musculature close to the squamocolumnar junction.

The EGJ is a mobile structure, with its mobility dependent on the contractile activity of the longitudinal muscle of the distal esophagus and the integrity and elastic properties of the phrenoesophageal membrane. This mobility complicates the detection and measurement of type I hiatal hernia, which is by far the most common type. Minimal perturbations, such as swallowing, esophageal distention, and esophageal instrumentation, are associated with esophageal shortening (and hence EGJ–hiatus disassociation) in the range of 2 cm. These perturbations are common in endoscopy and barium swallow, the two most common methods of diagnosing HH, and may explain the enormous variation in prevalence estimates, which range from 10% to 80% in North American populations. HH types II, III, and IV are easy to diagnose, but together constitute less than 15% of all HH cases [1].

J. Daes (✉)
Department of Minimally Invasive Surgery, Clinica Portoazul, Barranquilla, Colombia

A. Hanssen
Department of Surgery, Clinica Portoazul, Barranquilla, Colombia

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_16

16.2 Hiatal Hernia and Gastroesophageal Reflux Disease

The presence of HH is a known risk factor for gastroesophageal reflux disease (GERD) in both the general population and individuals with obesity, with many mechanisms involved [2]. The prevalence of HH and GERD in bariatric patients varies among studies, in part because of inherent difficulties in diagnosing HH and the wide variation in protocols for evaluating these patients.

In a retrospective study of 1389 patients, Wilson and colleagues found that excessive body weight was a significant independent risk factor for HH and was significantly associated with esophagitis, largely because of the increased prevalence of HH in these patients. They found that individuals with obesity were four times more likely than thin individuals to have HH and that a diagnosis of HH was associated with a fourfold increase in the likelihood of esophagitis [3].

We reported on a cohort of 373 patients who underwent laparoscopic sleeve gastrectomy (LSG), with a follow-up period of up to 22 months. All patients were evaluated preoperatively and intraoperatively for the presence of HH. Roughly 40% of patients had HH. Our evaluation revealed that 74% of patients with HH and 85% of patients with large HH had preoperative GERD [4].

16.3 Management of Hiatal Hernia During Laparoscopic Sleeve Gastrectomy

Because there is a clear correlation between HH and GERD in patients with obesity, it is logical that HH repair (HHR) should be part of bariatric procedures, as shown early in the adjustable gastric banding experience and in our own early LSG experience. However, the current literature shows no consensus on HHR during bariatric surgery. Some surgeons believe that the presence of GERD and/or HH is a relative contraindication for LSG and that a Roux-en-Y gastric bypass (RYGB) is a more suitable option for these patients [5]. However, others believe that aggressive search and repair of HH during LSG reduces the risk of postoperative GERD [6].

Many studies have concluded that HHR in patients undergoing LSG reduces GERD rates after surgery [4, 7–9]. The first systematic review to examine the efficacy and technical aspects of simultaneous LSG and HHR concluded that the combined approach is safe and effective and results in acceptable postoperative GERD rates, with 16 of 17 studies showing good outcomes; the authors therefore recommended this combined approach [10]. A prospective study evaluating the use of mesh to reinforce HHR during LSG concluded that even without mesh reinforcement the HHR group had a GERD rate of 10.5% at 21 months, with persistent GERD in 5.8% of patients and no de novo GERD cases [11]. However, some reports have found no difference in GERD rates after LSG with versus without HHR [12–14]. A prospective series comparing LSG with versus without HHR [15] found no difference in GERD rates, even when HH was present and not corrected. In that series the mean hernia size was small (1.0–1.5 cm). Notably, the entire group showed significant improvement in GERD rates after surgery, which suggests other beneficial effects, probably related to weight loss.

Dakour-Aridi conducted a review of the ACS-NSQIP database and found that 32,581 patients underwent LSG between 2010 and 2014. Of these, 4687 (14.4%) underwent concomitant HHR. The study concluded that HHR concomitant with LSH was safe and well tolerated [16]. The percentage of patients who underwent HHR was low, suggesting that HH was not always diagnosed or corrected by the surgeons. This is in stark contrast with the conclusions from a questionnaire-based survey at the Fourth International Consensus Summit on Sleeve Gastrectomy [17]. Of the 130 surgeons who responded to the questionnaire, 69% reported that they specifically look for HH; the remaining 31% only look for HH if it appears on preoperative studies or if there is a history of GERD. If HH is identified, 89% (114 surgeons) perform repair, whereas 11% do not. This difference in the percentage of surgeons performing HHR may be related to differences between a broad group of general bariatric surgeons and a group with a specific interest in LSG.

In a study involving more than 130,000 patients, Docimo and colleagues reported that concomitant HHR is significantly more commonly performed during LSG than during RYGB, suggesting a marked difference in the intraoperative management of HH across different bariatric procedures [18]. Madalosso et al. evaluated a group of 53 patients after RYGB in which no HHR was performed when HH was present and found abnormal esophageal acid exposure in 30% of patients at 6 months and in 17% at 39 months. However, the difference in acid exposure rates between patients with versus without HH did not reach statistical significance [19].

Paraesophageal hernia repair has been found to be safe and effective when performed simultaneously with bariatric procedures [20, 21].

Sleeve migration through the hiatus has been described and is probably underreported. HHR may not prevent and may exacerbate this complication [22].

16.4 Recommendations Based on the Current Literature

The natural progression of HH, with underreported sleeve and pouch migration and the clear association with GERD development, makes HHR theoretically desirable in all bariatric procedures.

LSG patients should receive long-term follow-up, ideally with endoscopic and functional studies. Data should be tabulated and results carefully analyzed to standardize our approach and improve the reliability of results. If we find a high rate of GERD after sleeve gastrectomy, even after careful HHR, we should offer patients with HH or GERD another procedure, such as RYGB.

We believe that the lack of standardization of bariatric procedures, most notably of LSG, may explain the wide variations in results, especially concerning GERD and the effect of HHR. We believe that careful attention to technical aspects during LSG, including prevention of relative stenosis, even small torsion, and fundus dilation in the sleeve, and an aggressive search for and formal repair of HH may result in lower rates of postoperative GERD.

16.5 Technique of Hiatal Hernia Repair

When HH is present, we completely free the esophageal–gastric union from the left and right crura, divide the phrenoesophageal membrane and periesophageal connective tissues, and continue the dissection well into the mediastinum to ensure a sufficient length of intra-abdominal esophagus (3–4 cm). The HH defect is then closed with nonabsorbable monofilament sutures placed posterior and anterior to the esophagus, depending on the size of the defect and the resulting position of the esophagus. We do not use a calibrating bougie for hiatal closure and are reluctant to use mesh to reinforce hiatal repairs until definitive data confirm the safety and effectiveness of slowly absorbable meshes. Paraesophageal hernias also require careful dissection and resection of the hernia sac.

16.6 Adjunct Procedures

We and others have found that the presence of HH, especially those larger than 3–4 cm, is associated with more severe GERD and a higher likelihood of recurrence after standard HHR correction during LSG. In our evaluation of 373 patients up to 22 months after LSG, 10 patients experienced GERD symptoms during the follow-up period; 8 of these patients had undergone HHR . HH recurred in most of these patients [4]. These findings and the reports of sleeve migration spurred the search for adjunct procedures to improve recurrence and GERD rates after HHR during LSG. A prospective study on the use of slowly resorbable meshes in HH measuring 4 cm or larger demonstrated that mesh reinforcement was an effective option for crural repair during LSG, with no HH recurrence [11]. Other studies have reached similar conclusions, with lower GERD rates after HHR with mesh reinforcement [23].

A feasibility study of phrenoesophagopexy during HHR in combination with LSG, in which nonabsorbable sutures are placed between the esophagus and the hiatal orifice at the 3, 7, and 11 o'clock positions, found the approach to be safe [24].

We are currently evaluating a series of 90 cases of concurrent LSG, HHR, and modified laparoscopic Hill procedure in patients with esophagitis, HH (regardless of size), GERD, or a combination of the three. The previously reported technique incorporates a modified Hill gastropexy with HHR during LSG [25, 26]. Thirty patients of the series have been evaluated for the severity of symptoms before and more than 6 months after surgery using the GERD-Health Related Quality of Life Questionnaire (GERD-HRQL) [27, 28]. Mean total GERD-HRQL was 20.96 before and 7.85 after surgery ($p < 0.01$). All patients are currently being evaluated with upper GI endoscopy and 3D CT scan images.

Other procedures, such as pexy of the Teres ligament and fundoplication, have been described as adjunct procedures during LSG [29, 30].

In conclusion, HHR as part of laparoscopic sleeve gastrectomy continues to be a controversial topic, with most surgeons currently choosing to repair HH during the procedure. An aggressive search for and repair of HH seems advisable for those groups with good results on gastroesophageal reflux symptoms and HH recurrence rates. Adjunct measures, including mesh reinforcement of crural closure, phreno-esophagopexy, or the Hill procedure, may improve results in selected cases.

Acknowledgments We thank Rebecca Tollefson, DVM, from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

References

1. Kahrilas PJ, Kim HC, Pandolfino JE. Approaches to the diagnosis and grading of hiatal hernia. Best Pract Res Clin Gastroenterol. 2008;22:601–16.
2. Ott DJ, Glauser SJ, Ledbetter MS, Chen MY, Koufman JA, Gelfand DW. Association of hiatal hernia and gastroesophageal reflux: correlation between presence and size of hiatal hernia and 24-hour pH monitoring of the esophagus. AJR. 1995;165:557–9.
3. Wilson LJ, Ma W, Hirschowitz BI. Association of obesity with hiatal hernia and esophagitis. Am J Gastroenterol. 1999;94:2840–4.
4. Daes J, Jimenez ME, Said N, Dennis R. Improvement of gastroesophageal reflux symptoms after standardized laparoscopic sleeve gastrectomy. Obes Surg. 2014;24(4):536–40.
5. Pomp A. Comment on: sleeve gastrectomy and crural repair in obese patients with gastro-esophageal reflux disease and/or hiatal hernia. Surg Obes Relat Dis. 2013;9:361–2.
6. Soricelli E, Iossa A, Casella G, Abbatini F, Calì B, Basso N. Sleeve gastrectomy and crural repair in obese patients with gastroesophageal reflux disease and/or hiatal hernia. Surg Obes Relat Dis. 2013;9:356–61.
7. Lyon A, Gibson SC, Deloyde K, Martin DJ. Gastroesophageal reflux in laparoscopic sleeve gastrectomy: hiatal findings and their management influence outcome. Surg Obes Relat Dis. 2015;11:530–7.
8. El Chaar M, Ezeji G, Claros L, Miletics M, Stoltzfus J. Short-term results of laparoscopic sleeve gastrectomy in combination with hiatal hernia repair: experience in a single accredited center. Obes Surg. 2016;26:68–76.
9. Daes J, Jimenez ME, Said N, et al. Laparoscopic sleeve gastrectomy: symptoms of gastroesophageal reflux can be reduced by changes in surgical technique. Obes Surg. 2012; 22:1874–9.
10. Mahawar KK, Carr WR, Jennings N, Balupuri S, Small PK. Simultaneous sleeve gastrectomy and hiatus hernia repair: a systematic review. Obes Surg. 2015;25:159–66.
11. Ruscio S, Abdelgawad M, Badiali D, Iorio O, Rizzello M, Cavallaro G, Severi C, Silecchia G. Simple versus reinforced cruroplasty in patients submitted to concomitant laparoscopic sleeve gastrectomy: prospective evaluation in a bariatric center of excellence. Surg Endosc. 2016;30:2374–81.
12. Samakar K, McKenzie TJ, Tavakkoli A, Vernon AH, Robinson MK, Shikora SA. The effect of laparoscopic sleeve gastrectomy with concomitant hiatal hernia repair on gastroesophageal reflux disease in the morbidly obese. Obes Surg. 2016;26:61–6.
13. Dakour Aridi H, Asali M, Fouani T, Alami RS, Safadi BY. Gastroesophageal reflux disease after laparoscopic sleeve gastrectomy with concomitant hiatal hernia repair: an unresolved question. Obes Surg. 2017a;27:2898–904.

14. Santonicola A, Angrisani L, Cutolo P, Formisano G, Iovino P. The effect of laparoscopic sleeve gastrectomy with or without hiatal hernia repair on gastroesophageal reflux disease in obese patients. Surg Obes Relat Dis. 2014;10:250–5.
15. Snyder B, Wilson E, Wilson T, Mehta S, Bajwa K, Klein C. A randomized trial comparing reflux symptoms in sleeve gastrectomy patients with or without hiatal hernia repair. Surg Obes Relat Dis. 2016;12:1681–8.
16. Dakour Aridi HN, Tamim H, Mailhac A, Safadi BY. Concomitant hiatal hernia repair with laparoscopic sleeve gastrectomy is safe: analysis of the ACS-NSQIP database. Surg Obes Relat Dis. 2017b;13:379–84.
17. Gagner M, Deitel M, Erickson AL, Crosby RD. Survey on laparoscopic sleeve gastrectomy (LSG) at the Fourth International Consensus Summit on Sleeve Gastrectomy. Obes Surg. 2013;23:2013–7.
18. Docimo S Jr, Rahmana U, Bates A, Talamini M, Pryor A, Spaniolas K. Concomitant hiatal hernia repair is more common in laparoscopic sleeve gastrectomy than during laparoscopic Roux-en-Y gastric bypass: an analysis of 130,772 cases. Obes Surg. 2018; https://doi.org/10.1007/s11695-018-3594-0. [Epub ahead of print].
19. Madalosso CA, Gurski RR, Callegari-Jacques SM, Navarini D, Mazzini G, Pereira MS. The impact of gastric bypass on gastroesophageal reflux disease in morbidly obese patients. Ann Surg. 2016;263:110–6.
20. Pham DV, Protyniak B, Binenbaum SJ, Squillaro A, Borao FJ. Simultaneous laparoscopic paraesophageal hernia repair and sleeve gastrectomy in the morbidly obese. Surg Obes Relat Dis. 2014;10:257–61.
21. Shada AL, Stem M, Funk LM, Greenberg JA, Lidor AO. Concurrent bariatric surgery and paraesophageal hernia repair: comparison of sleeve gastrectomy and Roux-en-Y gastric bypass. Surg Obes Relat Dis. 2018;14:8–13.
22. Saber AA, Shoar S, Khoursheed M. Intra-thoracic sleeve migration (ITSM): an underreported phenomenon after laparoscopic sleeve gastrectomy. Obes Surg. 2017;27:1917–23.
23. Balla A, Quaresima S, Ursi P, Seitaj A, Palmieri L, Badiali D, Paganini AM. Hiatoplasty with crura buttressing versus hiatoplasty alone during laparoscopic sleeve gastrectomy. Gastroenterol Res Prac. 2017, Article ID 6565403. Available at: https://www.ncbi.nlm.nih.gov/pubmed?cmd=search&term=Balla+A%5Bau%5D&dispmax=50.
24. Ellens NR, Simon JE, Kemmeter KD, Barreto TW, Kemmeter PR. Evaluating the feasibility of phrenoesophagopexy during hiatal hernia repair in sleeve gastrectomy patients. Surg Obes Relat Dis. 2017;13:1952–6.
25. Sanchez-Pernaute A, Talavera P, Pérez-Aguirre E, Dominguez-Serrano I, Rubio MA, Torres A. Technique of Hill's gastropexy combined with sleeve gastrectomy for patients with morbid obesity and gastroesophageal reflux disease or hiatal hernia. Obes Surg. 2016;26:910–2.
26. Gero D, Ribeiro-Parenti L, Arapis K, Marmuse JP. Sleeve gastrectomy combined with the simplified Hill repair in the treatment of morbid obesity and gastro-esophageal reflux disease: preliminary results in 14 patients. World J Surg. 2017;41:1035–9.
27. Velanovich V, Vallance SR, Gusz JR, Tapia FV, Harkabus MA. Quality of life scale for gastroesophageal reflux disease. J Am Coll Surg. 1996;183(3):217–24.
28. Velanovich V. The development of the GERD-HRQL symptom severity instrument. Dis Esophagus. 2007;20(2):130–4.
29. Da Silva LE, Alves MM, El-Ajouz TK, Ribeiro PC, Cruz RJ Jr. Laparoscopic sleeve-Collis-Nissen gastroplasty: a safe alternative for morbidly obese patients with gastroesophageal reflux disease. Obes Surg. 2015;25:1217–22.
30. Moon RC, Teixeira AF, Jawad MA. Safety and effectiveness of anterior fundoplication sleeve gastrectomy in patients with severe reflux. Surg Obes Relat Dis. 2017;13:547–52.

Chapter 17
Gastroesophageal Reflux Disease After Sleeve Gastrectomy

Antonio Iannelli and Francesco Martini

17.1 Introduction

Sleeve gastrectomy (SG) is currently the most common bariatric procedure performed worldwide [1, 2] due to its advantages including the low rate of complications, the short operative time, the absence of foreign material, the lack of gastrointestinal anastomosis and malabsorption, the patient's acceptance, and the feasibility to be converted into multiple other bariatric procedures. Indeed, two recent randomized trial showed that SG results in weight loss (WL) and comorbidity resolution and/or improvement that are not significantly different from those recorded after a Roux-en-Y gastric bypass (RYGB) [3, 4].

However, despite all these favorable features, there is an increasing evidence from the literature that the long-term occurrence of gastroesophageal reflux disease (GERD) is likely to represent the Achilles' heel of this procedure [5–9].

The aim of this chapter was to investigate the effect of SG on GERD according to the recent literature.

A. Iannelli (✉)
Digestive Surgery and Liver Transplantation Unit, Centre Hospitalier Universitaire de Nice – Archet 2 Hospital, Nice, France

Université Côte d'Azur, Nice, France
e-mail: iannelli.a@chu-nice.fr

F. Martini
Digestive and Bariatric Surgery Unit, Joseph Ducuing Hospital, Toulouse, France

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_17

17.2 The Heterogeneity of Criteria for GERD Diagnosis and Follow-Up in Bariatric Surgery

GERD is a disorder of the upper gastrointestinal tract that is defined by heartburn and acid regurgitation, which develops when reflux of the stomach contents causes troublesome symptoms and/or complications, according to the evidence-based consensus of the Montreal definition and the classification of gastroesophageal reflux disease, issued in 2006 [10]. GERD impacts on the daily life of affected individuals, interfering with physical activity, impairing social functioning, disturbing sleep, and reducing productivity at work.

Different mechanisms are implicated for the occurrence of GERD and reflux esophagitis, i.e., lower esophageal sphincter (LES) at a mediastinal position and/or with a short intraabdominal length, a low resting LES pressure (LESP), transient relaxation of the LES, increased intraabdominal or intragastric pressure (IGP), decreased esophageal clearance, increased acid sensitivity of the esophageal mucosa, and anatomic abnormalities of the esophagogastric junction (EGJ), such as hiatal hernia (HH). Moreover, hormones and nutritional factors, such as fat or alcohol, can influence the resting LESP.

Obesity is associated with an increased risk of GERD, with up to 50% in morbidly obese patients suffering from this condition [11]. Obesity may promote GERD by increasing intraabdominal pressure and the gastroesophageal pressure gradient, as well as inducing mechanical alterations to the EGJ. Pandolfino [12] found a relationship between increasing BMI and the prevalence of GERD, with a high BMI being associated with an elevated risk of GERD. De Vries et al. [13] found that increasing BMI was independently associated with increased IGP during inspiration and expiration, which was responsible for an increase in the gastroesophageal pressure gradient during inspiration. That study also showed that BMI, IGP, and the gastroesophageal pressure gradient were strong independent predictors for HH, which was the only independent predictor of GERD. Visceral fat, organomegaly, and elasticity of the support core muscles and ligaments also play important roles in generating an elevated IGP. Indeed, not all patients with elevated IGP will develop a HH, and not every patient with a HH will develop GERD. Furthermore, there is no linear correlation with GERD severity.

At endoscopy GERD can range from no visible esophageal injury, named nonerosive reflux disease (NERD), to erosive esophagitis (EE), which can, in turn, give rise to Barrett's esophagus (BE). The latter is a potential factor for the development of esophageal carcinoma [14, 15].

Importantly, esophageal sensitivity varies from one individual to another, and abnormal acid exposure is not always associated with GERD symptoms [16]. Borbely et al. found silent GERD in 25% of morbidly obese patients before SG, defined as objective evidence of GERD (esophagitis Los Angeles grade ≥ B and/or pathological esophageal acid exposure) in absence of symptoms. On the other hand, there is evidence that acid exposure as determined by 24-h pH studies is abnormal in only 45% of NERD patients compared with 75% of patients with EE and that the mean recorded number of reflux events and extent of acid exposure are significantly lower in NERD. Furthermore, it is acknowledged that responses to standard acid suppressive treatments are 20–30% lower in patients with NERD than those with EE. While more than one factor may account for this, evidence to date exists for the contribution of the phenomenon known as visceral hypersensitivity to the pathophysiology of these disorders [17].

The lack of correlation among acid exposure, severity of symptoms, and endoscopic features may be of major importance when explaining the variability of results from studies reporting on SG and GERD.

The quality of studies available in the literature is moderate, mainly due to a relative lack of prospectively based studies and the use of symptom reporting or proton pump inhibitors (PPIs) use instead of standardized questionnaires. Some studies report changes in endoscopic features, but only a minority objectively analyzed patients by esophageal manometry and 24-h pH monitoring. Another factor of heterogeneity is the timing of assessment of GERD prevalence, since the follow-up ranges from 1 month to more than 10 years.

17.3 Review of the Literature Concerning the Effect of Sleeve Gastrectomy on GERD

The analysis of the literature is challenged by the heterogeneity of the studies in regard to the definition of GERD the timing of patients' evaluation. Nevertheless, in spite of some conflicting results, there is a rising evidence for an increase in GERD prevalence after SG, related both to the worsening of preoperative GERD and the appearance of de novo GERD.

We report the results of the most relevant studies in the literature, according to the methods of GERD assessment.

17.3.1 Studies Using Questionnaires for Assessing Prevalence of GERD

We found 14 relevant studies using standardized questionnaires to monitor pre- and postoperative prevalence of GERD symptoms. Conflicting results are reported, with nine studies showing a negative and five studies showing a positive impact of SG on GERD.

For instance, Carter et al. [18] found that among 176 obese patients treated by SG, the incidence of GERD increased from 34.6% to 47.2%. Six other studies [19–24] found a relative increase in GERD symptoms ranging from 7% to 57.1%.

DuPree et al. [25] conducted a retrospective review of the Bariatric Outcomes Longitudinal Database over a 4-year period, including a total of 4832 patients, with preexisting GERD present in 44.5% of cases. Most patients (84.1%) continued to have GERD symptoms postoperatively, with only 15.9% demonstrating GERD resolution. De novo GERD rate was 8.6%.

The recent Swiss study by Borbely et al. [26] included 222 patients, followed up with questionnaires every 6 months, upper endoscopies after 1 year, and 24-h pHmetry after 2 years. SG led to a 52% rate of postoperative GERD, with 73% of patients presenting de novo symptoms. De novo GERD consisted of around half of preoperative silent GERD and completely de novo GERD. Among patients with preoperative silent GERD, 66% became symptomatic.

Analyzing studies with a positive impact of SG on GERD, Carabotti et al. [27] and Mohos et al. [28] only used questionnaires pre- and postoperatively and found a decrease in prevalence of 1.3% and 12.7%, respectively. Santonicola et al. [29] and Sharma et al. [30] used questionnaires, endoscopy, and scintigraphy and found a decrease in prevalence of GERD symptoms of 19.6% and 15.6%, respectively. Rebecchi et al. [31] used questionnaires, endoscopy, manometry, and 24-h pHmetry and found a relative decrease of 56% in reported symptoms. In their review and meta-analysis, Oor et al. [8] analyzed 11 studies using standardized questionnaires, containing a total of 641 patients with a follow-up ranging between 1 and 38 months. They found a pooled risk of 4.3% in prevalence difference between pre- and postoperative GERD.

17.3.2 New-Onset GERD Symptoms

The meta-analysis by Oor et al. [8] found 24 studies investigating new-onset GERD based on symptom evaluation, reporting a wide range of incidence, from 0% to 34.9%, with a follow-up varying between 1 and 60 months. Despite the high amount of heterogeneity among the included studies and a large variation in terms of follow-up, authors concluded that SG could induce serious GERD symptoms among patients without preoperative GERD complaints. A recent multicenter study by Sebastianelli et al. showed an increase in GERD rate from 22% before SG to 76% at more than 5 years after surgery [32]. Interestingly, three consecutive studies by the group of Himpens [33–35] revealed a biphasic pattern in the symptoms of GERD during longer-term follow-up GERD complaints were present in 22% of patients at 1 year, then incidence decreased to 3% at 3 years and grew up again to 23% at 6 years, remaining stable afterward up to more than 11 years (21.4%).

17.3.3 Changes in the Use of Anti-reflux Medications

We found three studies showing a negative influence of SG on PPIs usage and one study with a positive impact.

Catheline et al. found a 200% increase of PPIs use among 45 patients who had undergone a primary SG, with a follow-up of 5 years [36]. Genco et al. showed an increase in PPIs use from 19.1% before SG to 57.2% at a mean follow-up of 66 months after SG [37]. Similarly, Sebastianelli et al. described a rise in patients needing PPIs from 22% to 52% [32]. Rebecchi et al., on the other hand, showed a positive impact of SG on PPIs use. They prospectively analyzed 71 patients undergoing laparoscopic SG, and at 24-month follow-up, the number of patients requiring PPIs decreases by 71% [31].

Two studies compared SG to RYGB. Sheppard et al. found a significant increase in PPIs use in patients following SG compared to RYGB at 1 month to 2 years postoperatively, with a peak at 6 months [38]. Zhang et al. compared the resolution of comorbidities between patients undergoing laparoscopic SG and RYGB with a follow-up of 1 year [39]. No significant difference between pre- and postoperative use of anti-reflux medication was found.

In the analysis of these results, it is important to consider that the usage of anti-reflux medication is not a reliable parameter for GERD measurement since patients can use PPIs for other reasons (gastritis, dyspepsia, etc.…).

17.3.4 New-Onset Esophagitis

Nine studies reported the incidence of new-onset esophagitis, ranging from 6.3% to 63.3%, after a follow-up ranging between 1 and more than 10 years [20, 21, 26, 31, 32, 37, 40–43]. Among these studies, Sebastianelli et al. reported an increase in EE from 10% to 41% at more than 5 years after surgery, while the group of Genco showed 59.8% of new-onset EE at a mean follow-up of 66 months. Felsenreich et al. found a 30% incidence of EE at more than 10 years. A correlation between GERD symptoms and EE was found in two studies [32, 41], while two others found a lack of correlation [40, 42]. Lim et al. found a trend suggesting higher prevalence of EE with a sleeve diameter > 2 cm [40].

17.3.5 New-Onset Barrett's Esophagus

Genco et al. first published the alarming systematic endoscopy results of 17.2% of 110 patients with BE after SG at a median follow-up of 58 months [37]. The authors also reported that 26.4% of patients with BE had no GERD symptoms, while the rate of upward migration of the "Z" line was 73%, and the incidence and the severity of EE were increased. Soricelli et al. from the same group confirmed that 21% of patients with evidence of BE had no symptoms of GERD [42].

Felsenreich et al. also reported a high prevalence of BE of 15% at 10 years after SG that was associated with 45% of EE, while only 37% of patients complained of GERD symptoms [43]. The multicentric study by Sebastianelli et al. [32] confirmed a high prevalence of BE (18.8%) at the mean follow-up of 78 months, ranging from 60 to 132 months. All but one patient with evidence of BE complained of GERD symptoms, and 35% of them required systematic PPIs to control symptoms. Furthermore, there was no significant difference in the prevalence of BE among the five centers included. These data suggest that the incidence of BE after SG is independent of the surgical technique. Another novel result of this study was that weight loss failure (WLF) was the only factor significantly associated to BE at multivariate analysis.

17.3.6 Esophageal Adenocarcinoma

To our knowledge, only four cases of esophageal adenocarcinoma after SG have been reported to date in the literature. Two case reports [44, 45] described esophageal adenocarcinoma 4 months and 2.5 years after SG in two patients without previous endoscopic evaluation. Wright et al. [46] described esophageal adenocarcinoma 5 years after SG in a patient with normal previous preoperative gastroscopy. At the time of diagnosis, there was evidence of regional lymph node involvement, and liver metastases were detected during restaging after neoadjuvant chemoradiotherapy. El Khoury et al. [47] reported the case of a 55-year-old female patient who presented lower esophageal adenocarcinoma 3 years after complicated SG with known preoperative BE without dysplasia detected by gastroscopy. Multidisciplinary decision suggested treatment by endoscopic mucosectomy. The endoscopic control at 1 year did not highlight tumoral recurrence but still BE without dysplasia.

17.3.7 Changes in 24-H pHmetry Results

Four studies reported data following 24-h pH measuring as an objective instrument for determining the effect of SG on the prevalence of GERD. There appear to be controversial results regarding total acid exposure with three studies [22, 23, 48] showing a significant increase at 3-, 12-, and 12-month follow-up, respectively, while the study by Rebecchi et al. [31] found a significant decrease within the group of patients with pathologic preoperative 24-h pH results at 24-month FU. In particular, Gorodner et al. [23] prospectively assessed the esophageal function in 14 obese patients preoperatively and at 1 year after SG. The DeMeester score (DMS) increased from 12.6 to 28.4 ($p < 0.05$): the number of episodes longer than 5 min, the duration of longest episode, and the total acid exposure increased. Overall, de novo GERD developed in five (36%) patients, while preexisting GERD worsened in three (21%) patients. Similarly, Burgerhart et al. [22] found an increase in total acid exposure of 193% 3 months after laparoscopic SG. Coupaye et al. [48] also found that acid exposure time increased significantly 1 year after SG, with a de novo GERD rate of 52%.

Conversely, in a prospective study involving 65 patients (28 patients with preoperative pathological esophageal acid exposure and 37 patients with normal pH results), Rebecchi et al. [31] found SG to improve GERD. Within the pathologic group and the normal group, a postoperative decrease in total esophageal acid exposure of 58.8% and an increase of 9.4% respectively were found. De novo GERD was detected in only 5.4% of patients. The validity of their conclusions, however, is tempered by the loss to follow-up of approximately 40% of patients. Furthermore, they arbitrarily excluded some patients with abnormal pH results, stating that it was caused by retention of food in the proximal portion of the sleeve. Those patients were not considered to have pathologic reflux [49].

17.3.8 Changes in Combined pH-Impedance Results

In four studies, the effect of SG on GERD was determined using combined pH-impedance measurements. All studies showed a significant increase in acid exposure and number of reflux episodes, both acid and nonacid. Del Genio et al. [50] reported the results in a series of 25 obese patients with no preoperative GERD, who were evaluated with 24-h multichannel intraluminal impedance-pHmetry (MIIpH) monitoring preoperatively and 13 months postoperatively. They detected a significant increase in the median DMS, in the median percentage with esophageal pH < 4 in supine position, in the total number of reflux episodes and nonacid reflux episodes in both upright and recumbent position. Burgerhart et al. [22] also published a prospective study using 24-h MIIpH and concluded that SG increases esophageal acid exposure at 3 months after SG. Tolone et al. [51] found a significant increase in esophageal acid exposure and number of reflux episodes (both acid and alkaline) in 15 patients 1 year after SG. Georgia et al. [52] prospectively studied 12 obese patients without preoperative reflux symptoms by using 24-h MIIpH before and 1 year after LSG. DMS was abnormal in five patients (42.7%) before SG and in ten patients (83.3%) postoperatively. At 1 year after surgery, DMS was almost 2.5 times higher than before SG. The number of acid and especially nonacid reflux episodes increased, so did the number of reflux episodes that reaches the proximal esophagus.

17.3.9 Changes in Manometry Results

Concerning changes in LESP, controversial data are presented in the literature, with three studies reporting a significant decrease in LESP, two studies reporting a significant increase, and three studies reporting no significant changes in LESP following SG. Explanations for these discrepancies could be the variable time from surgery and the different methods and parameters used for esophageal assessment.

Three studies report a significant decrease in lower esophageal resting pressure (LESP) ranging from 26.1% to 39.9% with a follow-up ranging from 3 to 12 months following laparoscopic SG [20, 22, 23]. In particular, Braghetto et al. [20] prospectively evaluated 20 patients and showed that LESP significantly decreased in 85% of cases 6 months after surgery. Total length and abdominal length of the high-pressure zone were also reduced. The authors proposed the partial section of the sling fibers of the cardias as cause of these findings. Within both their two subgroups of patients, Rebecchi et al. [31] found no significant difference in pre- and postoperative LESP. Similarly Coupaye et al. [48] and Tolone et al. found no significant change in EGJ function. Paradoxically, Kleidi et al. [53] reported a significant increase in LESP of 12% at 1.5 month of follow-up. Petersen et al. [54] similarly found a significant increase of LESP of 118% and 153% at 6 days and 8 months following SG, respectively. LESP increased regardless of the WL, leading Petersen et al. to suggest that this manometric change is related to the position of the stapler in relation to the angle of His. Specifically, the closer the staple line to the EGJ, the higher the LESP.

Four studies [48, 50, 51, 55] reported on changes in esophageal motility following laparoscopic SG and were concordant in showing a significant increase in ineffective esophageal motility at 1 year after surgery.

Three studies [48, 51, 55] reported on maximal IGP after swallow and were concordant in showing that SG significantly increases IGP. In particular Coupaye et al. [48] found 50% patients with increased IGP after surgery, in accordance with 77% patients reported in the study of Mion et al. [55].

17.3.10 Role of Concomitant Hiatal Hernia Repair

The presence of a HH is not considered by many bariatric surgeons a contraindication to SG [56]. Indeed, 83% of participants to the International Sleeve Gastrectomy Expert Panel [57] agreed on an aggressive approach to identify and subsequently repair intraoperatively diagnosed HH when performing laparoscopic SG and considered HH a relative contraindication to SG unless repaired adequately. Furthermore, some authors suggest the need to assess hiatal crura preoperatively for the presence of a HH that may be missed at preoperative imaging and endoscopy [9].

However, the current evidence on this topic is limited by several factors: (1) there are very few studies including more than 100 patients; (2) mean follow-up is short; and (3) those studies that describe the HH repair (HHR) report different ways to close the hiatus – suture posterior cruroplasty (most common), suture anterior cruroplasty, and hiatal herniorrhaphy with mesh (biological or polypropylene mesh). In addition, all studies based their results on symptom evaluation without assessing postoperative GERD by 24-h pH monitoring.

We found seven studies showing a positive impact of concomitant HHR on postoperative GERD and only one study with a negative influence.

Sheppard et al. [38] reported that 15% of their 378 patients were found to have a significant HH requiring repair. There were no significant differences in GERD rates between patients with and without a HH, and no differences between those who had their HH repaired during surgery compared to those who did not. Daes et al. [58] reported on simultaneous SG and HHR in 142 patients out of 382 undergoing SG and found that only 8 patients (5.6%) suffered with GERD postoperatively. Of the remaining 240 patients, who did not have a HH intraoperatively, only two developed GERD postoperatively. Soricelli et al. [59] compared patients undergoing SG with patients undergoing SG and HHR. Of the patients diagnosed with a HH, 42% reported preoperative GERD symptoms, which disappeared in more than 80% of them at a mean follow-up of 18 months. In addition, the postoperative development of de novo reflux symptoms was significantly greater in patients who underwent a SG without HHR compared to those with HHR (22.9% vs 0%, $p = 0.01$). Genco et al. [37] found that incidence and severity of GERD symptoms, as well as incidence of BE, were lower, although not significantly so, in 16 SG patients with HHR than in 94 patients who underwent SG alone. Soliman [60] reported favorable results in 20 patients who had concomitant SG and a posterior crural repair. Interestingly, two of the patients with a large HH (>5 cm) had a polypropylene mesh repair. Thirteen patients reported resolution of GERD symptoms, and five reported improvement leading to minimal doses of PPIs at a mean follow-up of 7 months.

Gibson et al. [61] analyzed the results of SG and HHR in 500 patients. Interestingly, an anterior repair was performed in 265 patients and a posterior repair in 30 patients. The prevalence of GERD was reduced from 45% preoperatively to 6% postoperatively, and postoperative GERD was well controlled in all patients with PPI therapy. The use of a mesh in HH repair has been described by Ruscio et al. [62], who reported no mortality and no mesh-related complications in 48 patients undergoing LSG with onlay synthetic absorbable mesh-reinforced cruroplasty for a large HH (hiatal area defect >4 and < 8 cm^2). With a mean follow-up of 19 months, GERD symptoms resolved in 95% of patients, while de novo GERD symptoms developed in 3.6% of patients.

Santonicola et al. [29] reported that laparoscopic SG with concomitant HHR did not lead to an improvement in GERD symptoms and even resulted in a higher heartburn frequency-intensity scores. This is the only study not supporting positive results of HHR in terms of GERD control.

In their systematic review, in which case series and case reports were also included, Mahawar et al. [63] conclude that concomitant HHR is a safe procedure and can be recommended as an acceptable management strategy for obese patients with HH, providing acceptable postoperative GERD rates.

Concomitant HHR is challenging, since loose approximation of the hiatus predisposes to migration of the sleeve, whereas tight approximation predisposes to stenosis and dysphagia. Although the abovementioned studies support the positive effect of concomitant HHR, further randomized controlled trials comparing different techniques and providing long-term FU, as well as standardization of the technique of both laparoscopic SG and HHR, are needed to provide adequate information regarding the additional effect of HHR on GERD.

17.3.11 LSG with Anti-reflux Procedure

Two studies associated SG with an additional anti-reflux procedure.

Santoro et al. [64] selected obese patients with preoperative GERD. In addition to a laparoscopic SG, they also performed an anti-reflux procedure, consisting of hiatoplasty and cardioplication. They concluded that this did not add any morbidity nor influence WL but that it led to a significant reduction in the occurrence of GERD symptoms compared to laparoscopic SG alone, with a mean follow-up of 22 months. Nocca et al. [65] included 25 consecutive patients with preoperative GERD and operated on with a Nissen anti-reflux valve added to a standard SG, creating a so-called Nissen-Sleeve (N-Sleeve) gastrectomy. At 1 year only three (12%) patients were still complaining of reflux. They concluded the N-Sleeve to be a safe procedure which provides an adequate reflux control with no clear interference on the expected bariatric results of a standard SG.

17.4 Mechanisms Involved in Worsening or Improving GERD After SG

Two main factors are related to the occurrence of GERD after SG:

1. The transformation of a large compliant stomach into a long and narrow tube implies a lack of gastric compliance, with an increased IGP that correlates inversely with the diameter of the gastric tube and is increased when the pylorus is closed.
2. The dismantling of the anatomical anti-reflux mechanisms, including disruption to the His angle and resection of the sling fibers in the distal part of the lower sphincter, results in low LESP and sometimes in the herniation of part of the gastric sleeve into the posterior mediastinum.

Conversely, four main principles seem to explain the improvement of GERD after a SG, through the diminution in gastric refluxate [30, 31]:

1. The decrease in intraabdominal pressure due to WL
2. The reduced acid production related to resection of the acid-producing gastric fundus
3. The accelerated gastric emptying
4. The reduced gastric volume

The timing of assessment of GERD prevalence could play a role in explaining the wide variability of the results of the abovementioned studies whose follow-up ranged from 1 month to more than 10 years. Indeed, intraabdominal pressure depends on BMI, and long-term studies show a high rate of WLF after SG [43, 66]. Sebastianelli et al. found that WLF was significantly associated to BE. This result is in key with the previous study by Angrisani et al. in which the absence of GERD was associated with better WL results at 5 years [67].

Moreover, gastric dilatation is common after SG. Braghetto et al. [68] reported data on 15 SG patients undergoing CT scan gastric volumetry on postoperative day 3 and, repeatedly, at 24–36 months after surgery and found that the mean gastric volume had increased from 108 to 250 ml.

The link between GERD and WLF is still unclear; however, a few hypotheses can be done. First, in WLF, often the SG is dilated especially at the level of the remnant acid-secreting gastric fundus. This may, in turn, account for the loss of restriction with weight regain and increased GERD. Furthermore, the presence of GERD symptoms might modify eating behavior leading patients to eat more frequently to buffer acid.

17.5 The Influence of Surgical Technique on Postoperative GERD

There is increasing evidence supporting the key role of the surgical technique on the incidence of postoperative GERD.

Main surgical technical issues are

(a) The shape of the sleeve
(b) The size of the calibration tube
(c) The repair of a concomitant HH

The shape of the gastric sleeve is likely to play a major role in leading to GERD [69]. Technical mistakes include a relative narrowing at the junction between the vertical and horizontal parts of the sleeve, twisting of the sleeve [70], anatomical stenosis, funnel shape, and persistence of the gastric fundus. The role of the gastric antrum has not been fully clarified, but it is thought that extensive resection of the antrum may impair gastric emptying and favor GERD.

It has been speculated that the relative mid-gastric narrowing impairs the emptying of the upper part of the sleeve, causing food stasis and fermentation, while the retained fundus keeps producing acid, thus favoring the onset of reflux of acid gastric contents into the esophagus.

Keidar et al. [71] reviewed the UGI series obtained on postoperative day 1 in eight patients who developed postoperative GERD. They found that a combination of dilated upper portion of the sleeve and a relative narrowing of the mid-stomach was present in all patients. Similar findings were reported by Toro et al. [72]. They reviewed 76 patients who had routine UGI series on postoperative day 1 or 2 after SG and completed the GERD-HRQL score. Sleeve shape was classified as upper pouch, lower pouch, tubular, or dumbbell. At 12 months, 59.2% of patients did not report any GERD-related symptom, while only 7.8% complained moderate to severe reflux symptoms. Patients with the upper pouch shape had the highest severity of symptoms according to the GERD-HRQL score. The lower pouch shape was on the contrary associated with fewer GERD symptoms, suggesting an effective gastric emptying when the antrum is preserved.

The impact of the size of the bougie on the prevention of sleeve narrowing and GERD is unclear, since there is no standardization of the surgical technique, the diameter of the bougies used ranging between 26 Fr and 50 Fr [8]. One could hypothesize that using a small-sized bougie leads to disruption of a relative larger portion of the angle of His and a relative higher IGP, thereby potentially causing GERD symptoms. On the other hand, using a larger bougie size can cause weight regain and GERD symptoms due to an increased number of residual parietal cells [40]. Due to the small amount of studies using objective esophageal function tests, no conclusions regarding the association between bougie size and gastroesophageal function can be made.

The role of the concomitant HHR has been previously discussed in a dedicated paragraph.

On the base of the abovementioned studies, most authors conclude that with careful attention to the technical aspects of SG, including HHR and the proper angle under which to staple the sleeve, significantly reduced occurrence of GERD symptoms can be achieved. The recent multicentric study by Sebastianelli et al. [32] is likely to reopen the debate since they found no significant difference in the prevalence of BE among the five centers included at the mean follow-up of 78 months suggesting that is independently of the surgical technique.

17.6 Comparison Between the Impact of Sleeve Gastrectomy and Roux-en-Y Gastric Bypass on Postoperative GERD

A RYGB is considered the most effective bariatric procedure for GERD symptoms as it limits acid production into the small gastric pouch and reduces esophageal reflux because of the Roux-en-Y anatomy, which also retains the physical activity of the esophagus and gastric pouch within the abdomen [73]. Several studies have confirmed that a RYGB decreases exposure of acid to the esophagus [74–76].

Kim et al. [73] showed that conversion of a failed Nissen fundoplication to a RYGB resulted in excellent control of symptoms. Accordingly, Mion et al. [76] and Madalosso et al. [77] found similar results for a RYGB for GERD. Lastly, De Groot et al. [78] compared RYGB with restrictive procedures, such as gastric banding and vertical-banded gastroplasty, and found better control of symptoms associated with a RYGB. In this study, no data were available for SG as it is a relatively recent procedure. Mehaffey et al. [79] showed a significant reduction in GERD prevalence from 38.4% preoperatively to 28.6% at 10 years after RYGB.

Several studies compared the influence of SG and RYGB on GERD. All studies found RYGB to be significantly superior to SG in improving GERD.

Dupree et al. [25] analyzed a total of 4832 patients operated on for SG and 33,867 operated on for RYGB, with preexisting GERD present in 44.5% of the SG cohort and 50.4% of the RYGB cohort. GERD was assessed by questionnaires before and at 6 months after surgery. Most SG patients (84.1%) continued to have GERD symptoms postoperatively, with only 15.9% demonstrating GERD resolution. In addition, 9.0% of SG patients had worsening of their GERD symptoms postoperatively. Of LSG patients who did not demonstrate preoperative GERD, 8.6% developed de novo GERD postoperatively. In comparison, RYGB was associated with complete resolution of GERD symptoms in most patients (62.8%), stabilization of symptoms in 17.6%, and worsening of symptoms in 2.2% (all $p < 0.05$ vs SG).

Pallati et al. [80] reviewed a total of 22,870 patients with 6-month follow-up included in the Bariatric Outcomes Longitudinal Database, with evidence of GERD preoperatively. They found that GERD score improvement was best in RYGB patients (56.5%) followed by gastric banding (46%) and SG patients (41%).

In the randomized clinical trial of Peterli et al. [3], at the time of surgery, 44 (43.6%) of 101 patients in the SG group and 48 (46.2%) of 104 patients in the RYGB group experienced some degree of GERD. After 5 years, remission of reflux symptoms was seen in 25% of the SG group and in 60.4% of the RYGB group, and worsening of symptoms was more often seen in the SG group (31.8% vs 6.3%). In addition, 31.6% of patients who had no GERD at baseline reported de novo reflux symptoms 5 years after SG vs only 10.7% after RYGB (all $p < 0.05$).

17.7 High Incidence of Barrett's Esophagus After Sleeve Gastrectomy: The Need for an Endoscopic Surveillance

As already discussed in a previous paragraph, an alarming BE prevalence of 15–18.8% was found in three recent independent studies at 5–10-year follow-up, without correlation with GERD symptoms [32, 37, 43]. The policy of adopting systematic endoscopic exploration beyond 5 years after SG seems therefore to be judicious and appropriate especially in young patients. In the absence of correlation between BE prevalence and GERD symptoms, this policy should not rely on the presence of GERD symptoms.

Current recommendations on BE screening do not refer specifically to patients in the setting of bariatric surgery. Indeed, whereas SG is widely performed worldwide since more than a decade and it has been largely used as the restrictive part of the biliopancreatic diversion with duodenal switch, the occurrence of esophageal adenocarcinoma on BE remains an exceptional clinical entity [46, 47]. This may suggest that the process of malignant transformation due to GERD in the lower esophagus in the setting of SG may not be the same as in individuals without a history of SG. Although there is no clear explanation for this difference yet, a few hypotheses may be proposed. The effect of gastrectomy may alter the chemical characteristics of the refluxate, blunting its carcinogenic effect on the esophageal epithelium, and the time interval required for the malignant transformation may be longer in this setting. Obesity has also been shown to be a risk factor for esophageal adenocarcinoma independently of GERD, and the achieved WL may thus exert a protective effect [81].

As the magnitude of risk associated with malignant transformation of BE in the setting of SG is still not clear, the debate concerning the right attitude toward BE in patients with SG is still open. One possibility might be the use of systematic endoscopic surveillance as it is currently done in patients with BE who have no history of SG [82]. The alternative approach is a conversion to RYGB [83–86]. Indeed, the latter works as an anti-reflux procedure because the Roux-en-Y loop anatomy avoids bile reflux, and the small, lesser curvature-based gastric pouch excluding the acid-secreting gastric fundus dramatically limits the production of hydrochloric acid that may come in contact with the esophagus. It should be stressed that a conversional RYGB for GERD to address a SG complication should be done with a short gastric pouch excluding the gastric fundus. In cases of WLF, this tiny pouch can be coupled with a calibrated gastrojejunal anastomosis of 12 mm, which adds a strong restrictive effect to the anti-reflux effect of the RYGB to induce further WL. As the effect of a RYGB conversion on the evolution of Barrett's mucosa is still unclear, endoscopic surveillance should be wisely performed in this setting [87]. Furthermore, as the RYGB also dramatically reduces the symptoms of GERD, it might add further WL in patients presenting with insufficient WL or weight regain, representing an interesting alternative in those patients with WLF and BE [8]. Indeed, a significant association between BE and WLF was found by Sebastianelli et al. [32], suggesting that converting a failed SG to RYGB may represent a valuable option in a large proportion of these patients. The use of endoscopic techniques to retrieve metaplastic mucosa has also been proposed [88].

17.8 Conclusion

Despite all advantages of SG, there is increasing evidence from the literature that the long-term occurrence of GERD represents the Achilles' heel of this procedure.

Two anatomical factors are likely to favor GERD after SG: the reduction of the gastric compliance, with an increased IGP, and the dismantling of the anatomical anti-reflux mechanisms. The decrease in intraabdominal pressure due to WL is likely to partially counterbalance the previous factors, but its protective effect may be limited on the long term by a high rate of WLF.

The quality of studies in the literature concerning the effect of SG on GERD is moderate, mainly due to a relative lack of prospectively based studies and the use of symptom reporting and retrospective chart analysis instead of standardized questionnaires. Some studies report changes in endoscopic features, but only a minority report the outcomes of 24-h pH monitoring or esophageal manometry.

Moreover, the lack of correlation among acid exposure, severity of symptoms, and endoscopic features may be of major importance when explaining the variability of results from studies reporting on SG and GERD.

The use of validated questionnaires before and after surgery could be useful to improve the standardization of symptoms assessment, while the usage of anti-reflux medication such as PPIs correlates poorly with the presence of objectified GERD and should be discouraged.

Concerning invasive studies, endoscopic assessment is mandatory in preoperative workup, while the usage of esophageal function tests, providing the most objective answer to the influence of SG on GERD, is likely to remain limited to clinical research and complicated cases in clinical practice.

Despite the abovementioned limits, all recent studies with more than 5-year follow-up are concordant in showing an increase in GERD prevalence after SG, related both to the worsening of preoperative GERD and the appearance of de novo GERD. In particular, three recent studies [32, 37, 43] have shown an alarming BE prevalence of 15–18.8% at 5–10-year follow-up. Such a similarity in BE prevalence among different centers may hardly be explained by differences in surgical technique. Therefore, the policy of adopting systematic endoscopic exploration long term after SG seems to be judicious and appropriate especially in young patients.

As the magnitude of risk associated with malignant transformation of BE in the setting of SG is still not clear, the debate concerning the right attitude toward BE in patients with SG is still open. One possibility might be the use of systematic endoscopic surveillance as it is currently done in patients with BE who have no history of SG; the alternative approach is a conversion to RYGB in reason of its anti-reflux effect.

References

1. Angrisani L. The year of the sleeve supremacy. Obes Surg. 2014;2017(27):1626–7.
2. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J, et al. IFSO Worldwide Survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28:3783–94.
3. Peterli R, Wolnerhanssen BK, Peters T, Vetter D, Kroll D, Borbely Y, et al. Effect of laparoscopic sleeve gastrectomy vs laparoscopic Roux-en-Y gastric bypass on weight loss in patients with morbid obesity: the SM-BOSS randomized clinical trial. JAMA. 2018;319:255–65.
4. Salminen P, Helmio M, Ovaska J, Juuti A, Leivonen M, Peromaa-Haavisto P, et al. Effect of laparoscopic sleeve gastrectomy vs laparoscopic Roux-en-Y gastric bypass on weight loss at 5 years among patients with morbid obesity: the SLEEVEPASS randomized clinical trial. JAMA. 2018;319:241–54.
5. Chiu S, Birch DW, Shi X, Sharma AM, Karmali S. Effect of sleeve gastrectomy on gastroesophageal reflux disease: a systematic review. Surg Obes Relat Dis. 2011;7:510–5.
6. Hendricks L, Alvarenga E, Dhanabalsamy N, Lo Menzo E, Szomstein S, Rosenthal R. Impact of sleeve gastrectomy on gastroesophageal reflux disease in a morbidly obese population undergoing bariatric surgery. Surg Obes Relat Dis. 2016;12:511–7.
7. Iannelli A, Sans A, Martini F, Santonicola A, Iovino P, Angrisani L. Hiatal hernia, GERD, and sleeve gastrectomy: a complex interplay. Obes Surg. 2016;26:2485–7.

8. Oor JE, Roks DJ, Unlu C, Hazebroek EJ. Laparoscopic sleeve gastrectomy and gastroesophageal reflux disease: a systematic review and meta-analysis. Am J Surg. 2016;211:250–67.
9. Stenard F, Iannelli A. Laparoscopic sleeve gastrectomy and gastroesophageal reflux. World J Gastroenterol. 2015;21:10348–57.
10. Vakil N, van Zanten SV, Kahrilas P, Dent J, Jones R. The Montreal definition and classification of gastroesophageal reflux disease: a global evidence-based consensus. Am J Gastroenterol. 2006;101:1900–20.
11. Doulami G, Triantafyllou S, Natoudi M, Albanopoulos K, Leandros E, Zografos G, et al. GERD-related questionnaires and obese population: can they really reflect the severity of the disease and the impact of GERD on quality of patients' life? Obes Surg. 2015;25:1882–5.
12. Pandolfino JE. The relationship between obesity and GERD: "big or overblown". Am J Gastroenterol. 2008;103:1355–7.
13. De Vries DR, van Herwaarden MA, Smout AJ, Samsom M. Gastroesophageal pressure gradients in gastroesophageal reflux disease: relations with hiatal hernia, body mass index, and esophageal acid exposure. Am J Gastroenterol. 2008;103:1349–54.
14. Drahos J, Li L, Jick SS, Cook MB. Metabolic syndrome in relation to Barrett's esophagus and esophageal adenocarcinoma: results from a large population-based case-control study in the Clinical Practice Research Datalink. Cancer Epidemiol. 2016;42:9–14.
15. Eisen GM, Sandler RS, Murray S, Gottfried M. The relationship between gastroesophageal reflux disease and its complications with Barrett's esophagus. Am J Gastroenterol. 1997;92:27–31.
16. Ronkainen J, Aro P, Storskrubb T, Johansson SE, Lind T, Bolling-Sternevald E, et al. High prevalence of gastroesophageal reflux symptoms and esophagitis with or without symptoms in the general adult Swedish population: a Kalixanda study report. Scand J Gastroenterol. 2005;40:275–85.
17. Knowles CH, Aziz Q. Visceral hypersensitivity in non-erosive reflux disease. Gut. 2008;57:674–83.
18. Carter PR, LeBlanc KA, Hausmann MG, Kleinpeter KP, deBarros SN, Jones SM. Association between gastroesophageal reflux disease and laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2011;7:569–72.
19. Howard DD, Caban AM, Cendan JC, Ben-David K. Gastroesophageal reflux after sleeve gastrectomy in morbidly obese patients. Surg Obes Relat Dis. 2011;7:709–13.
20. Braghetto I, Csendes A, Korn O, Valladares H, Gonzalez P, Henriquez A. Gastroesophageal reflux disease after sleeve gastrectomy. Surg Laparosc Endosc Percutan Tech. 2010;20:148–53.
21. Tai CM, Huang CK. Increase in gastroesophageal reflux disease symptoms and erosive esophagitis 1 year after laparoscopic sleeve gastrectomy among obese adults. Surg Endosc. 2013;27:3937.
22. Burgerhart JS, Schotborgh CA, Schoon EJ, Smulders JF, van de Meeberg PC, Siersema PD, et al. Effect of sleeve gastrectomy on gastroesophageal reflux. Obes Surg. 2014;24:1436–41.
23. Gorodner V, Buxhoeveden R, Clemente G, Sole L, Caro L, Grigaites A. Does laparoscopic sleeve gastrectomy have any influence on gastroesophageal reflux disease? Preliminary results. Surg Endosc. 2015;29:1760–8.
24. Moon RC, Teixeira AF, Jawad MA. Is preoperative manometry necessary for evaluating reflux symptoms in sleeve gastrectomy patients? Surg Obes Relat Dis. 2015;11:546–51.
25. DuPree CE, Blair K, Steele SR, Martin MJ. Laparoscopic sleeve gastrectomy in patients with preexisting gastroesophageal reflux disease : a national analysis. JAMA Surg. 2014;149:328–34.
26. Borbely Y, et al. De novo gastroesophageal reflux disease after sleeve gastrectomy: role of preoperative silent reflux. Surg Endosc. 2019;33:789–93.
27. Carabotti M, Silecchia G, Greco F, Leonetti F, Piretta L, Rengo M, et al. Impact of laparoscopic sleeve gastrectomy on upper gastrointestinal symptoms. Obes Surg. 2013;23:1551–7.
28. Mohos E, Schmaldienst E, Prager M. Quality of life parameters, weight change and improvement of co-morbidities after laparoscopic Roux Y gastric bypass and laparoscopic gastric sleeve resection--comparative study. Obes Surg. 2011;21:288–94.

29. Santonicola A, Angrisani L, Cutolo P, Formisano G, Iovino P. The effect of laparoscopic sleeve gastrectomy with or without hiatal hernia repair on gastroesophageal reflux disease in obese patients. Surg Obes Relat Dis. 2014;10:250–5.
30. Sharma A, Aggarwal S, Ahuja V, Bal C. Evaluation of gastroesophageal reflux before and after sleeve gastrectomy using symptom scoring, scintigraphy, and endoscopy. Surg Obes Relat Dis. 2014;10:600–5.
31. Rebecchi F, Allaix ME, Giaccone C, Ugliono E, Scozzari G, Morino M. Gastroesophageal reflux disease and laparoscopic sleeve gastrectomy: a physiopathologic evaluation. Ann Surg. 2014;260:909–14; discussion 914–905.
32. Sebastianelli L, et al. Systematic endoscopy 5 years after sleeve gastrectomy results in a high rate of Barrett's esophagus: results of a multicenter study. Obes Surg. 2019;29:1462–69.
33. Arman GA, Himpens J, Dhaenens J, Ballet T, Vilallonga R, Leman G. Long-term (11+years) outcomes in weight, patient satisfaction, comorbidities, and gastroesophageal reflux treatment after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2016;12:1778–86.
34. Himpens J, Dapri G, Cadiere GB. A prospective randomized study between laparoscopic gastric banding and laparoscopic isolated sleeve gastrectomy: results after 1 and 3 years. Obes Surg. 2006;16:1450–6.
35. Himpens J, Dobbeleir J, Peeters G. Long-term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252:319–24.
36. Catheline JM, Fysekidis M, Bachner I, Bihan H, Kassem A, Dbouk R. Five-year results of sleeve gastrectomy. J Visc Surg. 2013;150:307–12.
37. Genco A, Soricelli E, Casella G, Maselli R, Castagneto-Gissey L, Di Lorenzo N, et al. Gastroesophageal reflux disease and Barrett's esophagus after laparoscopic sleeve gastrectomy: a possible, underestimated long-term complication. Surg Obes Relat Dis. 2017;13:568–74.
38. Sheppard CE, Sadowski DC, de Gara CJ, Karmali S, Birch DW. Rates of reflux before and after laparoscopic sleeve gastrectomy for severe obesity. Obes Surg. 2015;25:763–8.
39. Zhang N, Maffei A, Cerabona T, Pahuja A, Omana J, Kaul A. Reduction in obesity-related comorbidities: is gastric bypass better than sleeve gastrectomy? Surg Endosc. 2013;27:1273–80.
40. Lim CH, Lee PC, Lim E, Tan J, Chan WH, Tan HC, et al. Correlation between symptomatic Gastro-Esophageal Reflux Disease (GERD) and Erosive Esophagitis (EE) post-vertical Sleeve Gastrectomy (VSG). Obes Surg. 2019;29:207–14.
41. Viscido G, Gorodner V, Signorini F, Navarro L, Obeide L, Moser F. Laparoscopic sleeve gastrectomy: endoscopic findings and gastroesophageal reflux symptoms at 18-month follow-up. J Laparoendosc Adv Surg Tech A. 2018;28:71–7.
42. Soricelli E, Casella G, Baglio G, Maselli R, Ernesti I, Genco A. Lack of correlation between gastroesophageal reflux disease symptoms and esophageal lesions after sleeve gastrectomy. Surg Obes Relat Dis. 2018;14:751–6.
43. Felsenreich DM, Kefurt R, Schermann M, Beckerhinn P, Kristo I, Krebs M, et al. Reflux, sleeve dilation, and Barrett's esophagus after laparoscopic sleeve gastrectomy: long-term follow-up. Obes Surg. 2017;27:3092–101.
44. Sohn S, Fischer J, Booth M. Adenocarcinoma of the gastro-oesophageal junction after sleeve gastrectomy: a case report. ANZ J Surg. 2017;87:E163–4.
45. Scheepers AF, Schoon EJ, Nienhuijs SW. Esophageal carcinoma after sleeve gastrectomy. Surg Obes Relat Dis. 2011;7:e11–2.
46. Wright FG, Duro A, Medici JR, Lenzi S, Beskow AF, Cavadas D. Esophageal adenocarcinoma five years after laparoscopic sleeve gastrectomy. A case report. Int J Surg Case Rep. 2017;32:47–50.
47. El Khoury L, Benvenga R, Romero R, Cohen R, Roussel J, Catheline JM. Esophageal adenocarcinoma in Barrett's esophagus after sleeve gastrectomy: case report and literature review. Int J Surg Case Rep. 2018;52:132–6.
48. Coupaye M, Gorbatchef C, Calabrese D, Sami O, Msika S, Coffin B, et al. Gastroesophageal reflux after sleeve gastrectomy: a prospective mechanistic study. Obes Surg. 2018;28:838–45.
49. Patti MG, et al. Gastroesophageal reflux after sleeve gastrectomy. JAMA Surg. 2018;153:1147–48.

50. Del Genio G, Tolone S, Limongelli P, Brusciano L, D'Alessandro A, Docimo G, et al. Sleeve gastrectomy and development of "de novo" gastroesophageal reflux. Obes Surg. 2014;24:71–7.
51. Tolone S, Cristiano S, Savarino E, Lucido FS, Fico DI, Docimo L. Effects of omega-loop bypass on esophagogastric junction function. Surg Obes Relat Dis. 2016;12:62–9.
52. Georgia D, Stamatina T, Maria N, Konstantinos A, Konstantinos F, Emmanouil L, et al. 24-h multichannel intraluminal impedance PH-metry 1 year after laparoscopic sleeve gastrectomy: an objective assessment of gastroesophageal reflux disease. Obes Surg. 2017;27:749–53.
53. Kleidi E, Theodorou D, Albanopoulos K, Menenakos E, Karvelis MA, Papailiou J, et al. The effect of laparoscopic sleeve gastrectomy on the antireflux mechanism: can it be minimized? Surg Endosc. 2013;27:4625–30.
54. Petersen WV, Meile T, Kuper MA, Zdichavsky M, Konigsrainer A, Schneider JH. Functional importance of laparoscopic sleeve gastrectomy for the lower esophageal sphincter in patients with morbid obesity. Obes Surg. 2012;22:360–6.
55. Mion F, Tolone S, Garros A, Savarino E, Pelascini E, Robert M, et al. High-resolution impedance manometry after sleeve gastrectomy: increased intragastric pressure and reflux are frequent events. Obes Surg. 2016;26:2449–56.
56. Gagner M, Hutchinson C, Rosenthal R. Fifth International Consensus Conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12:750–6.
57. Rosenthal RJ, Diaz AA, Arvidsson D, Baker RS, Basso N, Bellanger D, et al. International Sleeve Gastrectomy Expert Panel Consensus Statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8:8–19.
58. Daes J, Jimenez ME, Said N, Dennis R. Improvement of gastroesophageal reflux symptoms after standardized laparoscopic sleeve gastrectomy. Obes Surg. 2014;24:536–40.
59. Soricelli E, Iossa A, Casella G, Abbatini F, Cali B, Basso N. Sleeve gastrectomy and crural repair in obese patients with gastroesophageal reflux disease and/or hiatal hernia. Surg Obes Relat Dis. 2013;9:356–61.
60. Soliman A. Laparoscopic crural repair with simultaneous sleeve gastrectomy: way in gastroesophageal reflux disease treatment associated with morbid obesity. J Minim Invasive Surg Sci. 2012;1:67–73.
61. Gibson SC, Le Page PA, Taylor CJ. Laparoscopic sleeve gastrectomy: review of 500 cases in single surgeon Australian practice. ANZ J Surg. 2015;85:673–7.
62. Ruscio S, Abdelgawad M, Badiali D, Iorio O, Rizzello M, Cavallaro G, et al. Simple versus reinforced cruroplasty in patients submitted to concomitant laparoscopic sleeve gastrectomy: prospective evaluation in a bariatric center of excellence. Surg Endosc. 2016;30:2374–81.
63. Mahawar KK, Carr WR, Jennings N, Balupuri S, Small PK. Simultaneous sleeve gastrectomy and hiatus hernia repair: a systematic review. Obes Surg. 2015;25:159–66.
64. Santoro S, Lacombe A, Aquino CG, Malzoni CE. Sleeve gastrectomy with anti-reflux procedures. Einstein (Sao Paulo). 2014;12:287–94.
65. Nocca D, Skalli EM, Boulay E, Nedelcu M, Michel Fabre J, Loureiro M. Nissen Sleeve (N-Sleeve) operation: preliminary results of a pilot study. Surg Obes Relat Dis. 2016;12:1832–7.
66. Castagneto Gissey L, Casella Mariolo JR, Genco A, Troisi A, Basso N, Casella G. 10-year follow-up after laparoscopic sleeve gastrectomy: Outcomes in a monocentric series. Surg Obes Relat Dis. 2018;14:1480–7.
67. Angrisani L, Santonicola A, Hasani A, Nosso G, Capaldo B, Iovino P. Five-year results of laparoscopic sleeve gastrectomy: effects on gastroesophageal reflux disease symptoms and co-morbidities. Surg Obes Relat Dis. 2016;12:960–8.
68. Braghetto I, Davanzo C, Korn O, Csendes A, Valladares H, Herrera E, et al. Scintigraphic evaluation of gastric emptying in obese patients submitted to sleeve gastrectomy compared to normal subjects. Obes Surg. 2009;19:1515–21.
69. Lazoura O, Zacharoulis D, Triantafyllidis G, Fanariotis M, Sioka E, Papamargaritis D, et al. Symptoms of gastroesophageal reflux following laparoscopic sleeve gastrectomy are related to the final shape of the sleeve as depicted by radiology. Obes Surg. 2011;21:295–9.
70. Iannelli A, Martini F, Schneck AS, Gugenheim J. Twisted gastric sleeve. Surgery. 2015;157:163–5.

71. Keidar A, Appelbaum L, Schweiger C, Elazary R, Baltasar A. Dilated upper sleeve can be associated with severe postoperative gastroesophageal dysmotility and reflux. Obes Surg. 2010;20:140–7.
72. Toro JP, Lin E, Patel AD, Davis SS Jr, Sanni A, Urrego HD, et al. Association of radiographic morphology with early gastroesophageal reflux disease and satiety control after sleeve gastrectomy. J Am Coll Surg. 2014;219:430–8.
73. Kim M, Navarro F, Eruchalu CN, Augenstein VA, Heniford BT, Stefanidis D. Minimally invasive Roux-en-Y gastric bypass for fundoplication failure offers excellent gastroesophageal reflux control. Am Surg. 2014;80:696–703.
74. Mejia-Rivas MA, Herrera-Lopez A, Hernandez-Calleros J, Herrera MF, Valdovinos MA. Gastroesophageal reflux disease in morbid obesity: the effect of Roux-en-Y gastric bypass. Obes Surg. 2008;18:1217–24.
75. Merrouche M, Sabate JM, Jouet P, Harnois F, Scaringi S, Coffin B, et al. Gastro-esophageal reflux and esophageal motility disorders in morbidly obese patients before and after bariatric surgery. Obes Surg. 2007;17:894–900.
76. Mion F, Dargent J. Gastro-oesophageal reflux disease and obesity: pathogenesis and response to treatment. Best Pract Res Clin Gastroenterol. 2014;28:611–22.
77. Madalosso CA, Gurski RR, Callegari-Jacques SM, Navarini D, Thiesen V, Fornari F. The impact of gastric bypass on gastroesophageal reflux disease in patients with morbid obesity: a prospective study based on the Montreal Consensus. Ann Surg. 2010;251:244–8.
78. De Groot NL, Burgerhart JS, Van De Meeberg PC, de Vries DR, Smout AJ, Siersema PD. Systematic review: the effects of conservative and surgical treatment for obesity on gastro-oesophageal reflux disease. Aliment Pharmacol Ther. 2009;30:1091–102.
79. Mehaffey JH, LaPar DJ, Clement KC, Turrentine FE, Miller MS, Hallowell PT, et al. 10-year outcomes after Roux-en-Y gastric bypass. Ann Surg. 2016;264:121–6.
80. Pallati PK, Shaligram A, Shostrom VK, Oleynikov D, McBride CL, Goede MR. Improvement in gastroesophageal reflux disease symptoms after various bariatric procedures: review of the Bariatric Outcomes Longitudinal Database. Surg Obes Relat Dis. 2014;10:502–7.
81. Lagergren J, Mattsson F, Nyren O. Gastroesophageal reflux does not alter effects of body mass index on risk of esophageal adenocarcinoma. Clin Gastroenterol Hepatol. 2014;12:45–51.
82. Spechler SJ, Souza RF. Barrett's esophagus. N Engl J Med. 2014;371:836–45.
83. Frezza EE, Ikramuddin S, Gourash W, Rakitt T, Kingston A, Luketich J, et al. Symptomatic improvement in gastroesophageal reflux disease (GERD) following laparoscopic Roux-en-Y gastric bypass. Surg Endosc. 2002;16:1027–31.
84. Gagner M, Braghetto I. A symposium on management of Barrett's in patients having bariatric surgery. Obes Surg. 2016;26:709.
85. Iannelli A, Debs T, Martini F, Benichou B, Ben Amor I, Gugenheim J. Laparoscopic conversion of sleeve gastrectomy to Roux-en-Y gastric bypass: indications and preliminary results. Surg Obes Relat Dis. 2016;12:1533–8.
86. Parmar CD, Mahawar KK, Boyle M, Schroeder N, Balupuri S, Small PK. Conversion of sleeve gastrectomy to roux-en-y gastric bypass is effective for gastro-oesophageal reflux disease but not for further weight loss. Obes Surg. 2017;27:1651–8.
87. Braghetto I, Csendes A. patients having bariatric surgery: surgical options in morbidly obese patients with Barrett's esophagus. Obes Surg. 2016;26:1622–6.
88. Parikh K, Khaitan L. Radiofrequency ablation coupled with Roux-en-Y gastric bypass: a treatment option for morbidly obese patients with Barrett's esophagus. J Surg Case Rep. 2016;(3). https://doi.org/10.1093/jscr/rjw007.

Chapter 18
Surgical Management of GERD After Sleeve: What to Do When Conservative Management Fails

Elias Choulseb and Natan Zundel

18.1 Introduction

Sleeve gastrectomy is the most commonly performed bariatric surgical procedure in the world. In the United States, it accounts for nearly 60% of all bariatric interventions [1]. Sleeve gastrectomy has proven to be a safe and effective procedure in the short and medium term although recently its long-term effects have been placed into question [2]. Sleeve gastrectomy is a conceptually simple operation, and it is considered to be less technically challenging than interventions requiring anastomosis; therefore the adoption rates among bariatric surgeons and general/laparoscopic surgeons performing bariatric cases have been very high. Due to multiple factors including a greater safety profile when compared to anastomotic procedures, patient acceptance has also been very high.

The pathophysiology of gastroesophageal reflux disease and obesity as well as the mechanisms of GERD in patient's after sleeve gastrectomy will be discussed extensively in other chapters, therefore we will focus mostly on the surgical aspect of the management of GERD after sleeve gastrectomy.

Surgical management is based on the following principles that cause reflux after sleeve gastrectomy; we need to address the lack of gastric compliance, the increased intraluminal pressure, and the LES pressure. We need to address technical/anatomical problems such as any narrowing or twisting during the sleeve dilation of the fundus and the persistence of hiatal hernias [3].

Approximately 70% of patients undergoing bariatric surgery for morbid obesity have symptomatic acid reflux. Concomitant hiatal hernias are found about 50% of

E. Choulseb
The Sleeve Gastrectomy Center, Jackson North Medical Center,
North Miami Beach, FL, USA

N. Zundel (✉)
Department of Surgery, University at Buffalo, Jackson North Medical Canter,
Miami, FL, USA

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_18

the patients with a BMI greater than 35. According to reported studies, close to 80% of patients have preoperative heartburn, 66% of patients have preoperative regurgitation, 49% of patients presented with endoscopic findings of esophagitis, and 18% of patients present with short-segment Barrett's esophagus. Up to 10% of patients may present with long-segment Barrett's esophagus [4].

One of the major concerns sleeve gastrectomy has brought up is its relationship with gastroesophageal reflux disease (GERD). Several hundreds of papers have been written trying to clarify the exact relationship between de novo GERD and sleeve gastrectomy, existing GERD and sleeve gastrectomy, and resolution of GERD after sleeve gastrectomy and different techniques to identify and prevent GERD from happening or change the bariatric procedure to an intervention with decreased tendency to promote GERD [5–7]. Although symptomatic management of this postoperative GERD may be challenging, the more pressing matter is the increased association between sleeve gastrectomy and esophageal lesions including erosive esophagitis and new development of dysplastic Barrett's esophagus [8]. While the incidence of adenocarcinoma of the esophagus after sleeve gastrectomy appears to be low, there are isolated reports of esophageal adenocarcinoma after sleeve gastrectomy; unfortunately some of these cases did not have a preoperative endoscopy, to prove the adenocarcinoma is a direct result of the reflux induced by the sleeve [9]. The most recent sleeve gastrectomy consensus places the existence of Barrett's esophagus as a contraindication for sleeve gastrectomy with 80% of the experts agreeing on this recommendation, in comparison with only 31% of the general surgeons who were in agreement with this recommendation [10]. Surprisingly a larger number of general surgeons believe a hiatal hernia is a contraindication to sleeve compared to the experts [10].

Although the exact number of patients that will suffer GERD after sleeve or what the consequence of this GERD will be in the future is still unknown, as bariatric surgeons we will have to face a group of patients with these symptomatology and possible complications. To date there is no algorithm to our knowledge that comprehensively addresses this issue keeping in mind that there is a number of patients who underwent a sleeve because they were not deemed proper candidates for a bypass or did not want a bypass for a variety of reasons, including the possible 20% lifetime long-term complications of the bypass that include internal hernia and marginal ulceration, among others [11].

While it is true that most sleeve-related GERD will be effectively treated with a conversion to Roux-en-Y gastric bypass, not every patient with GERD after reflux will require a bypass or would agree to have one. First key step in addressing the patient is to evaluate whether the patient was selected appropriately to have a sleeve and second is to determine the exact sleeve anatomy; are there anatomical factors that will make it more likely for this patient to experience reflux; is there dilated fundus? Is there a kink or stricture in the sleeve or is it an anatomically appropriate operation? We should pay important attention to the weight loss the patient has experienced with the sleeve. Patients who do not have adequate weight loss and have GERD symptoms should not undergo other therapies and should probably undergo a bypass; however it is our unpublished experience that patients with the association of poor weight loss after sleeve and difficult to treat GERD will correct their GERD after conversion, but their weight loss results are still marginal even with a well-constructed bypass.

18.2 Evaluation of the Patient with GERD After Sleeve Gastrectomy

Evaluation of a patient referring GERD after sleeve gastrectomy should start with a detailed history and physical examination; the presence or absence of GERD-related symptoms should be thoroughly documented as well as any prior treatments or therapy used to treat it. Obtaining preoperative and operative records is of paramount importance particularly in those patients who had their index procedure performed elsewhere. Any endoscopic findings and prior imaging available are important to determine what the best course of action would be. If the patient had preoperative and postoperative imaging such as UGI, it is useful to compare those with a recent study to look for anatomical problems that may have been not addressed at the time of the index operation or developed over time. After this information is obtained, we can classify the GERD after sleeve as:

1. De novo GERD
2. Preexisting GERD without improvement
3. Preexisting GERD with worsening/complication

Regardless of how we classify the GERD, an initial evaluation with imaging studies such as UGI and EGD is recommended. Comparison with any prior films if available is of significant value. Based on the UGI, we can determine if the shape of the sleeve falls into one of the following categories: tubular, dilated bottom, dilated upper, or dumbbell-shaped sleeve; we will also be able to evaluate esophageal peristalsis in real time and if there is associated hiatal hernias. We believe UGI under fluoroscopy provides important physiologic and anatomic information that can help guide our management approach, and therefore we offer it to all patients.

We follow the radiologic evaluation with endoscopy, and during endoscopy, we look for objective signs of reflux such as esophagitis, presence of bile in the stomach or esophagus, as well as missed or recurrent hiatal hernias. In patients with evidence of esophagitis or metaplasia, multiple biopsies are taken. During the endoscopy, subtle findings that suggest a kink or a stricture may be present.

In the absence of objective signs of gastroesophageal reflux disease on both endoscopy and upper GI series, we pursue physiologic testing followed by high-resolution manometry and pH monitoring. In those patients where clear reflux esophagitis is seen, this additional testing may not be necessary or may be performed in selected cases depending on what the surgical or endoscopic therapy would be.

18.3 Endoscopic and Surgical Management

Based in the experience of the senior author (Zundel), an algorithm was developed, according to symptoms, anatomical and physiological changes, and presence or absence of other complications like strictures or kinks, keeping in mind that a fair number of these patients won't accept to be converted to a LRYGBP in the first place (Fig. 18.1).

18.3.1 GERD + Normal Anatomy and Adequate Weight Loss

This is a common scenario and it accounts for most of the patients in our practice with these complaints; all of our patients are empirically placed on PPI regimen of 40 mg of omeprazole daily for 3 months, in those whose symptoms persist; despite this regimen we will increase the dose to 40 mg BID. Those who persist with symptoms despite a BID dose of omeprazole are switched to a newer class PPI such as dexlansoprazole, if symptoms are corrected with PPI, we evaluate patients at 3-month intervals and decrease the dose until PPI is discontinued. At 1-year follow-up, only 6% of our patients continue to experience symptoms of GERD requiring

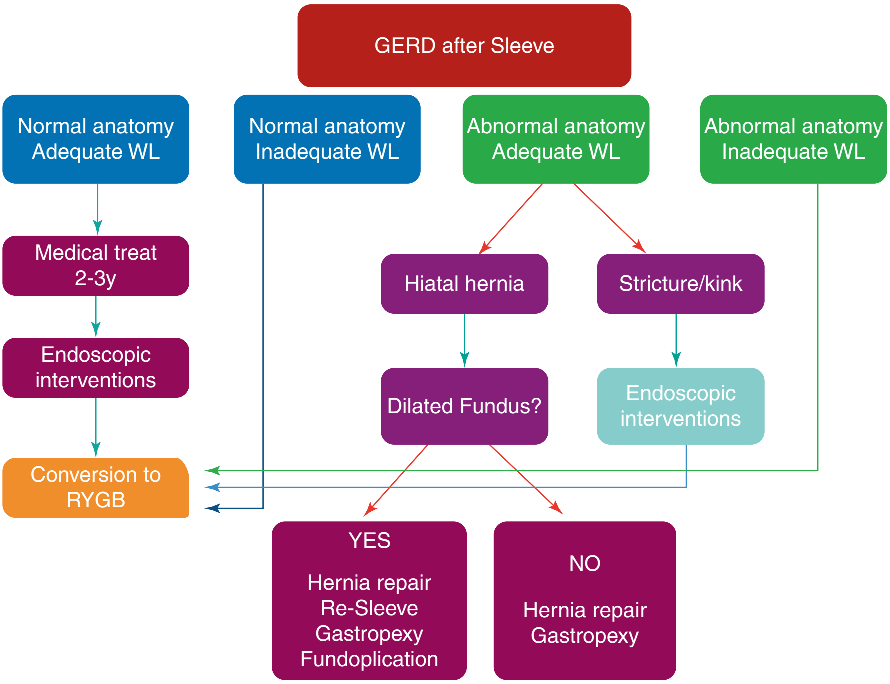


Fig. 18.1 Anchoring the esophagus to the base of the crus

medication. As long as the patient does not have additional symptomatology such as dysphagia or vomiting, no additional workup is performed. Yearly endoscopic screening is indicated for these patients. If the patient exhibits additional symptoms, we will obtain endoscopy and UGI to evaluate the anatomy of the sleeve; if both tests appear to be normal and the patient has symptomatic relief with PPI, we will monitor; and if there is no symptomatic relief, patients will go on to objective pH monitoring and impedance studies. Data by Himpens suggests most patients improve by 2 years.

Endoscopic interventions such as radiofrequency energy application (Stretta) have been investigated as possible therapeutic options to treat GERD after sleeve gastrectomy; currently patients completed enrollment at a clinical trial performed at Montefiore. Mattar et al. reported good efficacy in the use of Stretta in patients with GERD after gastric bypass [12, 13]. Magnetic sphincter augmentation with LINX has been recently proposed as a method of treatment for GERD after LSG [13, 14]. Although reports appear to be promising, this is a small group of patients reported with short-term follow-up. Cost of the device remains a concern. The potential for erosion of the LINX device as well as the difficulty in dealing with these erosions surgically should also be contemplated.

Lastly conversion to gastric bypass can be offered to this patient population; conversion to Roux-en-Y will likely resolve their GERD-related symptoms and maintain or continue to promote weight loss.

18.3.2 GERD + Normal Anatomy with Inadequate Weight Loss

This case scenario is in our opinion one of the most difficult to resolve; patients with well-constructed sleeves who experience inadequate weight loss will benefit from conversion to bypass as is related to their GERD-related symptoms; however their weight loss may be minimally affected by the conversion to the Roux-en-Y, and procedures like DS or SADI may increase the incidence of GERD up to 26% according to a paper published by Himpens.

In all patients with inadequate weight loss, intense multidisciplinary evaluation is needed, and there is likely to be noncompliance and external factors leading to the lack of/or insufficient weight loss.

18.3.3 GERD + Abnormal Anatomy with Adequate Weight Loss

As it has been described by many authors, abnormal sleeve anatomy which may include dilated upper portion of the sleeve, narrowing, twists or kinks at the level of the incisura, and the presence of hiatal hernia may be the cause for GERD after sleeve [13, 15, 16]. Efforts in identifying abnormal anatomy include UGI and endoscopic studies; when available it is valuable to compare the initial postoperative UGI study to evaluate if this is truly dilation or simply improper surgical technique. While some authors have proposed staying far away from the GE junction during the sleeve gastrectomy to prevent leaks (Rosenthal). It is sometimes difficult to estimate the amount of fundus being left behind. Properly dissecting the fat pad anteriorly as well as fully mobilizing the fundus posteriorly until the confluence of the right and left crus is seen from the left side is perhaps the only way to fully assess if the fundus has been completely mobilized. We previously thought that all sleeves with very redundant fundus were improperly performed index surgeries; however as we see more and more of these patients, we have encountered some with adequate sleeves which dilated significantly; although the former is much more frequent than the latter, we should try to identify patient factors that may lead to excessive stretching of the residual stomach, such as binge eating/overeating behavior and abuse of carbonated beverages, among others (Fig. 18.2). Novel surgical interventions such as using the dilated pouch to create a partial or total fundoplication have been presented in video sessions in recent meetings; these techniques should be approached with care since there is no data to validate them and they are mostly an experiment based on what may sound as a good idea. We do not advocate the use of these techniques until more data is available or outside clinical trials.

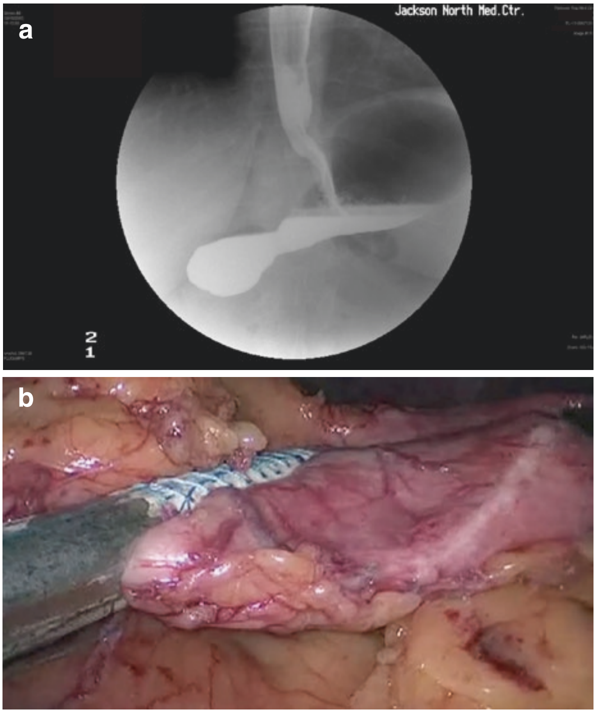
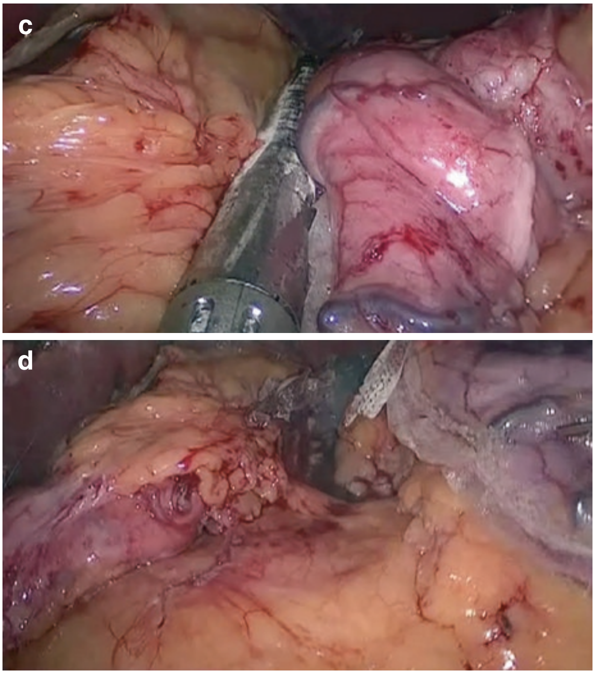


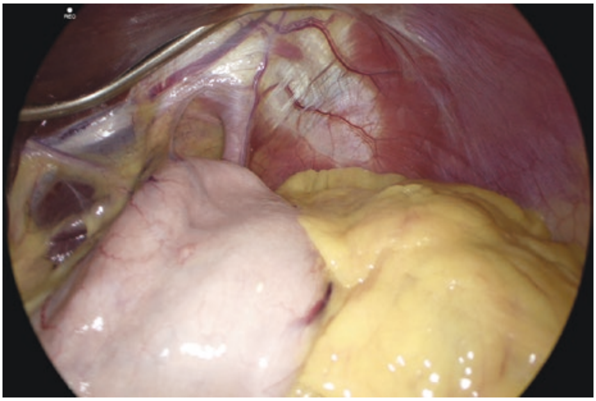
Fig. 18.2 (**a**) Fluoroscopic image with markedly dilated stomach. (**b–d**) Re-sleeve large fundus

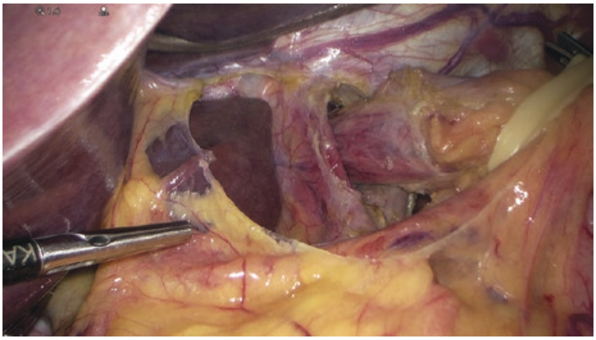
Fig. 18.2 (continued)



Although generally accepted as good practice, identifying and treating hiatal hernias during the index operation has been proven to be safe [17] and is advocated by some authors as a measure to improve outcomes and decrease GERD [7, 18] (Figs. 18.3 and 18.4). Several studies including a randomized trial show the effects of concurrently repairing a hiatal hernia may actually cause no difference or be detrimental [19]. More data is required to draw an objective conclusion, and once again the methods for hernia repair make this sample very heterogeneous. For large hiatal hernias over 4 cm, a study by Silecchia using synthetic bioabsorbable mesh revealed a remission of GERD symptoms in the 1% of the patients without mesh-related complications at 18 months with a recurrence rate of 2% [20]. Placing anchoring sutures from the esophagus to the base of the crus or to the top of the left crus has been described (Fig. 18.5); this fixation is different from fixation to the arcuate ligament described in the Hill repair. No data is available to draw a conclusion if these anchoring methods are useful.

If patients have anatomical abnormality such as a kink or stricture, we will offer serial dilation (Fig. 18.6). Identifying kinks or strictures in some cases requires careful attention to detail during endoscopic examination; the gastroscope will almost always pass through a kink; however identifying how much angle or torque of the scope is required to pass the incisura is key. We start conservatively with TTS-type balloons 18–20 mm (Fig. 18.7) in 2–3-week intervals and progress to 30 mm–35 mm achalasia balloon dilation (Fig. 18.8). While we understand that a





Figs. 18.3 and 18.4 Hiatal hernia with crural dissection

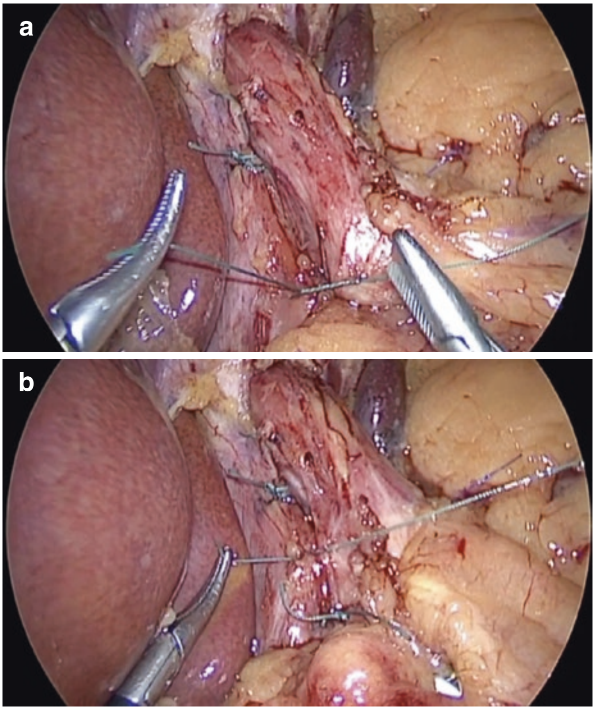


Fig. 18.5 (**a**, **b**) Anchoring the esophagus to the base of the crus (Courtesy Alvaro Valencia MD. Grupo Clinica Reina Sofia, Bogota, Colombia)

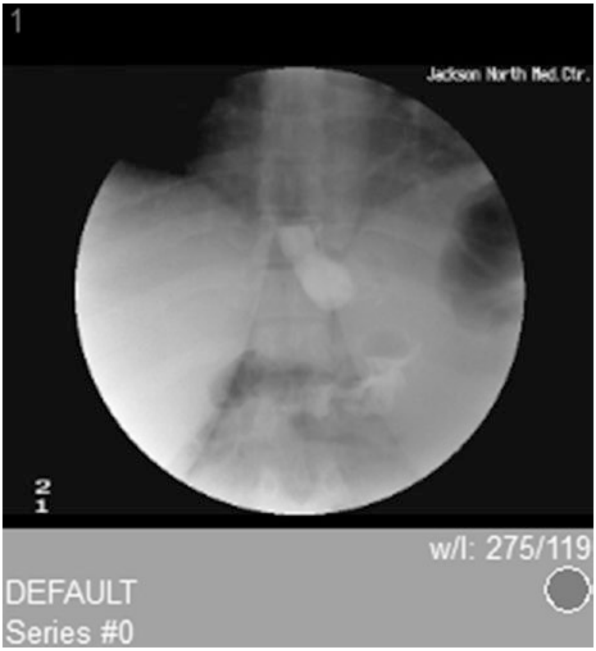


Fig. 18.6 Anchoring the esophagus to the base of the crus

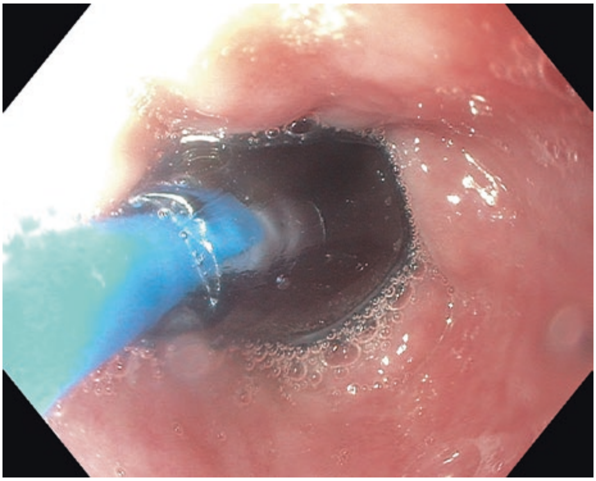


Fig. 18.7 Anchoring the esophagus to the base of the crus

true dilation can only be done with the achalasia balloon, the TS balloon does offer temporary symptomatic or resolution of the GERD in a subset of patients. Generally patients experience complete symptomatic relief after three sessions. If there is no improvement after five endoscopic sessions, we offer conversion to gastric bypass. The CRE dilation can be safely performed under sedation; however for the pneumatic dilation with achalasia balloons, we prefer airway control with endotracheal

Fig. 18.8 Anchoring the esophagus to the base of the crus

intubation and fluoroscopic guidance. Other dilation protocols are available and have reported good results [21]. Seromyotomy as described by Himpens [22] is a method that has been used to treat strictures; the complication rate including perforation appears to be high; therefore most will prefer conversion to bypass.

18.3.4 GERD + Abnormal Anatomy with Inadequate Weight Loss

In patients with poorly constructed sleeves with inadequate weight loss, the decision to re-sleeve the patient should be taken into very careful consideration, while the failure of weight loss is likely due to the inadequacy of the index procedure, which can also lead to GERD, and creating a tighter sleeve will likely cause the GERD symptoms to worsen; therefore conversion to RYGBP is likely the best therapeutic option.

References

1. ASMBS Website.
2. Felsenreich DM, Kefurt R, Schermann M, et al. Reflux, sleeve dilation and Barrett's esophagus after laparoscopic sleeve gastrectomy: long term follow up. Obes Surg. 2017;27(12):3092–101.
3. Stenard F, Iannelli A. Laparoscopic sleeve gastrectomy and gastroesophageal reflux. World J Gastroenterol. 2015;21(36):10348–57.

4. Melissas J, Braghetto I, Molina JC, et al. Gastroesophageal reflux disease and sleeve Gastrectomy. Obes Surg. 2015;25:2430–5.
5. Dakour Aridi HN, Tamim H, et al. Concomitant Hiatal hernia repair with laparoscopic sleeve gastrectomy is safe: analysis of the ACS-NSQIP database. Surg Obes Realt Dis. 2017;13(3):379–84.
6. Moon RC, Texeira AF, et al. Safety and effectiveness of anterior fundoplication sleeve gastrectomy in patients with severe reflux. Surg Obes Relat Dis. 2017;13(4):547–52.
7. Daes J, Jimenez ME, Said N, et al. Improvement of gastroesophageal reflux symptoms after standardized laparoscopic sleeve gastrectomy. Obes Surg. 2014;24(4):536–40. https://doi.org/10.1007/s11695-013-1117-6.
8. Soricelli E, Casella G, et al. Lack of correlation between gastroesophageal reflux disease symptoms and esophageal lesions after sleeve gastrectomy. Surg Obes Relat Dis. 2018;14:751.
9. Wright FG, Duro A, et al. Esophageal adenocarcinoma five years after laparoscopic sleeve gastrectomy. A case report. Int J Surg Case Rep. 2017;32:47–50.
10. Gagner M, Hutchinson C, et al. Fifth international consensus conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6.
11. Chousleb E, Chousleb A. Management of post bariatric complications. J Gastrointest Surg. 2017;21(11):1946–53.
12. Mattar SG, Qureshi D, et al. Treatment of refractory gastroesophageal reflux disease with radiofrequency energy (Stretta) in patients after Roux en Y gastric bypass. Surg Endosc. 2006;20:850–4.
13. Rebecchi F, Marco AE, et al. Gastroesophageal reflux disease and morbid obesity: to sleeve or not to sleeve? World J Gastroenterol. 2017;23(13):2269–75.
14. Desart K, Michel M, et al. Gastroesophageal reflux management with the LINX system for gastroesophageal reflux disease following laparoscopic sleeve gastrectomy. J Gastrointest Surg. 2015;19:1782–6.
15. Himpens J, Dobbeleir, et al. Long term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252:319–24.
16. Keidar A, Appelbaum L, et al. A dilated upper sleeve can be associated with severe postoperative gastroesophageal dysmotility and reflux. Obes Surg. 2010;20:140–7.
17. Dakour AHN, Tamim H, et al. Concomitant hiatal hernia repair with laparoscopic sleeve gastrectomy is safe: analysis of the ACS-NSQIP database. Surg Obes Relat Dis. 2017;13(3):379–84.
18. Page PL, Martin D, Taylor C, et al. Does Hiatal hernia repair affect gastroesophageal reflux symptoms in patients undergoing laparoscopic sleeve gastrectomy. Surg Endosc. 2018;32(5):2373–80.
19. Snyder B, Wilson E, Wilson T, et al. A randomized trial comparing reflux symptoms in sleeve gastrectomy patients with or without hiatal hernia repair. Surg Obes Relat Dis. 2016;12(9):1681–8.
20. Silecchia G, Iossa A, Cavallaro G, et al. Reinforcement of Hiatal hernia defect repair with absorbable mesh fixed with non-permanent devices. Minim Invasive Ther Allied Technol. 2014;23(5):302–8.
21. Zundel N, Hernandez JD, Galvao M, et al. Strictures after laparoscopic sleeve gastrectomy. Surg Laparosc Endosc Perc Tech. 2010;20(3):154–8.
22. Vilallonga R, Himpens J, van de Vrande S. Laparoscopic management of persistent strictures after laparoscopic sleeve gastrectomy. Obes Surg. 2013;23(10):1655–61. https://doi.org/10.1007/s11695-013-0993-0.

Part IV
Nontraditional Sleeve Gastrectomy

Chapter 19
The Endosleeve

Mousa Khoursheed, Jaber Al-Ali, Vitor Ottoboni Brunaldi, and Manoel Galvao Neto

19.1 Introduction

Obesity is a major risk factor for diabetes and cardiovascular disease and thus has enormous consequences for the health system itself. According to the World Health Organization, more than 1.9 billion people are overweight (2014), of which 600 million people are obese (body mass index BMI $\geq$ 30 kg /m^2) [1]. In the United States, more than one-third of adults and 17% of children and adolescents are obese [2].

Bariatric surgery is a well-established procedure for patients with body mass index (BMI) $\geq$40 kg/m^2 or in cases of BMI $\geq$ 35 kg/m^2 with comorbidities. Currently, sleeve gastrectomy and gastric bypass are the most widely performed bariatric procedures [3]. In patients with class I and II obesity without comorbidities, the best treatment technique is still uncertain. Surgical interventions are limited in their application and acceptance by patients [4]. Unfortunately, only 1% of patients who

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-28936-2_19) contains supplementary material, which is available to authorized users.

M. Khoursheed (✉)
Department of Surgery, Kuwait Health Sciences Center, Jabriya, Kuwait

Department of Surgery, Faculty of Medicine, Kuwait City, Kuwait
e-mail: khoursheed@hsc.edu.kw

J. Al-Ali
Department of Medicine, Faculty of Medicine, Kuwait University, Kuwait City, Kuwait

V. O. Brunaldi
Gastrointestinal Endoscopy Unit, University of São Paulo Medical School, São Paulo, Brazil

M. G. Neto
Surgery Department, Florida International University, Miami, FL, USA

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_19

qualify for bariatric surgery pursue surgical options due to the fear of risks and complications associated with bariatric surgery [5, 6].

Endoscopic techniques have emerged as effective treatments for overweight and obesity. The most widely practiced endoscopic procedure is the intragastric balloon placement [7]. Those devices have the potential risks of migration, gastrointestinal ulceration, and potential weight recidivism following device retrieval [8]. In 2008 [9] and in 2010 [10], the feasibility of transoral endoscopic gastric volume reduction for the management of obesity was reported by using a superficial endoscopic suturing device that mimicked vertical banded gastroplasty surgical anatomy. Its technical feasibility was improved in 2013 [11].

Several endoluminal procedures with different devices have been reported trying to reduce the gastric volume thus promoting weight loss. Endoluminal gastric plication (EGP) procedures can be offered to a higher number of untreated obese patients who were denied surgery, or unwilling to undergo surgery, and those patients with class I and II obesity. It allows earlier management in childhood and adolescents obesity and may also be a good option in elderly obese patients.

The term endoscopic sleeve gastroplasty (ESG) was coined as a reference to the current main EGP modality: the Apollo method. It entails gastric volume reduction via placement of full-thickness suturing of the anterior wall, greater curvature, and posterior wall of the stomach. In addition to imbrication of the greater curvature, the stomach is shortened. The OverStitch™ device (Apollo Endosurgery, Austin, Texas, USA) mimics the way physicians deploy sutures by hand. It provides full-thickness endoscopic suturing on a flexible platform, delivering a surgical standard of care through the flexible endoscope. Therefore, it minimizes the trauma of surgical access by taking advantage of natural orifices to deliver surgical tools to targeted areas. Moreover, contrary to the LSG, the ESG maintains the anatomic structure, innervation, and blood supply of the stomach with potential for reversibility, repeatability, and conversion to bariatric surgery if necessary.

Possible mechanisms for weight loss include a delay in gastric emptying and restriction, but further research is needed to clarify mechanisms of action and weight loss durability. A study demonstrated statistically significant physiologic changes associated with ESG including early satiety, delayed gastric emptying, and a trend toward increased insulin sensitivity [12]. The long-term durability and predictors of poor response are yet to be defined. It requires further clinical validation, particularly in the context of prospective controlled trials. Moreover, for ESG to increase in use, one must learn how to master the technique and to define a learning curve for new practitioners.

Our chapter aims to review clinical data on ESG and other EGP procedures for the treatment of obesity, overweight, and related diseases.

19.2 Indications and Contraindications

The specific indications for the procedure were based on obesity parameters (BMI 30–49 kg/m^2) with previous failed attempts with conventional treatment of obesity and the willingness and ability of patients to be treated by a multidisciplinary team, that is, patients who adequately understand and commit themselves to undergo multidisciplinary follow-up for obesity for at least 1 year. Some authors limit the procedure to adults between 21 and 60 years old.

The procedure is usually contraindicated in patients (1) with potentially bleeding lesions (e.g., ulcers and acute gastritis), (2) with neoplastic findings, (3) on therapeutic anticoagulation, and (4) with psychiatric disorders (mental retardation, manic-depressive psychosis, severe depression, schizophrenia, and untreated eating behavior disorders) that interfere with their ability to actively engage with the post-procedural instruction and recommended lifestyle adjustments. Coagulopathy and psychiatric disorders were identified through blood tests and interviews. Other contraindications entail (5) esophageal and gastric vascular abnormalities, (6) organ failure, (7) pregnancy/lactation, (8) a history of stroke, (9) large hiatal hernia (>3 cm), and (10) any prior gastric surgery.

Some authors use DVT prophylaxis; however, it may contribute to postoperative bleeding, and since the majority of patients undergoing this procedure are overweight or mildly obese, DVT prophylaxis may not be mandatory. All procedures should be performed under general anesthesia and CO2 insufflation with routine intravenous prophylactic antibiotics. Patients are placed in either the left-lateral or the supine position. A diagnostic EGD should be performed to confirm the absence of exclusion criteria.

19.3 Postoperative Care

Some experts request oral contrast studies to assess the gastroplasty anatomy at 24 hours, but that is optional. Bleeding complications may be excluded by blood tests when suspected. A liquid diet is usually initiated at 8 h postprocedure, analgesia preferably with non-opioid drugs, and patients are usually discharged within 24 hours. A specialized dietitian must be involved in the patient's treatment since the beginning.

Patients should be on a liquid diet the day before the procedure and continued for 2 weeks, followed by progression from hypocaloric liquids to small semisolid meals over 4 weeks. Exercise initially consists of walking, with a progressive increase in intensity that parallels the diet progression. Weekly contacts are recommended to evaluate performance and provide solutions for problems related to compliance with lifestyle modifications that patients may have experienced. Patients should be given proton pump inhibitors, antiemetics, analgesics, and antispasmodics.

It is preferable to schedule oral contrast studies to assess the gastroplasty at 3 and 24 months. Gastroscopy is also recommended at 6 or 12 months to assess the tightness of the sutures and of the endosleeve.

Baseline and follow-up examinations include assessment of weight, height, and BMI. Outcomes at 1, 3, 6, 12, and 24 months should be (1) change in body weight (TBWL), (2) percentage loss of initial body weight (%TBWL), (3) percentage of excess body weight loss (percentage of weight lost compared with excess weight, defined as current weight minus the weight corresponding to a BMI of 25 kg/m^2) (%EWL), and (4) change in BMI.

19.4 Endoscopic Gastric Plication Procedures

19.4.1 Bard EndoCinch Suturing System (C. R. Bard, Inc., Murray Hill, NJ, USA)

The EndoCinch procedure was first introduced in 2008 using the Bard EndoCinch Suturing System (C. R. Bard, Inc., Murray Hill, NJ), which is an investigational device in the United States to be mounted on an Exera 145 gastroscope (Olympus Medical System Corp., Tokyo, Japan) and that uses 3-0 polypropylene suture [9]. The EndoCinch was then applied for the primary treatment of obesity by performing an endoluminal vertical gastroplasty – an analog of a bariatric surgery called vertical banded gastroplasty. The stitch configuration was composed of one continuous suture running through 5–7 bites of tissue or stitch points (Figs. 19.1 and 19.2). However, studies failed to demonstrate long-term efficacy of the EndoCinch procedure; therefore it is no longer commercially available.

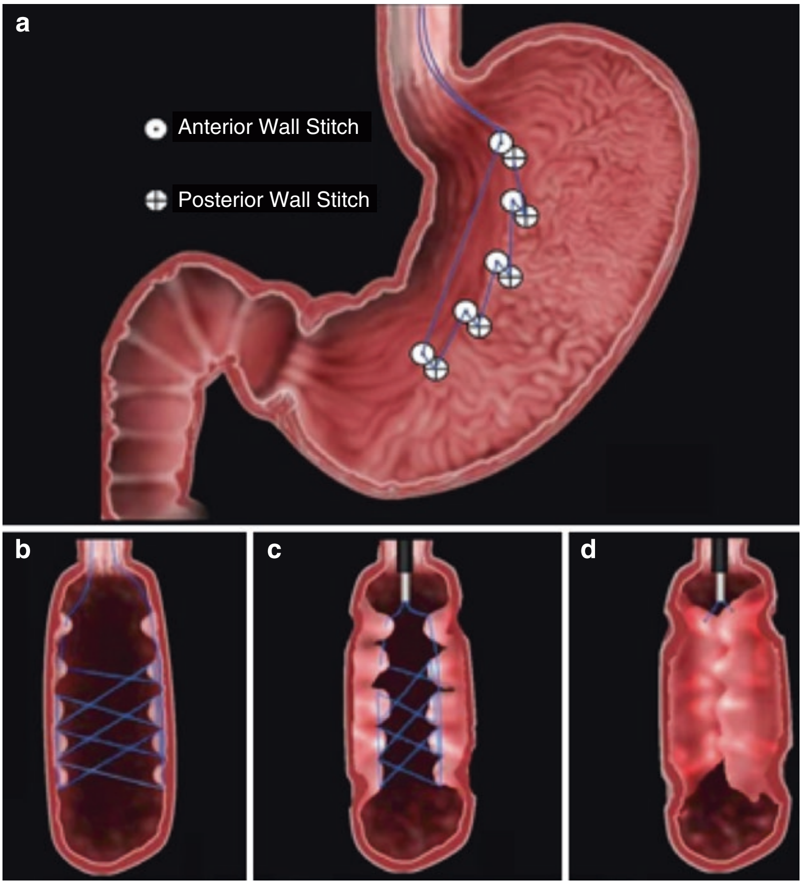


Fig. 19.1 (**a**–**d**) Schematics of the EndoCinch procedure

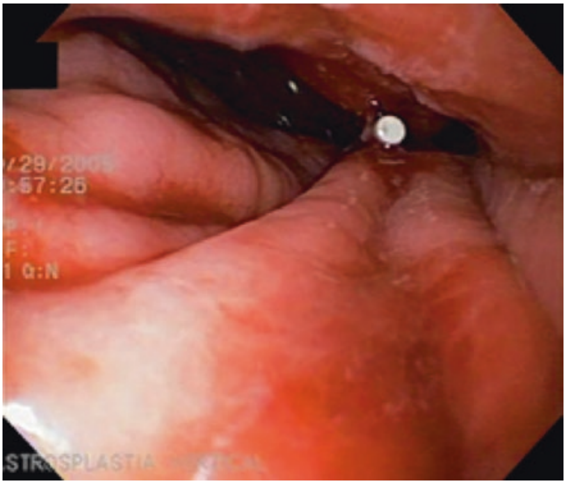


Fig. 19.2 The endoscopic appearance of the EndoCinch procedure

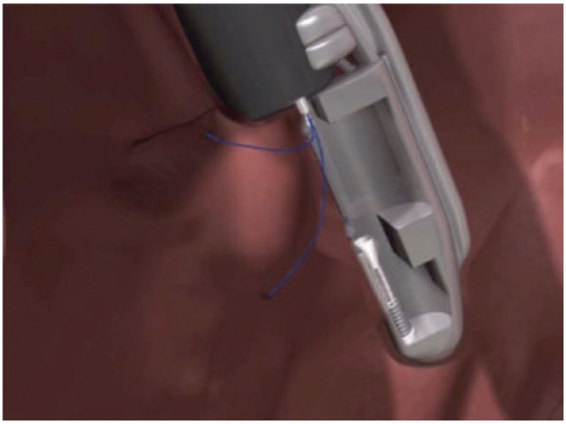


Fig. 19.3 Schematic of the RESTORe stitching

19.4.2 RESTORe (Bard/Davol, Warwick, RI, USA)

The RESTORe Suturing System device (Bard/Davol, Warwick, RI, USA) was approved by the FDA. It is a single intubation multistitch device that does not require an overtube for insertion. The suturing device includes a suction capsule placed at the end of a standard endoscope. After the capsule is placed in the desired position on the gastric mucosa, suction is applied to pull the stomach wall into the chamber, and a suture is passed through the tissue. The capsule is rolled off the tissue, and the needle is then advanced again to capture the suture tag at the end of the capsule. RESTORe could perform deeper-thickness suturing than the EndoCinch and does not need to be removed and reinserted for suture reloading. It was used in the transoral gastric volume reduction as intervention for weight management in the TRIM trial [9]. Just as it happened with BARD, long-term data did not prove the effectiveness of the RESTORe procedure; therefore it has been discontinued (Fig. 19.3).

19.4.3 Endoscopic Sleeve (OverStitch™; Apollo Endosurgery, Austin, TX)

The Apollo OverStitch device (Apollo Endosurgery, Inc., Austin, TX, USA) is a stitching device used to create endoscopic sleeve gastroplasty. It is commercially available in many countries now, and the FDA has already approved for GI tissue apposition in general. It evolved from the Eagle Claw device [13] and has been employed for many other procedures including closure of perforations in the esophagus and colon [14, 15], stent fixation [16], fistulas and leaks closure [17, 18], ESD and related offshoots such as submucosal tunnel endoscopic resection (STER) and endoscopic full-thickness resection (EFTR) [19], EMR and perforations during peroral endoscopic myotomy (POEM) [20], and after weight regain following RYGB and sleeve gastrectomy [21–23].

It is mounted onto a double-channel therapeutic gastroscope and is outfitted with a cap-based flexible endoscopic suturing system (OverStitch; Apollo Endosurgery, Austin, TX) to perform the procedure. The suturing device consists of a needle driver, a catheter-based suture anchor, and an actuating handle. A specific cuffed esophageal overtube (Apollo Endosurgery, Austin, Texas, USA) (US Endoscopy, Mentor, OH) is inserted to safeguard the esophagus and prevent decompression of the insufflated stomach. Some experts use APC demarcation lines along the anterior and posterior walls to direct the stitching.

The helix device (Helix; Apollo Endosurgery) is used to grasp tissue allowing sequential full-thickness bites. Rotating the helix device handle clockwise 180° usually guarantees full-thickness tissue grasping and allows it to be pulled into the gap of the open suturing device. A 2/0 polypropylene suture is applied, beginning at the anterior wall at the level of the *incisura angularis* with further bites taken on the greater curvature and then the posterior wall. The suture line was then continued in a retrograde fashion within 1 cm proximal to the initial row, from posterior wall to the anterior wall, via the greater curvature. Once the needle is driven through the gastric wall, the needle tip with the attached suture is transferred to the curved driver (reloaded). After completion of the suture pattern, the needle is released from the curved driver to anchor the end of the suture. The needle tip serves as a T-tag anchor. A cinching device is advanced and firmly squeezed to cinch and cut the threaded suture to tightly approximate the opposing gastric walls, creating a full-thickness volume reduction plication. The suture should be pulled tight so as to bring the tissue together. Each suture consists of six to eight bites along the anterior/greater curvature/posterior gastric wall before it is cinched. Because this is not a continuous staple line but rather an invagination of the greater curvature of the stomach, intraluminal gaps exist along the plication line. These gaps are of no clinical consequences as far as trapping food and are similar to gaps seen with surgical plications of the greater curvature for weight loss. A second layer of sutures is placed over the length of the central sleeve in an interrupted pattern to further reduce the gastric volume and reinforce the sleeve if needed. The suture pattern has evolved from a very few cases addressing the fundus to the majority in which it is left open, so the patient can have a pouch and some accommodation ability. In this sense, a small fundal pouch should remain at the end of each procedure.

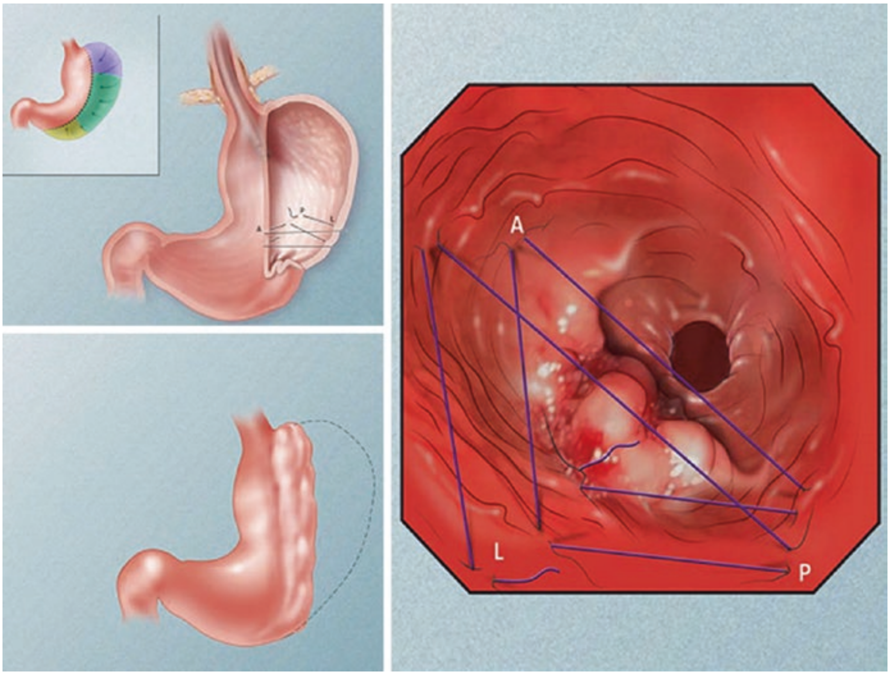


Fig. 19.4 Drawing of the ESG procedure with the initial technique when the fundus was routinely sutured. Currently, the fundus is left open, and typically a fundal pouch remains at the end of the procedure

The luminal diameter after completion of the procedure is around 13–16 mm, and the estimated volume of the stomach is approximately 100 mL. This technique reduces the entire stomach along the greater curvature, creating sleeve-like anatomy. Video 1 shows a standard ESG procedure with the current technique (Fig. 19.4).

19.4.4 Primary Obesity Surgery Endolumenal (POSE™) (USGI Medical)

The procedure is performed using the Incisionless Operating Platform (IOP; USGI Medical, San Clemente, CA, USA). The device creates tissue plications by opposing tissue and then deploying and anchoring full-thickness plications. The device uses a four-channel platform, with a 4.9 mm visualization endoscope, a rotatable tissue grasper and suture cutter (g-Prox), a tissue helix (g-Lix), and a suture anchor deployment catheter (g-Cath).

To perform the POSE procedure, the IOP is retroflexed and used to create two parallel rows with 4–5 plications each. This reduces the fundic apex to the level of the gastroesophageal junction. After the forward view is restored, a ridge of 3–4 plications is then created at the intersection of the gastric body and gastric antrum, across from the incisura.

It works by restricting contact of ingested food, activating gastric stretch receptors in response to food, and partially defunctionalizing the fundus by limiting its ability to accommodate a meal. The distal plications slow antral contractions and delay complete gastric emptying, thereby reducing hunger and initiating earlier and prolonged satiety. It is performed under general anesthesia and CO2 insufflation. A standard gastroscopy should be routinely performed prior to the procedure. Despite initial studies showed good outcomes, long-term data showed POSE procedure to be ineffective [24]; therefore it is currently being modified, and new studies are needed to prove safety and efficacy (Figs. 19.5 and 19.6).

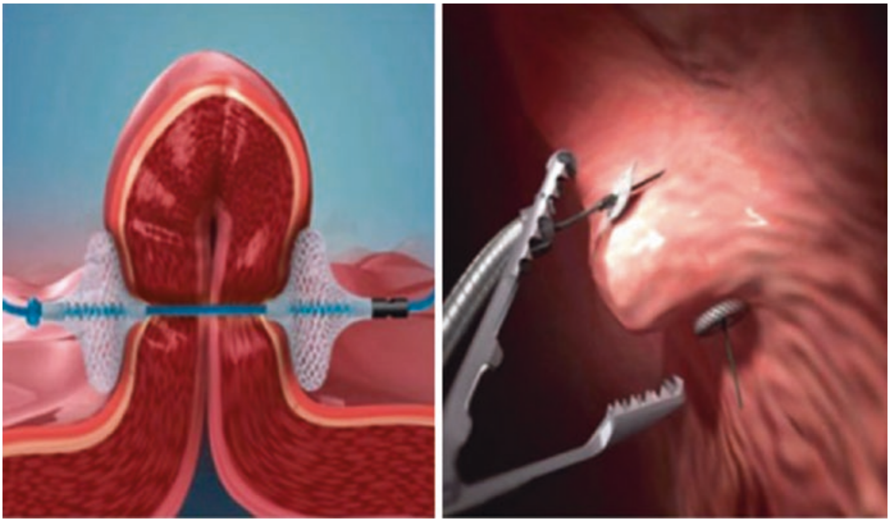


Fig. 19.5 Tissue plications using the Incisionless Operating Platform (IOP; USGI Medical, San Clemente, CA, USA)

Fig. 19.6 Schematics of the POSE procedure

19.5 Long-Term Results

Previous studies have shown that a total body weight loss greater than 10% is associated with improvement in obesity-related comorbidities [25]. Some endoscopic bariatric procedures can safely achieve such threshold in most patients who are unwilling to undergo surgery or those who are still not eligible to undergo surgery. Furthermore, an international consensus recommends that endoscopic bariatric and metabolic therapies (EBMT) should have an incidence of serious adverse events of 5% or less and should result in 25% or more EWL at 12 months. Moreover, the EWL should be at least 15% higher than that of the control group [26].

The gastric plication (GP), or gastric imbrication, is a restrictive procedure that was first reported by Kirk in 1968 [27]. During this procedure, the stomach was folded over and stitched to itself, resulting in a 75% reduction in gastric size. Four different endoscopic procedures, the so-called EGP procedures, have been reported to date trying to mimic the effects of GP, namely, the Bard EndoCinch Suturing System (C. R. Bard, Inc., Murray Hill, NJ), the RESTORe suturing system (Bard/Davol, Warwick, RI), endoscopic sleeve gastroplasty (Apollo Endosurgery, Austin, TX), and the Incisionless Operating Platform for Primary Obesity Surgery Endolumenal (USGI Medical, San Clemente, CA). Since the ESG is the only currently available worldwide, the review on outcomes will be restricted to that procedure.

19.5.1 OverStitch (OverStitch; Apollo Endosurgery, Austin, TX)

An international procedure development trial was first started in 2012 [28]. Abu Dayyeh et al. (2013) reported the technical feasibility of the ESG in a pilot study enrolling four human subjects. Approximately ten interrupted full-thickness opposing sutures were delivered. Closure of the fundus was established with a two-layer set of as many as five sets of opposing sutures. Closure of this proximal compartment was intended to avoid creating a blind cavity within which undigested food could collect. No serious adverse events were reported [11]. Furthermore, Abu Dayyeh et al. (2017) reported a mean of 72% EWL of 5/8 patients (62.5%) at 20 months. However, the three remaining individuals regained all the weight lost at 20 months. After ESG, physiological analyses of four participants showed a decrease by 59% in caloric consumption to reach maximum fullness ($P = 0.003$), slowing of gastric emptying of solids ($P = 0.03$), and a trend toward increased insulin sensitivity ($P = 0.06$). Four hours after solid meal ingestion, 32.25% of the meal was retained in a small gastric fundus cap after ESG compared with 5.25% before the procedure. There were no statistically significant changes in ghrelin, leptin, GLP-1, and PYY levels. However, three patients out of the full cohort ($n = 25$) had serious adverse events (a perigastric inflammatory collection, a pulmonary embolism, and a small pneumothorax) but made full recoveries with no need for surgical interventions [12].

Gontrand Lopez-Nava et al. reported the ESG in 20 patients with a mean body weight reduction of 19.3 ± 8.9 kg at 6 months (17.8% TBWL; $p < 0.05$). No adverse events were reported. A total of ten patients (50%) agreed to perform endoscopy at 6 months, and all patients showed suture stability with intact gastroplasty. Also, the oral contrast study on the day after the procedure was similar to those performed at 3 and 6 months [29]. Another 55 patients were included in another report, and after 6 months, patients had a mean absolute weight loss of 18.9 kg and an EWL of 55.3%. There were no major complications, although some patients had abdominal pain (50%) and nausea (20%), which were treated with painkillers and antiemetics [30]. A 1-year study of 50 patients has shown that the mean BMI changed from 37.7 ± 4.6 to 30.9 ± 5.1 kg/m^2 at 12 months and mean %TBWL was 19.0 ± 10.8. (13 patients). No serious adverse events were reported [31].

In 2016, Lopez-Nava et al. published a single-center study assessing predictive factors for weight loss. Twenty-five patients undergoing ESG were followed for 1 year. In the linear regression analysis, adjusted by initial BMI, they showed that variables associated with % TBWL were the frequency of nutritional ($\beta = 0.563$, $p = 0.014$) and psychological contacts ($\beta = 0.727$, $p = 0.025$). The number of nutritional and psychological contacts was predictive of good weight loss results [32].

A multicenter study (3 centers) included 248 consecutive patients in a retrospective analysis. At 6 and 24 months, 33/248 and 35/92 patients were lost to follow-up. At 6 and 24 months, %TBWL was 15.2% and 18.6%, respectively. At 24 months, % of patients achieving ≥10% TBWL was 84.2%. On multivariable linear regression analysis, only %TBWL at 6 months strongly predicted %TBWL at 24 months. Five (2%) serious adverse events occurred: two perigastric inflammatory fluid collections (adjacent to the fundus) that resolved with percutaneous drainage and antibiotics, one self-limited extra-gastric hemorrhage that required blood transfusion, one pulmonary embolism 72 h after the procedure, and one pneumoperitoneum and pneumothorax requiring chest tube placement. All five patients recovered fully without surgical intervention. The limitations of this study included lack of a control group, short follow-up, absence of endoscopic or radiographic evaluation of the plication durability, and significant loss to follow-up rate at 24 months [33].

An international multicenter trial performed ESG in different centers from India, Panama, the Dominican Republic, Spain, and the United States. The trial was performed in three phases. In phase III, which employed the current ESG technique, 77 patients were included. The mean weight loss was 16.0 ± 0.8% at 6 months and 17.4 ± 1.2% at 12 months ($n = 44$). There were no significant adverse events postprocedure or during the follow-up period [34].

The largest experience in the world was recently published by Alqahtan and colleagues. The study reported the ESG in 1000 patients. Mean % total weight loss (n; N; follow-up rate) at 6, 12, and 18 months was 13.7 ± 6.8% ($n = 369$; $N = 423$; 87.2%), 15.0 ± 7.7% ($n = 216$; $N = 232$; 93.1%), and 14.8 ± 8.5 ($n = 54$; $N = 63$; 85.7%), respectively. Twenty-four patients were readmitted: severe abdominal pain ($n = 8$), of whom three had ESG reversal; postprocedure bleeding ($n = 7$), two of whom received two units of packed red blood cells each; perigastric collection with pleural effusion ($n = 4$), three of whom underwent percutaneous drainage; and postprocedure fever with no sequelae ($n = 5$). Eight patients were revised to sleeve gastrectomy, and five had redo ESG. No patient required emergency intervention, and there were no mortalities [35].

19.6 Comparison with Other Procedures

Fayad et al. compared the 6-month weight loss outcomes and adverse events of ESG with LSG (laparoscopic sleeve gastrectomy) in a case-matched cohort study. A total of 54 ESG patients were matched to 83 LSG patients. At the 6-month follow-up, %TBWL (compared with baseline) was significantly lower in the ESG group compared with the LSG group (17.1% + 6.5% vs 23.6% + 7.6%, $p < 0.01$). On the other hand, ESG patients had significantly lower overall rates of adverse events compared with LSG patients (5.2% vs 16.9%, $p < 0.05$). New-onset GERD was also significantly lower in the ESG group compared with the LSG group (1.9% vs 14.5%, $p < 0.05$). At 6 months, 72.2% of ESG patients and 88.57% of LSG patients achieved >15% TBWL [36].

Novikov et al. compared the outcomes of ESG with LSG. This non-matched cohort study demonstrated that LSG achieved superior %TBWL compared with ESG at 6 months (23.48% vs 14.37%, $p < 0.001$) and 12 months (29.28% vs 17.57%, $p < 0.001$). However, a subgroup analysis at 12 months demonstrated similar weight loss outcomes in patients with BMI < 40 kg/m^2. The length of stay was shorter (0.34 + 0.73 days vs 3.09 + 1.47 days, $p < 0.001$), and there were fewer adverse events in the ESG group compared to the LSG group (2.20% vs 9.17%, $p < 0.05$) [37].

Table 19.1 summarizes all currently available evidence regarding the ESG at treating obesity and overweight.

19.7 Learning Curve

Most bariatric procedures are considered high-risk procedures and should be performed in a hospital setting. Theoretical learning, as well as hands-on courses, is essential. The cognitive aspects of bariatric endoscopy include understanding the pathophysiology of obesity, different management options for obesity including lifestyle therapy, medications, bariatric endoscopy, and bariatric surgery, and in which patient population and when bariatric endoscopy should be considered. A clear understanding of endoscopic bariatric and metabolic therapy devices and procedures including their mechanisms of action, efficacy, and risk profile is crucial [44].

As for any surgical procedure, greater experience leads to technical improvement and reduction of adverse events, shortens the duration of the procedure, and may impact on main outcomes. In this sense, to define a learning curve for ESG is of paramount importance. By using a penalized B-spline regression and a cumulative sum (CUSUM) analysis, Saumoy et al. found that efficiency was attained after 38

Table 19.1 Summary of ESG outcomes

No.	Authors/year/ country	Study type	Sample (M:F)	Patients characteristics	Procedure time (minutes)	Longest follow-up	Weight loss outcomes	Other outcomes	Related adverse events
1	Abu Dayyeh et al. (2013) USA [11]	Single-center feasibility study	Total: 4 (1:3)	Mean age: 36 ± 11 yearsMean BMI: 36 ± 2.0 kg/m^2	Range: 172–245	3 months	Not reported		Serious: noneMinor: abdominal pains and nausea (3/4); GERD (1/4)
2	Sharaiha et al. (2015) USA [38]	Single-center prospective series	Total: 10 (3:7)	Mean age: 43.7yearsMean BMI: 45.2 ± 8.8 kg/m^2	Median: 157 (118–360)	6 months	**1. EWL (%) =** 18, 28, 30 (1, 3, and 6 months**2. AWL (kg) =** 11.5, 19.4, 33 (1, 3, and 6 months)**3. BMI reduction =** 4.9 kg/m^2	Mean waist circumference loss of 21.7 cm	Serious: noneMinor: abdominal pain and nausea (8/10); chest pain (2/10)
3	Lopez-Nava et al. (2015) Spain [29]	Single-center prospective series	Total: 20 (4:16)	Mean age: 45.8 ± 8.4 yearsMean BMI: 38.5 ± 4.8 kg/m^2	Mean: 75 (40–120)	6 months	**1. EWL (%) =** 24.6 ± 14.3, 39.3 ± 19.9, 53.9 ± 26.3 (1, 3, and 6 months).2. AWL (kg) = 8.2 ± 2.5, 13.6 ± 4.8, 19.3 ± 8.9 (1, 3, and 6 months).3. TWL (%) = 7.6 ± 2.2, 12.4 ± 3.9, 17.8 ± 7.5		None

4	Lopez-Nava et al. (2015) Spain [31]	Single-center prospective series	Total: 50 (13:37)	Mean age: 43.0 ± 9.0 yearsMean BMI: 37.7 ± 4.6 kg/m^2	Mean: 66	12 months	1. EWL (%) = 22.6 ± 10.5, 40.2 ± 17.3, 53.5 ± 26.2, 57.0 ± 33.9 (1,3,6, and 12 months).2. AWL (kg) = 7.4 ± 2.7, 13.5 ± 5.6, 18.7 ± 8.9, 21.6 ± 13.5 (1,3,6, and 12 months).3. TWL (%) = 6.9 ± 2.1, 12.6 ± 4.3, 17.2 ± 7.5, 19 ± 10.8 (1,3,6, and 12 months)		Serious: noneMinor: epigastric pain (25/50), nausea (10/50)
5	Lopez-Nava et al. (2016) Spain [32]	Single-center prospective series	Total: 25 (5:20)	Mean age: 44.5± 8.2 yearsmean BMI: 38.5 ± 4.6 kg/m^2	Mean: 80 (50–120)	12 months	1. EWL (%) = 24.0 ± 11.8, 40.5 ± 16.5, 53.9 ± 24.8, 54.6 ± 31.9 (1,3,6, and 12 months)2. AWL (kg) = 7.9 ± 2.7, 14.1 ± 5.5, 19.6 ± 9.1, 21.1 ± 12.6 (1,3,6, and 12 months)3. TWL (%) = 7.4 ± 2.3, 12.9 ± 4.3, 17.8 ± 7.5, 18.7 ± 10.7 (1,3,6, and 12 months)4. BMI reduction (kg/m^2) = 2.8 ± 0.8, 4.9 ± 1.6, 6.9 ± 2.9, 7.3 ± 4.2 (1,3,6, and 12 months)		Serious: noneMinor: abdominal pain (50%), nausea (20%)

(continued)

Table 19.1 (continued)

No.	Authors/year/ country	Study type	Sample (M:F)	Patients characteristics	Procedure time (minutes)	Longest follow-up	Weight loss outcomes	Other outcomes	Related adverse events
6	López-Nava Breviere et al. (2016) Spain [30]	Single-center prospective series	Total: 55 (13:42)	Mean age: 43.5 ± 8.1 yearsMean BMI: 37.7 ± 4.5 kg/m^2	Not reported	6 months	1. EWL (%) = 23.1 ± 10.2, 43.3 ± 16.2, 55.3 ± 23.8 (1,3, and 6 months)2. AWL (kg) = 7.7 ± 2.9, 13.3 ± 4.0, 18.9 ± 9.5 (1, 3, and 6 months) 3. TWL (%) = 7.1 ± 2.2, 13.3 ± 4.0, 17.3 ± 7.0 (1, 3, and 6 months)		Serious: noneMinor: abdominal pain (50%), nausea (20%)
7	Galvão-Neto et al. (2016) Brazil [39]	Case report	Total: 1 (1:0)	Age: 56 yearsBMI: 35.2 kg/m^2	50	Not reported	Not reported		Serious: noneMinor: self-limited pneumoperitoneum and mild abdominal pain
8	Sharaiha et al. (2017) USA [40]	Single-center prospective series	Total: 91 (29:62)	Mean age: 43.9 ± 11.3 yearsMean BMI: 38.6 ± 7.0 kg/m^2	Mean: 98.3 ± 39.3	24 months	1. TWL (%) = 14.4, 17.6 and 20.9% (6, 12, and 24 months)	Significant improvement in waist circumference, systolic blood pressure, mean HbA1c, alanine aminotransferase, serum triglycerides. Reduction in the mean size of the stomach (34.8–20.4 cm, $p < 0.001$)	Serious: perigastric leak (1/91, managed with percutaneous drainage and antibiotics)Minor: nausea (35/91); abdominal pain (25/91)

9	Abu Dayyeh et al. (2017) USA [12]	Single-center prospective series	Total: 25 (4:21)	Mean age: 47.6 ± 10 yearsMean BMI: 35.5 ± 2.6 kg/m^2	Mean: 217 ± 17 (first 5 ESGs); 98 ± 4 (last 5 ESGs)	20 months	1. EWL (%) = 53 ± 17, 56 ± 23, 54 ± 40, 45 ± 41 (6,9,12, and 20 months)	Delayed gastric emptying for solids at 4 h. Significant reduction in caloric intake and time for termination of the meal (pre-ESG vs 3 months post-ESG)	Serious: 1 perigastric inflammatory serous fluid collection (improved with percutaneous drainage and antibiotics); 1 pulmonary embolism; 1 pneumoperitoneum and pneumothorax (chest tube placement) Minor: abdominal pain (17/25); nausea (17/25); hospital admission for pain and nausea (8/25)
10	Kumar N et al., (2018) Dominican Republic,Spain, USA [34]	Multicenter prospective series	Total: 77 with current ESG technique (18:59)	Mean age: 41.3 ± 1.1 yearsMean BMI: 36.1 ± kg/m^2	Not reported	12 months	1. TWL (%) = 16.0 ± 0.8, 17.4 ± 1.2 (6 and 12 months)2. AWL (kg) = 16.4 ± 0.9, 18.9 ± 1.5 (6 and 12 months)	Patients resumed daily activities in 1–3 days	Serious: noneMinor: frequent abdominal pain and nausea
11	Sartoretto et al. (2018) Australia and USA [41]	Multicenter prospective series	Total: 112 (35:77)	Mean age: 45.1 ± 11.7Mean BMI: not reported	Not reported	6 months	1. EWL (%) = 28.2 ± 18.3, 39.9 ± 17.3, 50.3 ± 22.4 (1, 3, and 6 months)2. AWL (kg) = 9 ± 4.6, 12.9 ± 6.4, 16.4 ± 10.7 (1, 3, and 6 months)3. TWL (%) = 8.4 ± 4.1, 11.9 ± 4.5, 14.9 ± 6.1 (1, 3, and 6 months)	Absence of previous bariatric procedure was predictor of greater TWL	Serious: 2 gastrointestinal bleedings and 1 perigastric fluid collection (treated with antibiotics only). Mild: nausea, vomiting, and abdominal pain in a large proportion of patients

(continued)

Table 19.1 (continued)

No.	Authors/year/ country	Study type	Sample (M:F)	Patients characteristics	Procedure time (minutes)	Longest follow-up	Weight loss outcomes	Other outcomes	Related adverse events
12	Graus-Morales et al. (2018) Spain [42]	Single-center prospective series	Total: 148 (27:121) - different stitching pattern	Mean age: 41.5 ± 10 yearsMean BMI: 35.1 ± 5.5 kg/m^2	Majority of procedures completed in 45–60 min	18 months	1. EWL (%) = 50.5 ± 56, 64.93 ± 51, 70.79 ± 68, 75.4 ± 85, 79.25 ± 43 (3, 6, 9, 12, and 18 months)2. AWL (kg) = 11.53 ± 4.7, 15.5 ± 7.41, 16.89 ± 8.63, 17.62 ± 9.22, 18.5 ± 9 (3, 6, 9, 12, and 18 months)3. TWL (%) = 11.59 ± 3.82, 15.45 ± 5.9, 16.79 ± 7.01, 17.53 ± 7.57, 18.66 ± 7.3 (3, 6, 9, 12, and 18 months)	The subgroup with BMI ≤ 35 kg/m^2 reached almost the ideal weight at 12 months of follow-up (EWL = 98%)	Serious: 1 sustained abdominal pain, 1 gastrointestinal bleeding.Mild: frequent mild epigastric pain and vomits
13	Ruiz et al. (2017) Spain and Brazil [43]	Retrospective non-matched cohort (ESG x LGCP x SG)	Total: 357 (ESG 253+ LGCP 38 + SG 66)	Mean age: not reported Mean BMI (ESG): 37.29 kg/m^2	Not reported	24 months	1. EWL (%) = 56.08 (24 months) 2. AWL (kg) = 18.33 (24 months) 3. BMI reduction (kg/m^2) = 6.97 (24 months)	Similar BMI at final follow-up despite greater weight loss for LCGP and SG. Shorter length of stay (1 day vs 3 days) and fewer overall adverse events for the ESG group	Serious: 1.18% (0 reoperations) Mild: not reported

14	Novikov et al. (2018) USA [37]	Retrospective cohort (ESG x LAGB x LSG)	Total: ESG 91 (29:62) + LSG 120 (26:94) + LAGB 67 (13:54)	Mean age (ESG): 43.8 ± 11.2 yearsMean BMI (ESG): 38.6 ± 6.9 kg/m^2	Not reported	12 months	1. TWL (%) = 14.4, 17.5 (6 and 12 months).At 6 and 12 months, LSG achieved the greatest %TWL compared to ESG and LABG ($p <$ 0.001)	The subgroup analysis for BMI < 40 kg/m^2 showed no significant difference in %TWL at 12 months when comparing the three different techniques. The length of stay was significantly shorter for ESG	Serious (ESG): 1 perigastric inflammatory serous fluid collection (improved with percutaneous drain). Mild (ESG): not reportedThe ESG had fewer overall adverse events compared to LSG or LAGB (2.20 vs9.17 vs 8.96%, p value <0.05)
15	Fayad et al. (2018) USA [36]	Retrospective matched cohort (ESG x LSG)	Total: ESG 54 (23:31) + LSG 83 (24:59)	Mean age (ESG): 48 (24–72) yearsMean BMI (ESG): 43 (30–65) kg/m^2	Not reported	6 months	1. TWL (%) = 9.8 ± 2.5, 17.1 ± 6.5 (1 and 6 months).The ESG had greater TWL than LSG at 1 month ($p <$ 0.001) but lower at 12 months ($p < 0.001$)	For patients BMI < 40 kg/m^2, the difference in TWL diminished sharply, but there was still a borderline superiority of the LSG over the ESG ($p = 0.05$). The ESG patients had a significantly lower rate of overalladverse events	Serious (ESG): 2 upper GI bleeding and 1 perigastric fluid collection. Mild (ESG): not reported

BMI body mass index, *GERD* gastroesophageal reflux disease, *EWL* excess weight loss, *AWL* absolute weight loss, *TWL* total weight loss, *ESG* endoscopic sleeve gastroplasty, *LSG* laparoscopic sleeve gastrectomy, *LAGB* laparoscopic adjustable gastric band

ESGs and mastery after 55 procedures [45]. Such robust statistical analysis provided reliable evidence on the learning curve of the ESG.

19.8 Metabolic Effect

Sharaiha et al. evaluated 91 patients after 6 months ($n = 73$), 12 months ($n = 53$), and 24 months ($n = 12$). Patients lost 14.4% of their total body weight at 6 months (80% follow-up rate), 17.6% at 12 months (76% follow-up rate), and 20.9% at 24 months (66% follow-up rate) after ESG. At 12 months, they had statistically significant reductions in levels of hemoglobin A1c ($p = 0.01$), systolic blood pressure ($p = 0.02$), waist circumference ($p < 0.001$), alanine aminotransferase ($p < 0.001$), and serum triglycerides ($p = 0.02$). However, there was no significant change in low-density lipoprotein after vs before ESG ($p = 0.79$). There was one serious adverse event (1.1%), a perigastric leak that was managed nonoperatively.

Seventy percent of patients at 12-month follow-up achieved clinical success as defined by greater than 15% TBWL. There was a statistically significant change in HbA1c between baseline and at 12 months after ESG in the overall cohort (mean + SD, 6.1% + 1.1% vs 5.5% + 0.48%, respectively; $p = 0.05$). In patients with diabetes or prediabetes, there was an even greater reduction in HgA1c (mean + SD, 6.6% + 1.2% vs 5.6% + 0.51%, respectively; $p = 0.02$). Furthermore, five patients in total were able to stop insulin, and two patients stopped all medications. There were significant reductions in SBP (129.0 + 13.4 mm Hg vs 122.2 + 11.69 mm Hg [$p = 0.02$]), TG (131.84 + 83.19 mmol/dL vs 92.36 + 39.43 mmol/dL [$p = 0.02$]), and ALT (42.4 vs 22 in men, $p = 0.05$, and 28 vs 20 in women, $p = 0.01$) when compared between baseline and 12 months after ESG, respectively [40].

Despite all exciting results of the ESG at short, mid, and long term, controlled studies are still lacking. Current ongoing trials will certainly fill this literature gap in the near future.

References

1. Organization WH (2016) Overweight and obesity – global observatory data. https://www.who.int/gho/ncd/risk_factors/overweight_text/en/. Accessed 1 Aug 2019.
2. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of childhood and adult obesity in the United States, 2011-2012. JAMA. 2014;311:806–14.
3. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J, Buchwald H, Scopinaro N. IFSO worldwide survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28:3783. https://doi.org/10.1007/s11695-018-3450-2.
4. Wharton S, Serodio KJ, Kuk JL, Sivapalan N, Craik A, Aarts M-A. Interest, views and perceived barriers to bariatric surgery in patients with morbid obesity. Clin Obes. 2016;6:154–60.
5. Buchwald H, Oien DM (2013) Metabolic/bariatric surgery worldwide 2011. 427–436.

6. Chang S-H, Stoll CRT, Song J, Varela JE, Eagon CJ, Colditz GA. The effectiveness and risks of bariatric surgery: an updated systematic review and meta-analysis, 2003-2012. JAMA Surg. 2014;149:275–87.
7. Abu Dayyeh BK, Kumar N, Edmundowicz SA, Jonnalagadda S, Larsen M, Sullivan S, Thompson CC, Banerjee S. ASGE bariatric endoscopy task force systematic review and meta-analysis assessing the ASGE PIVI thresholds for adopting endoscopic bariatric therapies. Gastrointest Endosc 82. 2015;e5:425–38.
8. Rohde U, Hedback N, Gluud LL, Vilsboll T, Knop FK. Effect of the EndoBarrier Gastrointestinal Liner on obesity and type 2 diabetes: a systematic review and meta-analysis. Diabetes Obes Metab. 2016;18:300–5.
9. Fogel R, De Fogel J, Bonilla Y, De La Fuente R. Clinical experience of transoral suturing for an endoluminal vertical gastroplasty: 1-year follow-up in 64 patients. Gastrointest Endosc. 2008;68:51–8.
10. Brethauer SA, Chand B, Schauer PR, Thompson CC. Transoral gastric volume reduction for weight management: technique and feasibility in 18 patients. Surg Obes Relat Dis. 2010;6:689–94.
11. Abu Dayyeh BK, Rajan E, Gostout CJ. Endoscopic sleeve gastroplasty: a potential endoscopic alternative to surgical sleeve gastrectomy for treatment of obesity. Gastrointest Endosc. 2013;78:530–5.
12. Abu Dayyeh BK, Acosta A, Camilleri M, Mundi MS, Rajan E, Topazian MD, Gostout CJ. Endoscopic sleeve gastroplasty alters gastric physiology and induces loss of body weight in obese individuals. Clin Gastroenterol Hepatol. 2017;15:37–43.e1.
13. Chiu PWY, Hu B, Lau JYW, Sun LCL, Sung JJY, Chung SSC. Endoscopic plication of massively bleeding peptic ulcer by using the Eagle Claw VII device: a feasibility study in a porcine model. Gastrointest Endosc. 2006;63:681–5.
14. Henderson JB, Sorser SA, Atia AN, Catalano MF. Repair of esophageal perforations using a novel endoscopic suturing system. Gastrointest Endosc. 2014;80:535–7.
15. Pauli EM, Delaney CP, Champagne B, Stein S, Marks JM. Safety and effectiveness of an endoscopic suturing device in a human colonic treat-and-resect model. Surg Innov. 2013;20:594–9.
16. Sharaiha RZ, Kumta NA, Doukides TP, et al. Esophageal stenting with sutures: time to redefine our standards? J Clin Gastroenterol. 2015;49:e57–60.
17. M.F. C, S.A. S, J.B. H, S. A, A. A. Successful closure of enteric fistulas using the apollo overstitch suturing system. Gastroenterology. 2014;146:S142–3.
18. R.R. W, P. J, C.C. T. Endoscopic repair of post-operative gastrointestinal fistulae using a novel endoscopic suturing device: technical feasibility and safety. Gastroenterology. 2011;140:S118.
19. Kantsevoy SV, Bitner M, Mitrakov AA, Thuluvath PJ. Endoscopic suturing closure of large mucosal defects after endoscopic submucosal dissection is technically feasible, fast, and eliminates the need for hospitalization (with videos). Gastrointest Endosc. 2014;79:503–7.
20. J.R. A, J. D-B, M.A. A, J.A. B, M.M. P, A.B. C, P. M, J.C. S, S.V. K (2012)Comparison of endoscopic suturing techniques for closure of the transgastric entrance site for notes procedures. Gastrointest Endosc 75:AB273.
21. Sharaiha RZ, Kedia P, Kumta N, Aronne LJ, Kahaleh M. Endoscopic sleeve plication for revision of sleeve gastrectomy. Gastrointest Endosc. 2015;81:1004.
22. Eid G. Sleeve gastrectomy revision by endoluminal sleeve plication gastroplasty: a small pilot case series. Surg Endosc. 2017;31:4252–5.
23. Schulman AR, Kumar N, Thompson CC. Transoral outlet reduction: a comparison of purse-string with interrupted stitch technique. Gastrointest Endosc. 2018;87:1222–8.
24. Sullivan S, Swain JM, Woodman G, et al. Randomized sham-controlled trial evaluating efficacy and safety of endoscopic gastric plication for primary obesity: the ESSENTIAL trial. Obesity (Silver Spring). 2017;25:294–301.
25. Daniel S, Soleymani T, Garvey WT. A complications-based clinical staging of obesity to guide treatment modality and intensity. Curr Opin Endocrinol Diabetes Obes. 2013;20:377–88.

26. Chand B. A pathway to endoscopic bariatric therapies: ASGE/ASMBS task force on endoscopic bariatric therapy. Surg Obes Relat Dis. 2011;7:672–82.
27. Kirk RM. Gastric imbrication as a method of weight control. Br J Surg. 1968;55:867.
28. Kumar N, Sahdala HNP, Shaikh S, Wilson EB, Manoel GN, Zundel N, Thompson CC. Mo1155 endoscopic sleeve gastroplasty for primary therapy of obesity: initial human cases. Gastroenterology. 2014;146:S-571–2.
29. Lopez-Nava G, Galvao MP, Da Bautista-Castano I, Jimenez A, De Grado T, Fernandez-Corbelle JP. Endoscopic sleeve gastroplasty for the treatment of obesity. Endoscopy. 2015;47:449–52.
30. Lopez-Nava Breviere G, Bautista-Castano I, Fernandez-Corbelle JP, Trell M. Endoscopic sleeve gastroplasty (the Apollo method): a new approach to obesity management. Rev Esp Enferm Dig. 2016;108:201–6.
31. Lopez-Nava G, Galvao MP, Bautista-Castano I, Jimenez-Banos A, Fernandez-Corbelle JP. Endoscopic sleeve gastroplasty: how I do it? Obes Surg. 2015;25:1534–8.
32. Lopez-Nava G, Galvao M, Bautista-Castaño I, Fernandez-Corbelle JP, Trell M. Endoscopic sleeve gastroplasty with 1-year follow-up: factors predictive of success. Endosc Int open. 2016;4:E222–7.
33. Lopez-Nava G, Sharaiha RZ, Vargas EJ, et al. Endoscopic sleeve gastroplasty for obesity: a multicenter study of 248 patients with 24 months follow-up. Obes Surg. 2017;27:2649–55.
34. Kumar N, Abu Dayyeh BK, Lopez-Nava Breviere G, et al. Endoscopic sutured gastroplasty: procedure evolution from first-in-man cases through current technique. Surg Endosc. 2018;32:2159–64.
35. Alqahtani A, Al-Darwish A, Mahmoud AE, Alqahtani YA, Elahmedi M. Short-term outcomes of endoscopic sleeve gastroplasty in 1000 consecutive patients. Gastrointest Endosc. 2018;89:1132. https://doi.org/10.1016/j.gie.2018.12.012.
36. Fayad L, Adam A, Schweitzer M, et al. Endoscopic sleeve gastroplasty versus laparoscopic sleeve gastrectomy: a case-matched study. Gastrointest Endosc. 2018;89:782. https://doi.org/10.1016/j.gie.2018.08.030.
37. Novikov AA, Afaneh C, Saumoy M, et al. Endoscopic sleeve gastroplasty, laparoscopic sleeve gastrectomy, and laparoscopic band for weight loss: how do they compare? J Gastrointest Surg. 2018;22:267–73.
38. Sharaiha RZ, Kedia P, Kumta N, DeFilippis EM, Gaidhane M, Shukla A, Aronne LJ, Kahaleh M. Initial experience with endoscopic sleeve gastroplasty: technical success and reproducibility in the bariatric population. Endoscopy. 2015;47:164–6.
39. Galvao-Neto MDP, Grecco E, de STF, de QLG, Silva LB, Campos JM. Endoscopic sleeve gastroplasty – minimally invasive therapy for primary obesity treatment. Arq Bras Cir Dig. 2016;29(Suppl 1):95–7.
40. Sharaiha RZ, Kumta NA, Saumoy M, et al. Endoscopic sleeve gastroplasty significantly reduces body mass index and metabolic complications in obese patients. Clin Gastroenterol Hepatol. 2017;15:504–10.
41. Sartoretto A, Sui Z, Hill C, et al. Endoscopic sleeve gastroplasty (ESG) is a reproducible and effective endoscopic bariatric therapy sui for widespread clinical adoption: a large, international multicenter study. Obes Surg. 2018;28:1812–21.
42. Graus Morales J, Crespo Perez L, Marques A, Marin Arribas B, Bravo Arribas R, Ramo E, Escalada C, Arribas C, Himpens J. Modified endoscopic gastroplasty for the treatment of obesity. Surg Endosc. 2018;32:3936–42.
43. Ruiz AG, Breviere GL-N, Coll EE, Duran JN, Neto MG, Gebelli JP. Endoscopic gastroplasty VS. sleeve gastrectomy and laparoscopic gastric plication. A comparative study. Surg Obes Relat Dis. 2017;13:S9.
44. Jirapinyo P, Thompson CC. Training in bariatric and metabolic endoscopic therapies. Clin Endosc. 2018;51:430–8.
45. Saumoy M, Schneider Y, Zhou XK, Shukla A, Kahaleh M, Aronne L, Sharaiha RZ. A single-operator learning curve analysis for the endoscopic sleeve gastroplasty. Gastrointest Endosc. 2018;87:442–7.

Chapter 20
Staplerless Sleeves, and All Sewing Devices

Jose Luis Leyba and Salvador Navarrete Llopis

The incidence of obesity has been rising throughout the world, especially in developing nations. Due to the unacceptably high failure rate of medical treatment alone, bariatric surgery has risen as a safe alternative by providing a substantially more effective treatment strategy to achieve weight reduction and the resolution of associated comorbidities [1, 2].

Various bariatric surgical procedures have been described and remain viable options today. Sleeve gastrectomy has gained popularity among bariatric surgeons and has become the most frequently performed bariatric procedure in the United States [3]. This shift may be explained by a number of recent studies demonstrating the effectiveness of this operation when compared to other prevalent though more technically demanding and anatomically altering procedures such as gastric bypass or biliopancreatic diversion [4–10].

While this procedure gains attractiveness, its application is limited by its high cost, which is largely attributable to the use of laparoscopic staplers. In the developing world especially, this cost comprises a proportionally high amount of the overall cost of this operation. Hence, the use of laparoscopic stapling devices limits the widespread application of this operation in the public health systems of developing nations.

While laparoscopic staplers provide an effective means for transection and approximation of gastric tissue, alternatives such as bipolar coagulation devices are

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-28936-2_20) contains supplementary material, which is available to authorized users.

J. L. Leyba (✉)
Universidad Central de Venezuela, Hospital Universitario de Caracas, Clínica Santa Sofia, Caracas, Venezuela

S. Navarrete Llopis
Clínica Santa Sofía, Caracas, Venezuela

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_20

described. Experimental studies and case reports have demonstrated that these devices combined with conventional suture techniques safely provide successful tissue approximation and healing as evidenced histologically and supported by good patient outcomes [11–13].

A more widespread use in clinical application for these bipolar coagulation devices is the transection of the mesentery and vascular bundles of various organs (e.g., splenic vessels, renal vessels) without the necessity of sutures, staples, or clips. In rat and rabbit animal models of appendectomy, bipolar coagulation demonstrated effective transection of the appendix with comparable hemostasis and leak rate results to standard technique [11, 12, 14]. In efforts to investigate bipolar coagulation in intestinal anastomosis, studies demonstrated feasibility, but these were limited by lack of comparison to conventional methods [13, 15].

The bipolar device LigaSure Atlas™ (Valleylab, Tyco, Boulder, CO, USA) was introduced in 1998. It has a high frequency generator to provide bipolar energy to achieve tissue fusion. It employs what has been termed "instant response technology" which measures electric resistance of tissue between the jaws of the instrument and uses that measurement to apply a bipolar current to generate an appropriate voltage. This feedback-based mechanism provides vessel sealing without generating excess thermal spread and in turn limits damage of the surrounding tissue. The energy produced within the jaws of the instrument along with the application of pressure results in the rupture and reformation of hydrogen cross-links, ultimately yielding melting of collagen and elastin fibers and formation of a plastic-like sheet creating a tissue seal [16].

Vessel sealing technology has evolved with new devices demonstrating increase in hemostatic capacity, with liver sealing devices being a prime example. Although to date there are few studies that evaluate intestinal tissue fusion, experimental studies using porcine intestinal tissue and animal models such as those discussed earlier demonstrate feasibility in intestinal fusion even allowing for complete intestinal anastomosis [13, 17, 18].

In 2005 Himpens et al. reported a staple-free laparoscopic Roux-en-Y gastric bypass technique. He describes transection of the stomach and jejunum with bipolar coagulation, followed by securement of transection lines with manual suture [19]. From their success, it was felt the technique had potential for extension to other bariatric procedures such as sleeve gastrectomy and duodenal switch. Just 1 year later, Ramos et al. published their experience with a similar technique without major complications [20].

Using an experimental model to determine pressure tolerance in gastric transection, Lopez et al. compared four methods: stapler, stapler plus reinforcement suture, LigaSure™ (LS), and LS plus reinforcement suture. The LS plus reinforcement suture group showed the highest levels of tolerance to pressure and provided additional support for investigation of this technique [21].

In addition to their high cost, tissue stapling devices carry inherent risks over bipolar energy devices such as staple-line bleeding, stapler misfiring, leaks, and fistula formation. However, potential disadvantages to a bipolar energy device include potential for harmful thermal spread and the need for suture reinforcement which adds greater technical complexity and implies a longer learning curve.

Our technique of staplerless sleeve gastrectomy uses bipolar coagulation to perform transection and temporary seal, followed by two-layered suture reinforcement for closure of the gastric tube, keeping the principles of the original technique intact [22].

20.1 Surgical Technique

Under the administration of general anesthesia, the patient is placed in a modified lithotomy position. One dose of sultamicillin is given prior to incision. The surgeon is positioned at the foot of the bed between the legs, the first assistant on the left side of the patient, and the camera assistant on the right. Pneumoperitoneum is achieved using Veress needle entry. Five ports are placed as follows: (1) a left paramedian 12-mm port 1 inch above the umbilical scar, (2) a 12-mm port in the right midclavicular line, (3) a 12-mm trocar in the left midclavicular line, (4) a 5-mm trocar at the level of the left axillary line, and (5) a 5-mm port in the epigastrium for liver retraction (Fig. 20.1). The patient is then positioned in reverse Trendelenburg.

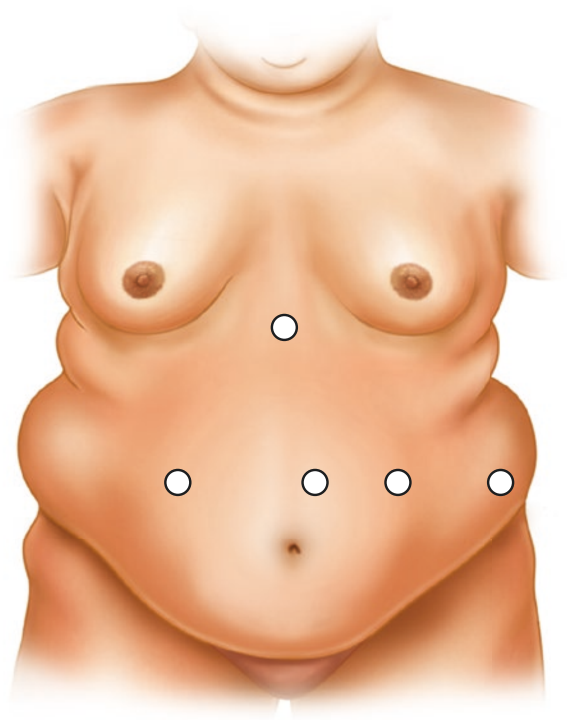


Fig. 20.1 Port site placements

The vascular supply of the greater curvature of the stomach is divided using ultradissection starting 5 cm proximal to the pylorus and progressing cephalad until the His angle. This division faces the short gastric vessels until obtaining complete exposure of the left crus, including division of a frequently seen retrofundic vessel that originates from the splenic artery.

The gastric tube is created over a 42-French bougie. A previously fired 60-mm linear laparoscopic stapler is used to define the transection line and facilitate LS tissue transection. The distal stomach is grasped close to the bougie, and the stapler is used to compress the stomach tissue along the transection line moving proximally (note tissue is compressed using the stapler, though no staples are placed). This provides the surgeon the ability to demarcate the transection line using a familiar device and mimicking conventional technique and provides tissue compression to help LS sealing (Fig. 20.2). After each 4 LS applications on its highest power setting (number 3 on the generator power scale), a full-thickness running suture (Vicryl® 2-0) is used in the gastric tube to make sure that it is hermetically closed (Fig. 20.3). Essential in the placement of this stitch is adequate dissection of the adipose tissue near the angle of His to provide adequate exposure of the gastric tube serosa in this area. Next, an overlapping seromuscular running stitch using 2-0 Prolene® suture is

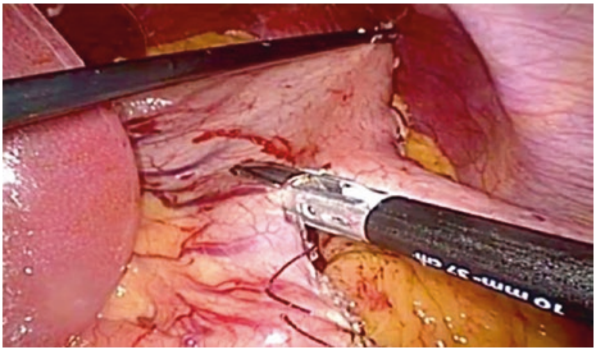


Fig. 20.2 Gastric division using the LigaSure Atlas™

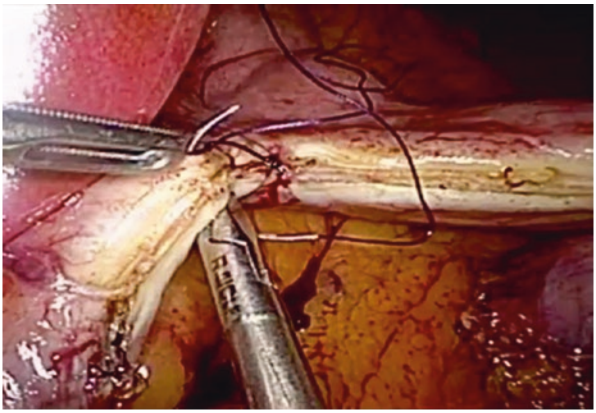


Fig. 20.3 Full-thickness running suture

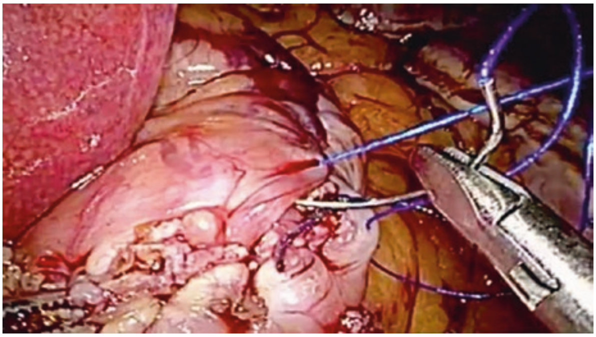


Fig. 20.4 Seromuscular running suture

applied from the His angle to the gastric antrum (Fig. 20.4). After the placement of the second and final running stitch, a closed suction drain is placed in the left subdiaphragmatic space, and the specimen is removed using a laparoscopic specimen retrieval bag. Finally the liver retractor and all ports are removed under direct vision.

20.2 Perioperative Care

Similar to our standard technique using a laparoscopic stapling device, patients receive 3 g of sultamicillin preoperatively and sequential compression devices for DVT prophylaxis. We do not use prophylactic heparin, which is our usual protocol.

Bariatric phase I diet is started on postoperative day 1, and patients are discharged once the adequate oral intake was achieved.

Postoperative pain is managed with scheduled intravenous NSAIDs, and intravenous narcotics are given as needed. Patients are discharged with liquid Tylenol.

Postoperatively all patients receive daily acid suppression medication with esomeprazole, in addition to a multivitamin and mineral supplement.

20.3 Discussion

Laparoscopic sleeve gastrectomy is an increasingly popular procedure for weight loss with a rise in prevalence from 0% to 53.6% of the world total from 2003 to 2016 [3]. Sustainable positive effects such as weight loss and improvement in obesity-related diseases have been demonstrated after sleeve gastrectomy, providing support for comparable health benefits seen in other bariatric procedures. Additional appeal for sleeve gastrectomy is relatively less technical complexity and faster operative times [4–10].

Laparoscopic sleeve gastrectomy is traditionally performed using multiple staple loads to transect the stomach in the creation of a gastric tube. Laparoscopic stapling devices are very expensive and are rarely available in countries with low income per capita, especially in public health hospitals. One alternative to achieve safe gastric transection is the bipolar coagulation devices such as LigaSure™ along with reinforcing suture. Bipolar coagulation provides gastric transection and a temporary seal, allowing the surgeon to place reinforcement stitches to securely close the stomach with no gastric content spillage.

The use of the bipolar coagulation with the purpose of tissue transection and sealing has been published in experimental models. Bipolar coagulation allows for the melting of tissue collagen and elastin fibers and forming formation of a plastic-like sheet creating a tissue seal. Histologic examination of transected organs in these studies demonstrated an inflammatory process with stromal reaction and connective tissue formation nearly indistinguishable from the one produced by manual sutures and has created much interest in determining efficacy in clinical practice [13, 16–18]. The LigaSure™ device is a well-known bipolar coagulation device commonly used to control vascular bundles. LigaSure™ utilizes a feedback-based mechanism to provide tissue sealing and impressive hemostasis without generating excess thermal spread and in turn limits damage of the surrounding tissue, making it a good option for temporary gastric transection.

The first case of staplerless hollow viscus transection in bariatric surgery was published by Dr. Himpens, who reported a series of ten patients from which two underwent sleeve gastrectomy [19]. Afterward Dr. Ramos in Brazil described the results of a series of 30 patients who underwent a Roux-en-Y gastric bypass using the LigaSure™ device as a substitute for the mechanic suture and reinforcing the transection line with manual suturing [20]. An average surgical time of 150 min was reported with no increase in perioperative morbidity.

More recently Rezvani et al. reported a robotic staplerless sleeve gastrectomy using the harmonic scalpel for gastric transection in a patient with past medical history of an allergic reaction to the metallic components of previously placed hardware [23].

Catanzano et al. described a similar staplerless sleeve gastrectomy technique using the harmonic device for gastric transection and reported good outcomes [24].

Potential advantages of the staplerless technique are:

1. Lesser complications related to the use of the staplers, like staple-line bleeding, staple misfiring, and fistula formation.
2. The technique can be applied in patients with history of allergies to metallic components in whom the use of staplers is contraindicated.
3. Significantly reduced operative costs, which is an especially limiting factor in developing nations where less money is available for healthcare spending and import logistics complicate availability.

Cost-related issues around bariatric surgery have risen, and we are seeing resurgence of staplerless bariatric techniques such as gastric plication initially described by Tretbar in 1976 and its laparoscopic version recently published by Talebpour in 2007 [25, 26]. It is worth noting that despite the initial enthusiasm with gastric plication, the vast majority of the results published have been discouraging as we have witnessed a relatively high complication rate and less weight loss when compared to sleeve gastrectomy [27–30].

In our study of staplerless sleeve gastrectomy [22], we did not have major morbidity, and we achieved a short hospital stay (2.3 days) with excellent short-term results in weight loss. Our surgical time was longer when compared to our conventional sleeve gastrectomy using staplers (117 min vs 82 min) [4, 22]. This difference is likely attributable to the technical challenge that the procedure entails. This technique requires the surgeon to have strong experience in the bariatric operations and be advance in laparoscopy.

In the majority of our patients, the LigaSure™ was unable to fully temporarily seal the stomach at the level of the antrum, likely due to the thickness of the gastric wall at that point; however, there was no major contamination of the surgical field as all patients had underwent orogastric suction while under anesthesia. It was noted though that this sealing failure was associated with a more laborious technique when performing the first closure layer and increased operative duration.

Important technical details in this procedure that should be paid close attention include:

1. The adipose tissue surrounding the angle of His must be completely dissected and removed in order to perform an adequate suture closure.
2. Once the calibrating bougie (42Fr) is in place, the gastric wall must be compressed with the [used] stapler load in order to collapse the tissue. This maneuver will facilitate the sealing with the LigaSure™ and also mimics the suture line if a stapler would have been used. Therefore we should expect the same diameter of the gastric tube as in conventional sleeve gastrectomy, maintaining the restrictive component of the procedure.
3. The surgical specimen must be removed using a sterile bag to avoid contamination of the surgical site. Given that the gastric remnant wall is sealed with the LigaSure™, removing it without a bag would produce a dehiscence of the transection line of the specimen thus contaminating the wound.

Some potential disadvantages that we must take into account are a longer learning curve, complications related to the failure of the suture line (leaks and fistulas), and the possibility of thermal spread injuries. At the beginning of the learning curve, we recommend the surgeon to select less complex patients by avoiding those with super obesity, severe hepatic steatosis, left liver lobe hypertrophy, and surgical revisions.

20.4 Conclusions

Staplerless laparoscopic sleeve gastrectomy using the LigaSure™ device and manual intracorporeal suture reinforcement is a feasible alternative when the laparoscopic stapler is not available or its use is contraindicated. This is particularly important in developing countries due to the potential decrease in surgical costs related to this technique.

References

1. Sjostrom L, Narbro K, Sjostrom C. Effects of bariatric surgery on mortality in Swedish obese subjects. N Engl J Med. 2007;357:741–52.
2. Picot J, Jones J, Colquitt JL, Gospodarevskaya E, Loveman E, Baxter L. The clinical effectiveness and cost-effectiveness of bariatric (weight loss) surgery for obesity: a systematic review and economic evaluation. Health Technnol Assess. 2009;13:1–190.
3. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J, et al. IFSO Worldwide survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28:3783–94.
4. Leyba JL, Aulestia SN, Llopis SN. Laparoscopic Roux-en-Y gastric bypass versus laparoscopic sleeve gastrectomy for the treatment of morbid obesity. A prospective study of 117 patients. Obes Surg. 2011;21:212–6.
5. Kehagias I, Karamanakos SN, Argentou M, Kalfarentzos F. Randomized clinical trial of laparoscopic Roux-en-Y gastric bypass versus laparoscopic sleeve gastrectomy for the management of patients with BMI < 50 kg/m^2. Obes Surg. 2011;21:1650–6.
6. Leyba JL, Aulestia SN, Llopis SN. Laparoscopic Roux en Y gastric bypass versus laparoscopic sleeve gastrectomy for the treatment of morbid obesity. A prospective study with 5 years of follow-up. Obes Surg. 2014;24:2094–8.
7. Perrone F, Bianciardi E, Ippoliti S, Nardella J, Fabi F, Gentileschi P. Long-term effects of laparoscopic sleeve gastrectomy versus Roux-en-Y gastric bypass for the treatment of morbid obesity: a monocentric prospective study with minimum follow-up of 5 years. Updat Surg. 2017;69:101–7.
8. Lim DM, Tailer J, Bertucci W, Riffenburg RH, O'Leary J, Wisbach G. Comparison of laparoscopic sleeve gastrectomy to laparoscopic Roux-en-Y gastric bypass for morbid obesity in a military institution. Surg Obes Relat Dis. 2014;10:269–76.
9. Shoar S, Saber AA. Long-term and midterm outcomes of laparoscopic sleeve gastrectomy versus Roux-en –Y gastric bypass: a systematic review and meta-analysis of comparative studies. Surg Obes Relat Dis. 2017;13:170–80.
10. Salminen P, Helmiö M, Ovaska J, Juuti A, Leivonen M, Peromaa-Haavisto P, et al. Effect of laparoscopic sleeve gastrectomy vs laparoscopic Roux-en-Y gastric bypass on weight loss at 5 years among patients with morbid obesity: the SLEEVEPASS randomized clinical trial. JAMA. 2018;16:241–54.
11. Miquilarena R, Coronel P, Arocha R, Troconis E, Navas H. Cierre del muñón apendicular con LigaSure en conejos: un reporte preliminar. Rev Venez Cir. 2006;59:8–11.
12. Elemen L, Yazir Y, Tugay M, Akay A, Aydin S, Yanar K, et al. LigaSure compared with ligatures and endoclips in experimental appendectomy: how safe is it? Pediatr Surg Int. 2010;26:539–45.
13. Salameh JR, Scwartz JH, Hildebrandt DA. Can LigaSure seal and divide the small bowel? Am J Surg. 2006;191:791–3.
14. Aslan A, Karaveli C, Elpek O. Laparoscopic appendectomy without clip or ligature. An experimental study. Surg Endosc. 2008;22:2084–7.
15. Santini M, Fiorelli A, Messina G, Accardo M. The feasibility of LigaSure to create intestinal anastomosis: results of ex vivo study. Surg Innov. 2015;22:266–73.
16. Kenedy JS, Stranahan PL, Taylor KD, Chandler JG. High-burst-strength, feedback-controlled bipolar vessel sealing. Surg Endosc. 1998;12:876–8.
17. Sorgato N, Bernante P, Pelizzo MR. Application of the LigaSure tissue sealing system to intestinal resection. Experimental and clinical trial. Ann Ital Chir. 2008;79:383–8.
18. Holmer C, Winter H, Kröger M, Nagel A, Jeanicke A, Lauster R, et al. Bipolar radiofrequency-induced thermofusion of intestinal anastomoses-feasibility of a new anastomosis technique in porcine and rat colon. Langenbeck's Arch Surg. 2011;396:529–33.
19. Himpens J, Leman G, Sonnevile T. Laparoscopic Roux-en-Y gastric bypass performed without staples. Surg Endosc. 2005;19:1003.

20. Ettinger JE, Ramos AC, Azaro E, Galvão-Neto MP, Nello CA, Galvão MS, et al. Staplerless laparoscopic gastric bypass: a new operation in bariatric surgery. Obes Surg. 2006;16:638–45.
21. Lopez J, Villalonga R, Targarona EM, Balague C, Enriquez L, Rivera R, et al. Can LigaSure™ be used to perform sleeve gastrectomy? – Tensile strength and histological changes. Minim Invasive Ther Allied Technol. 2014;23:144–51.
22. Leyba JL, Llopis SN, Aulestia SN, Ochoa R, Azuaje E. Staplerless laparoscopic sleeve gastrectomy. Preliminary report. Surg Obes Relat Dis. 2017;13:701–4.
23. Rezvani M, Sucandy I, Antanavicius G. Totally robotic staplerless vertical sleeve gastrectomy. Surg Obes Relat Dis. 2013;9:e79–81.
24. Catanzano M, Grundy L, Bekheit M. Staplerless laparoscopic sleeve gastrectomy: reasoning and technical insights. Obes Surg. 2018;28:854–61.
25. Tretbar LL, Taylor TL, Sifers EG. Weight reduction. Gastric plication for morbid obesity. J Kans Med Soc. 1976;77:488–90.
26. Talebpour M, Amoli BS. Laparoscopic total vertical plication in morbid obesity. J Laparoendosc Adv Surg Tech A. 2007;17:793–9.
27. Toprak ŞS, Gültekin Y, Okuş A. Comparison of laparoscopic sleeve gastrectomy and laparoscopic gastric plication: one year follow-up results. Ulus Cerrahi Derg. 2015;32:18–22.
28. Grubnik VV, Parfentyev RS, Medvedev OV, Kresyun MS. Randomized controlled comparative investigation of efficacy of laparoscopic plication of big gastric curvature and laparoscopic sleeve gastrectomy. Klin Khir. 2015;8:9–12.
29. Chouillard E, Schoucair N, Alsabah S, Alkandari B, Montana L, Dejonghe B, et al. Laparoscopic gastric plication (LGP) as an alternative to laparoscopic sleeve gastrectomy (LSG) in patients with morbid obesity: a preliminary, short-term, case-control study. Obes Surg. 2016;26:1167–72.
30. Albanese A, Prevedello L, Verdi D, Nitti D, Vettor R, Foletto M. Laparoscopic gastric plication: an emerging bariatric procedure with high surgical revision rate. Bariatr Surg Pract Patient Care. 2015;10:93–8.

Chapter 21
Robotic Sleeve Gastrectomy

Carlos Vaz, José Manuel FORT, and Ramon Vilallonga

21.1 Introduction

With the increasing worldwide prevalence of obesity, bariatric surgery is in continuous development; actually, surgery represents the most effective long-term method for treating obesity and its comorbidities. However, surgery in patients with obesity may be technically demanding for the surgeon, due to the limitations of laparoscopic instruments and the characteristics of obese patients, including hepatomegaly and the amount of intraabdominal fat. This is why, over the years, methods of minimal invasion have been designed that replace conventional surgery and have the well-known benefits of minimal invasion, such as less postoperative pain, decreased inhospital stay, and decreased morbidity of the patient [1].

Sleeve gastrectomy was initially used as an initial step in high-risk patients, those who have BMI greater than 60; at follow-up these patients had a significant weight loss and resolution of comorbidities, but it was not until 2008 that the indications of the sleeve gastrectomy were published as a single procedure [1].

The history of the sleeve gastrectomy began in 1990, with the modification of Marceau to the biliopancreatic diversion of Scopinaro, performing a gastrectomy and thus reducing the acid secretion to the ileum and reducing the incidence of marginal ulcers. Sleeve gastrectomy has become popular because it is technically easier compared to gastric bypass or biliopancreatic bypass, although it has a complication rate of 0.7–4% [2].

C. Vaz
Robotic Surgery Unit, Center for the Treatment of Obesity and Diabetes Hospital CUF Infante Santo, Lisbon, Portugal

J. M. FORT · R. Vilallonga (✉)
Endocrine, Metabolic and Bariatric Unit, Vall d'Hebron University Hospital, Universitat Autònoma de Barcelona, Center of Excellence for the EAC-BC, Barcelona, Spain

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_21

In 1998, the first robotic surgery in the field of bariatric was carried out by Dr. Guy Cadière and Dr. Jacques Himpens in Belgium, in order to improve the patient's quality of care and the development of robotic surgery [3].

Robotic sleeve gastrectomy can be considered a good bariatric procedure to undergo a learning curve.

21.2 Robotic Sleeve Gastrectomy Procedure

21.2.1 Pneumoperitoneum and Trocar Placement (Da Vinci S, Si, SI HD)

The pneumoperitoneum is created by Veress needle technique inserted at the left hypochondrium. All trocars were inserted under direct vision. A 12-mm port was inserted 12 cm under the xiphoid and 2 cm left for the camera. The camera trocar is an extra-large 150-mm-long trocar (XCEL trocar, Ethicon Endo-Surgery, Cincinnati, OH, USA) that allowed the right connection with the robotic arm. A left 12-mm working port is inserted and clearly located around 6 cm to the left of the previous trocar. The right 12-mm working port was positioned 6 cm from the camera trocar as mentioned above. Most of the time, an 11-mm trocar was placed laterally to the left hypochondrium. This 11-mm trocar allows the table assistant to assist. This trocar can be optional in many cases. An 8-mm da Vinci trocar was placed on the anterior axillary line to allow liver retraction. Liver retraction, however, can be done with a Nathanson retractor in the subxiphoid area. With this trocar positioning, all 8-mm da Vinci trocars could be used through the 12-mm trocars previously mentioned. In fact, the double-cannulation technique allows easy exchange of da Vinci instruments and also allows removal of the robotic arm and use of the trocar as a standard trocar for endostappling purposes. This special cannulation of the standard trocars and da Vinci trocars allows the table surgeon to use the endostapler for the gastric resection (Figs. 21.1 and 21.2). The da Vinci camera is locked in the midline trocar after complete insertion of all instruments. The docking was then done, including the positioning of the cart over the patient's head (covered with a head protector designed for this purpose). At this moment of the procedure, the setup and docking were complete, and the procedure can start (Fig. 21.3).

21.2.2 Pneumoperitoneum and Trocar Placement (Da Vinci Xi)

In this novel version, da Vinci Xi trocars measure 8 mm, and the camera can be introduced in any trocar. Also in this novel device, there is a possibility to use robotic endostapler during the procedures. This can avoid the double-cannulation technique. However, there is still a need to include a 12-mm trocar to assist and include non-robotic endostaplers. Available robotic endostaplers are 45-mm long.

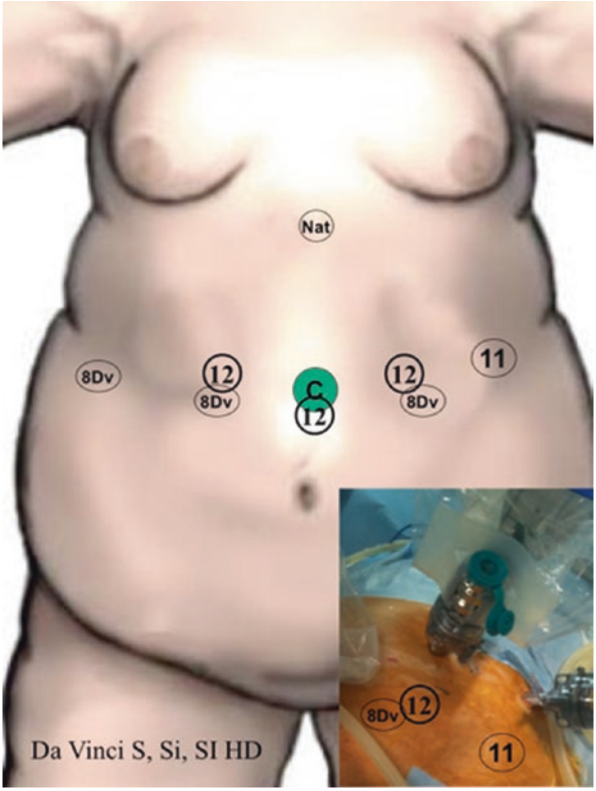


Fig. 21.1 Trocar placement for robotic sleeve gastrectomy with Si Da Vinci including double cannulation technique

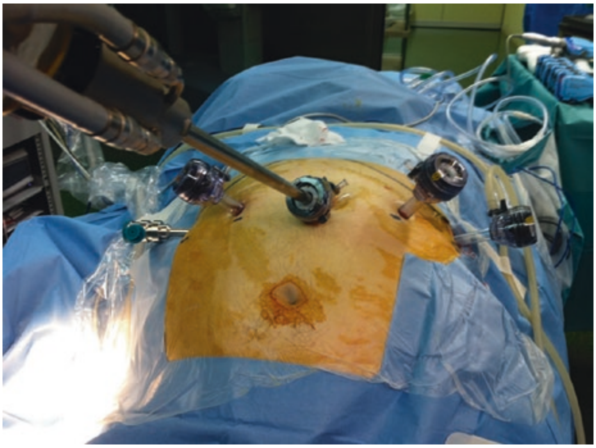


Fig. 21.2 Trocar placement for robotic sleeve gastrectomy with Si Da Vinci including double cannulation technique

Fig. 21.3 Trocar placement for robotic sleeve gastrectomy with Si Da Vinci including double cannulation technique. Docking has been already performed and in the Da Vinci Si the docking comes from the head of the patient

The pneumoperitoneum is created by Veress needle technique inserted at the left hypochondrium. All trocars were inserted under direct vision. A 8-mm da Vinci port was inserted 12 cm under the xiphoid and 2 cm left for the camera. A left 12-mm da Vinci working port (instruments and endostaplers) is inserted and clearly located around 6 cm to the left of the previous trocar. From this trocar, robotic endostapler or standard endostapler should be used considering that the articulation toward the esophagogastric junction is acceptable. If not, during the procedure, the left trocar should be used for stapler including the change of a 8-mm trocar to a 12-mm trocar. Most of the time, an 8-mm da Vinci trocar is placed laterally to the left hypochondrium. This 8-mm da Vinci trocar allows the traction of the stomach toward the spleen controlled by the same surgeon. An 8-mm da Vinci trocar was placed on the anterior right axillary line to allow traction and sometimes including liver retraction. The most lateral 8-mm robotic trocars can be used alone according to the surgeon's preference or patient's anatomy needs. If necessary, a Nathanson retractor is used in the subxiphoid area to retract the liver (Fig. 21.4a). The da Vinci camera is locked in the midline trocar after complete insertion of all instruments. The docking was then done, including the positioning of the cart over the patient's head (covered with a head protector designed for this purpose). Once the camera is inside the abdomen, the targeting is done considering the esophagogastric junction as a target point. At this moment of the procedure, the setup and docking were complete, and the procedure began (Fig. 21.4b).

21.2.3 Section of the Short Gastric Vessels: Opening of the Gastric Transcavity

The console surgeon was able, at this point, to proceed with the opening of the lesser epiploic sac at the level of the greater curvature (Fig. 21.5). For this purpose, a grasper was used in the left hand, and the da Vinci modified harmonic scalpel was

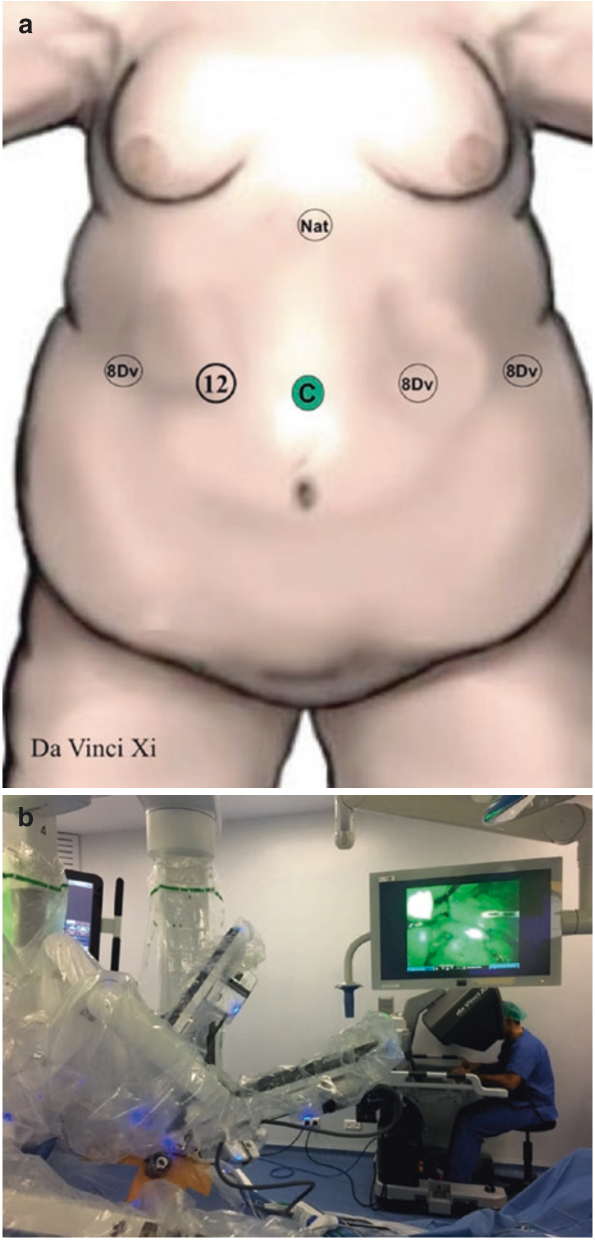


Fig. 21.4 (**a**) Trocar placement for robotic sleeve gastrectomy with Xi Da Vinci. (**b**) Docking has been already performed and in the Da Vinci Xi allows the docking to come from the right side of the patient

installed in his right hand. The third da Vinci arm used another forceps to retract the liver. All the gastric dissection is completely robotic (Fig. 21.6a, b).The division of the gastrocolic and gastrosplenic ligament is performed until reaching the gastro-esophageal junction (GEJ). The robot ensures precision, especially in the upper part of the stomach, where you need to avoid any injury to the spleen and properly visualize the short vessels and GEJ. Dissection begins at 5 cm from the pylorus up to the upper part of the stomach.

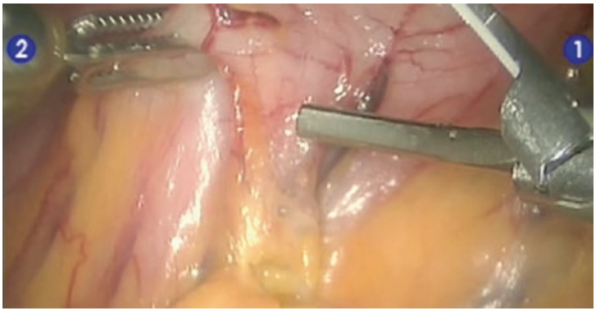


Fig. 21.5 Opening of the lesser epiploic sac at the level of the greater curvature

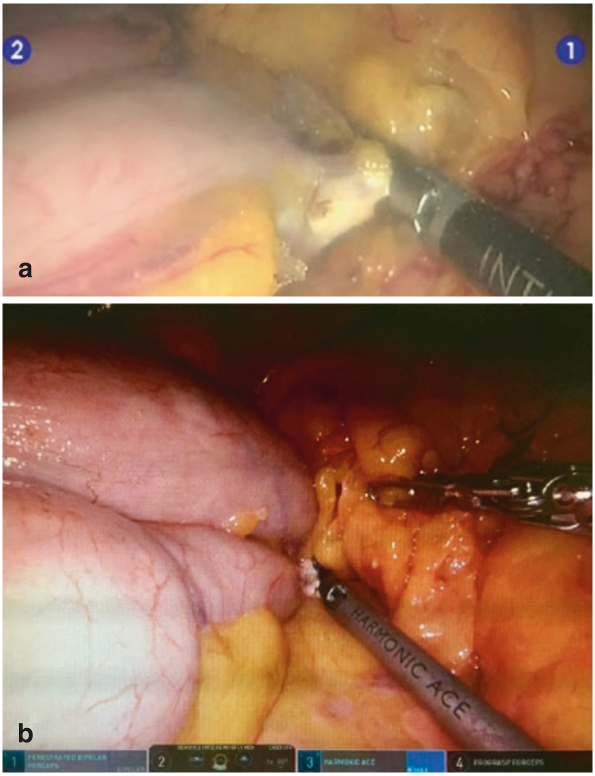


Fig. 21.6 (**a**) Gastric dissection is completely robotic. (**b**) The division of the gastrocolic and gastrosplenic ligament is performed until reaching the gastroesophageal junction (GEJ)

21.2.4 Sleeve Calibration, Section, and Extraction

An important time of the sleeve gastrectomy confection is during its section. For this purpose, the anesthesiologist inserted a 32 Fr bougie to calibrate the sleeve. The robotic bedside cart does not give any difficulty to the anesthesiologist in order to place the bougie. At this stage of the procedure, a laparoscopic stapler or robotic stapler can be used. A specially designed for this purpose is used (Echelon 60 Endopath stapler, endoscopic linear cutter straight, Ethicon Endo-Surgery, Cincinnati, OH, USA). The complete transection of the stomach is done using a different cartridge. First, a green cartridge was used to divide at the level of the antrum, beginning 5 cm from the pylorus (Fig. 21.7a, b). A bougie was kept in place in order to allow the endostapler to be applied toward its lateral edge. The table surgeon did this maneuver twice. After the first two staples, if needed in the old robotic system, the right arm was again docked, and the left robotic arm was switched to the left lateral 11-mm trocar. The right arm was decannulated from the 12-mm trocar without moving the robot. This maneuver is performed within a few seconds. In order to continue the section of the sleeve, the table surgeon inserted a stapler loaded with blue cartridges. In the da Vinci Xi, there is no need to perform any decannulation, and all staplers are done from the 12-mm trocar (Fig. 21.8). Once transected, the remnant stomach evacuated from the abdominal cavity. We preferred to remove the specimen through the left 12-mm working trocar (Fig. 21.9a, b). Also the specimen

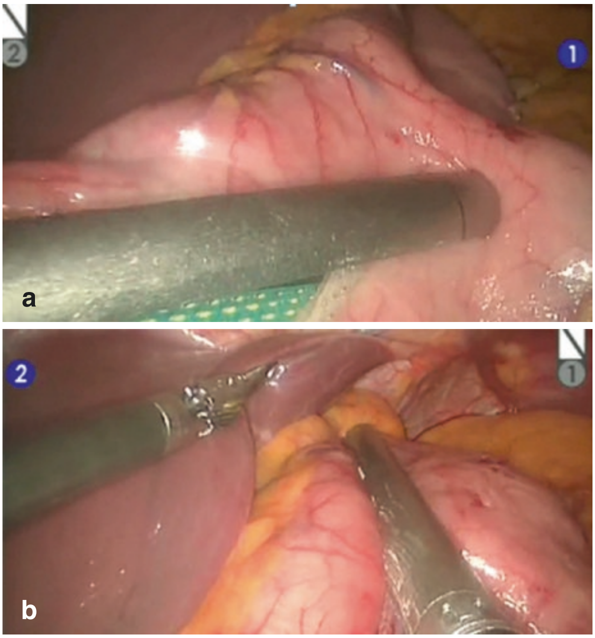


Fig. 21.7 (**a**) Complete transection of the stomach is done using a different cartridge size. First, a green cartridge was used to divide at the level of the antrum. (**b**) Fundus transection using blue stapling cartridge (EthiconEndosurgery, Cincinnati, OH, USA)

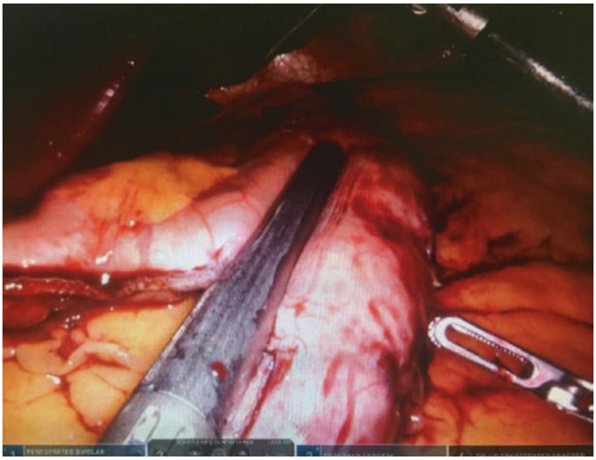


Fig. 21.8 Complete transection of the stomach is done using Da Vinci endostappler (Endosurface, Da Vinci) Da Vinci Xi model

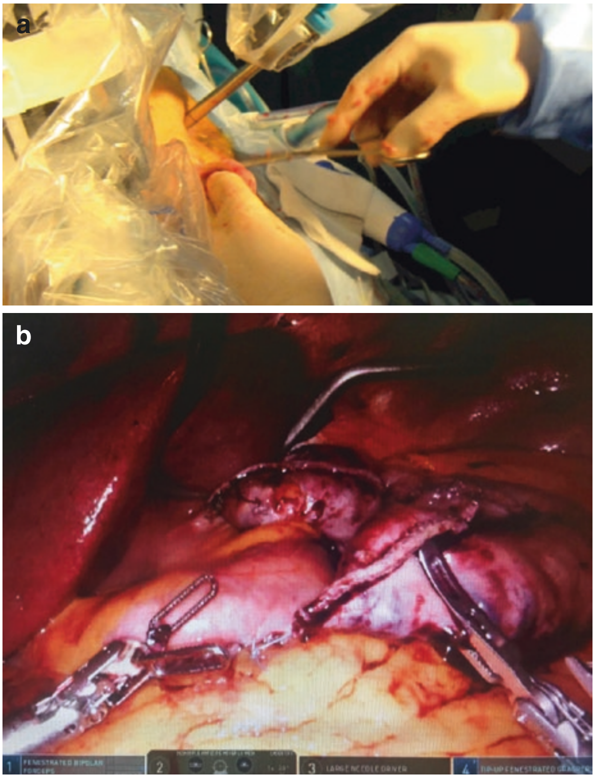


Fig. 21.9 Complete specimen extraction (**a**) under control of the surgeon (**b**)

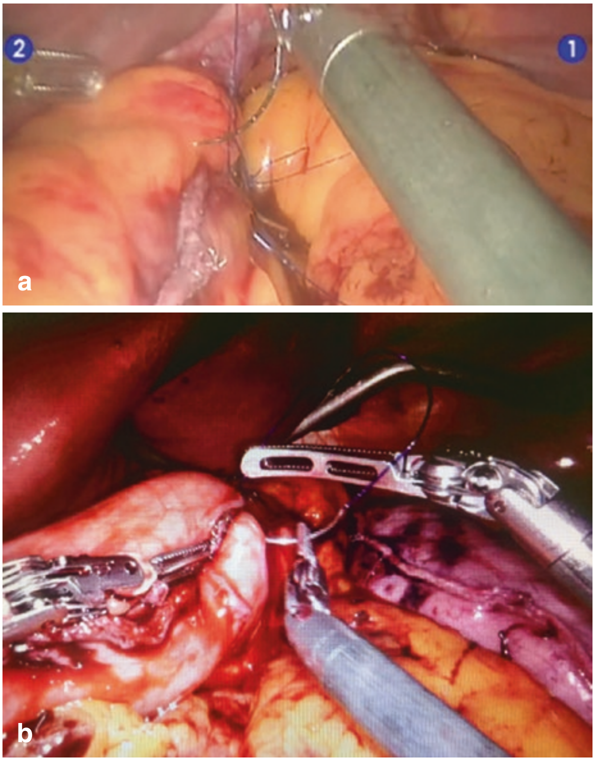


Fig. 21.10 (**a**) and (**b**) Complete robotic continuous invaginating resorbable suture of the stapling line was performed (monocryl (3/0); Ethicon-Endosurgery)

can be extracted at the end of the procedure. The table surgeon introduced then a robotic needle holder in the left trocar, and a complete robotic continuous invaginating resorbable suture of the stapling line was performed (Monocryl (3-0); Ethicon Endo-Surgery) (Fig. 21.10a, b). A robotic needle holder was used for this purpose. In some patients, a Seamguard® buttress material reinforcement was used due to technical problems. The anesthesiologist filled the sleeve with diluted methylene blue and performed an air test in order to detect any leakage from the staple line. For this maneuver, the surgeon blocks the outlet at the level of the antrum close to the pylorus in order to visualize the shape, the apparent volume, and any leak of the stomach.

There are few literatures describing the use of the robotic technology in the sleeve gastrectomy, but all the literature has described the safety of the procedure and also has equivalent results with the laparoscopic surgery in terms of weight loss; they also indicate the increase of operative time and the cost of the procedure [4–7]. Robotic sleeve gastrectomy in a fully robotic way or assisted has shown to be a procedure to include for the learning curve of the robotic technology [8].

Romero R et al. compared three of the most severe complications of the sleeve, which are bleeding, stenosis, and leakage, in a series of 134 cases operated via robot compared to 3148 cases of laparoscopic surgeries and found a decrease in these complications in the robotic group, reporting 0% leakage compared to 1.97% in laparoscopic, 0% stenosis compared to 0.43% in the laparoscopic group, and 0–70% bleeding compared to 1.21% [4].

In a comparative study by Elli, E et al. in which 304 laparoscopic surgeries were compared to 105 robotic surgeries, the surgical time was 110.67 min for the robotic group while 84.18 min in the laparoscopic group [6].

The safety of the procedure allows institutions to introduce robotic techniques to residents and can also be used as a preliminary step for more complex robot-assisted procedures such as gastric bypass or revision surgery [7, 8]. The learning curve has been estimated in 20 cases [8]. In the bariatric field, the possibility to include manual suturing reinforcement is interesting in the SG procedure under robot, as it allows a training under the console.

Conflict of Interests Disclosure Statement None of the authors has any conflict of interest for this paper.

References

1. Nguyen N, Blackstone R, Ponce J, Rosenthal R. The ASMBS textbook of bariatric surgery. New York: Springer; 2015.
2. Frezza EE, Reddy S, Gee LL, Wachtel MS. Complications after sleeve gastrectomy for morbid obesity. Obes Surg. 2009;19:684–7.
3. Cadiere GB, Himpens J, Vertruyen M, Favretti F. The world's first obesity surgery performed by a surgeon at a distance. Obes Surg. 1999;9:206–9. PubMed PMID: 10340781
4. Romero R, Kosanovic R, Rabaza J, Seetharmaiah R. Robotic sleeve gastrectomy: experience of 134 cases and comparison with systematic review of the laparoscopic approach. Obes Surg. 2013;23:1743–52.
5. Schraibman V, Macedo A, Epstein M, Soares M, Maccapani G, Matos D. Comparison of the morbidity, weight loss, and relative costs between robotic and laparoscopic sleeve gastrectomy for the treatment of obesity in Brazil. Obes Surg. 2014;24:1420–4.
6. Elli E, Gonzalez-Heredia R, Sarvepalli S, Masrur M. Laparoscopic and robotic sleeve gastrectomy: short and long term results. Obes Surg. 2015;25:967–74.
7. Kannan U, Ecker BL, Choudhury R, Dempsey DT, Williams NN, Dumon KR. Laparoscopic hand-assisted versus robotic-assisted laparoscopic sleeve gastrectomy: experience of 103 consecutive cases. Surg Obes Relat Dis. 2016;12:94–9.
8. Vilallonga R, Fort JM, Caubet E, Gonzalez O, Armengol M. Robotic sleeve gastrectomy versus laparoscopic sleeve gastrectomy: a comparative study with 200 patients. Obes Surg. 2013;23:1501–7.

Chapter 22
Vertical Clipped Gastroplasty: *The BariClip*

Natan Zundel, Gustavo Plasencia, and Moises Jacobs

22.1 Introduction and History

During the last 20 years, morbid obesity has reached epidemic proportions around the world. More than one in two adults and one in six children are overweight or obese. It is estimated that there are 671 million people who are obese (BMI > 30) in the world. Many studies to date have shown that the only lasting treatment for this condition and its comorbidities is surgery. As such, during the last 15 years, bariatric surgery has increased in popularity, helped mainly by the sleeve gastrectomy (SG), which has become the most prevalent procedure performed in the world today. The adjustable gastric band (AGB) is also being placed; however it has decreased in popularity and in numbers in the last few years due to its lower weight loss outcomes and the side effects (reflux, vomiting) experienced by patients.

SG involves stapling the stomach in a vertical fashion with removal of a large majority of the stomach, resulting in a restrictive pouch in continuity with the normal anatomy. The AGB, which requires no stapling or tissue removal and is reversible, constitutes placing a semi-horizontal band that causes a partial obstruction of the gastric lumen and requires adjustments and maintenance for success.

In a design that marries the best qualities of the SG with the AGB, the BariClip (BC) is a removable medical device that is placed vertically parallel to the lesser curvature (Table 22.1), separating the stomach into a restricted medial segment where food passes and into an excluded larger lateral gastric segment. However, unlike the band which is placed horizontally, the BC decreases oral intake by restriction not

N. Zundel (✉) · G. Plasencia · M. Jacobs
Department of Surgery, University at Buffalo, Jackson North Medical Center, Miami, FL, USA

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_22

obstruction, and the BC requires no maintenance or adjustments. Also, unlike the sleeve, it is reversible and is placed without the use of staples and without removal of any tissue. Unlike both the SG and the AGB, the BariClip causes minimal reflux.

The BC (Fig. 22.1a–c) consists of a silicone-covered titanium backbone with an inferior flexible hinged opening that separates a medial lumen from an excluded

Table 22.1 Comparison of procedures

	AGB	Sleeve	BariClip
Restrictive		X	X
Vertical		X	X
Maintenance	X		
Stapling		X	
No tissue removal	X		X
Metabolic		X	?
No reflux			X
Removable	X		X

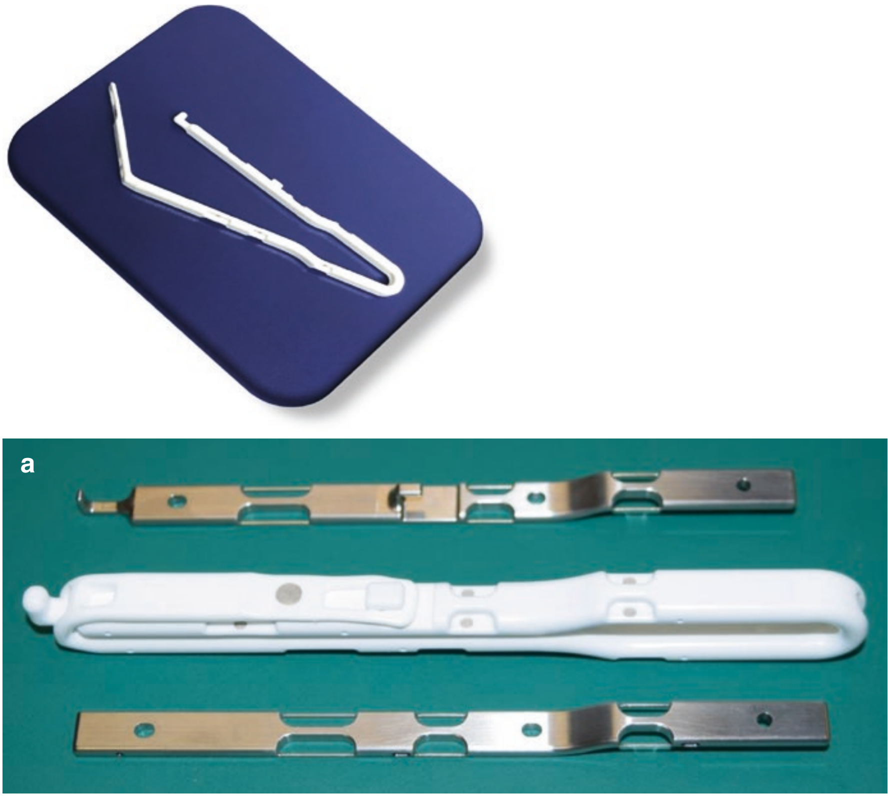
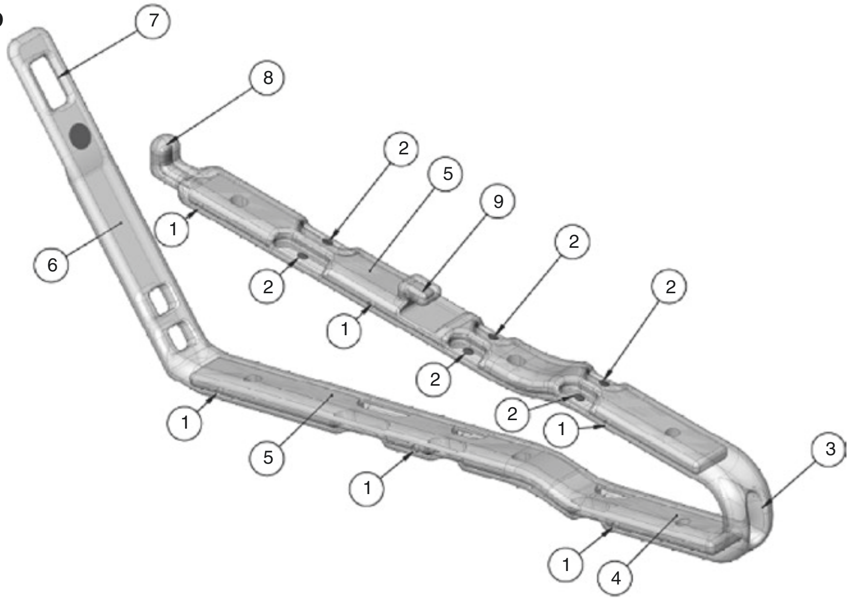


Fig. 22.1 (**a**) The BariClip. (**b**) Silicone outer covering, inner titanium limbs. (**c**) BariClip device and components

b



ITEM NO.	DESCRIPTION
1	Substrate Alignment Pinholes for Silicone Overmolding
2	Indentation Areas for Suturing to Stomach
3	Laparoscopic Placement Device Handle Groove
4	Fluid Path Passageway (inferior B-CLAMP© aperture)
5	Anterior and posterior Clamping Segments
6	Adjustable Clamping Pressure Position Strap
7	Clamp Closure Assist Groove
8	Strap Security Locking Pin
9	Clamp Closing Latch

Fig. 22.1 (continued)

lateral gastric pouch. The inferior opening allows the gastric juices to empty from the fundus and the body of the stomach into the distal antrum. It measures 14.5 cm in length, has a 2.5 cm inferior opening, and fits through a 12 cm trochar when opened flat.

22.2 Surgical Technique

A subxiphoid trochar is used for liver retraction, an assistant grasper is passed through a left anterior axillary port, a camera is passed through a left midclavicular port, and the surgeon works through an umbilical port and a right midclavicular port. If a hiatal hernia is identified, it is dissected and repaired in a posterior fashion.

The first step (Fig. 22.2a) in the implantation process is to dissect the angle of His creating a space between the esophagus and spleen, separating the superior fundus adjacent to the esophagus from the diaphragm (Fig. 22.2b). A window is then created on the greater curvature, extending from the proximal antrum to the lower third of the gastric body, with transection of posterior adhesions to help mobilize this area of the incisura and antrum. This window is wide enough to allow comfortable suturing of the posterior BC to the upper stomach, to visualize the base

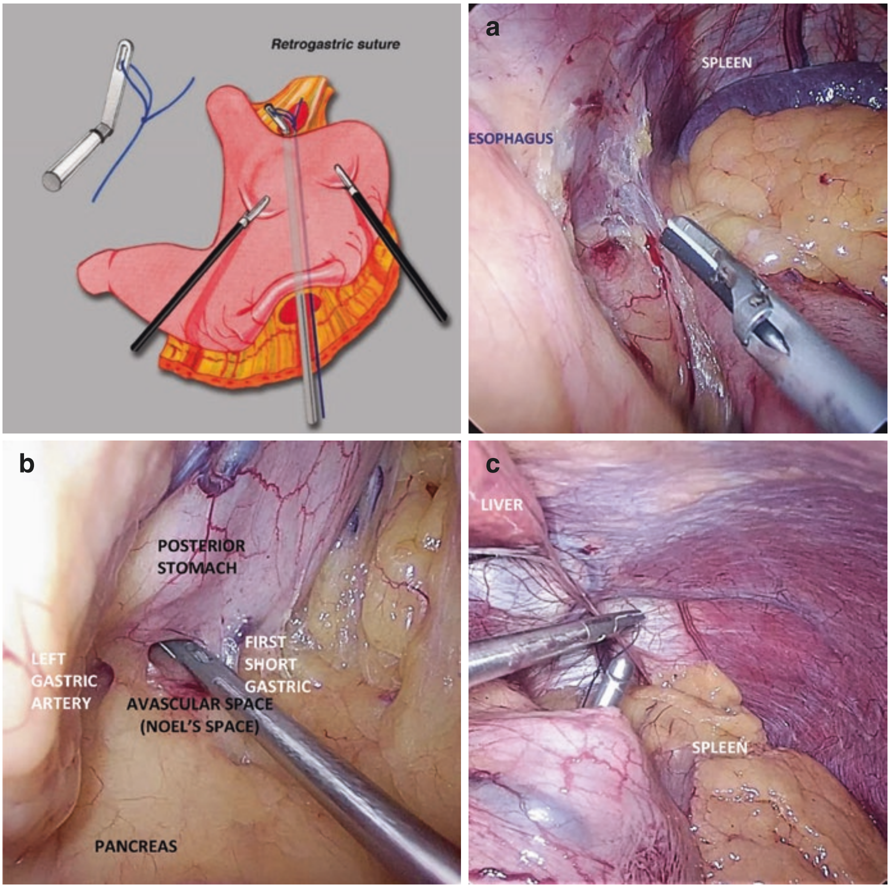


Fig. 22.2 (**a**) Creation of retrogastric tunnel through a window in the greater curvature with a small opening at the angle of His. An articulating (Goldfinger type) dissector used for clip placement. (**b**) Dissecting the angle of His. (**c**) Creating retrogastric window. (**d**) Passing articulating dissector with suture at the angle of His

of the mesentery of the stomach, and to allow exposure of the posterior fundus and the first short gastric artery. Through the umbilical trochar, an articulating dissector is passed into the lesser sac to a created space between the left gastric vessels and the first short gastric artery at the base of this mesentery, superior to the pancreas. This is an avascular plane. The articulated dissector is passed through this avascular space (Noel's Space) (Fig. 22.2c) and flexed to 90°, coming out at the previously dissected angle of His (Fig. 22.2d).

Attached to the tip of this dissector is a long suture (~110 cm) which is then separated from the dissector and pulled out the right midclavicular trochar. The other end of the suture, outside the body via the umbilical trochar, is attached to the BC at its flexible closing belt. The posterior limb of the unfolded BC is then passed through the umbilical trochar and directed posteriorly to the stomach into the lesser sac while at the same time pulling from the suture at the right midclavicular trochar. These combined maneuvers bring the posterior limb into the lesser sac (Fig. 22.3). The anterior limb of the BC is also passed into the abdominal cavity and then flipped onto the anterior surface of the stomach once it is free of the umbilical trochar. At this stage the floppy belt of the BC is pulled up into the angle of His and out of the lesser sac (Fig. 22.4) and is then hooked to the latch on the anterior limb. A 32–36 F bougie is passed perorally, and then the clip is fixated, ensuring the lumen at the incisura is not compromised. Fixation is achieved by suturing through titanium rimmed indentations on the silicone of the BC. Suturing posteriorly is the most technically challenging portion of the procedure (Fig. 22.5). The clip is designed in such a way to allow endoscopic examination of the excluded stomach through the inferior aperture (Fig. 22.6).

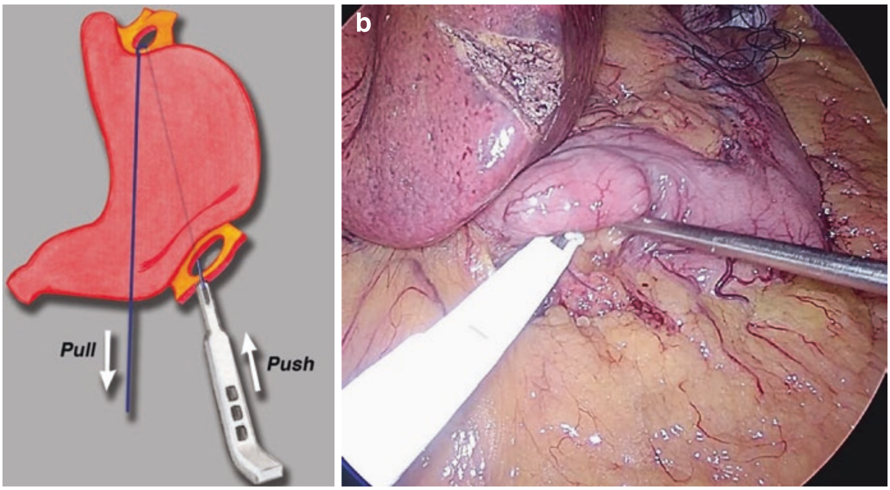


Fig. 22.3 (**a**) Passing gastric clip posterior to the stomach. (**b**) BariClip insertion

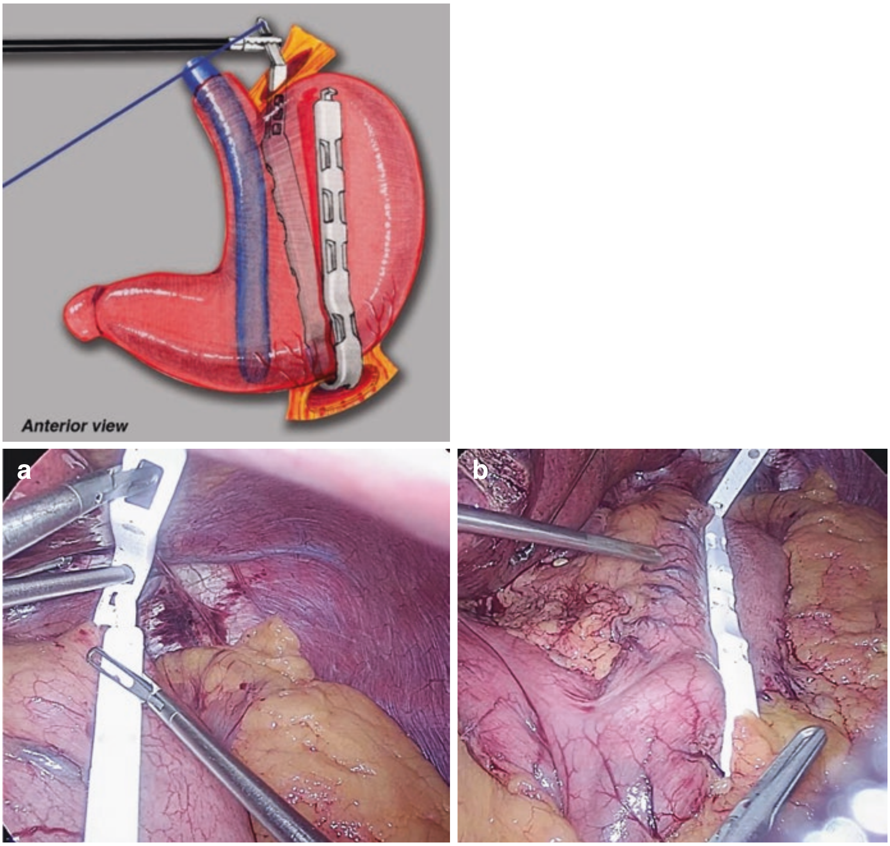
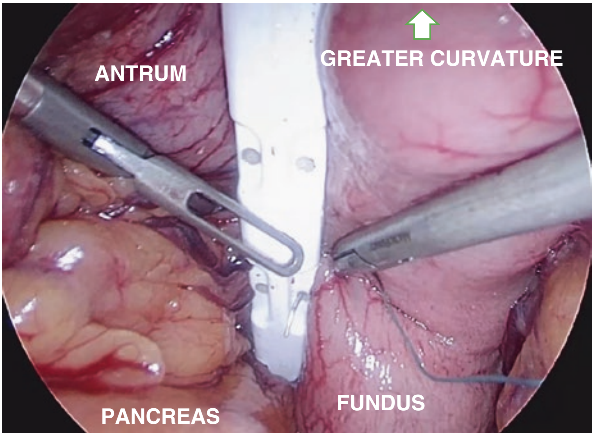


Fig. 22.4 (**a**) Anterior limb of gastric clip on anterior surface of the stomach. (**b**) Closing the clip by pushing the locking pin through the inferior open latch. The inferior latch is almost always used. (**c**) Closed clip, bougie in the lumen

Fig. 22.5 View seen looking cephalad through inferior greater curvature window, suturing the elevated posterior stomach



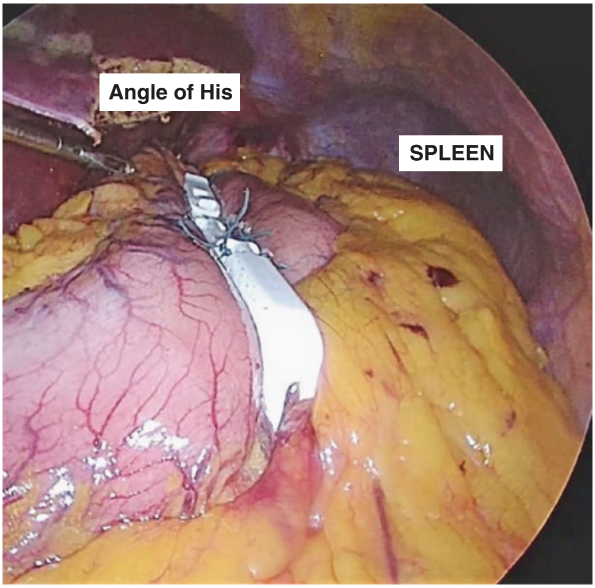


Fig. 22.6 Completion of vertical gastric clip placement

22.2.1 Diagnostic Studies

Once placed the resultant lumen of the stomach resembles that of the SG as can be seen by this UGI (Fig. 22.7).

Since the inferior aperture of the BC doesn't have a titanium base, it is wide and flexible enough to allow examination of the excluded portion of the stomach by a gastroscope. The gastroscope can pass through the inferior aperture of the clip and look back toward the excluded fundus (Fig. 22.8). The diameter and the flexibility of the inferior aperture to distend allow for wide drainage of the fundus and body of the stomach.

22.2.2 Complications

To minimize erosions the BC was designed to have low closing pressures (Table 22.2). The closing pressures are lower than an insufflated band. Even so, two erosions have been reported since implantation in humans began in November 2012.

Both erosions occurred because of situations with a chronically decreased gastric outlet, leading to increased intraluminal pressures: one was a patient with chronic slippage, and the other patient had a 13 cm clip (no longer used) with smaller, narrower inferior aperture. Both patients presented with partial engulfing of the clip into the lumen, without any free contamination. The patients had no signs of infection, or of severe pain, only mild discomfort. Both were diagnosed on elective

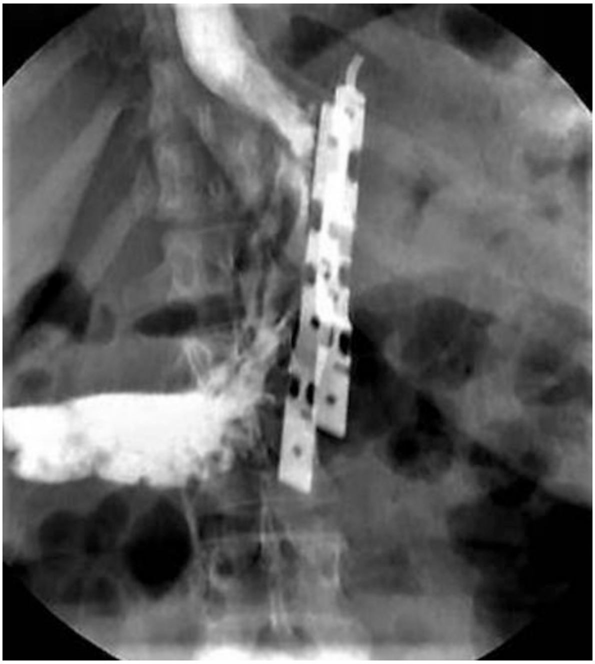


Fig. 22.7 UGI. Lumen similar to sleeve

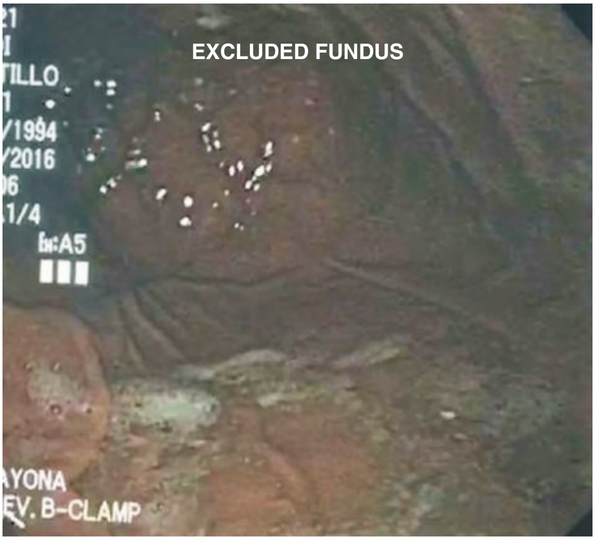


Fig. 22.8 Endoscopic view of the excluded stomach

endoscopies, and both were removed laparoscopically without any complications and required only suturing the defect (Fig. 22.9).

The other significant complication of the BC is slippage. This occurred more frequently with earlier versions of the clip, but since a titanium border was added to the suturing indentations of the clip (Fig. 22.10), the sutures have held in place, and

Table 22.2 Lap band vs. gastric clip pressure analysis

LAP BAND VS. GASTRIC CLIP PRESSURE ANALYSIS

Device	Pressure (psi)	Pressure (gr/mm^2)
Lap Band (5 cc Fill Volume)	6.341	4.458
Lap Band (10 cc Fill Volume)	9.059	6.369
Clip	5.81	4.15

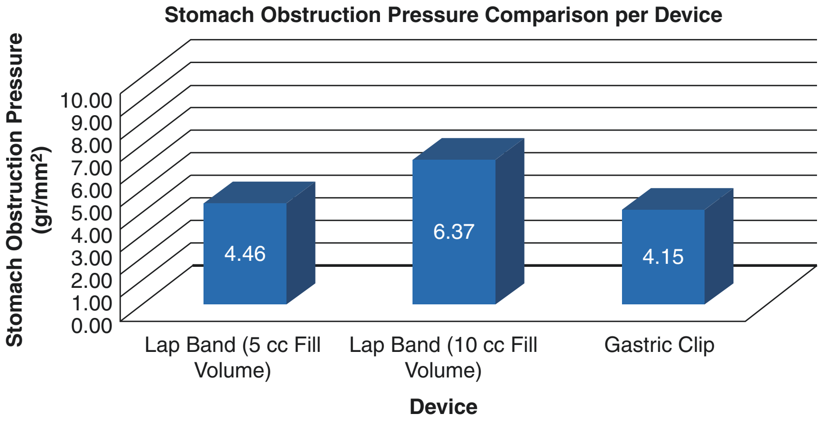


Fig. 22.9 Endoscopic view of the eroded clip

Fig. 22.10 Titanium rimmed indentation through which clip is anchored to gastric wall

Fig. 22.11 Chronic slippage. Contrast passing through pliable limbs of clip because of low closing pressure (low erosions) into the excluded stomach and out into an antrum. Contrast follows the path of least resistance

the incidence of slippage has decreased significantly. Also, a change in technique consisting of transection of the posterior adhesions and attachments of the antrum and incisura and of passage of the clip through the posterior avascular space (Noel's Space) medial to the first short gastric has also helped reduced slippage.

A posterior slippage (Fig. 22.11) consists of the inferior portion of the clip being pushed toward the lesser curvature, blocking the main lumen. However, because of the low closing pressure of the clip, nutrients can pass through the pliable limbs of the clip into the excluded stomach and into the antrum.

Anterior slippage (Fig. 22.12a) occurs when the superior portion of the clip is not brought out next to the esophagus, but closer to the spleen leaving a segment of fundus not being excluded. This is a technical result from poor placement.

If a patient develops persistent abdominal discomfort with or without bloating, nausea, and/or vomiting, slippage should be considered. An UGI will easily confirm

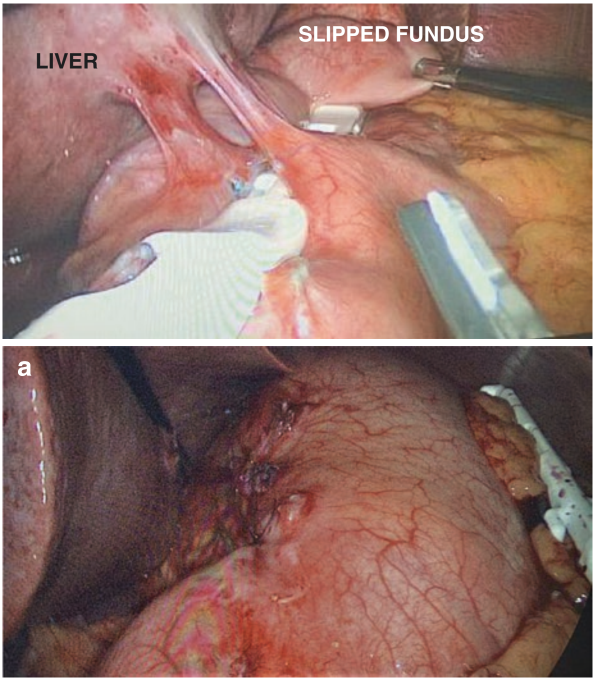


Fig. 22.12 (**a**) Anterior slippage. Non-excluded fundus slips medially, pushing superior clip laterally. (**b**) The stomach after clip removal post-slippage. Notice normal appearing stomach, except inflammation at old suture sites

the diagnosis. If there is a gastric outlet obstruction, patients will present with pain, nausea, and vomiting. Immediate removal or repositioning should be performed. If there is slippage but no gastric outlet obstruction, and clinically the patient is stable, elective removal or repositioning should be undertaken (Fig. 22.12b). All chronic slippages should be repaired. The anatomy and function of the stomach return to its normal state after clip removal.

22.3 Results

As more experience of this procedure is gained, results will continue to improve. The original pilot study contained results for a novel technique in evolution. With experience and improvements in the clip and technique, weight loss improved while decreasing complications. The report below from the initial pilot study includes the better newer results along with the older poorer results. From a historical perspective, the Magenstrasse and Mill procedure which is similar in scope to the BC offers stable 60% weight loss at 5 years. Further studies will need to verify this.

Between November 2012 and July 2018, 162 patients underwent BC placement. Upon consultation with the European Union regulatory agencies, by protocol, 15 clips were to be removed after different lengths of time of implantation to prove

Table 22.3 Complications following BC

Complication	Rate	Management
Slippage	5.5% (*n* = 9)	Two explanted, two revised, five treated conservatively
Erosion	1.2% (*n* = 2)	Explanted
GERD	4.3% (*n* = 7) the first month 0.6% (*n* = 1) after 1 month	PPI

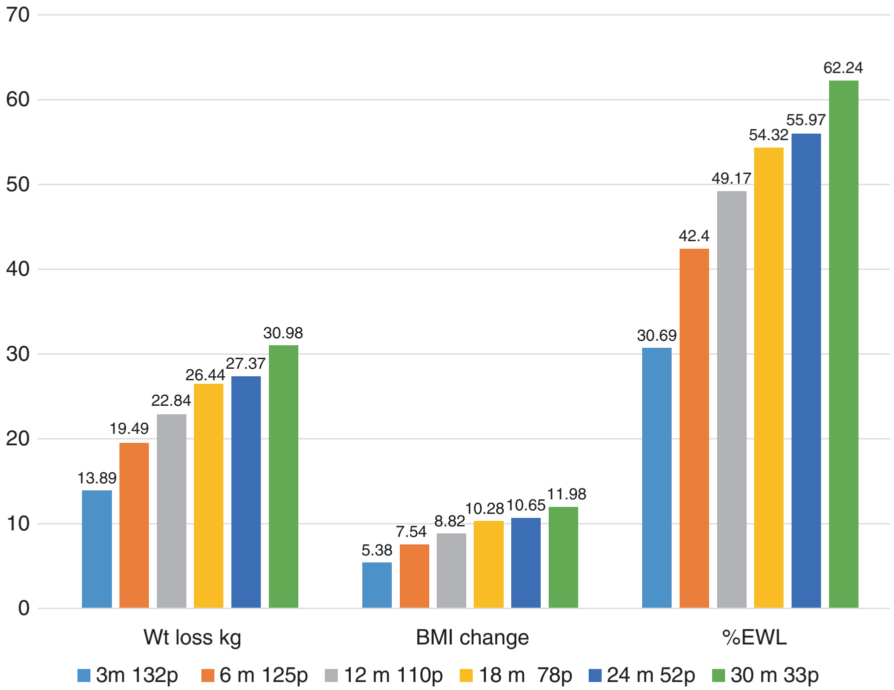


Fig. 22.13 Weight loss analysis

reversibility. Other patients had their clips removed for different surgical complications that are summarized in Table 22.3. These patients, after clip removal, were not included statistically going forward. One hundred thirty-two patients were included in weight loss analysis (Fig. 22.13). The mean percent excess weight loss (%EWL) were 30.7, 42.4, 49.1, 54.3, 55.9, and 62.2, respectively, at 3, 6, 12, 18, 24, and 30 months. The mean weight loss and BMI's loss were 13.9 kg and 5.4, 19.5 kg and 7.5, 22.8 kg and 8.8, 26.4 kg and 10.2, 27.4 kg and 10.7, and 30.9 kg and 11.9, respectively, at 3, 6, 12, 18, 24, and 30 months.

The quality of life (QoL) was previously reported [1] and assessed for 85. The analysis of the Moorehead-Ardelt Quality of Life Questionnaire showed a significant improvement of the scores for each of six dimensions. The variation of the

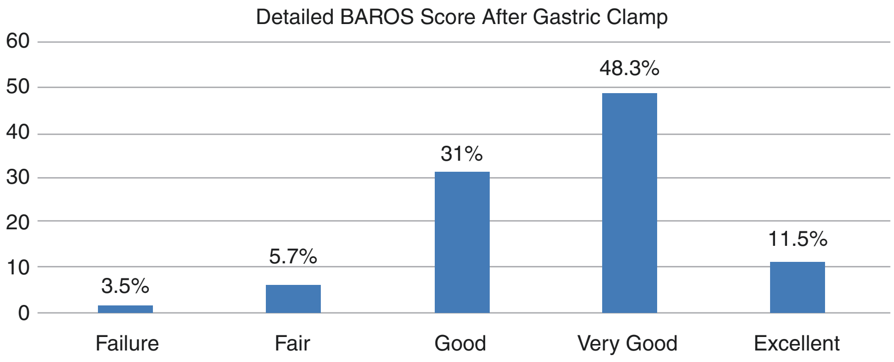


Fig. 22.14 Quality of life

scores of QoL is significant ($p < 0.001$). For item 1 ("I usually feel…"), the quality of life was improved by 181%, for item 2 ("I enjoy physical activities") by 262%, for item 3 ("I have satisfactory social contacts") by 69%, for item 4 ("I am able to work") by 19%, for item 5 ("The pleasure I get out of sex") by 41%, and for item 6 ("The way I approach food is….") by 418%.

The quality of life was also analyzed regarding the complications and resolution of different medical conditions included in the BAROS score (Fig. 22.14). The results showed failure for 1.2% of patients and fair for 6.1% of cases. The quality of life assessed as good for 26 patients (31.8%), as very good was described for 39 patients (47.5%), and excellent in 11 patients (13.4%), respectively.

To date, no infections, no conversions, no transfusions, or no deaths have occurred.

22.4 Discussions

The constant need to find a new bariatric operation represents a clear sign that all the current procedures have certain limitations and complications. The reason why LSG became the most common performed bariatric procedure is the best ratio between complications and weight loss results. Still, many patients and surgeons are incriminating the LSG for two major disadvantages: postoperative GERD and procedure's irreversibility. The BC has the same restriction principle as LSG with a similar volume of the gastric tube. Compared with the LAGB, the BC offers the same advantage of reversibility, but with improved quality of life. LSG requires stapling and cutting resulting in a 1–3% [2, 3] leak rate, which can be a devastating complication. Sleeve patients also report a significant incidence of reflux (10–20%) [4], which may adversely affect the quality of life resulting in long-term medical therapy, or conversion to a gastric bypass that subsequently can present a small percentage of reflux. The main advantage the gastric clip has over other bariatric procedures is the safety benefit for patients.

Particular attention during the preclinical studies was offered to the closing pressure of the device, and the BC was designed to minimize the closing force so that the limbs would simply oppose the anterior and posterior walls of the stomach, to minimize the possibility of erosions and ischemia. The experience with the gastric band with the two different techniques (pars flaccida and perigastric) taught us a lesson about gastric migration. Himpens et al. [5] have reported a rate up to 28% for the band erosion with the perigastric technique. A further review [6] showed a decreased incidence of band erosion with the modification to the pars flaccida technique to about 1–2%. With up to a 6-year follow-up of the BC, erosion has only been reported in two patients (1.2%).

The BC is a new device used to create a tubular gastric pouch similar to the sleeve gastrectomy and to the Magenstrasse and Mill (M&M) procedure [7, 8], resulting in similar early 2-year results (Fig. 22.13). It is interesting to note that the M&M procedure showed stable weight loss results up to 5 years of 60%. The difference between M&M and BC is the reversibility of the BC and the absence of the possibility of gastro-gastric fistula, the main reason of failure for M&M procedure.

The reflux in bariatric surgery represents a main concern especially for SG. To date, conversion to a gastric bypass represents the most common surgical treatment option for patients with severe gastroesophageal reflux disease following SG. The authors theorize that because of the low pressure within the lumen of the BC, reflux is very unlikely. Any high intraluminal pressure of the main lumen should cross over through the limbs of the clip into the excluded stomach.

Bobowicz et al. [9] used BAROS to evaluate SG outcomes in 84 patients 5 years after surgery. An overall very good result was achieved in 30% of patients, whereas no effects were reported by 13% of respondents. Similar or even better results were recorded with BC: 60% of patients assessed the quality of life post-BC as very good or excellent.

22.5 Conclusions

The BariClip represents a new bariatric procedure that mimics the principle of LSG but with completely reversible mechanism and with significantly decreased rates of reflux. The procedure consists of a nonadjustable clip that is vertically placed parallel to the lesser curvature. The benefits are the capability of doing this without any stapling, resection, change in anatomy, or need for maintenance while at the same time being a reversible procedure. After more than 6 years of clinical use, the complication rate seems acceptable with good weight loss results and up to 92.7% of patients with improved QoL.

Further experience and studies will determine if there is a subset of patients that may benefit more than others, such as lower BMI patients, the elderly, children, or adolescents.

References

1. Noel P, Nedelcu AM, Eddbali I, Zundel N. Laparoscopic vertical clip gastroplasty – quality of life. Surg Obes Relat Dis. 2018;14(10):1587–93.
2. Aurora AR, Khaitan L, Saber A. Meta-analysis of leak after laparoscopic sleeve gastrectomy for morbid obesity. SAGES. 2011.
3. Aurora AR, et al. Sleeve gastrectomy and the risk of leak: a systemic analysis of 4,888 patients. Surg Endosc. 2012;26(6):1509–15.
4. Rosenthal RJ. International sleeve gastrectomy expert panel consensus statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8:8–19.
5. Himpens J, Cadière GB, Bazi M, Vouche M, Cadière B, Dapri G. Long-term outcomes of laparoscopic adjustable gastric banding. Arch Surg. 2011;146(7):802–7.
6. Singhal R, Bryant C, Kitchen M, Khan KS, Deeks J, Guo B, Super P. Band slippage and erosion after laparoscopic gastric banding: a meta-analysis. Surg Endosc. 2010;24(12):2980–6.
7. Johnston D, Dachtler J, Sue-Ling HM, King RF, Martin IG. The Magenstrasse and Mill operation for morbid obesity. Obes Surg. 2003;13(1):10–6.
8. De Roover A, Kohnen L, Deflines J, Lembo B, Goessens V, Paquot N, Lauwick S, Kaba A, Joris J, Meurisse M. Laparoscopic Magenstrasse and Mill gastroplasty. First results of a prospective study. Obes Surg. 2015;25:234–41.
9. Bobowicz M, Lehmann A, Orłowski M, et al. Preliminary outcomes 1 year after laparoscopic sleeve gastrectomy based on Bariatric Analysis and Reporting Outcome System (BAROS). Obes Surg. 2011;21(12):1843–8.

Part V
Treatment of Complications

Chapter 23
Sleeve Gastrectomy: Prevention and Treatment of Bleeding

Jaideepraj Rao and Wah Yang

23.1 Introduction

Laparoscopic sleeve gastrectomy (LSG), while initially conceived as a first-stage procedure before a biliopancreatic diversion or a Roux-en-Y gastric bypass, has now been established as an effective single-stage procedure in the treatment of morbid obesity. Common complications of a LSG include haemorrhage, stapler-line leak, abscess, stricture, nutritional deficiency and gastroesophageal reflux disease [1].

The incidence of postoperative bleeding after LSG ranges from 1% to 6% [2, 3]. The bleeding may be intra- or extraluminal or present during the surgery or in the postoperative period. Bleeding during surgery may result in prolonged surgery time or necessitate conversion from laparoscopic to open. Postoperative bleeding may result in the need for reoperation, lead to prolonged hospital stay and if not drained may develop into an abscess. Haematoma formation is associated with an increased risk of leaks [4], one of the most feared complications after a sleeve gastrectomy.

J. Rao (✉)
Upper GI, Bariatric & Minimal Access Surgery, Tan Tock Seng Hospital, Singapore, Singapore

W. Yang
Department of Metabolic and Bariatric Surgery of the First Affiliated Hospital of Jinan University, Guangzhou, China

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_23

23.2 Intraoperative Bleeding

23.2.1 Patient Factors

23.2.1.1 Coagulopathy

Preoperative assessment of the patient should be done in conjunction with the anaesthetist. The assessment includes taking a thorough history of medications the patient is current taking and performing routine blood investigations such as platelet count and prothrombin time (PT)/partial thromboplastin time (PTT) to assess for a hypercoagulable state. Anti-platelets and anticoagulants need to be stopped for an appropriate amount of time prior to surgery. Patients on warfarin may need to be bridged with subcutaneous clexane or intravenous heparin, depending of the risk profile of the patient.

We discourage our patients from taking traditional medicine or herbal supplements for at least a week prior to surgery. Administration of 1 g of tranexamic acid after induction has been shown to have less staple-line bleeding, less intraoperative blood loss and quicker operating times [5].

23.2.1.2 Fatty Liver

An enlarged fatty liver increases the complexity and difficulty of the surgery in patients undergoing bariatric surgery [6]. Hepatomegaly has been cited as the most common cause for conversion from laparoscopic to open RYGB [7]. A 12-week programme of very low caloric diet (VLCD) has been shown to decrease the liver volume by 19.2–28.7%, with 80% of the observed liver reduction taking place in the first 2 weeks [8]. Modest preoperative weight loss through 2 weeks of preoperative VLCD has been shown to reduce the perceived difficulty of the surgery, as well as the incidence of postoperative complications, especially infections [6]. A liver that is fatty is more likely to fracture and bleed during manipulation or retraction [9].

While such bleeding is seldom life threatening, it nonetheless interferes with the conduct of the surgery. Bleeding from a liver fracture can be stopped with application of a unipolar diathermy, or by applying pressure over the affected area, or by using haemostatic agents.

We advocate a 2-week preoperative VLCD programme in all patients undergoing bariatric surgery.

23.2.2 Technical Factors

23.2.2.1 Bleeding from Gastric Vessels

The remarkable rise of laparoscopic surgery would not have been possible without advances in energy devices that dissect tissues and achieve haemostasis. The two main types of energy are bipolar or ultrasonic energy. While most devices use either energy source, some have a combination of both bipolar and ultrasonic energy.

In sleeve gastrectomy, the greater omentum and short gastric vessels are dissected off the greater curvature using an energy device. Applying the energy device as close to the greater curve as possible, where the vessel diameter is the smallest, can minimize bleeding from feeding vessels.

It is imperative to understand the device being used. Some devices seal vessels up to 7 mm, while others only seal vessels up to 5 mm. Energy devices tend to produce heat, especially the ultrasonic devices. The temperature of ultrasonic devices rises to >100 °C during use [10], and the active blade should be visualized at all times during dissection to avoid inadvertent damage to tissues and vessels.

Some fundamental principles should be followed when using energy devices, regardless of energy type. The device should be *completely* applied across a vessel before activating the instrument. Patience is needed when using energy devices; release of the energy device before complete sealing of the vessel will inadvertently result in retraction of an incompletely sealed vessel with potentially catastrophic results. Traction is important in allowing visualization of the tissues; however too much traction during application of the energy device may result in shearing of vessels before complete sealing.

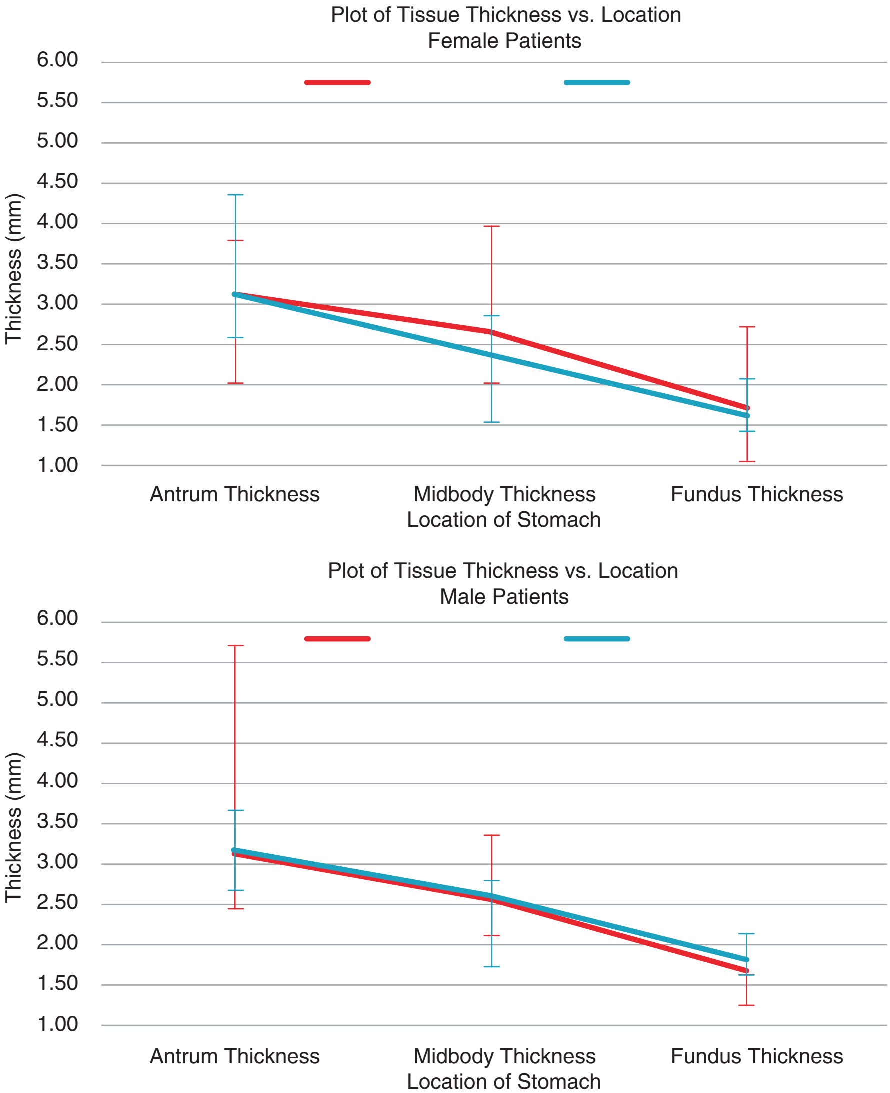
Bleeding from the vessels of the greater omentum can be easily controlled, but bleeding from the short gastric vessels is feared. If bleeding from the short gastric vessels is encountered, first compress the area of bleeding with gauze. Adequate exposure and visualization of the area is paramount to proper haemostasis. Achieving adequate exposure may necessitate putting in more ports. The bleeding can be tackled with clips, energy device, oversewing of the bleeding vessel or haemostatic agents. If the bleeding is from a vessel close to the spleen, it is advisable to use compression or haemostatic agents rather than an energy device. Convert from laparoscopic to open surgery if necessary.

23.2.2.2 Staple-Line Bleeding

The stomach has varying thickness along its entire length, with the tissue being thickest at the antrum and thinnest at the fundus [11], as seen in Table 23.1. A mismatch between staple height and tissue thickness may lead to incomplete staple formation, staple-line bleeding or a leak. Certain newer generation staplers have technology that automatically adjusts the firing speed of the stapler in variable tissue thickness to optimize staple formation. There are various staple cartridges available which accommodates different tissue thickness, as illustrated in Fig. 23.1 [12]. We err on using a thicker staple for a given tissue thickness. It would be prudent to use a black cartridge when performing a sleeve gastrectomy on patients who had previous gastric bands as the tissue may be thicker due to fibrosis and inflammation.

Staple-line reinforcement reduces the incidence of bleeding. Shikora et al. [13] conducted a meta-analysis comparing three methods of staple-line reinforcements to

Table 23.1 Plots of tissue thickness vs location for female and male patients



Adapted from Huang and Gagner [11]

no reinforcement and found bleeding rates of 1.16% with bovine pericardial strips, 2.09% with absorbable polymer membrane, 2.41% with oversewing of the staple line and 4.94% when no reinforcement was performed. One drawback to using a buttressed stapler would be the increased cost. It is also not recommended to oversew a buttressed staple line. If buttressing material used, its thickness must be accounted for when choosing a staple cartridge [11]. Other alternatives to a buttressing include

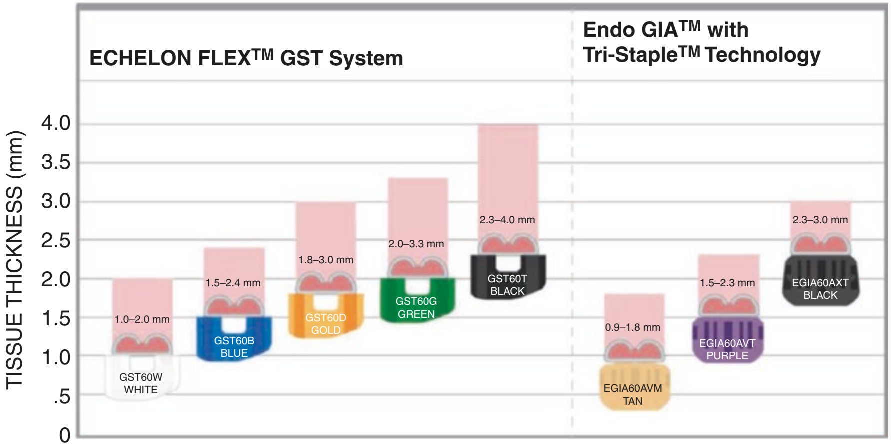


Fig. 23.1 Tissue thickness accommodation for Ethicon Echelon™ and Endo GIA™ Tri-Staple systems (Adapted from Thompson et al. [12])

applying fibrin glue or performing Lembert's suture to invert the suture line, both of which have been shown to decrease staple-line bleeding to 0.1–0.3% [14, 15].

De Angelis et al. [16] describe a protocol involving the adjustment of systolic blood pressure to 140 mmHg, while pneumoperitoneum is simultaneously reduced to 10 mmHg in order to identify any potential spots of bleeding. Intraluminal bleeding is not common, and while not widely practised, some surgeons routinely perform intraoperative gastroscopy to assess for any intraluminal bleeding.

Avoid applying the stapler too tight against the bougie prior to firing; consider withdrawing the bougie slightly after closing the stapler to ensure that it is snug but not too tight. Avoid acute angling of the staple line. When bleeding from the staple line is noted, haemostasis can be achieved by applying metal clips, monopolar diathermy, haemostatic agents or oversewing the bleeding spot.

23.3 Postoperative Bleeding

Our recommended management algorithm for postoperative bleeding is outlined in Fig. 23.2.

Patients with postoperative intraluminal bleed may present with haematemesis, coffee ground vomitus or melena. Early gastroscopy should be arranged, and haemostasis can be achieved with adrenaline injection, clips or heater/bipolar probe.

Extraluminal bleeding may present with tachycardia, hypotension, abdominal pain, fever or a drop in haemoglobin levels. A high index of suspicion is needed in any patient with pallor and tachycardia post-surgery, and an early computed tomographic (CT) scan should be arranged to assess for extraluminal bleed. A small haematoma can be treated conservatively; however the prudent solution in patients

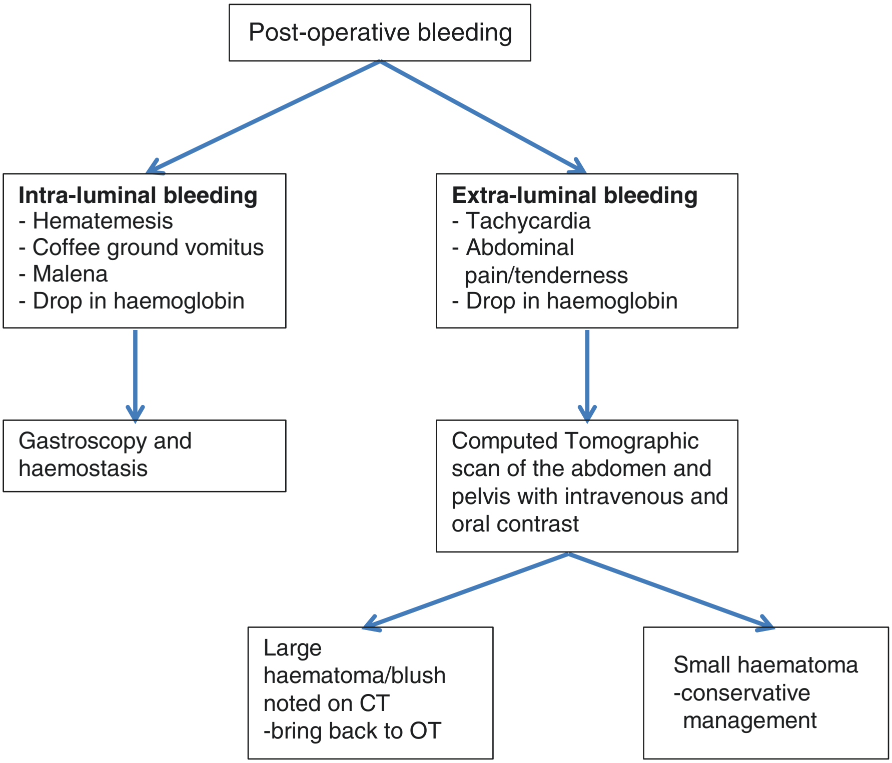


Fig. 23.2 Management algorithm of postoperative bleeding

with a large haematoma would be to bring the patient back to the operating room to surgically drain the haematoma and inspect the staple line for any ongoing bleeding. A large haematoma, if left alone, is at risk of getting infected and developing into an abscess with concurrent risk of sepsis. A large haematoma also increases the risk of a staple-line leak or fistula formation [4, 9]. Angioembolization can be considered if a blush is seen on CT; however the bleeding is usually from the staple line without a feeding vessel and hence not amenable to angioembolization unless bleeding originates from the divided short gastric vessels.

Acknowledgement Thanks to Danson Yeo for his special contribution.

References

1. Sarkhosh K, Birch DW, Sharma A, et al. Complications associated with laparoscopic sleeve gastrectomy for morbid obesity: a surgeon's guide. Can J Surg. 2013;56:347–52.
2. Melissas J, Koukouraki S, Askoxylakis J, et al. Sleeve gastrectomy: a restrictive procedure? Obes Surg. 2007;17:57–62.

3. Frezza EE. Laparoscopic vertical sleeve gastrectomy for morbid obesity. The future procedure of choice? Surg Today. 2007;37:275–81.
4. Warner DL, Sasse KC. Technical details of laparoscopic sleeve gastrectomy leading to lowered leak rate: discussion of 1070 consecutive cases. Minim Invasive Surg. 2017;2017:4367059.
5. Chakravartty S, Sarma DR, Chang A, et al. Staple line bleeding in sleeve gastrectomy-a simple and cost-effective solution. Obes Surg. 2016;26:1422–8.
6. Van Nieuwenhove Y, Dambrauskas Z, Campillo-Soto A, et al. Preoperative very low-calorie diet and operative outcome after laparoscopic gastric bypass: a randomized multicenter study. Arch Surg. 2011;146:1300–5.
7. Schwartz ML, Drew RL, Chazin-Caldie M. Laparoscopic Roux-en-Y gastric bypass: preoperative determinants of prolonged operative times, conversion to open gastric bypasses, and postoperative complications. Obes Surg. 2003;13:734–8.
8. Colles SL, Dixon JB, Marks P, et al. Preoperative weight loss with a very-low-energy diet: quantitation of changes in liver and abdominal fat by serial imaging. Am J Clin Nutr. 2006;84:304–11.
9. Jossart GH. Complications of sleeve gastrectomy: bleeding and prevention. Surg Laparosc Endosc Percutan Tech. 2010;20:146–7.
10. Eto K, Omura N, Haruki K, et al. A comparison of laparoscopic energy devices on charges in thermal power after application to porcine mesentery. Surg Laparosc Endosc Percutan Tech. 2015;25:e37–41.
11. Huang R, Gagner M. A thickness calibration device is needed to determine staple height and avoid leaks in laparoscopic sleeve gastrectomy. Obes Surg. 2015;25:2360–7.
12. Thompson SE, Young MT, Lewis MT, et al. Initial assessment of mucosal capture and leak pressure after gastrointestinal stapling in a porcine model. Obes Surg. 2018;28:3446–53.
13. Shikora SA, Mahoney CB. Clinical benefit of gastric staple line reinforcement (SLR) in gastrointestinal surgery: a meta-analysis. Obes Surg. 2015;25:1133–41.
14. Sepulveda M, Astorga C, Hermosilla JP, et al. Staple line reinforcement in laparoscopic sleeve gastrectomy: experience in 1023 consecutive cases. Obes Surg. 2017;27:1474–80.
15. Coskun H, Yardimci E. Effects and results of fibrin sealant use in 1000 laparoscopic sleeve gastrectomy cases. Surg Endosc. 2017;31:2174–9.
16. De Angelis F, Abdelgawad M, Rizzello M, et al. Perioperative hemorrhagic complications after laparoscopic sleeve gastrectomy: four-year experience of a bariatric center of excellence. Surg Endosc. 2017;31:3547–51.

Chapter 24
Leaks and Fistulas After Sleeve Gastrectomy

Camilo Boza, Ricardo Funke, and Camilo Duque S.

Laparoscopic sleeve gastrectomy (LSG) is the most commonly performed metabolic and bariatric surgery. Several studies have found that it is a safe and effective procedure; however, it is not free of complications, two of them, such as postoperative leaks and hemorrhage in the staple line, are the most feared. Leaks are more frequent with rates reported between 0.75% and 3% [1]. It is a serious complication, being the second cause of death after bariatric surgery with a mortality rate that ranges between 0% and 1.4% [2]. Gastric leakage in the context of an LSG is a difficult leak to cure, compared to leaks in other bariatric surgeries; it is usually of late presentation and only becomes evident due to peritoneal and systemic infectious complications that many times require invasive treatments such as surgeries, drainages, or stents involving prolonged hospital stays with great economic impact. Bransen et al. [3] calculated the additional cost of €9284 after a leak of a LSG. Ahmed et al. [4] developed a model to estimate the total cost of treatment in UK hospitals. They established three realistic scenarios that reflected the severity of the leaks. They compared the costs in both the National Health System and the private system. The actual costs of treating a postoperative leak were £14,543–68,980 in the UK National Health System and from £29,212 to £115,009 for a patient who pays on his or her own. The most common location of a leak of the staple line was the proximal third of the stomach. In a recent publication, Cesana et al. [5], in 1738 LSG, reported 2.8% of leaks, of which 6% were evident in the distal third of the staple line and 94% in the proximal third. In the majority of patients, the diagnosis was made within 3 weeks after surgery (88.9%).

Its treatment is variable, without a standard algorithm to follow. Most of the data shows that the management must be planned according to the clinical evaluation, the moment of diagnosis, and the location of the leak.

C. Boza · R. Funke (✉) · C. Duque S.
Department of Digestive Surgery, Clinica Las Condes, Santiago, Chile
e-mail: rfunke@clinicalascondes.cl

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_24

24.1 Pathogenesis

Its genesis can be explained by multiple factors during the construction of the sleeve. One of the most reliable hypotheses for the development of leaks is the one proposed by Baker et al. [6]. They refer two groups of causes of leaks in LSG, those related to mechanical aspects and those related to ischemia.

The *mechanical factors* are related to the creation of the gastric tube and are generally responsible for acute leaks (appear within the first days of surgery):

1. High pressure system. As demonstrated by Yehoshua et al. [7], who evaluated intragastric pressures before and after LSG in 20 patients with morbid obesity. Before gastric resection, the mean basal intragastric pressure was 19 mmHg (range, 11–26 mmHg); after surgery, the pressure increased to 34 mmHg (range, 21–45 mmHg). Also Mion et al. [8], based on high-resolution manometry, in 53 post-LSG patients, reported the presence of increased intragastric pressure (more than 30 mmHg) in 77% of patients. In addition, gastric hypertension can affect the healing process and lengthen the time for the closure of a leak.
2. The construction of the sleeve creating a stenosis in the middle third as a result of the closeness of the line of staples to the incisura angularis or the twisting of the sleeve by the asymmetrical disposition of the sutures or the inadequate size that will depend on whether the sutures are tight or loose in relation to the bougie and the size of the bougie. These mistakes further increase intra-sleeve pressure, which can lead to dilation of the upper portion of the tube.
3. Failure in the creation of the stapling line. The thickness of the wall, the parietal tension, the displacement of the interstitial fluid at the time of stapling, the cartridge selection, the operation of the stapler, and the cut without shearing are the determining factors for an adequate stapling. Therefore, optimal stapling must be done with materials in excellent condition; conserving gastric symmetry; avoiding excessive traction; allowing an adequate compression time of the tissue (wait at least 15 s before firing), which favors the displacement of the interstitial liquid that allows a correct sealing and cutting of the gastric wall; and choosing the cartridge correctly, according to the parietal thickness. The incorrect size of the staples increases the risk of leaks and the improper configuration of the closed staples, due to the difference between the staples and the tissue, whether due to a bad seal or excessive compression that exceeds the resistance of the tissue and causes breakage or perforations parietals. It is important to keep in mind that the thickness of the gastric wall is not constant and varies in the anatomical sectors of the stomach. An article published by Gagner, M. et al. [9] determined the range of gastric thickness in the three areas of stapling during LSG. They showed an interesting and accurate measurement of the thickness of the wall (Table 24.1). They reported that male patients had a thicker gastric antrum in relation to females (3.12 vs. 3.09 mm), while female patients had a thicker mid-gastric body (3.09 vs. 2.57 mm), as did proximal areas (1.72 vs. 1.67 mm). The maximum fundus thickness reached 2.8 mm in women and 2.3 mm in men, and the antrum was as thick as 4.1 mm in women and 5.4 mm in men. It is seen that in general,

Table 24.1 Statistical summary of tissue thickness

	Grosor del antro (mm)	Grosor del cuerpo (mm)	Grosor del fondo (mm)
Mujer (*N* = 15)			
Media ± SD	3.09 ± 0.62	2.64 ± 0.60	1.72 ± 0.59
Media ± SD	3.09 ± 0.553	2.34 ± 0.349	1.61 ± 0.279
Min	2.00	2.00	1.05
Max	4.07	4.00	2.83
Cuartil 1–25%	2.63	2.23	1.32
Cuartil 2–50%	3.10	2.50	1.50
Cuartil 2–75%	3.53	2.88	2.03
Hombre (*N* = 11)			
Media ± SD	3.12 ± 0.81	2.57 ± 0.42	1.67 ± 0.32
Media ± SD	3.17 ± 0.324	2.6 ± 0.391	1.81 ± 0.453
Min	2.45	2.12	1.24
Max	5.39	3.46	2.28
Cuartil 1–25%	2.72	2.29	1.37
Cuartil 2–50%	2.92	2.45	1.65
Cuartil 2–75%	3.21	2.82	1.85

Huang and Gagner [9]

this thickness decreases, in ascending direction from the pylorus to the angle of His. In addition, they documented that men had a longer average staple line, 22.9 vs. 19.9 cm, respectively. These results are similar to those obtained by Elariny et al. [10]. The correct choice of the cartridge in the prevention of the leak is then decisive.

4. Bougie size. Other possible mechanical factor involved in the genesis of the gastric leak in LSG is the size of the bougie. In the expert consensus statement in 2012, 87% of the panelists agreed that it was important to use a bougie to measure the size of the sleeve and the optimal size of the bougie should be between 32 and 36 Fr [11]. The meta-analysis of Parikh, Gagner et al. [12] collected 9991 patients with LSG and found that the size of bougie on average was 38.2 ± 6.4 Fr for all studies. The size <40 Fr was used in 69% of the patients. The authors found 198 leaks in 8922 patients. The risk of leakage decreased with a bougie ≥40. Similar results are reported by Aurora AR, et al. [13] in a systematic review ($n = 4888$ patients). The use of bougie with a size of 40 Fr or greater was associated with a leak rate of 0.6% compared to those who used smaller sizes whose leakage rate was 2.8%. This strong evidence supports the use of bougie ≥40 Fr to decrease leak rates without affecting % EWL. This was ratified at the Fifth International Consensus Conference: current state of sleeve gastrectomy [14], in its conclusion, the smaller the size of the bougie and the tighter the sleeve, the greater the incidence of leakage.
5. Distance from the pylorus. With respect to the distance from the pylorus at which the gastric transection begins, Parikh [12] reported that in 92 articles representing 8744 patients, the most common distance used is ≥5 cm from the pylorus (68%

of the patients). There is a debate about where the LSG should start. Some surgeons believe that starting >5 cm from the pylorus will improve gastric emptying through antral preservation and decrease intraluminal pressure (and possibly decrease the leak). Others believe that starting the LSG closer to the pylorus will lead to better long-term weight loss results. Although they revealed that the most common surgical technique uses bougie <40 Fr (average general: 38 Fr), it starts at ≥5 cm from the pylorus and uses a combination of green and blue cartridges and commonly with bioabsorbable reinforcement. Their data suggest that the largest size of a bougie (≥40 Fr) can decrease the leak rate without significantly affecting weight loss up to 3 years and that the distance from the pylorus does not seem to affect the rate of leakage or weight loss.

Ischemic aspects related to gastric leakage are related to the most common location of leakage, which is near the esophagogastric junction. Saber AA et al. [15] focused their research on gastric wall perfusion, based on the evaluation of the computed tomography, and showed that the perfusion of the gastric wall is significantly reduced in the angle of His and in the gastric fundus, unlike other gastric areas. This was particularly evident for obese patients compared to nonobese patients and was statistically significant only in the fundus. Ninety-six percent of the experts in the 2012 consensus [11] considered important to stay away from the GE junction in the last stapling. The deficit in blood supply and oxygenation in the gastric proximal third after LSG prevents the proper healing process and therefore is more susceptible to leakage.

Other factors of ischemia of the gastric wall are the heat generated by the electrocautery used during the dissection and infections of nearby tissues, which could be coadjuvants in the development of gastric leaks.

Understanding the pathogenesis will help us avoid these complications and encourage us to practice all the strategies to reduce them.

24.2 Personal Risk Factors

The risk factors that increase the rate of leakage in the staple line not only depend on the construction of the sleeve; there are also particular factors of the patients that increase the risk for this complication. A recent German multicenter observational study [16], involving 5400 patients with LSG as a primary procedure, analyzed the risk factors that increase the rate of leakage in the staple line and reported an association between male sex (2.5 times $p = 0.02$) and the BMI between 50 and 59.9 kg/m^2 with a rate of 1.6%, with $p < 0.01$ being statistically significant. The presence of at least one comorbidity did not increase the risk of leakage in that study (2%, $p = 0.24$). In addition, in patients with a history of laparotomy, the leak rate increased to 4.4%. An increased risk was also shown for procedures with conversion to open technique (14.6%, $p < 0.01$). For the revision LSG as in the cases of LSG after the gastric band and the re-sleeve, the risk of leakage is greater due to the dense adhesions, scarring, and ischemic tissues.

24.3 Classification of Leaks

Leaks can be classified according to the time of onset, the clinical presentation, the location of the leak, and the radiological appearance. Multiple authors have proposed different classifications, but since the Fifth International Consensus Conference [14], it has been universally accepted as:

- Acute <7 days
- Early 1–6 weeks
- Late 6–12 weeks
- Chronic >12 weeks

According to the clinical presentation and extension of the dissemination, they are classified into:

- Type I or subclinical, those that appear as a localized leak, contained without dissemination, with few clinical manifestations and easy to treat medically.
- Type II are those with dissemination or extension to the abdominal or pleural cavity, through an irregular way, with the appearance of contrast (methylene blue, radiological contrast) or food through any abdominal drainage, with serious clinical consequences.

According to the clinical and radiological findings, Rached AA et al. [17] propose to classify them as:

- Type A, are microperforations without clinical or radiographic evidence of leakage
- Type B, are leaks detected by radiological studies, but without clinical findings
- Type C, is a leak that is presented in radiological studies and with clinical evidence

According to their location they are classified as:

- Proximal third
- Middle third
- Distal third

24.4 Clinical Presentation

Gastric leaks can cause significant morbidity, such as sepsis, hemodynamic instability, multi-organ failure, and even death. The clinical presentation can vary widely, from fully asymptomatic patients diagnosed with routine imaging studies (type A as mentioned above) to those showing signs and symptoms of septic shock with radiological evidence of leakage (type C), through symptoms such as fever, left shoulder pain, nausea, vomiting, abdominal pain, peritonitis or evidence of leukocytosis, tachycardia, tachypnea and hypotension or like any type of clinical combination in this spectrum of signs and symptoms. Early leaks usually present with sudden abdominal pain, accompanied by fever and tachycardia, while late leaks tend to present with insidious abdominal pain commonly associated with fever.

Csendes et al. [18] and Dakwar et al. [19] agree that fever and tachycardia are the most important clinical factors in the diagnosis of postoperative gastric leak. Its presence without clear origin, after surgery, should raise the index of suspicion of a possible complication and alert the surgeon to perform additional radiological investigations to rule out the presence of leaks. Csendes believes that tachycardia is the earliest symptoms and the most important and constant clinical finding. A tachycardia above 120 beats/min is a strong indicator of leakage and systemic compromise.

The evolution depends on the comorbidities of the patient, the amount of the leak, and the time of detection and establishment of a correct treatment.

24.5 Diagnosis

There is still no consensus on the most sensitive and specific modality for the diagnosis of a gastric leak after the LSG, in which if there is consensus, it is that early detection is associated with better results and that a high index of suspicion is clinical is the Cornerstone in timely detection and successful resolution.

In many centers, upper digestive radiographic studies are routinely indicated to identify early leaks, although there is no consensus as to whether the image should be routinely or selectively ordered. Triantafyllidis G et al. [20] published a study that included 85 patients undergoing LSG, who underwent routine contrast-traction gastrography on the 3 postoperative day (DPO3) to exclude early complications. If a leak was detected, an additional image with computed tomography (CT) was performed to confirm the finding. Gastrography detected all leaks and provided information on the dissemination of the contrast in the abdominal cavity. The role of CT in the treatment of complications of LSG is both diagnostic and therapeutic. It was useful in confirming leaks, evaluating the abdominal cavity to detect the presence, location, and extension of abscesses and draining them percutaneously, avoiding open surgery. They conclude that gastrography with oral contrast is a relatively simple and inexpensive radiological study, which plays an important role in the diagnosis of two of the main complications of LSG, such as leakage and stenosis. The familiarity with the normal postoperative anatomy and the different patterns of the gastric remnant and their correlation with the clinical signs are important for the correct interpretation of the image. They consider that the radiological evaluation is important in the early postoperative period of LSG for the diagnosis and management of complications. However, Gärtner D et al. [21], in 307 sleeve gastrectomies, found 6 leaks; all patients developed clinical symptoms, such as abdominal pain, tachycardia, or fever. In one case, the leak was detected by gastrography with contrast swallow; in other cases the radiological findings were normal. No leaks were detected in asymptomatic patients. They conclude that gastrography, performed routinely, is not recommended for postoperative courses without complications. A high clinical suspicion of gastric leak should be followed immediately with a CT scan with oral and intravenous contrast. Ultrasound images usually do not detect anomalies, perhaps due to obesity and the small size of the collections or because of their subdiaphragmatic and retro-gastric location. A CT scan will differentiate localized and diffuse abdominal leakage and identify abscesses or fistulous tracts. A leak of contrast material in the CT scan may or may not be identified. The absence of contrast leakage commonly occurs in early leaks, probably due to a temporary sealing of the leak in the acute period.

24.6 Leak Prevention

Several surgical techniques have been used to reduce this morbidity, such as the use of staple-line reinforcement products, drains in the immediate postoperative period, different sizes of bougie, and different distances with respect to the pylorus where stapling begins.

Although multiple studies and meta-analyses evaluate the impact of these techniques, the findings are inconsistent with respect to their effectiveness in prevention or their impact on long-term results due to the small sample size and low leakage event rates. That limits the power of these studies. Iossa A et al. [22], in their review of the pathogenesis and risk factors for post-LSG leakage, conclude with a list of recommendations to prevent them, based on the evidence and consensus of the experts:

1. Use bougie size ≥40 Fr.
2. Begin the gastric transection at 5 cm from the pylorus.
3. Use the proper cartridges from the antrum to the bottom.
4. Reinforce the line of staples.
5. Follow an adequate line of staples.
6. Remove the staples from the device.
7. Maintain adequate traction in the stomach before stapling.
8. Stay at least 1 cm from the angle of His.
9. Control the bleeding of the staple line.
10. Perform an intraoperative test with methylene blue.

As for routinely putting intraperitoneal drains after LSG, there is controversy. Most pot-LSG leaks usually occur after the drain is removed. Despite this fact, some groups persist in the use of drains for two main reasons. First, a drain may allow the detection of an acute leak related to a technical failure, which increases the likelihood of successful early surgical management and second, the presence of a drain allows the detection and treatment of postoperative bleeding before the onset of symptoms and signs suggesting the diagnosis [23]. However, there is no conclusive evidence on the use of drains.

Regarding the use of reinforcement materials for the stapling line, the literature is controversial about its impact on the prevention of leaks. The meta-analysis of Gagner et al. [24], including 88 studies and 8920 patients, showed that fistula and hemorrhage rates are significantly reduced when reinforcement is used. But he concludes by saying, “The Panel of Experts reached a consensus that the reinforcement of the staple line reduces bleeding along the staple line and there was no consensus on whether it reduces the leakage rate or if it should be done routine way.

24.7 Treatment

The treatment of leaks in the postoperative context of LSG has many controversies and difficulties in adopting a standard algorithm. Early diagnosis and timely treatment of a gastric leak after LSG are difficult and are still a matter of debate. Worldwide, the most common is that patients are discharged in good clinical conditions, on the second postoperative day, tolerating a liquid diet. But the leak is diagnosed several days after surgery. When the diagnosis of post-LSG gastric leakage is made, it becomes a professional and emotional challenge for the bariatric surgeon, who must decide between different approaches ranging from immediate surgical exploration, conservative therapy with percutaneous drains or endoscopic devices, to the reoperation for conversion to LGBYR or total gastrectomy in the worst scenarios.

The main thing is the hemodynamic stabilization and the infectious control avoiding the progression to a septic shock. Adequate drainage of collections and gastric effluent is essential, avoiding new collections, together with broad-spectrum antibiotics in the treatment of gastric leaks. If a drain was placed inside the operation, it must be conserved, or if the leak occurred later in the course of the recovery, the installation of some is a priority.

To summarize we define the priorities in the treatment of these leaks:

- Control and prevent sepsis.
- Adequate drainage of collections and gastric effluent.
- Prevent or resolve obstruction secondary to twisting or stenosis of the sleeve.
- Adequate nutritional support, prioritizing the enteral route either by enteral tube that progresses beyond the duodenum or a jejunostomy, and in the case of not being able to access this route, there is no doubt in the parenteral option.
- Always proceed according to the patient’s clinical status that prevails over imaging findings and subjective perceptions of improvement or stability.

24.8 Acute Leak

In all patients with clinical suspicion of an acute leak after LSG, the main thing is to define the stability and the hemodynamic repercussion of the abdominal inflammatory process, orienting us in two possible scenarios:

1. The patient with possible gastric leak with peritoneal inflammatory signs and hemodynamic instability, in which there is no discussion that the best option is to reoperate preferably laparoscopically, performing an adequate lavage of the abdominal cavity, draining all types of collections and also installing drains to evacuate the gastric effluent, and decreasing the possibility of new collections. Accompanying this surgical procedure, an adequate clinical support, antibiotic therapy, and nutritional support should be guaranteed, preferably via the enteral route distal to the duodenum. All authors agree not to recommend the primary suture of the leak. Most patients who underwent primary sutures failed, due to persistent leakage (the orifice cannot be clearly identified) or failure of the suture (inflamed and friable tissue) [6], especially if they were performed afterward of the third day of the initial operation. The main thing in this group of patients is to solve the abdominal infectious component and be able to contain the inflammatory response, and then the treatment of the leak will be defined.
2. The patient with symptoms suggestive of gastric leak and stable hemodynamic. In these patients, the first is to demonstrate the existence of leakage and abscesses, for which a superior digestive fluoroscopic study with a water-soluble contrast medium and a CT scan of the abdomen and pelvis with oral and intravenous contrast should be performed.

   In the case of leakage and/or evidence of intra-abdominal collections or free fluid, in our group we opted for surgical conduct via laparoscopy, as in the previous scenario, doing an exhaustive surgical lavage, and installation of drainages, as well as antibiotic and nutritional treatments as it matches. Other groups opt for conservative management, installation of drainages and evacuation of collections percutaneously, antibiotic therapy, and enteral nutritional support. Some also add endoscopic therapy with stenting. In our group, we prefer to postpone the placement of the stent until there is persistence of the leak after the first reoperation manifested as persistence of gastric fluid, contrast, or methylene blue through the drain tube after installation. At that time we considered the endoscopic therapy that is preferably a stent. Other sealing mechanisms such as the Ovesco system, the clips, or cyanoacrylate are left for very exceptional cases.

   There are also groups who, to assess the size of the leak and clarify if the patient has also an stenosis, perform upper endoscopy. They also ensure the feeding route by placing a nasojejunal feeding tube and plan the placement of an endoscopic stent.

The lack of international algorithms due to the low rate of this complication causes several groups to adopt different treatment options, some with good results and techniques that can enrich the therapeutic arsenal of surgeons, although with little evidence. Musella, M et al. [25] propose the repair of acute leaks evidenced before 48 hours of LSG. By laparoscopy, washing of the abdominal cavity is performed, careful isolation of the greater gastric curvature and with the methylene blue test the leak zone is detected, a series of points are passed to achieve optimum traction at the edges of the leak (Fig. 24.1), and a stapler is placed underneath, rebuilding the staple line. Then a new methylene blue test is performed; later, it is completed with a thorough washing of the abdominal cavity and with the placement

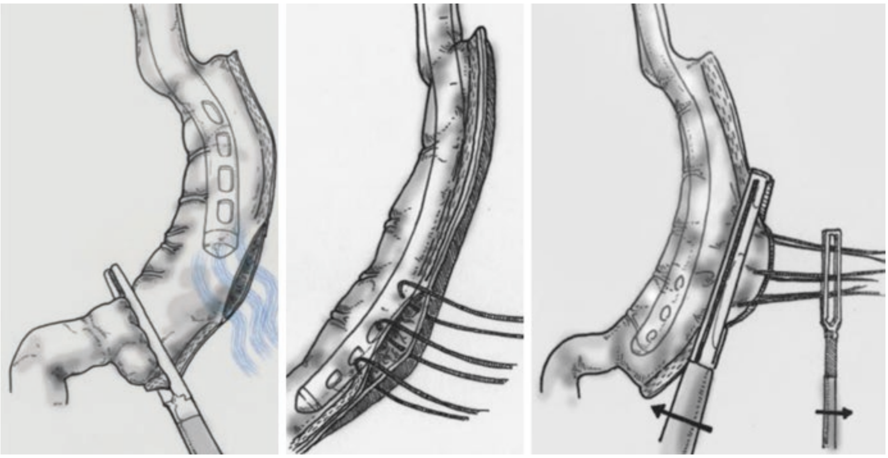


Fig. 24.1 Taken from Musella, M et al. [25]

of two drainage tubes, one aligned to the line of the staple and another that surrounds the spleen, below the diaphragm. A nasogastric tube is left during the first 24 h after surgery. This group treated three patients with their technique, and after oral liquid diet 5 days after the surgical repair, they were discharged between 9 and 10 days POP.

We consider it a surgical approach that can be resolve this patients, but it becomes an option for a very low number of patients. As we explained before, the vast majority of leaks occur after 48 h, and more than 90% originate in the proximal third of the sleeve, and this technique is more feasible in distal leaks.

As a last option, if the patient has an acute leak with stenosis not susceptible to endoscopic stent placement and poor response to conservative treatment, it should be considered previous nutritional optimization, the surgical conversion to LGBYR.

24.9 Early and Late Leakage

The therapeutic approach for early and late leaks in clinically stable patients is very variable and equally without consensus. The vast majority of surgeons opt for the adoption of a conservative approach with adequate hydration, inhibitors of the proton pump, NPO, nutritional support preferably by enteral route, percutaneous drainage of any collection, and broad-spectrum antibiotic therapy. In view of the low invasive nature and the expectant nature of conservative treatment, strict follow-up should be continued, and the leak should be evaluated with a contrasted superior digestive image, until making sure of the total occlusion of the leak. When there is any concern about healing, more invasive approaches should be considered, such as endoscopic treatments with stents.

24.9.1 Chronic Leakage

The management of presentation leaks very late, considered chronic or chronic as part of the evolution of the treatments performed, some with partial improvement, others without any response, is a great challenge to the therapeutic arsenal with scientific evidence. Remain as options, retry endoscopic therapies that have failed or that are not attempted or a more aggressive behavior but with better evidence as is the surgical conversion to a gastric bypass. The gastrojejunal anastomosis in Roux-en-Y has also been reported, in which the jejunal limb is anastomosed on the leak and in extreme cases the performance of a total gastrectomy with esophageal jejunum anastomosis.

24.9.2 Endoscopic Treatments

As already stated, leaks in all temporal stages can be tributary to endoscopic treatments, either as coadjuvants in the treatment or as a curative option. Various modalities can be used in treatment, such as the deployment of a stent at the site of the leak. In addition, there is at the endoscopist's discretion a range of complementary treatments such as cyanoacrylate glue and metal clips [Resolution Clip (Boston Scientific Corporation, USA), Over-the-Scope Clip® (OTSC®, Ovesco Endoscopy, Germany)].

Among these, endoprosthetics or stent is the current gold standard modality. Initially they were used to treat the stenosis, and it was demonstrated that they diminish the intramural pressure (for many the origin of the leakage post-LSG), so its use gained a space in the treatment of the leaks of the proximal and middle third, due to the advantage of restarting oral feeding and the possibility of continuing treatment on an outpatient basis with the return to the patient's home. The use of coated self-expanding metal esophageal stents has been recognized as a safe and effective method since 2007, when Serra et al. [26] reported for the first time on its use for the treatment of leakages after LSG or a duodenal switch and reported its use in six patients, achieving control of leaks in 83% of cases. The accumulated clinical experience with the use of self-expandable coated stents for the closure of the gastrointestinal fistula has shown a highly variable closure rate of 44–100% [27, 28].

Complications of this treatment modality include stent migration (11.1–83%, mean 45.3%) and difficulty in removing the stent, which is a feared complication and has been described with the use of uncovered stents [27, 28].

A flexible, self-expanding, covered esophageal metal stent such as the (Beta stent) specially designed for sleeve leakage can be used to exclude the leakage site if it is small and is present just after the UEG. It is reported that the success rate of stent placement is 50–84% in the treatment of acute leaks and chronic fistulas but with a 60% probability of stent migration [29]. Mega stent can also be used (Mega stent, Taewoong Medical Industries, Gangseo-gu Songjung-dong, South Korea) [30], which is a longer covered self-expanding metal stent (available in 18 and

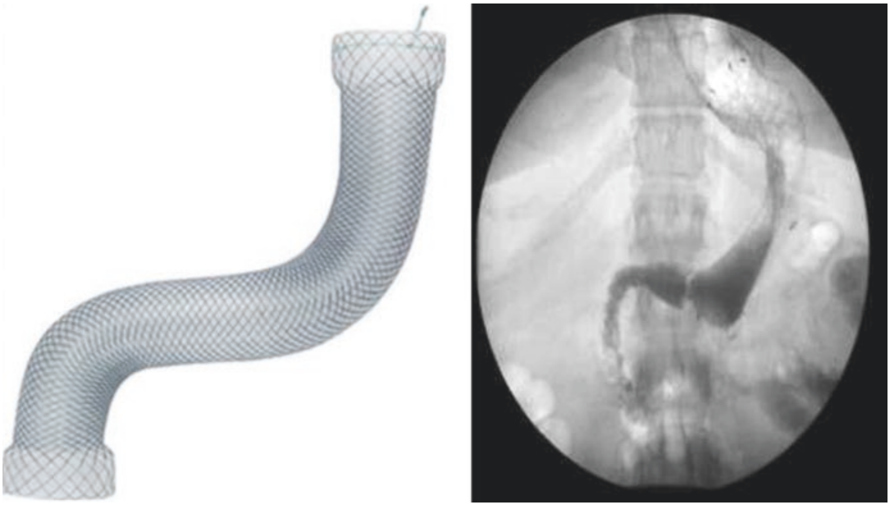
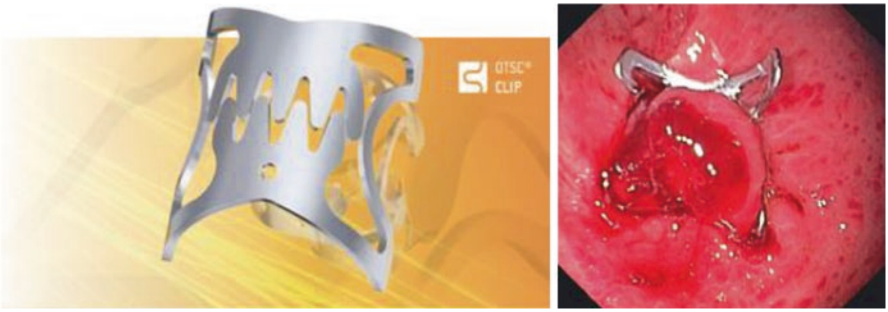


Fig. 24.2 The mega stent (Taewoong Medical Industries, South Korea) (length, 230 mm; diameter, 24–28 mm) covered with silicone

23 cm), designed specifically for subsequent leaks to the sleeve. The proximal and distal ends are slightly flared with a high edge profile, which allows a firmer anchorage (Fig. 24.2). The body of the stent is longer than that of the esophageal stents. As it is placed through the pylorus, it can play a role in decompressing the stomach; at the same time it excludes leakage.

In addition, the large diameter (22, 24 and 28 mm) provides optimal adhesion between the stent and the gastric wall, even in the antral portion, which gives adequate radial resistance to dilate a possible stenosis. Finally, although completely covered, the stent networks are flexible enough, which allows a correct adaptation of the stent in the postoperative anatomy of the gastric sleeve. A great advantage is that the displacement of this stent is rare due to its length, and the food can be continued orally, and it is not necessary to interrupt them. Garofalo F, et al. [31], in 11 patients with 872 LSG leakage performed, the placement of a mega stent was successful in eight of nine patients (88.8%), including primary and secondary treatment. In the endoscopic evaluation after removal of the stent, a pressure ulcer was observed in the prepyloric region in the landing zone of the stent. However, this endoscopic finding did not correlate with any symptoms after stent removal. No difficulties or intraoperative complications were observed during the installation or removal of these stents.

However, stent coverage whose purpose is to lead to the natural sealing of a defect and complete closure of a leak can be more challenging, requiring other options such as endoscopic injection of Histoacryl or the use of fibrin sealants or a clipping system (OTSC®, Ovesco AG, Tübingen, Germany). After debridement or clearance of infected materials, an endoscopic injection of fibrin sealant can lead to successful closure of chronic leaks or fistulas. Usually, several sessions are required. Several small series demonstrated a complete closure rate of 100% of the leak or fistula after bariatric surgeries, when combined with surgical or endoscopic drainage, or the insertion of a stent. As for the endoclips, these were initially used for hemostasis, later published trials for the treatment of mucosal defects, such as perforations and fistulas in the esophagus, colon, and duodenum. They were extrapolated to be used in the gastric sleeve leak and led to the development of new clips (OTSC) that have more promising results. A recent retrospective study showed that the use of OTSCs in patients with postoperative leakage, iatrogenic perforation, or spontaneous rupture of the upper gastrointestinal tract have higher clinical success rates, shorter hospital stay, and treatment of less duration and complications. However, it is difficult to apply this promising result to the treatment of post-bariatric leakage, because the study does not include any cases of post-bariatric surgery. The difficulty in the placement of the OTSC in the case of a leakage of the LSG is known because the most frequent position of the leak is close to the UEG and makes the deployment of the OTSC more challenging, and it is often difficult to reach the edges of a large defect, and these edges present an important inflammatory reaction in acute cases or a more fibrous reaction in chronic cases, which limits the grip of the edges even with the help of patented endoscopic forceps.

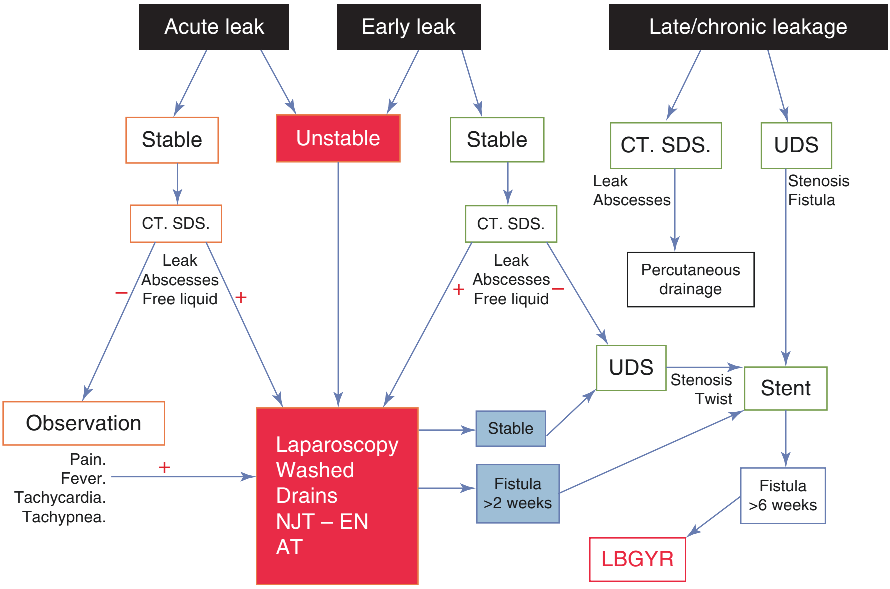


Recent studies have given more arguments for the use in bariatric postoperatives. Like the one by Keren et al. [32] presented a series of 26 patients who underwent endoscopic treatment with OTSC after GS leaks. The number of endoscopy sessions varied from 2 to 7 (median, 3). Five cases (19.2%) had treatment failures: two of them had an antral leak, and the remaining three had a proximal leak in the staple line. Twenty-one leaks (80.76%) were treated successfully. Four of the 21 were treated successfully with a combination of OTSC and stent placement. Similarly, in a retrospective study, Mercky et al. [33] confirmed the safety and efficacy of the OTSC in the treatment of gastric fistula. Nineteen patients were treated for leaks after LSG. Eleven cases (57.8%) were treated successfully with OTSC alone and four (21.1%) with a combination of OTSC and self-expanding stent, and in four (21.1%) even the combined treatment failed.

The sealing materials include fibrin glue and cyanoacrylates. The glue of fibrin acts by the dual effect, as a plug that directly occluded the defect and as a promoter of healing. It is absorbed after 4 weeks and is replaced by cicatricial connective tissue.

The use of endoluminal vacuum therapy (E-Vac) has also been described as an alternative treatment in the case of upper gastrointestinal leaks. Smallwood et al. [34] reported the results of the therapy with E-Vac after intestinal leaks; healing was achieved in all patients (*n*: 6) after an average of 35.8 days range: 7–69 days) and 7.2 different changes of E-Vac (range: 2–12). Similarly, Leeds et al. [35] presented very encouraging results in the treatment of LSG leaks with a success rate of E-Vac therapy in 89% (8/9) of the cases. Although the therapy with E-Vac has shown interesting results, concerns regarding its feasibility in the real world revolve around the obligatory Endo-SPONGE changes that are made every 3–5 days under general anesthesia.

In our experience, in the presence of leaks we prefer early surgical treatment for proper washing of the abdominal cavity and placement of drains, since our patients leave the surgical room without drainage routinely. We do not perform the primary suture of defects in reoperations. We prefer bypass conversion in case of chronic leaks although in selected cases depending on the nutritional and septic status, we go to stent endoscopic treatments we have no experience with OTSC. This is the algorithm we follow.



NJT Nasojejunal tube
CT Computed tomography
SDS Superior digestive series
EN Enteral nutrition
AT Antibiotic therapy
UDS Upper digestive endoscopy

References

1. Al-Kurd A, Grinbaum R, Abubeih A, Verbner A, Kupietzky A, Mizrahi I, Mazeh H, Beglaibter N. Not all leaks are created equal: a comparison between leaks after sleeve gastrectomy and Roux-En-Y gastric bypass. Obes Surg. 2018;28(12):3775–82. https://doi.org/10.1007/s11695-018-3409-3.
2. Jurowich C, Thalheimer A, Seyfried F, et al. Gastric leakage after sleeve gastrectomy-clinical presentation and therapeutic options. Langenbeck's Arch Surg. 2011;396(7):981–7.
3. Bransen J, Gilissen LP, van Rutte PW, Nienhuijs SW. Costs of leaks and bleeding after sleeve gastrectomies. Obes Surg. 2015;25(10):1767–71.
4. Ahmed A, Adamo M, Balchandra S. The real costs of treating early post-operative leaks following sleeve gastrectomy procedures. Obes Surg. 2015;25(Suppl 1):S45–O144.
5. Cesana G, Cioffi S, Giorgi R, Villa R, Uccelli M, Ciccarese F, Castello G, Scotto B, Olmi S. Proximal leakage after laparoscopic sleeve gastrectomy: an analysis of preoperative and operative predictors on 1738 consecutive procedures. Obes Surg. 2018;28(3):627–35. https://doi.org/10.1007/s11695-017-2907-z.
6. Baker RS, Foote J, Kemmeter P, Brady R, Vroegop T, Serveld M. The science of stapling and leaks. Obes Surg. 2004;14(10):1290–8.
7. Yehoshua RT, Eidelman LA, Stein M, et al. Laparoscopic sleeve gastrectomy–volume and pressure assessment. Obes Surg. 2008;18(9):1083–8.
8. Mion F, Tolone S, Garros A, et al. High-resolution impedance manometry after sleeve gastrectomy: increased intragastric pressure and reflux are frequent events. Obes Surg. 2016;26(10):2449–56.
9. Huang R, Gagner M. A thickness calibration device is needed to determine staple height and avoid leaks in laparoscopic sleeve gastrectomy. Obes Surg. 2015;25(12):2360–7.
10. Elariny H, González H, Wang B. Tissue thickness of human stomach measured on excised gastric specimens from obese patients. Surg Technol Int. 2005;14:119–24.
11. Rosenthal RJ, International Sleeve Gastrectomy Expert Panel, Diaz AA, et al. International Sleeve Gastrectomy Expert Panel Consensus Statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8(1):8–19.
12. Parikh M, Issa R, McCrillis A, Saunders JK, Ude-Welcome A, Gagner M. Surgical strategies that may decrease leak after laparoscopic sleeve gastrectomy: a systematic review and meta-analysis of 9991 cases. Ann Surg. 2013;257(2):231–7.
13. Aurora AR, Khaitan L, Saber AA. Sleeve gastrectomy and the risk of leak: a systematic analysis of 4,888 patients. Surg Endosc. 2012;26:1509–15.
14. Gagner M, Hutchinson C, Rosenthal R. Fifth International Consensus Conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6. https://doi.org/10.1016/j.soard.2016.01.022.
15. Saber AA, Azar N, Dekal M, et al. Computed tomographic scan mapping of gastric wall perfusion and clinical implications. Am J Surg. 2015;209(6):999–1006.
16. Benedix F, Benedix DD, Knoll C, Weiner R, Bruns C, Manger T, Stroh C, Obesity Surgery Working Group. Are there risk factors that increase the rate of staple line leakage in patients undergoing primary sleeve gastrectomy for morbid obesity? Obes Surg. 2014;24(10):1610–6.
17. Rached AA, Basile M, El Masri H. Gastric leaks post sleeve gastrectomy: review of its prevention and management. World J Gastroenterol. 2014;20(38):13904–10.
18. Csendes A, Braghetto I, León P, Burgos AM. Management of leaks after laparoscopic sleeve gastrectomy in patients with obesity. J Gastrointest Surg. 2010;14:1343–8.
19. Dakwar A, Assalia A, Khamaysi I, Kluger Y, Mahajna A. Late complication of laparoscopic sleeve gastrectomy. Case Rep Gastrointest Med. 2013;2013:136153.
20. Triantafyllidis G, Lazoura O, Sioka E, Tzovaras G, Antoniou A, Vassiou K, Zacharoulis D. Anatomy and complications following laparoscopic sleeve gastrectomy: radiological evaluation and imaging pitfalls. Obes Surg. 2010;21(4):473–8. https://doi.org/10.1007/s11695-010-0236-6.

21. Gärtner D, Ernst A, Fedtke K, Jenkner J, Schöttler A, Reimer P, Blüher M, Schön MR. Routine fluoroscopic investigations after primary bariatric surgery. Chirurg. 2016;87:241–6. https://doi.org/10.1007/s00104-015-0063-3.
22. Iossa A, Abdelgawad M, Watkins BM, Silecchia G. Leaks after laparoscopic sleeve gastrectomy: overview of pathogenesis and risk factors. Langenbeck's Arch Surg. 2016;401(6):757–66. https://doi.org/10.1007/s00423-016-1464-6.
23. Doumouras AG, Maeda A, Jackson TD. The role of routine abdominal drainage after bariatric surgery: a metabolic and bariatric surgery accreditation and quality improvement program study. Surg Obes Relat Dis. 2017;13(12):1997–2003.
24. Gagner M, Buchwald JN. Comparison of laparoscopic sleeve gastrectomy leak rates in four staple-line reinforcement options: a systematic review. Surg Obes Relat Dis. 2014;10:713–23.
25. Musella M, Milone M, Bianco P, Maietta P, Galloro G. Acute leaks following laparoscopic sleeve gastrectomy: early surgical repair according to a management algorithm. J Laparoendosc Adv Surg Tech A. 2016;26(2):85–91. https://doi.org/10.1089/lap.2015.0343.
26. Serra C, Baltasar A, Andreo L, et al. Treatment of gastric leaks with coated self-expanding stents after sleeve gastrectomy. Obes Surg. 2007;17(7):866–72.
27. Bege T, Emungania O, Vitton V, et al. An endoscopic strategy for management of anastomotic complications from bariatric surgery: a prospective study. Gastrointest Endosc. 2011;73(2):238–44.
28. Eloubeidi MA, Talreja JP, Lopes TL, Al-Awabdy BS, Shami VM, Kahaleh M. Success and complications associated with placement of fully covered removable self-expandable metal stents for benign esophageal diseases (with videos). Gastrointest Endosc. 2011;73(4):673–81.
29. Eubanks S, Edwards CA, Fearing NM, Ramaswamy A, de la Torre RA, Thaler KJ, et al. Use of endoscopic stents to treat anastomotic complications after bariatric surgery. J Am Coll Surg. 2008;206:935–9.
30. Galloro G, Magno L, Musella M, Manta R, Zullo A, Forestieri P. A novel dedicated endoscopic stent for staple-line leaks after laparoscopic sleeve gastrectomy: a case series. Surg Obes Relat Dis. 2014;10:607–11.
31. Garofalo F, Noreau-Nguyen M, Denis R, Atlas H, Garneau P, Pescarus R. Evolution of endoscopic treatment of sleeve gastrectomy leaks: from partially covered to long, fully covered stents. Surg Obes Relat Dis. 2017;13(6):925–32. https://doi.org/10.1016/j.soard.2016.12.019. Epub 2016 Dec 26.
32. Keren D, Eyal O, Sroka G, et al. Over-the-scope clip (OTSC) system for sleeve gastrectomy leaks. Obes Surg. 2015;25(8):1358–63.
33. Mercky P, Gonzalez JM, Aimore Bonin E, et al. Usefulness of over-the-scope clipping system for closing digestive fistulas. Dig Endosc. 2015;27(1):18–24.
34. Smallwood NR, Fleshman JW, Leeds SG, Burdick JS. The use of endoluminal vacuum (E-Vac) therapy in the management of upper gastrointestinal leaks and perforations. Surg Endosc. 2016;30(6):2473–80.
35. Leeds SG, Burdick JS. Management of gastric leaks after sleeve gastrectomy with endoluminal vacuum (E-Vac) therapy. Surg Obes Relat Dis. 2016;12(7):1278–85.

Chapter 25
Image Guide Percutaneous Abdominal Interventions for Leaks Following Sleeve Gastrectomy

Mariano Palermo and Mariano Gimenez

25.1 Background

One of the most dangerous complications after bariatric surgery are leaks due to inadequate tissue healing, allowing the exit of gastrointestinal material through the staple or suture line [1]. It can be as high as 2.4% in the sleeve gastrectomy [2–4] while in the RYGB can reach the 5.6% incidence in large series [5]. After SG, leaks can occur at the stapler line of it, being more common at the proximal third of the stomach in 89% of cases [4].

Although most anastomotic leaks occur 5–7 days after surgery and are thought to be related to ischemia, 95% of anastomotic leaks that occur within 2 days of surgery probably result from technical error [6]. It is important to know this because as sooner the fistula emerges more likely to have committed a technical error during the surgery, and this will indicate that a reoperation may be needed because this kind of leaks tends to come out as a peritonitis. On the other hand, if more time have passed, it is possible that the leak appears as an abdominal abscess or collection, and in these cases, a minimally invasive approach can be attempted by draining the abscess by a percutaneous approach [7–15].

Given the complexity of these abscesses, it is necessary in many cases to perform the drainage under computed tomography scan (CT) guidance. While in more easy cases, like big abscesses near the abdominal wall, ultrasound guidance can be used.

M. Palermo (✉)
Diagnomed, University of Buenos Aires, Buenos Aires, Argentina

M. Gimenez
University of Buenos Aires, Buenos Aires, Argentina

Percutaneous Surgery, IHU-IRCAD, Strasbourg, France

DAICIM Foundation, Buenos Aires, Argentina

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_25

25.2 Materials and Technique

It is very important for the surgeons to know all the different materials regarding image guide percutaneous surgery. The surgeon should know the different types of guide wires (Fig. 25.1), drainages with its different internal fixation systems (Fig. 25.2), and the stents. Also the surgeon has to have skills in imaging diagnosis methods as ultrasound and CT scan in order to do the diagnosis and the treatment of the leak [15].

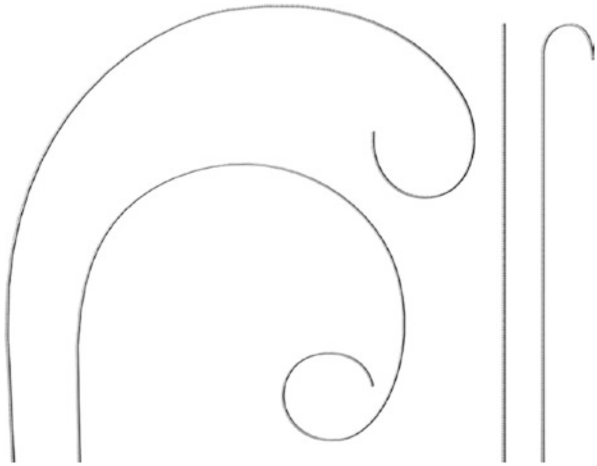


Fig. 25.1 "0.035" flexible wire with "J" tip. It is important to use a "J" tip wire in order to roll up the wire inside the abscess and not break the abscess's wall

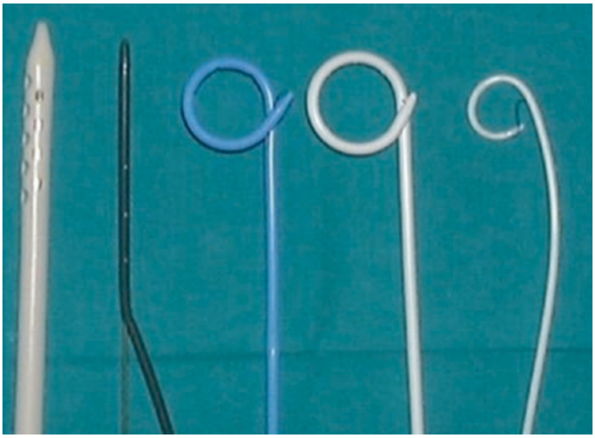


Fig. 25.2 Different types of multipurpose catheters. Diameters from 8 to 12 Fr. As thicker the fluid of the abscess bigger should be the diameter of the catheter. Catheters with "pigtail" fixation must be used in order to avoid accidental dislocation

The technique consists in performing a puncture of the abscess with a 16-gauge needle under image guidance, and then a 0.035″ wire with "J" tip (the first one showed in Fig. 25.1) is inserted through the needle until it is rolled up inside the abscess in order to secure the access. Once this is confirmed with the image guidance, a multipurpose catheter as shown in Fig. 25.2 is placed inside the abscess with the Seldinger technique. The most common catheter used is the pigtail one with its different sizes (8.10 and 12 Fr.)

25.3 Percutaneous Treatment of Leaks After Sleeve Gastrectomy

The diagnosis of these abscesses sometimes can be challenging because it could be difficult to differentiate the abscess from the digestive lumen. The absence of wall, the location, and the size of the abscess could help to differentiate it from normal structures, and in the case of doubt, an upper gastrointestinal series could help to recognize the fistula (Fig. 25.3a and b). This study must be done with soluble contrast in order to avoid further complications due to contrast leakage [8–15].

In the next figures, we will show some cases of our series. In Fig. 25.4 we can observe a big abscess after SG locates under the left lobe of the liver, drained with a pigtail drain under CT scan guidance. In Fig. 25.5a and b, we can see another abscess located more on the left (yellow arrow) also drained by a minimally invasive

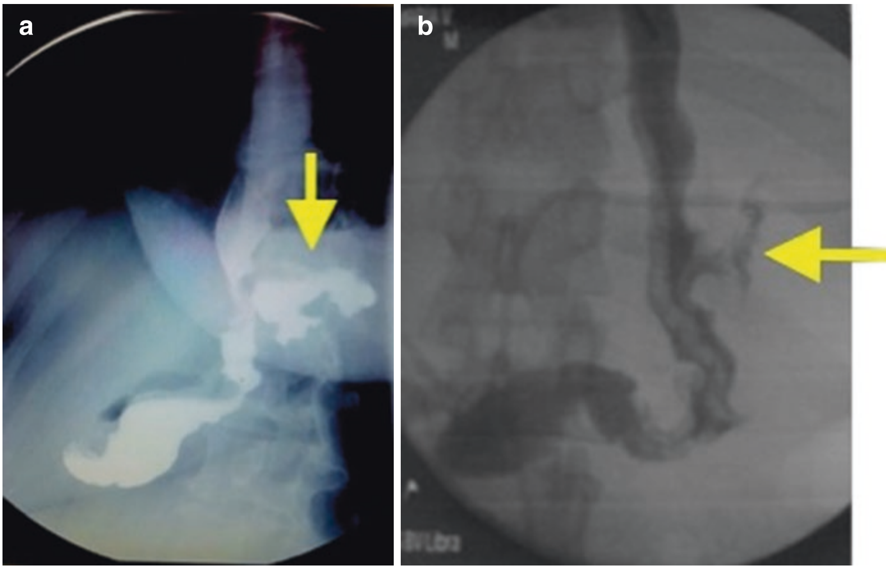


Fig. 25.3 (**a**, **b**) Fistulography of patients with sleeve gastrectomy. Contrast is instilled through the catheter, and the sleeve can be seen

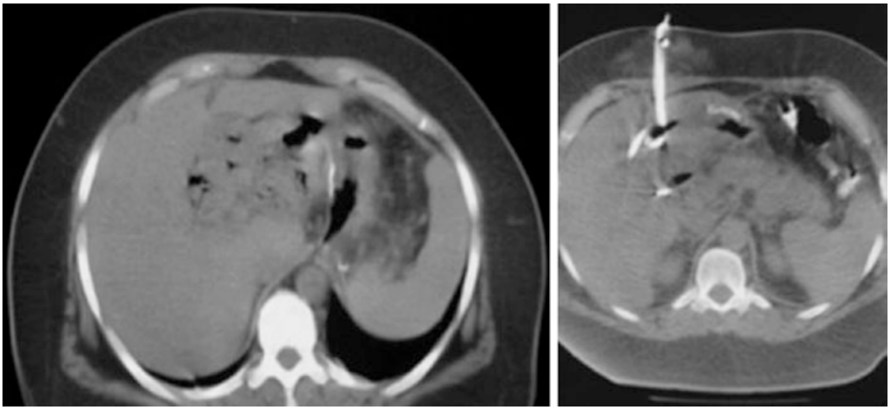


Fig. 25.4 Central abdominal abscess after sleeve gastrectomy, the multipurpose catheter placement can be observed. Notice how the catheter goes through the liver left lobe; if the patient has an adequate coagulation and platelet count, this doesn't generate further complications, but it is important not to puncture any significant vascular or biliary branch

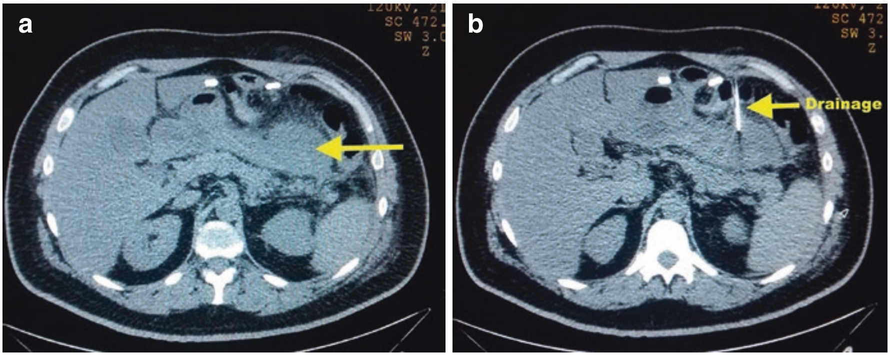


Fig. 25.5 (**a**, **b**) Lateral abdominal abscess after sleeve gastrectomy and the multipurpose catheter placement

approach with a pigtail drain. In Fig. 25.6a we can observe the case of a fistula after SG treated previously with a stent (green arrow) with not good outcome because we see in the yellow arrow that the leak is still there after the placement of the stent. An intermediate cavity was observed (red arrow) which was drained. In Fig. 25.6b we can see the correlation with a CT scan where the stent (green arrow) and the pigtail drain (red arrow) can be observed. In Fig. 25.7a and b, we diagnose the abscess with CT scan and ultrasound, and the drainage of the collection was performed (Fig. 25.7c). In Fig. 25.8 we see the case of a gastrocolic fistula after re-sleeve gastrectomy. This patient was treated with a minimally invasive approach by placing an endoscopic stent (green arrow) and a percutaneous pigtail drain for the abscess (yellow arrow), observed in Fig. 25.8b. In Fig. 25.9a–d, we see a big abscess after SG was drained using a 10 Fr pigtail drain under CT, and a 3D reconstruction can be observed to see the drainage with more details.

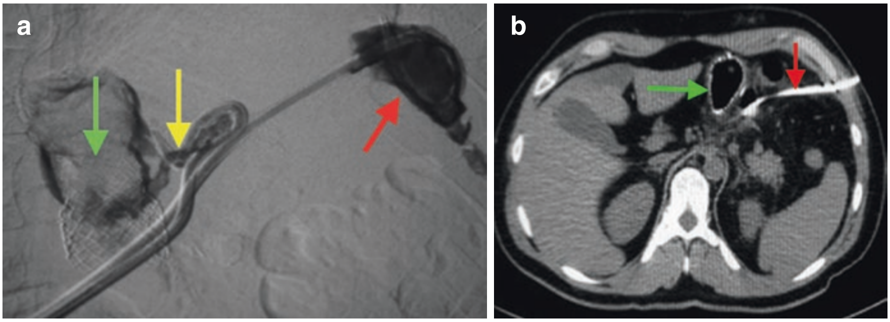


Fig. 25.6 (**a**, **b**) Stent placement in a patient with sleeve gastrectomy fistula. (**a**) Green arrow, gastric stent. Yellow arrow, the fistula. Red arrow, intermediate cavity with drainage. (**b**) Red arrow, abscess with drainage, in green arrow the stent

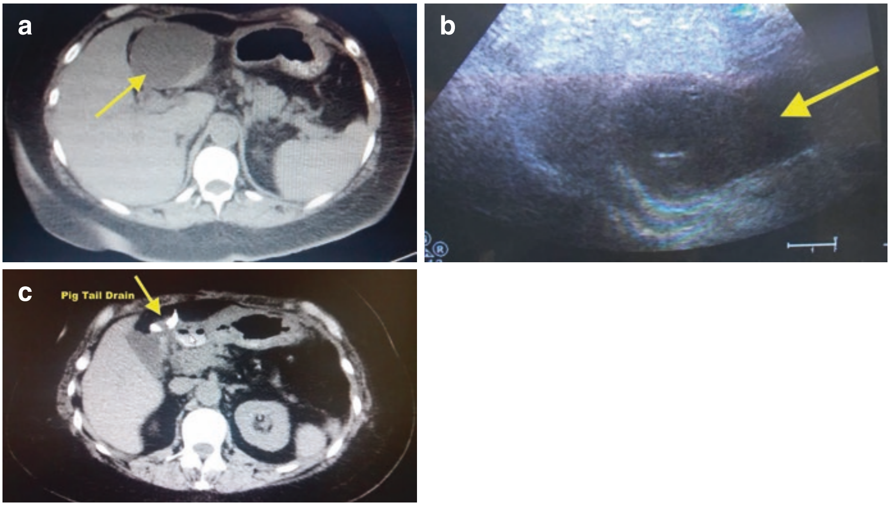


Fig. 25.7 CT scan (**a**) and ultrasound (**b**) showing in yellow arrow the abscess. (**c**) The pigtail drain

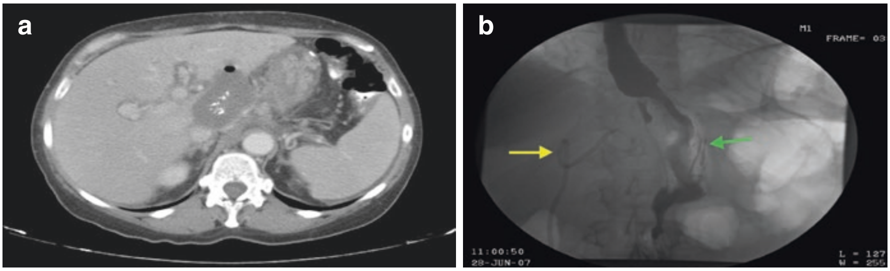


Fig. 25.8 (**a**, **b**) An endoscopic stent placement and image guide percutaneous pigtail drain placed after a leak and gastrocolic fistula. Combined endoscopic and percutaneous approaches

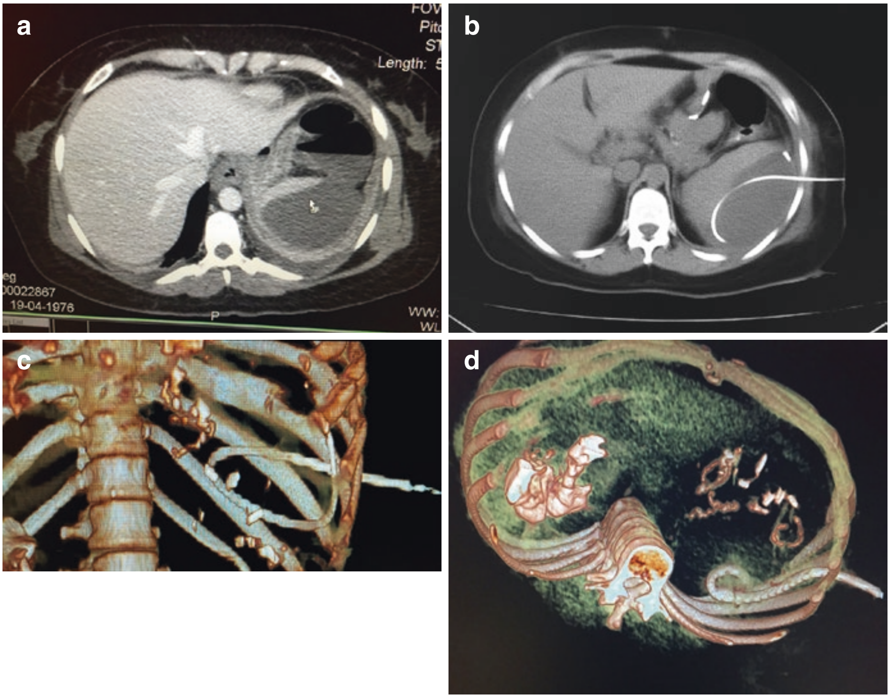


Fig. 25.9 (**a**–**d**) Sequence and drainage under CT scan guidance of a big abscess after sleeve gastrectomy

Once the catheter is placed, follow-up must be done by paying attention to the patient's clinic evolution and the catheter's semiology (Fig. 25.10) [9–15]. If the patient persists with systemic inflammatory response syndrome (fever, increased heart rate, hypoxemia, or increased white blood cell count), a new image should be done. In the case of a residual abscess or intermediate cavity along the fistula, a new drainage should be performed. On the other hand, if no abscess is present and generalized free liquid in the abdominal cavity is found, the possibility of a relaparoscopy must be considered.

It is also important to consider the drainage characteristics. If the catheter persists with a high amount of fluid and this fluid looks like gastric or intestinal fluid, a new image also must be done. In this case a fistulography could be useful to confirm the communication between the abscess and the digestive lumen.

Once the infection is controlled and SIRS is no more present, an adequate nutrition and a high proteins level are essential to achieve the closure of the fistula. In order to accomplish this, a nasojejunal tube must be placed with the tip distal to the fistula to avoid leakage of the enteral feeding [11–15].

With this image guide percutaneous approach, 70% of the fistulas heal, and no further treatment is necessary, but sometimes months should pass in order to

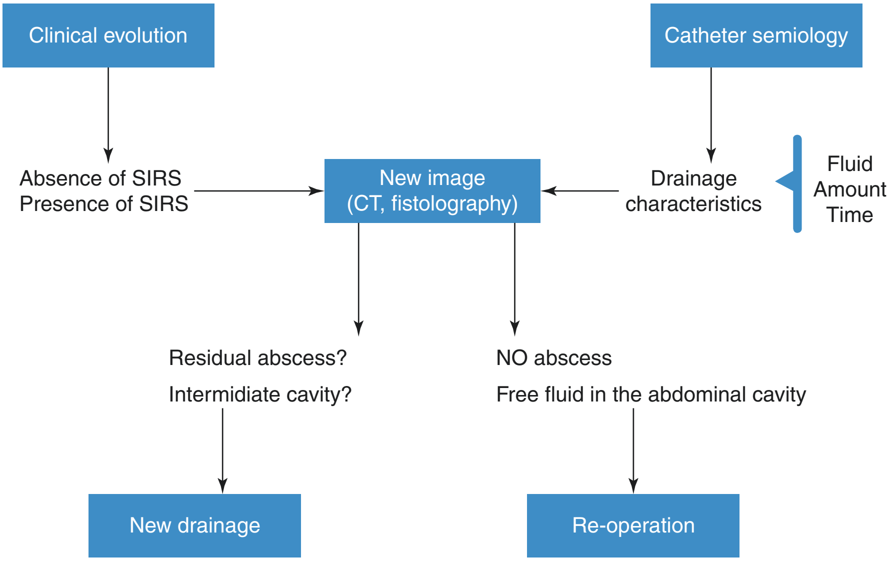


Fig. 25.10 Algorithm of catheter follow-up (SIRS: systemic inflammatory response syndrome)

reach the success. In cases that the fistula does not heal, further treatment must be performed like fully covered gastric stent placement [14, 15]. The goal of this procedure is to block the leakage with the stent cover until the fistula heals. Although it may seem a great solution, some problems may arise like stent migration or leakage persistence due to filtration between the gastric wall and the stent cover [12–15].

25.4 Conclusion

Image guide percutaneous surgery strongly has a role in the treatment of complications following leaks after sleeve gastrectomy. We think that the combination of IR, endoscopy, and laparoscopy will solve more than 90% of the complications by these approaches. And in these ones, IR and endoscopy will treat the majority of them, leaving laparoscopy for extreme and acute cases. The minimally invasive treatment of fistula after bariatric surgery is safe and effective and allows avoiding relapses in a significant number of cases. However, the complexity of drainage in these patients determines the management of these treatments by a trained group.

It is important for the bariatric surgeon to recognize these complications and know which of them can be solved in a minimal invasive way in order to offer to the patients the best treatment.

References

1. Mokdad AH, Bowman BA, Ford ES, Vinicor F, Marks JS, Koplan JP. The continuing epidemic of obesity and diabetes in the United States. JAMA. 2001;286:1195–200.
2. Buchwald H, Avidor Y, Braunwald E, et al. Bariatric surgery: a systematic review and meta-analysis. JAMA. 2004;292:1724–37.
3. Encinosa WE, Bernard DM, Du D, Steiner CA. Recent improvements in bariatric surgery outcomes. Med Care. 2009;47(5):531–5.
4. Aurora AR, Khaitan L, Saber AA. Sleeve gastrectomy and the risk of leak: a systematic analysis of 4,888 patients. Surg Endosc. 2012;26:1509–15. https://doi.org/10.1007/s00464-011-2085-3.
5. Livingston EH, Ko CY. Assessing the relative contribution of individual risk factors on surgical outcome for gastric bypass surgery: a baseline probability analysis. J Surg Res. 2002;105(1):48–52.
6. Baker RS, Foote J, Kemmeter P, Brady R, Vroegop T, Serveld M. The science of stapling and leaks. Obes Surg. 2004;14(10):1290–8.
7. Warschkow R, Tarantino I, Ukegjini K, Beutner U, Güller U, Schmied BM, Müller SA, Schultes B, Thurnheer M. Concomitant cholecystectomy during laparoscopic Roux-en-Y gastric bypass in obese patients is not justified: a meta-analysis. Obes Surg. 2013;23:397–407.
8. Gimenez ME, Berkowski D, Cordoba P. Obstrucción biliar benigna. In: Gimenez M, Guimaraes M, Oleaga J, Sierre S, editors. Manual de técnicas intervencionistas guiadas por imágenes. Buenos Aires: Ediciones Journal; 2011. p. 119–38.
9. Kint JF, van den Bergh JE, van Gelder RE, Rauws EA, Gouma DJ, van Delden OM, Laméris JS. Percutaneous treatment of common bile duct stones: results and complications in 110 consecutive patients. Dig Surg. 2015;32:9–15. https://doi.org/10.1159/000370129.
10. García-García L, Lanciego C. Percutaneous treatment of biliary stones: sphincteroplasty and occlusion balloon for the clearance of bile duct calculi. AJR. 2004;182:663–70.
11. Szulman C, Giménez M, Sierre S. Antegrade papillary balloon dilation for extrahepatic bile duct stone clearance: lessons learned from treating 300 patients. J Vasc Interv Radiol. 2011;22(3):346–53.
12. Gil S, de la Iglesia P, Verdú JF, de España F, Arenas J, Irurzun J. Effectiveness and safety of balloon dilation of the papilla and the use of an occlusion balloon for clearance of bile duct calculi. AJR Am J Roentgenol. 2000;174(5):1455–60.
13. Aquafresca PA, Palermo M, Rogula T, Duza GE, Serra E. Complicações cirúrgicas tardias após by-pass gástrico: revisão da literatura. Arq Bras Cir Dig. 2015;28(2):139–43.
14. Palermo M, Gimenez M, Gagner M. Laparoscopic gastrointestinal surgery. Novel techniques, extending the limits. AMOCA. 2015.
15. Lutfi R, Palermo M, Cadiere GB, editors. Global bariatric surgery. The art of weight lost across the borders. Cham: Springer; 2018.

Chapter 26
Strictures After Sleeve Gastrectomy

Jacques M. Himpens

26.1 Introduction

According to the official definition [1], a stenosis is an abnormal narrowing of a passage or orifice in the body; a stricture is a gradual stenosis mostly caused by scar tissue. All strictures are stenoses, but stenosis can be caused by a multitude of factors, such as spasms (e.g. Schatzki's ring), webs or diaphragms, and functional narrowing by acute angulation. There are two types of stenosis of the sleeved stomach: first, the "organic" narrowing of the lumen (true stricture) (Fig. 26.1) and, second, the "functional" stenosis caused by acute angulation of the sleeve lumen (corkscrew deformity) [2]. The current chapter will focus on the "organic" stenosis or stricture.

26.2 Sleeve Gastrectomy Stricture

Since its first reported performance as part of the duodenal switch biliopancreatic diversion (1999), and the first literature report as isolated procedure in 2000 [3] laparoscopic sleeve gastrectomy (LSG) recently has become the most popular weight loss procedure across the world [4]. The reasons for this evolution are multiple, including patient request and surgeon's preference [5], encouraging short- and mid-term and, recently, long-term results especially in terms of weight loss [6].

Despite the popularity of LSG, undesired side effects continue to occur, even in the hands of the most experienced surgeons. One of the most frequent unwanted consequences is gastroesophageal reflux (GERD), a condition that can be elicited by a number of situations, including hiatal hernia and lower esophageal sphincter

J. M. Himpens (✉)
Delta CHIREC Hospitals, Brussels, Belgium

St Pierre University Hospital, Brussels, Belgium

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_26

Fig. 26.1 Artist impression of sleeve stricture

(LES) deficiency because of disruption of the sling fibres at the cardia [7]. In some occasions, however, the cause of GERD after LSG is stenosis/stricture of the stomach body, a condition that occurs in between 0% and 9.3% of the cases [8, 9]. In our experience [10], the most usual location of stenosis/stricture is the incisura, but, according to others [11, 12], the most usual site is the mid-body. Strictures can occur early after the sleeve gastrectomy (primary strictures) and are caused either by stapling too close to the calibration tube or by oversewing the staple line [13]. Late strictures (secondary strictures) are caused by scarring and fibrotic retraction [12].

26.3 Clinical Signs

A stricture of the sleeved stomach may be highly symptomatic and, besides GERD, cause significant dysphagia and frequent vomiting of thick, usually white slime [11].

26.4 Diagnosis

Despite the often-impressive magnitude of the symptoms accompanying a stricture, the diagnosis is often quite difficult to achieve because the stricture may still allow unhindered passage of the gastroscope at upper endoscopy (unhindered passage of the scope is often the most important diagnostic sign of the absence of stenosis for endoscopists) [8]. In a study of a cohort of patients after LSG, it appeared that (only) 67% of patients with diagnosis of stenosis at barium swallow had a stenosis at endoscopy [14]. The diagnosis of the condition therefore is most often radiologic rather than endoscopic. New X-ray techniques allow for three-dimensional CT reconstruction of the stomach, which amongst other achievements avoids false-negative images obtained with conventional radiology techniques [15].

26.5 Treatment

There are several therapeutic options to address a stricture of the gastric body after sleeve gastrectomy. Conversion to (Roux-en-Y) gastric bypass (RYGB) is the most frequently cited and probably the most effective and safest option [16]. Laparoscopic conversion of the strictured sleeve to RYGB should imply transection of the stomach proximal to the stenosis [17] (Fig. 26.2). In the literature, the outcomes of conversion from SG to RYGB are good, however, at the cost of a significant number of complications [18]. Nevertheless, after conversion, the clinical signs of stricture are solved in some 75% of the cases [18].

However, patients often are reluctant to undergo this treatment mode because bypassing the stomach and duodenum has significant consequences, including the well-known specific dietary restrictions linked with the dumping syndrome (both early and late) and the necessity to take vitamins and minerals. Of note, recent evidence indicates that nutritional supplements are mandatory after sleeve gastrectomy as well [19].

Consequently, techniques have been developed trying to avoid conversion into bypass. One such technique consists of addressing the stenosis itself while preserving the sleeve configuration.

Hence, the stenosis can be treated by seromyotomy, i.e. incising the stenosis longitudinally through all the stomach layers short of the mucosa (Fig. 26.3) [20, 21]. This technique resembles Heller's myotomy for achalasia [22].

As for Heller's myotomy, the incision should be quite generous and reach at least 1 cm beyond the limits of the stricture. Seromyotomy appears to be quite effective in terms of immediate symptom control, but the technique suffered from a significant number of severe complications, especially leaks (36% of the cases). All complications could be managed conservatively or laparoscopically, but in terms of long-term outcomes, a number of patients experienced recurrence of symptoms and eventually still needed conversion to RYGB [20]. In order to avoid the complications inherent with seromyotomy, in analogy with the approach of intestinal stenosis, we recently started performing stricturoplasty (Fig. 26.4) [23]. We performed this technique in six patients so far, with early good results and no complications (unpublished results). Because long-term outcomes are not yet known, it is however too early to recommend this approach.

Another approach to deal with the stenosis itself is to resect the segment of the stomach that harbours the stenosis. After devascularizing the stenotic part of the stomach, a wedge or cylinder of the stomach, encompassing the stenosis, is resected, and a manual or mechanical end-to-end anastomosis is performed (Fig. 26.5). This technique is called wedge resection, wedge gastrectomy [21], median gastrectomy [24], or segmental gastrectomy. Resection is particularly seductive in cases where

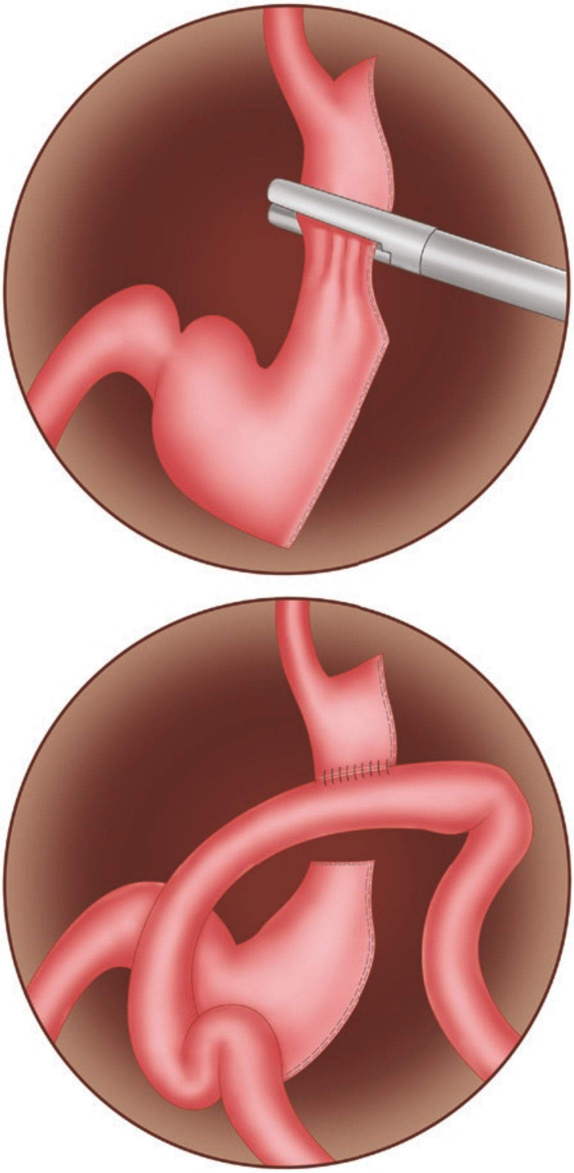


Fig. 26.2 Conversion of sleeve gastrectomy in gastric bypass for stricture

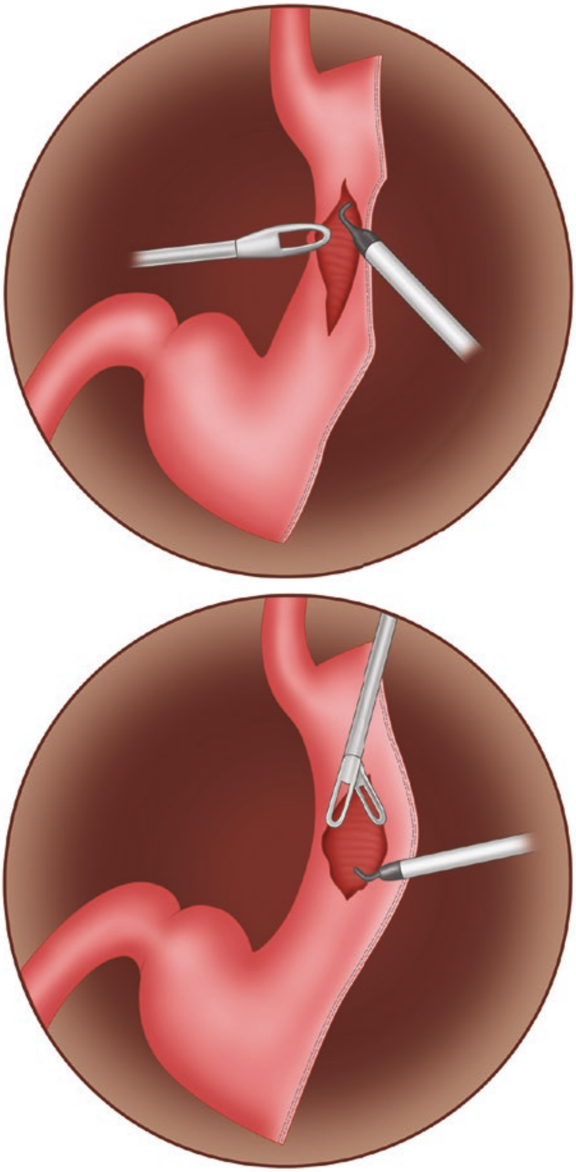


Fig. 26.3 Seromyotomy for sleeve stricture

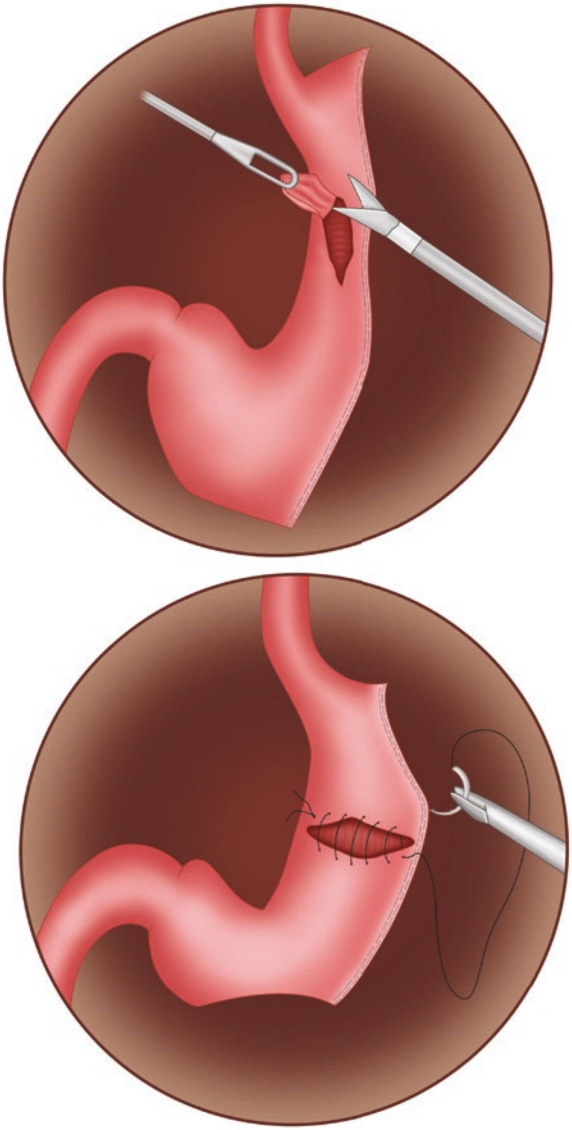


Fig. 26.4 Stricturoplasty

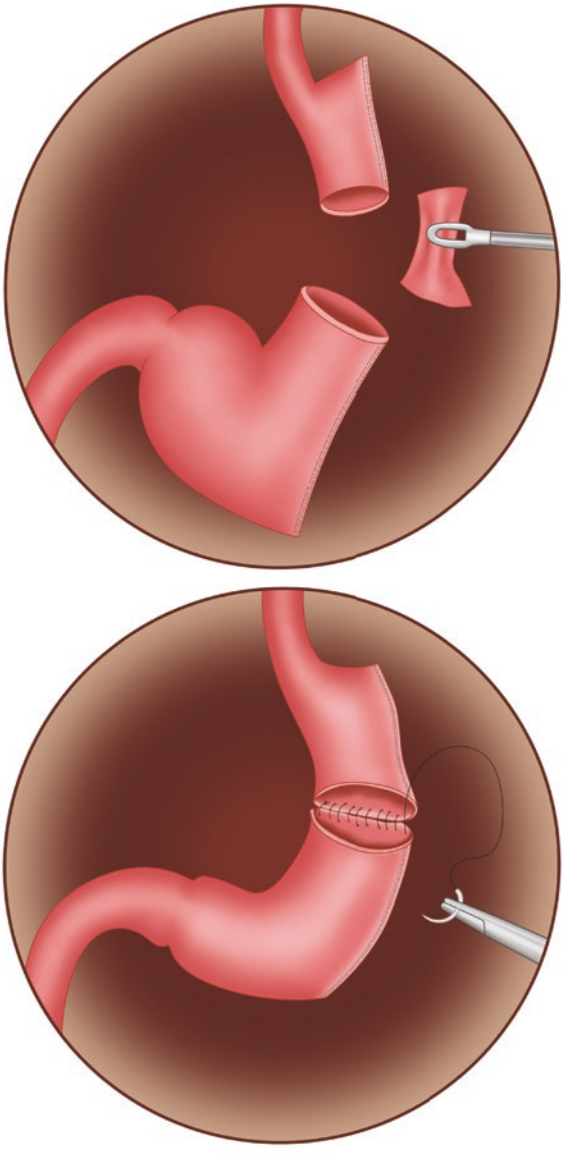


Fig. 26.5 Gastric resection for stricture

the stricture is accompanied by a corkscrew deformity because resection concomitantly deals with the acute axial angulation. The resection-reanastomosis technique has its own drawbacks, such as recurrence of the stenosis [21, 24].

Lastly, the post-sleeve stricture can be approached by endoscopic techniques. One such technique is the placement of self-expandable stents. All types of stents have been described, including metallic covered stents, metallic partly covered, and plastic stents [25].

Aburajab and colleagues [26] claimed a 100% success rate in terms of resolution of stricture by using covered stents that stayed in place for some 6 weeks. However, the study cohort in this retrospective study was small (some 27 participants), and the authors recorded a 35% migration rate. Along the same lines, Manos et al. reported a success rate of 94% in 18 patients treated by a similar technique [27].

Alternatively, the endoscopic treatment may consist of balloon dilation, if needed complemented by stent placement. This approach resulted in an 88% symptoms improvement, but nonresponders still required conversion to RYGB [28].

With balloon dilation, Nath et al. [8] obtained a success rate of 69% in the 10% of LSG patients who developed stricture or corkscrew deformity. Similarly, Burgos et al. [29] obtained remission in 80% of the cases, but the patient group was small, and the patients who suffered a failure still needed conversion to Roux-en-Y gastric bypass. More recently, Dhorepatil et al. [12] reported an eventual success rate of 31/33 (93%) for balloon dilatation of post-sleeve strictures. They stressed the importance of using larger size balloons and longer session times (up to 40 mm, insufflation kept for 30 min). Best outcomes have been described with high-pressure achalasia balloons [30].

26.6 Prevention

In face of the recalcitrant nature of strictures after SG, prevention obviously is of the utmost importance. It appears that intraoperative endoscopy may favourably interfere with the development of postoperative stenosis. Nimeri et al. [31] recently demonstrated that the use of an intraluminal gastroscopy during the confection of the sleeve gastrectomy helped reduce the incidence of stenosis from 3.2% to 0%. Thanks to the intraoperative gastroscopy, the surgeon was able to detect (and indeed, remove) narrowing oversewing sutures. The danger for stenosis by oversewing had already been stressed years ago by an Italian study [32] and was confirmed in a recent retrospective US study [33].

Another significant factor believed to affect complications after SG is the size of the bougie used, the smaller size being linked with a higher leak and stenosis rate [34]. More recent literature data however seems to indicate that a bougie size smaller than 36 French does not cause more complications/stenosis than larger bougie size [35].

26.7 Conclusion

Strictures rarely occur after sleeve gastrectomy. Diagnosis is sometimes difficult, despite striking symptomology, i.e. dysphagia, vomiting, and, especially, GERD. Laparoscopic treatment can consist of dealing directly with the stenosis by seromyotomy or segmental resection, but both techniques are prone to leaks and recurrent disease. Balloon dilation with or without stent treatment has encouraging outcomes. Preferred treatment however is (laparoscopic) conversion to Roux-en-Y gastric bypass.

References

1. Taber's Cyclopedic Medical Dictionary, by Venes D and Taber CW, F.A Davis Company eds, 2005 ISSN 1065–1357.
2. Donatelli G, Dumont JL, Pourcher G, Tranchart H, Tuszynski T, Dagher I, Catheline JM, Chiche R, Marmuse JP, Dritsas S, Vergeau BM, Meduri B. Pneumatic dilation for functional helix stenosis after sleeve gastrectomy: long-term follow-up (with videos). Surg Obes Relat Dis. 2017;13(6):943–50.
3. Ren CJ, Patterson E, Gagner M. Early results of laparoscopic biliopancreatic diversion with duodenal switch: a case series of 40 consecutive patients. Obes Surg. 2000;10(6):514–23.
4. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J, Buchwald H, Scopinaro N. IFSO Worldwide Survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28(12):3783–94.
5. Kallies KJ, Ramirez LD, Grover BT, Kothari SN. Roux-en-Y gastric bypass versus sleeve gastrectomy: what factors influence patient preference? Surg Obes Relat Dis. 2018;14(12):1843–9.
6. Arman GA, Himpens J, Dhaenens J, Ballet T, Vilallonga R, Leman G. Long-term (11+ years) outcomes in weight, patient satisfaction, comorbidities, and gastroesophageal reflux treatment after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(10):1778–86.
7. Braghetto I, Lanzarini E, Korn O, Valladares H, Molina JC, Henriquez A. Manometric changes of the lower esophageal sphincter after sleeve gastrectomy in obese patients. Obes Surg. 2010;20(3):357–62.
8. Nath A, Yewale S, Tran T, Brebbia JS, Shope TR, Koch TR. Dysphagia after vertical sleeve gastrectomy: evaluation of risk factors and assessment of endoscopic intervention. World J Gastroenterol. 2016;22(47):10371–9.
9. Brethauer SA, Hammel JP, Schauer PR. Systematic review of sleeve gastrectomy as staging and primary bariatric procedure. Surg Obes Relat Dis. 2009;5:469–75.
10. Vilallonga R, Himpens J, van de Vrande S. Laparoscopic management of persistent strictures after laparoscopic sleeve gastrectomy. Obes Surg. 2013;23(10):1655–61.
11. Rebibo L, Hakim S, Dhahri A, Yzet T, Delcenserie R, Regimbeau JM. Gastric stenosis after laparoscopic sleeve gastrectomy: diagnosis and management. Obes Surg. 2016;26(5):995–1001.
12. Dhorepatil AS, Cottam D, Surve A, Medlin W, Zaveri H, Richards C, Cottam A. Is pneumatic balloon dilation safe and effective primary modality of treatment for post-sleeve gastrectomy strictures? A retrospective study. BMC Surg. 2018;18(1):52.

13. Iannelli A, Treacy P, Sebastianelli L, Schiavo L, Martini F. Perioperative complications of sleeve gastrectomy: review of the literature. J Minim Access Surg. 2019;15(1):1–7.
14. Levy JL, Levine MS, Rubesin SE, Williams NN, Dumon KR. Stenosis of gastric sleeve after laparoscopic sleeve gastrectomy: clinical, radiographic and endoscopic findings. Br J Radiol. 2018;91(1089):20170702.
15. Blanchet MC, Mesmann C, Yanes M, Lepage S, Marion D, Galas P, Gouillat C. 3D gastric computed tomography as a new imaging in patients with failure or complication after bariatric surgery. Obes Surg. 2010;20:1727–33.
16. Langer FB, Bohdjalian A, Shakeri-Leidenmühler S, Schoppmann SF, Zacherl J, Prager G. Conversion from sleeve gastrectomy to Roux-en-Y gastric bypass–indications and outcome. Obes Surg. 2010;20(7):835–40.
17. Lacy A, Ibarzabal A, Pando E, Adelsdorfer C, Delitala A, Corcelles R, Delgado S, Vidal J. Revisional surgery after sleeve gastrectomy. Surg Laparosc Endosc Percutan Tech. 2010;20(5):351–6.
18. Landreneau JP, Strong AT, Rodriguez JH, Aleassa EM, Aminian A, Brethauer S, Schauer PR, Kroh MD. Conversion of sleeve gastrectomy to Roux-en-Y gastric bypass. Obes Surg. 2018;28(12):3843–50.
19. Ben-Porat T, Elazary R, Goldenshluger A, Sherf Dagan S, Mintz Y, Weiss R. Nutritional deficiencies four years after laparoscopic sleeve gastrectomy-are supplements required for a lifetime? Surg Obes Relat Dis. 2017;13:1138.
20. Dapri G, Cadière GB, Himpens J. Laparoscopic seromyotomy for long stenosis after sleeve gastrectomy with or without duodenal switch. Obes Surg. 2009;19(4):495–932.
21. Vilallonga R, Himpens J, van de Vrande S. Laparoscopic management of persistent structures after laparoscopic sleeve gastrectomy. Obes Surg. 2013;23(10):1655–61.
22. Costantini M, Salvador R, Capovilla G, Vallese L, Costantini A, Nicoletti L, Briscolini D, Valmasoni M, Merigliano S. A thousand and one laparoscopic Heller myotomies for esophageal achalasia: a 25-year experience at a single tertiary center. J Gastrointest Surg. 2019;23(1):23–35. https://doi.org/10.1007/s11605-018-3956-x. Epub 2018 Sep 20.
23. Chang PC, Tai CM, Hsin MC, Hung CM, Huang IY, Huang CK. Surgical standardization to prevent gastric stenosis after laparoscopic sleeve gastrectomy: a case series. Surg Obes Relat Dis. 2017;13(3):385–90.
24. Kalaiselvan R, Ammori BJ. Laparoscopic median gastrectomy for stenosis following sleeve gastrectomy. Surg Obes Relat Dis. 2015;11(2):474–722.
25. Moon RC, Teixeira AF, Bezerra L, Alhinho HCAW, Campos J, de Quadros LG, de Amorim AMB, Neto MG, Jawad MA. Management of bariatric complications using endoscopic stents: a multi-center study. Obes Surg. 2018;28(12):4034–8.
26. Aburajab MA, Max JB, Ona MA, Gupta) K, Burch M, Michael Feiz F, Lo SK, Jamil LH. Covered esophageal stenting is effective for symptomatic gastric lumen narrowing and related complications following laparoscopic sleeve gastrectomy. Dig Dis Sci. 2017;62(11):3077–83.
27. Manos T, Nedelcu M, Cotirlet A, Eddbali I, Gagner M, Noel P. How to treat stenosis after sleeve gastrectomy? Surg Obes Relat Dis. 2017;13(2):150–4.
28. Agnihotri A, Barola S, Hill C, Neto MG, Campos J, Singh VK, Schweitzer M, Khashab MA, Kumbhari V. An algorithmic approach to the management of gastric stenosis following laparoscopic sleeve gastrectomy. Obes Surg. 2017;27(10):2628–36.
29. Burgos AM, Csendes A, Braghetto I. Gastric stenosis after laparoscopic sleeve gastrectomy in morbidly obese patients. Obes Surg. 2013;23(9):1481–6.
30. Zundel N, Neto M. Comment on: pneumatic dilation for functional helix stenosis after sleeve gastrectomy: long-term follow-up (with videos). Surg Obes Relat Dis. 2017;13(6):950.
31. Nimeri A, Maasher A, Salim E, Ibrahim M, El Hadad M. The use of intraoperative endoscopy may decrease postoperative stenosis in laparoscopic sleeve gastrectomy. Obes Surg. 2016;26(7):1398–401.
32. Musella M, Milone M, Bellini M, Leongito M, Guarino R, Milone F. Laparoscopic sleeve gastrectomy. Do we need to oversew the staple line? Ann Ital Chir. 2011;82(4):273–7.

33. Guerrier JB, Mehaffey JH, Schirmer BD, Hallowell PT. Reinforcement of the staple line during gastric sleeve: a comparison of buttressing or oversewing, *versus* no reinforcement – a single-institution study. Am Surg. 2018;84(5):690–4.
34. Gagner M, Hutchinson C, Rosenthal R. Fifth International Consensus Conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6.
35. Guetta O, Ovnat A, Czeiger D, Vakhrushev A, Tsaban G, Sebbag G. The impact of technical surgical aspects on morbidity of 984 patients after sleeve gastrectomy for morbid obesity. Obes Surg. 2017;27:2785.

Chapter 27
Endoscopic Approach in the Treatment of Sleeve Gastrectomy Complications

Thierry Manos and Josemberg Marins Campos

27.1 Endoscopic Treatment of Leaks After Sleeve Gastrectomy (SG)

27.1.1 Introduction

This chapter is divided into two parts, in the first one, we will describe the endoscopic treatment of leaks after sleeve gastrectomy (SG) and, in the second part, we will focus on the treatment by endoscopy of stenosis after SG.

Laparoscopic sleeve gastrectomy (LSG) progressively evolved to become the most frequent bariatric procedure both in France and in the United States [1, 2]. LSG is generally considered a straightforward procedure; however, postoperative complications can occur. Although the rate of gastric leaks (GL) after LSG decreased in recent series [3, 4] to 1–2% or less [5], it is still regarded as the most serious complication, due to its difficult healing process using a nonstandardized endoscopic approach.

Despite the improvement in the comprehension of how to prevent leaks, unfortunately, we still have difficult cases. This situation probably will remain so, even if leak rate after LSG is decreasing.

Two main reasons explain why sleeve leaks seem more severe than bypass leaks: First, a sleeve leak is more difficult to heal compared to other bariatric surgery techniques. This is probably explained by the mechanism itself of the sleeve gastrectomy, which is based on the creation of a high-pressure gastric tube, and the location near the esophagogastric junction. The second reason is the absence of standardization in the leak management, in particular using endoscopic approach. Numerous

T. Manos (✉)
Clinique Bouchard, Marseille, France

J. M. Campos
Centro de Obesidade e Diabetes, Hospital Santa Joana Recife, Recife, PE, Brazil

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_27

papers have been written about different GL approaches, but few can be found summarizing an algorithm for the endoscopic treatment [6–8].

The state of the art in the management of leaks following LSG categorizes leaks according to the period of diagnosis after the initial operation. A sleeve consensus has established the following data [9]: acute gastric leak is defined as one, which occurred before postoperative day 7. These leaks in general present high output (Fig. 27.1).

Late gastric leak is defined as one that occurs later than 6 weeks after the initial procedure. It often presents with a less severe clinical picture due to a smaller output. Symptoms are mild, sometimes only marked by episodes of back pain and fever spikes up to a maximum of 38 °C over a period of several weeks. For hemodynamically stable patients, in the absence of fever or any other signs of sepsis, a conservative treatment can be attempted. It consists of abscess drainage by interventional radiologist or by endoscopic intervention (internal drainage with pigtail), PPI treatment, antibiotic therapy, and by initiating parenteral nutrition.

GL are categorized as chronic gastric leak after 12 weeks of diagnosis with remission of major inflammatory signs with constant output.

Every option should be known by every bariatric center, but gastric leak treatment should be tailored for each patient, according to diagnosis time, endoscopic findings, and predefined algorithm. The purpose of this chapter is to review different methods of endoscopic treatment to leaks following LSG and to establish a well-defined algorithm and, in the second part of it, we will describe the treatment of stenosis after SG. The authors have done an extensive review and description of all the available current endoscopic approaches. Even if the authors used only part of this armamentarium, this chapter offers a detailed and balanced view of all different perspectives (for endoscopic stents, pigtails, septotomy, E-VAC, or clips).

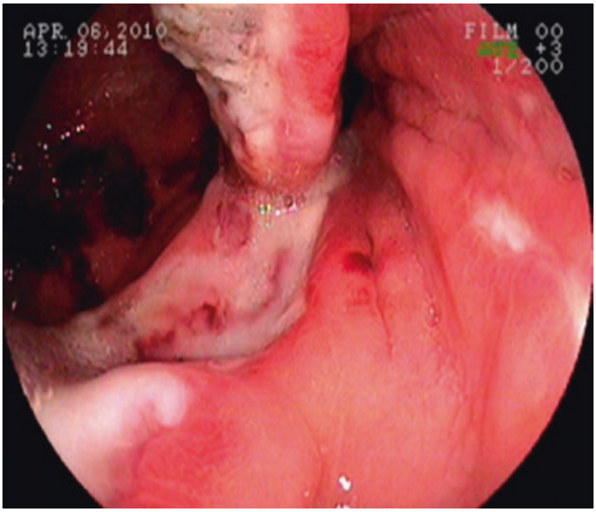


Fig. 27.1 Endoscopic view of acute gastric leak with a pouch stenosis, a septum, and a perigastric abscess cavity

Table 27.1 Literature review with stent migration rate

Author (year)	Patients	Stent migration (%)	Initial surgical procedure
Eisendrath et al. (2011) [12]	88	11.1	
Himpens et al. (2013) [13]	47	14.9	15 LSG; 10 RYGBP 3 minigastric bypass 19 revisional surgery
Barthet et al. (2011) [14]	27	59	2 RYGBP 25 LSG
Thompson et al. (2012) [15] review	67	16.9	na
Edwards et al. (2008) [16]	6	83	RYGBP
Msika et al. (2013) [17]	9	11.1	LSG
Salinas et al. (2006) [18]	17	5.88	RYGBP
Puig et al. (2014) [19]	21	47	5 leaks (4 LSG) 16 strictures (15 RYGBP)
Sharaiha et al. (2014) [20]	38	42.1	20 strictures 18 leaks
Alazmi et al. (2014) [21]	17	6	17 leaks (LSG)

27.1.2 Stents

Some centers have advocated the use of fully covered expandable metallic prosthesis placed endoscopically [7, 10, 11]. However, results in the literature are not consistent because of migration or poor tolerance of the prosthesis, which seems to be quite common (5.8–11.1%). The review of the literature with respect to migration of endoscopic stents for leaks after bariatric surgery is summarized in Table 27.1. Marquez et al. assume that these migrations were frequent due to the use of unsuitable material, since they were originally planned for the treatment of esophageal strictures [22].

Fully covered SEMS may have higher rates of migration than partially covered SEMS, since the last stimulates tissue ingrowth, thus helping to secure the stent in situ (Fig. 27.2). The use of a partially covered SEMS mandates removal and replacement, when required, at shorter and regular intervals (<3 weeks), to prevent robust tissue ingrowth and difficult extraction [19].

At the beginning of the experience, the use of stents in bariatric surgery was suggested for 6 weeks or more in order to be efficient for the resolution of an anastomotic leak in gastric bypass. Mucosal ulceration and integration of the stent into the mucosa were two complications that have historically been attributed to stents inserted for longer periods and placing stents that were not fully covered.

Fistula formation secondary to serious mucosal erosion by SEMS has been documented in the literature. One study reported major erosions causing tracheoesophageal fistulas in two out of 23 patients [23], and another described a cohort where stent erosion into pulmonary artery occurred in one out of 31 patients, requiring major operation [24]. Certainly, the formation of the aortoesophageal fistula implies many other factors. The radial traction of the SEMS may erode through the wall of

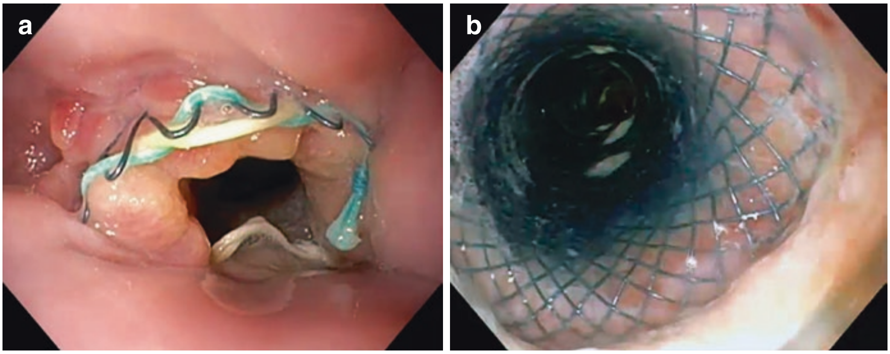


Fig. 27.2 Endoscopic view of a partially covered stent. (**a**) Proximal edge is firmly fixed to the esophageal mucosa. (**b**) Mucosal hyperplasia at the proximal uncovered portion (1.5-cm) of the stent

the esophagus and result in a fistulous tract between the aorta and esophagus. This is also the combined effect of infection and local pressure on the esophagus caused by the esophageal stent.

Niti-S BetaTM stent was specifically designed for anastomotic leakage after bariatric surgery. It is uncertain if the double bump mechanism created to prevent migration causes specific complications and whether it contributes to esophageal ulceration and development of an aortoesophageal fistula [25].

High index of suspicion for this complication may be necessary when there is bleeding around the stent placement site or if the patient is hemodynamically unstable. Appropriate workup is necessary to assess aortoesophageal fistula with emergency vascular management if present. Ideally, the management of aortoesophageal fistulas is done by endovascular aortic repair to control bleeding in the acute setting, either as a stand-alone procedure or combined with a more definitive management in an elective setting.

Garofalo et al. [26] reported their initial successful experience with The Megastent™. They have offered all the consistent and clear information necessary to understand why the novel stent seems to have certain advantages in the treatment of LSG leaks. They emphasize three aspects:

- The longer length allows the stent to cross the incisura angularis, reducing the pressure in the proximal part of the sleeve.
- The large stent size may reduce its migration.
- Its fully covered nature ensures easy removal of the stent at the end of the treatment.

Thompson et al. [15] reported a comprehensive review regarding the use of stents in the treatment of bariatric surgery leaks. At that time, no case of aortic injury or aortoesophageal fistula after stent use was reported. Our current review identified four cases of such dreaded complication of stent use in bariatric surgery and the statement of “no stent-associated mortality” must be revised. Surprisingly, three out of four cases were following RYGBP. Probably, many complications following LSG were unreported.

27.1.3 Endoscopic Internal Drainage (EID): Pigtails

Pigtail stent simultaneously drains the infected collection and acts as a foreign body, thus promoting the re-epithelialization of the mucosa defect (Fig. 27.3). A systematic evaluation between 4 and 6 weeks after pig tail placement should be considered in order to reactivate the pigtail effect. More importantly, the replacement of the pigtail will cause additional trauma and will stimulate the formation of granulation tissue.

Pigtail drain use was initially described by Pequignot et al. [27] in postsleeve gastrectomy leaks. They claim it to be efficacious, better-tolerated, requiring fewer procedures per patient, and with shorter healing time than the covered SEMS. Furthermore, Donatelli et al. [28] reported their extensive experience on 67 patients about systematic use of endoscopic internal drainage by pigtail as the first intention management of leaks following LSG.

In our initially experience [6], the pigtail was successfully used in 15 out of 19 patients. Later one, the pigtail consolidate the position of cornerstone of endoscopic treatment of leak following LSG, being the most important component of our actual algorithm of treatment. Complications associated to pigtail use are rare, but we should mention the migration [29].

Fig. 27.3 Pigtail drains inserted through the fistulous orifice after sleeve gastrectomy

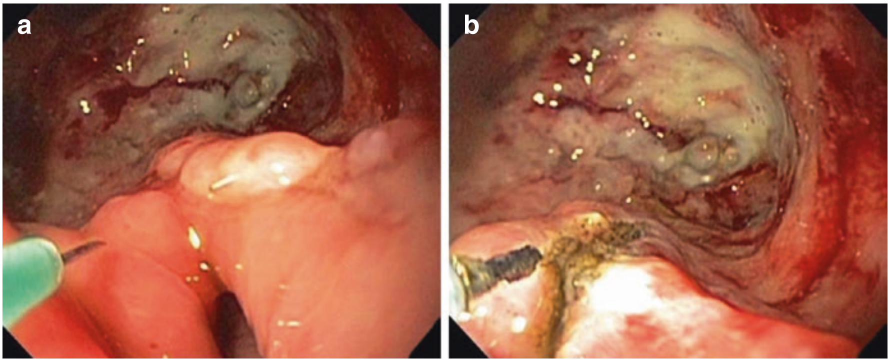


Fig. 27.4 Endoscopic view of the septotomy technique. (**a**) Perigastric abscess cavity, gastric pouch stenosis, and septum with a needle-knife. (**b**) The septum was incised

27.1.4 Septotomy

Septotomy technique employs the same principle of peritoneal abscess complete drainage into the gastric lumen. The septum separating the abscess cavity and the gastric lumen is incised and divided (Fig. 27.4), resulting in the complete exposure of the lumen of both cavities. After the endoscopic septotomy, the leak and its content are redirected from the abscess cavity toward the gastric lumen, thus favoring the healing from peripheral surface and suppressing the accumulation of contents, which contributed to the abscess formation. This procedure decreases the collection expansion, and hence, it provides tissue healing. Septotomy is a feasible approach and has been described and studied for the past years by many authors, which reported good outcomes in terms of clinical and radiologic resolution of the leak [30, 31].

An association with pneumatic balloon dilation is essential for treating the concomitant stenosis at the level of the angulus. By addressing the distal stenosis of the sleeve, it results in decreased intraluminal pressure, and it favors content flow through the lumen. The procedure must be performed with an achalasia balloon (Rigiflex® balloon 30–35 mm) over a stainless steel or superstiff guide wire in consecutive dilation sessions with stepwise increments in dilation pressure from 15 to 25 psi. In order to be efficient, the dilatation must be aggressive. Once the balloon is inflated under radiological guidance, the correction of gastric tube axis is easily observed. For chronic fistula after LSG, systematic pneumatic dilation every 10–15 days for at least a 3-month period together with endoscopic septotomy is recommended by the authors (Fig. 27.5). The more "forced" dilations may lead to mucosal laceration, but with only minor bleeding, and hemostasis is not required.

Additional studies reported success with endoscopic septotomy use in conjunction with pneumatic balloon dilation for the management of sleeve leaks [32, 33]. They reported reduction in the hospital stay and in the need for reintervention.

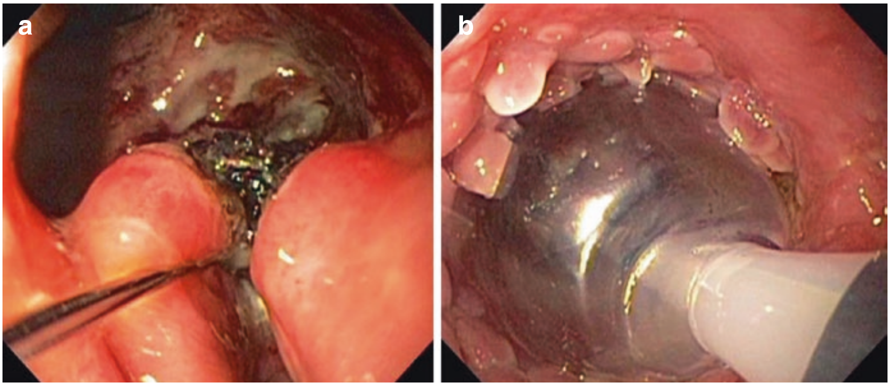


Fig. 27.5 Endoscopic view of the achalasia balloon dilation technique after septotomy. (**a**) A guide wire is placed in the gastric lumen. (**b**) The 30-mm balloon is inflated in the lumen and placed against the divided septum

The septotomy can complicate with free air into abdomen, which is treated conservatively with antibiotics. It is obvious that all endoscopic maneuvers should be performed by CO_2 insufflation. Bleeding at the time of endoscopic septotomy can occur, and it is generally self-limited. When necessary, hemostasis may be achieved by endoscopic clips or by electrocoagulation. Blood transfusion was never required.

According to preliminary results, septotomy combined with pneumatic balloon dilation has the potential to become the gold standard for chronic leak. The limitation of the technique will be the learning curve as it remains a technically demanding procedure. For this reason, a standardization of this technique is necessary, its indications should be accurately explained, and the timing of its application should be defined.

27.1.5 Endoscopic VAC Therapy

Endoscopic vacuum-assisted closure system (E-VAC) is a new method of endoscopic internal drainage. It is based on negative pressure therapy used for the treatment of GI leaks in patients who are resistant to standard endoscopic and surgical treatment procedure. Currently, there is very limited data on the use of E-VAC, but it has provided another treatment modality for LSG leaks and has slowly become a first-line treatment for such defects in some institutions [34, 35].

The form of the endosponge is adapted to the leak cavity and constructed from the small granulo-foam package in which a tunnel is created through its center to the tip without exiting the sponge. The length of the endosponge depends on the lumen of the fistula cavity, and its diameter is limited by the size of the esophageal lumen.

Leeds and Burdick recommended a 4-day serial exchange regimen in order to decrease the in-hospital stay in patients undergoing E-VAC therapy. The interval can vary. A longer period could be associated with a saturation of the fenestrations in the foam overwhelmed by GI secretions and a limited capacity of the VAC efficiency. Simultaneously, the granulation tissue around the VAC becomes significant and the replacement could be extremely traumatic after 4 days. A shorter period will limit the use of endosponge. Even so, the duration of therapy is long and the number of endoscopic interventions is high. Currently, therapy duration remains long and the number of endoscopic interventions is high.

27.1.6 Ovesco

The endoscopic over-the-scope clips OTSC® (Ovesco Endoscopy AG, Tübingen, Germany) seem to close some early small fistulas. This system efficiency was proven in the literature and also in our experience in two patients. Surace et al. [36] reported their experience with the use of the OTSC® system in a heterogeneous group of patients with gastrointestinal fistula. Their subanalysis of a total sample contains 19 patients, which include 11 subjects who presented with GL after sleeve gastrectomy. They report 91% successful closure rate. Another successful experience was reported by Conio et al. [37]. The two main limitations of the over-the-scope clips are the lateral view of the leak and the quality of the tissue. First, this approach demands a perpendicular view on the leak with the endoscope in order to achieve a good equal closure of both edges of the leak. This represents a technical challenge in a well-calibrated sleeve. Secondly, in our experience, the tissue quality in the acute phase of the inflammation will not permit a good closure by this approach. Fibrotic tissue occurs after 6–8 weeks of pigtail treatment, and over-the-scope clips could be attempted as a second-line treatment in these situations. Our two cases of leak treated with over-the-scope clips cannot advocate the success of this approach.

27.1.7 Discussions

Esophagogastric junction represents an anatomical area of weakness for any digestive suture. Fundic wall is thinner, and vascularization is more precarious than in the rest of the stomach. This area under the cardia is more sensitive to technical failure or to any increase in intragastric pressure. Experience showed us that almost all leaks after LSG originate in this location, namely, just below the GE junction [22].

In our opinion, there is no stricture induced by the sleeve itself when the staple line is well aligned. When stenosis occurs, it is usually of two types: a functional one (endoscope passage is possible, but the sleeve is twisted and various degrees of rotation are necessary to pass the scope through the gastric lumen—the so-called Helix stenosis) or a mechanical one (when endoscope passage is very difficult or impossible). In both cases, the algorithm should include the treatment of both pathologies: the leak and the stenosis.

In early, acute phase, there are two options for the stenosis: aggressive balloon dilation or stent. When the leak diameter is not so important, the placement of one, two, or even three pigtails associated with balloon dilation is recommended for a better quality of life. When the leak is too important (larger of 12 mm—the endoscope caliber), a stent deployment is suitable even if the quality of life is impaired. Pigtail drains present many advantages when compared with stents (no stent migration, less pain, and more patient tolerance). In the group of patients without stenosis (functional or mechanical), the use of stenting can be associated with higher migration rate due to the lack of stenosis, and in these cases, the pigtail represents the gold standard in our activity. The endoscopic septotomy in the acute phase should be extremely limited, even if sometimes, it has offered spectacular results. For teams with good experience, the E-VAC could be an interesting treatment option.

In the chronic phase, if the leak cavity or diameter is not important, the pigtail could be replaced with satisfactory results. On the contrary, the persistence of a cavity with a fibrotic septum imposes the endoscopic septotomy as treatment of choice.

27.1.8 Conclusion

In our experience, GL following LSG management must be tailored to meet several criteria: the type of leak (acute or chronic), the size of the fistulous site, and the presence of stenosis (functional or mechanical). There are special indications discussed in this chapter for endoscopic stents, pigtails, septotomy, E-VAC, or clips. The decision to use one specific endoscopic approach must be based on endoscopic findings.

27.2 Gastric Stenosis After Sleeve Gastrectomy

27.2.1 Introduction

The incidence of gastric stenosis (GS) in patients who undergo LSG is 0.7–4% [38]. Typical symptoms include food intolerance, vomiting, epigastric pain, regurgitation, swelling, and de novo gastroesophageal reflux disease symptoms and may lead to excessive weight loss, dehydration, and malnutrition [39–41]. The gastric stenosis usually occurs at the *incisura angularis* or at the stomach body, nearly 4 cm below of the gastroesophageal junction [38, 40]. It may result due to staple line rotation, scarring in a kinked shape, excessive imbrication of the staple-line, or excessive retraction during the stapling of the greater curvature (Fig. 27.6) [38, 40, 42]. In this chapter, we describe diagnosis and therapeutic endoscopic approach of the strictures after sleeve gastrectomy.

Fig. 27.6 Lumen narrowing due to a gastric rotation in the middle of the pouch after sleeve gastrectomy (SG)

The GS can be classified into mechanical or functional stenosis. The functional stenosis occurs when gastric sleeve is twisted and can be diagnosed using an upper gastrointestinal endoscopy (UGE) that shows a kinked sleeve [39, 42]. Mechanical stenosis occurs when the passage of the endoscope is very difficult or impossible, due to excessive intraluminal narrowing and the swallow study shows segmental narrowing of the stomach or stagnation of the oral contrast above the stricture (Fig. 27.7) [39, 42]. Stenosis can also be classified according to the time of presentation as acute or chronic. Acute stenosis may be due to mucosal edema, external compression, and, in some cases, due to kinking [40, 43]. Chronic stenosis usually corresponds to fibrotic tissue strictures, and they can be a result of ischemia, retraction due to scarring, and inclusion of the esophagogastric junction in the staple line. Some patients had previous surgery, such as antireflux surgery (gastric fundoplication) or adjustable gastric banding (Figs. 27.8 and 27.9) [40, 43].

Endoscopic Diagnosis (Fig. 27.10)

- Presence of the intraluminal septum in the proximal part of the sleeve
- Axial deviation or tortuosity sleeve
- Difficulty to pass the endoscope through the incisura angularis or the gastric body

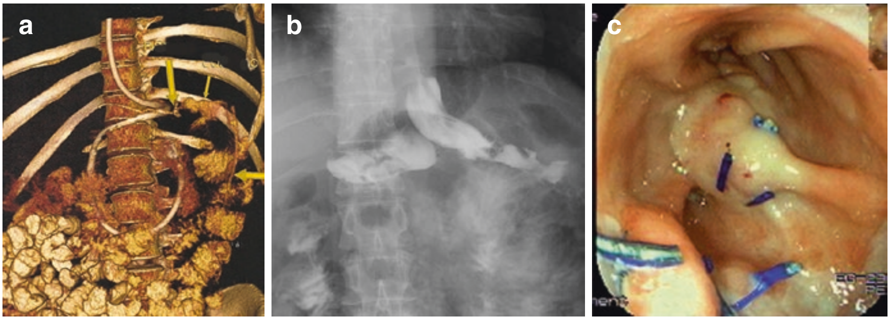


Fig. 27.7 (**a**) Twisted gastric pouch is identified on CT scan, (**b**) on contrast X-ray, and (**c**) on upper gastrointestinal endoscopy (UGE)

Fig. 27.8 A proximal angulation of the gastric pouch is identified on contrast X-ray. It is a result of revisional surgery of conversion from fundoplication to SG

Fig. 27.9 A double lumen narrowing after conversion from AGB to SG is shown in the contrast X-ray

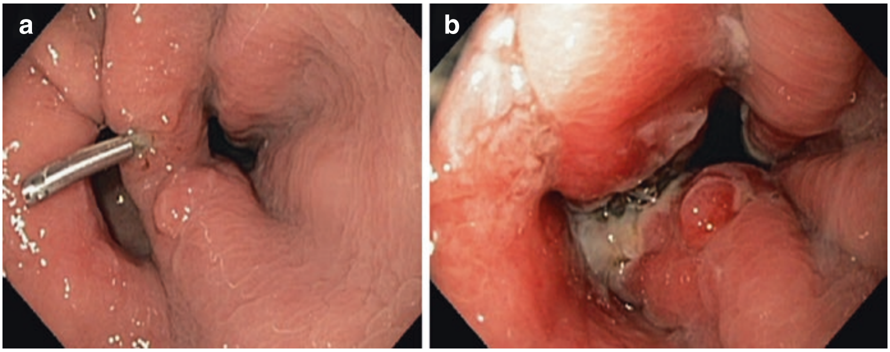


Fig. 27.10 Gastric stenosis with a septum in the proximal area of the pouch. (**a**) A gastric septum and a metallic clip. (**b**) The septum was cut using an electrocautery to increase the pouch diameter

Endoscopic Therapy

The approach of gastric stenosis after SG varies according to postoperative day (POD) and clinical presentation (Table 27.1).

27.2.1.1 Endoscopic Achalasia Balloon Dilation

In the first month, food intolerance is also due to mucosal edema, and the initial approach should include nutritional support and intravenous hydration [40]. In some cases, steroids can be administrated to reduce mucosal inflammatory response and improve the symptoms. Gastroscopy should be performed when there is severe food intolerance, and it is the best option to identify anatomical features of mechanical or functional stenosis. In the same session, endoscopic balloon dilation with 20 or 30 mm can be performed (Fig. 27.11).

POD	Clinical presentation	Management
<30	GERD-like symptoms + food intolerance + excessive weight loss	Nutritional support IV hydration Steroids Diagnostic UGE Balloon dilation (20 mm)
>30	Symptoms remain: UGE: stricture and/or axial deviation	Balloon dilation (30 mm)
>45	Symptoms improvement	Balloon dilation (30 mm)
>60	Symptoms remission	Balloon dilation (30 mm)
>90	Asymptomatic	Follow-up

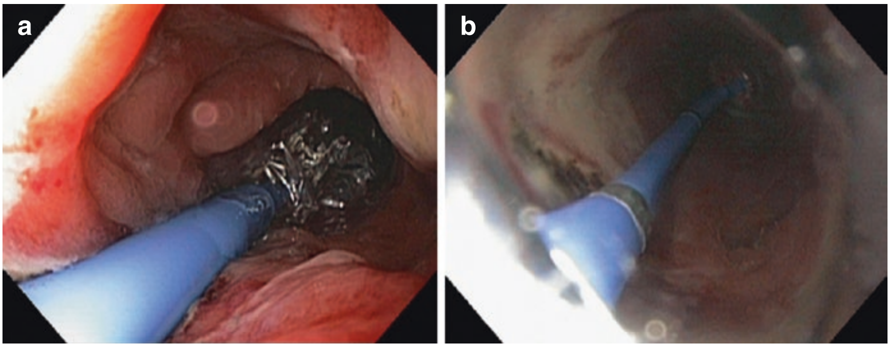


Fig. 27.11 Endoscopic balloon dilation with 30-mm diameter. (**a**) Deflated achalasia balloon. (**b**) Inflated balloon is compressing the stenosis area in the gastric wall

If the patient remains symptomatic at 30th POD, endoscopic balloon dilation (30 mm) is the first therapeutic option [38–42]. In a recent study by Dhorepatil et al., 33 patients with gastric stricture underwent endoscopic balloon dilation (30 mm). The success rate was 93.9%, and only one patient had undergone revisional surgery [41]. In another series by Rebibo et al., 17 patients with gastric stenosis after LSG had submitted to balloon dilation as first-line approach. The success of the endoscopic approach was 88.2% (*n* = 15) and the remaining two patients, in whom the endoscopic therapy had failed, underwent revisional surgery (conversion to RYGB) (*n* = 2) [39]. In the most cases, one session of the endoscopic balloon dilation is enough; however, sometimes, the patient requires several approaches, especially in cases of chronic stenosis associated with intense fibrotic tissue [38, 40, 41]. The authors recommend that patients with gastric stenosis should be submitted at least to three sessions of endoscopic dilation, in order to reduce recurrence of stricture

27.2.1.2 Endoscopic Stenostomy (or Septotomy) + Achalasia Balloon Dilation

The late period (>3 months), patients usually present progressive dysphagia to fluids followed by dysphagia to solids, weeks to months after LSG [19, 40, 43]. These cases are difficult to approach, due to chronic inflammatory responses, leading to fibrosis [38, 40, 43]. Several endoscopic sessions can be necessary and, in some cases, "stenotomy" can be performed, using argon plasma coagulation or endoscopic needle-knife electrocautery to make incision along the longitudinal axis in four quadrants, including the muscular layer (Fig. 27.10) [40, 43, 44].

27.2.1.3 Endoscopic Implant of Self-Expandable Metallic Stents (SEMSs)

This device has been used to treat gastric stricture, mainly in difficult cases [19, 38, 42, 45]. However, consistent results are lacking. In a case series by Puig et al. the resolution of chronic strictures after LSG was reported for only 12.5% of patients [19]. However, placement of a stent may allow early discontinuation of parenteral nutrition or enteral tube nutrition and re-establish oral nutrition in order to reverse malnutrition before revisional surgery [19].

In the case of intractable stricture, revisional surgery should be promptly performed. Strictureplasty or conversion to Roux en-Y gastric bypass (RYGB) is possible [39, 40, 46]. Total gastrectomy represents the extreme solution in a rare case of very proximal strictures that make impossible convert to RYGB.

References

1. Lazzati A, Guy-Lachuer R, Delaunay V, Szwarcensztein K, Azoulay D. Bariatric surgery trends in France: 2005–2011. Surg Obes Relat Dis. 2014;10(2):328–34.
2. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2011. Obes Surg. 2013;23(4):427–36.
3. Parikh M, Issa R, McCrillis A, et al. Surgical strategies that may decrease leak after laparoscopic sleeve gastrectomy: a systematic review and meta-analysis of 9991 cases. Ann Surg. 2013;257(2):231–7.
4. Sakran N, Goitein D, Raziel A, et al. Gastric leaks after sleeve gastrectomy: a multicenter experience with 2,834 patients. Surg Endosc. 2013;27(1):240–5.
5. Noel P, Nedelcu M, Gagner M. Impact of the surgical experience on leak rate after laparoscopic sleeve gastrectomy. Obes Surg. 2016;26(8):1782–7.
6. Nedelcu M, Manos T, Cotirlet A, Noel P, Gagner M. Outcome of leaks after sleeve gastrectomy based on a new algorithm adressing leak size and gastric stenosis. Obes Surg. 2015;25(3):559–63.
7. Tan TJ, Kariyawasam S, Wijeratne T, et al. Diagnosis and management of gastric leaks after laparoscopic sleeve gastrectomy for morbid obesity. Obes Surg. 2010;20:403–9.
8. Nedelcu M, Skalli M, Delhom E, et al. New CT scan classification of leak after sleeve gastrectomy. Obes Surg. 2013;23(8):1341–3.
9. Rosenthal RJ, International Sleeve Gastrectomy Expert Panel, Diaz AA, et al. International Sleeve Gastrectomy Expert Panel consensus statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8(1):8–19.
10. Serra C, Baltasar A, Andreo L. Treatment of gastric leaks with coated self-expanding stents after sleeve gastrectomy. Obes Surg. 2007;17:866–72.
11. Eubanks S, Edwards CA, Fearing NM, et al. Use of endoscopic stents to treat anastomotic complications after bariatric surgery. J Am Coll Surg. 2008;206:935–8.
12. Swinnen J, Eisendrath P, Rigaux J, et al. Self-expandable metal stents for the treatment of benign upper GI leaks and perforations. Gastrointest Endosc. 2011;73(5):890–9.
13. El Mourad H, Himpens J, Verhofstadt J. Stent treatment for fistula after obesity surgery: results in 47 consecutive patients. Surg Endosc. 2013;27(3):808–16.
14. Bège T, Emungania O, Vitton V, et al. An endoscopic strategy for management of anastomotic complications from bariatric surgery: a prospective study. Gastrointest Endosc. 2011;73(2):238–44.
15. Puli SR, Spofford IS, Thompson CC. Use of self-expandable stents in the treatment of bariatric surgery leaks: a systematic review and meta-analysis. Gastrointest Endosc. 2012;75(2):287–93.
16. Edwards CA, Bui TP, Astudillo JA, et al. Management of anastomotic leaks after Roux-en-Y bypass using self-expanding polyester stents. Surg Obes Relat Dis. 2008;4:594–9; discussion 599–600.
17. Simon F, Siciliano I, Gillet A, Castel B, Coffin B, Msika S. Gastric leak after laparoscopic sleeve gastrectomy: early covered self-expandable stent reduces healing time. Obes Surg. 2013;23(5):687–92.
18. Salinas A, Baptista A, Santiago E, Antor M, Salinas H. Self-expandable metal stents to treat gastric leaks. Surg Obes Relat Dis. 2006;2(5):570–2.
19. Puig CA, Waked TM, Baron TH, et al. The role of endoscopic stents in the management of chronic anastomotic and staple line leaks and chronic strictures after bariatric surgery. Surg Obes Relat Dis. 2014;10(4):613–7.
20. Sharaiha RZ, Kim KJ, Singh VK, et al. Endoscopic stenting for benign upper gastrointestinal strictures and leaks. Surg Endosc. 2014;28(1):178–84.

21. Alazmi W, Al-Sabah S, Ali DA, Almazeedi S. Treating sleeve gastrectomy leak with endoscopic stenting: The Kuwaiti experience and review of recent literature. Surg Endosc. 2014;28(12):3425–8.
22. Marquez M, Ayza FM, Belda LR, et al. Gastric leak after laparoscopic sleeve gastrectomy. Obes Surg. 2010;20:1306–11.
23. Speer E, Dunst CM, Shada A, Reavis KM, Swanström LL. Covered stents in cervical anastomoses following esophagectomy. Surg Endosc. 2016;30(8):3297–303.
24. Licht E, Markowitz AJ, Bains MS, et al. Endoscopic management of esophageal anastomotic leaks after surgery for malignant disease. Ann Thorac Surg. 2016;101(1):301–4.
25. Boerlage TC, Hermanides HS, Moes DE, Tan IL, Houben GM, Acherman YI. Aorto-oesophageal fistula after oesophageal stent placement in a patient with a Roux-en-Y gastric bypass. Ann R Coll Surg Engl. 2016;98(8):e178–80.
26. Garofalo F, Noreau-Nguyen M, Denis R, Atlas H, Garneau P, Pescarus R. Evolution of endoscopic treatment of sleeve gastrectomy leaks: from partially covered to long, fully covered stents. Surg Obes Relat Dis. 2017;13(6):925–32.
27. Pequignot A, Fuks D, Verhaeghe P, et al. Is there a place for pigtail drains in the management of gastric leaks after laparoscopic sleeve gastrectomy? Obes Surg. 2012;22:712–20.
28. Donatelli G, Dumont JL, Cereatti F, et al. Treatment of leaks following sleeve gastrectomy by endoscopic internal drainage (EID). Obes Surg. 2015;25(7):1293–301.
29. Donatelli G, Airinei G, Poupardin E, et al. Double-pigtail stent migration invading the spleen: rare potentially fatal complication of endoscopic internal drainage for sleeve gastrectomy leak. Endoscopy. 2016;48(Suppl 1 UCTN):E74–5. https://doi.org/10.1055/s-0042-102446. Epub 2016 Mar 7.
30. Baretta G, Campos J, Correia S, Alhinho H, Marchesini JB, Lima JH, Neto MG. Bariatric postoperative fistula: a life-saving endoscopic procedure. Surg Endosc. 2015;29(7):1714–20.
31. Campos JM, Pereira EF, Evangelista LF, et al. Gastrobronchial fistula after sleeve gastrectomy and gastric bypass: endoscopic management and prevention. Obes Surg. 2011;21(10):1520–9.
32. Mahadev S, Kumbhari V, Campos JM, et al. Endoscopic septotomy: an effective approach for internal drainage of sleeve gastrectomy-associated collections. Endoscopy. 2017;49(5):504–8.
33. De Lima JH. Endoscopic treatment of post vertical gastrectomy fistula: septotomy associated with air expansion of incisura angularis. Arq Bras Cir Dig. 2014;27(Suppl 1):80–1.
34. Szymanski K, Ontiveros E, Burdick JS, Davis D, Leeds SG. Endolumenal vacuum therapy and fistulojejunostomy in the management of sleeve gastrectomy staple line leaks. Case Rep Surg. 2018;2018:2494069. https://doi.org/10.1155/2018/2494069. eCollection 2018.
35. Leeds SG, Burdick JS. Management of gastric leaks after sleeve gastrectomy with endoluminal vacuum (E-Vac) therapy. Surg Obes Relat Dis. 2016;12(7):1278–85.
36. Surace M, Mercky P, Demarquay JF, et al. Endoscopic management of GI fistulae with over-the-scope clip system. Gastrointest Endosc. 2011;74(6):1416–9.
37. Conio M, Blanchi S, Repici A, et al. Use of an over-the scope clip for endoscopic sealing of a gastric fistula after sleeve gastrectomy. Endoscopy. 2010;42(Suppl 2):E71–2.
38. Agnihotri A, Barola S, Hill C, Neto MG, Campos J, Singh VK, et al. An algorithmic approach to the management of gastric stenosis following laparoscopic sleeve gastrectomy. Obes Surg. 2017;27(10):2628–36.
39. Rebibo L, Hakim S, Dhahri A, Yzet T, Delcenserie R, Regimbeau J. Gastric stenosis after laparoscopic sleeve gastrectomy: diagnosis and management. Obes Surg. 2016;26(5):995–1001.
40. Zundel N, Hernandez JD. Strictures after laparoscopic sleeve gastrectomy. Surg Laparosc Endosc Percutan Tech. 2010;20(3):154–8.
41. Dhorepatil AS, Cottam D, Surve A, Medlin W, Zaveri H, Richards C, et al. Is pneumatic balloon dilation safe and effective primary modality of treatment for post-sleeve gastrectomy strictures ? A retrospective study. BMC Surg. 2018;18:52.
42. Manos T, Nedelcu M, Cotirlet A, Eddbali I, Gagner M, Noel P. How to treat stenosis after sleeve gastrectomy? Surg Obes Relat Dis. 2016;13(2):150–4.

43. Turiani D, De Moura H, Jirapinyo P. Endoscopic tunneled stricturotomy in the treatment of stenosis after sleeve gastrectomy. VideoGIE. 2018;4(2):68–71.
44. Campos JM, Ferreira FC, Teixeira AF, Lima JS, Moon RC, D'Assunção MA, et al. Septotomy and balloon dilation to treat chronic leak after sleeve gastrectomy: technical principles. Obes Surg. 2016;26(8):1992–3.
45. Moon RC, Teixeira AF, Bezerra L, Cristina H, Wahnon A, Campos J, et al. Management of bariatric complications using endoscopic stents: a multi-center study. Obes Surg. 2018;28(12):4034.
46. Deslauriers V, Beauchamp A, Garofalo F, Atlas H, Denis R, Garneau P, Pescarus R. Endoscopic management of post-laparoscopic sleeve gastrectomy stenosis. Surg Endosc. 2017;32(2):601–9.

Part VI
Revisional Surgery

Chapter 28
Conversion from Sleeve Gastrectomy to RYGB

Rene Aleman, Emanuele Lo Menzo, Samuel Szomstein, and Raul J. Rosenthal

28.1 Introduction

Overweight and obesity continue to have a concerning upward trend in worldwide health. According to the World Health Organization (WHO), since 1975 obesity has tripled across the globe. In 2016, nearly 2 billion adults were overweight, of which 650 million were obese [1]. As widely supported by clinical practice and current literature, obesity is both a preventable and treatable condition. Bariatric surgery has proven to achieve long-term weight loss and resolution of obesity-related comorbidities. Accordingly, the International Federation for Surgery of Global and Metabolic Disorders (IFSO) has recognized laparoscopic sleeve gastrectomy (LSG) as a primary bariatric procedure since 2014 [2]. Popular as this procedure might be, it has potential for complications and failure. In general, 40% of all bariatric procedures will require reoperation, which includes revisions, reversals, or conversions [2]. This chapter focuses primarily on the indications and techniques for conversion from primary LSG to laparoscopic Roux-en-Y gastric bypass (LRYGB).

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-28936-2_28) contains supplementary material, which is available to authorized users.

R. Aleman · E. Lo Menzo · S. Szomstein · R. J. Rosenthal (✉)
Department of General Surgery, The Bariatric & Metabolic Institute, Cleveland Clinic Florida, Weston, FL, USA
e-mail: alemanr@ccf.org; lomenze@ccf.org; szomsts@ccf.org; rosentr@ccf.org

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_28

28.1.1 Background

Laparoscopic sleeve gastrectomy surged as a restrictive bariatric procedure from the idea of a vertically shaped gastroplasty that aimed to modify the flow of nutrients. The basic physiologic idea of such a configuration of the gastrectomy comes from the identification of the lesser curvature as the "*magenstrasse*," or "street of the stomach," where the nutrients preferentially travel. The contemporary concept of LSG came as a result from the techniques described by Hess, Marceau, Scopinaro, and DeMeester during the late 1980s and early 1990s. The modern concept of LSG was introduced by Michel Gagner et al. as a staged approach to laparoscopic biliopancreatic diversion with duodenal switch (BPD-DS). Although BPD-DS is very effective for weight loss due to its restrictive and malabsorptive components, it carries significant postoperative morbidity. Thus, a two-step approach with isolated sleeve gastrectomy was first suggested for high-risk *superobese* patients. However, the durable weight loss effect of the LSG and the rare need for the second-step completion of the BPD-DS determined the adoption of LSG as a stand-alone procedure.

According to the latest update on worldwide bariatric surgery, which includes data from 550 hospitals in 51 countries over 5 continents, 46% of the operations consisted of LSGs with an evident increment during the last 2 years [2]. Laparoscopic sleeve gastrectomy has gained popularity due to its simplicity, overall safety, efficacy in weight loss, and resolution of associated comorbidities, while maintaining an intact gastrointestinal (GI) tract [3–7]. Regardless of its worldwide success rates, LSG may inevitably fail due to insufficient weight loss, weight regain, postoperative complications, and substandard improvement of comorbidities [8, 9]. Failure and complications of bariatric procedures determine the necessity for reoperational interventions after primary surgeries. As stated by the American Society for Metabolic and Bariatric Surgery (ASMBS), the different reinterventions after primary bariatric surgery can be classified based on indications, types of procedures, and outcomes [10]. Based on the indications, the reoperations can be further subclassified into non-responders and complications. Based on the final anatomical outcome, the reoperations can be divided in revisions, conversions, and reversals. As previously mentioned, this chapter will focus on the reoperation evaluation and perioperative treatment of conversion of LSG to LRYGB in non-responders.

28.2 Evaluation

28.2.1 Indications

As LSG continues to gain popularity as a primary bariatric procedure, there will be an unequivocal parallel increment in the need for reoperation, more specifically, a need for conversion. An adequate surgical approach for the conversion of LSG to

LRYGB includes a thorough understanding of the rationale for the reoperation. The failure of the LSG is typically multifactorial and includes three separate components: the pathophysiological one, the mechanical one, and the patient compliance to lifestyle changes [11]. In general, the main reasons for reoperation after LSG include either lack of response to weight loss or weight regain and postoperative complications. Most commonly the conversion of LSG is secondary to failure of weight loss or weight recidivism [12]. In this regard, the safety of the conversion from LSG to LRYGB has been well-established [12–17].

Despite the lack of consensus, the definition of non-responders to bariatric surgery entails inadequate weight loss or weight regain with reoccurrence of associated comorbidities. However, significant controversy exists in the quantification of poor response. It is easier to understand what success is after bariatric surgery. Success after primary bariatric surgery is defined as the sustained control of weight loss, accompanied by resolution or improvement of comorbidities and quality of life. In terms of quantification, for both restrictive and malabsorptive procedures, the Adelaide study group proposed excess weight loss (EWL) as a numerical scale to classify success or failure. A cutoff of 50% or more in EWL was set to stand for success, while having less than 40% of EWL was considered failure [18]. However, the non-responders should be based on the expected weight loss results of the bariatric procedure being performed. A unified measure, although objective, disregards the abundant differential implications of currently available bariatric surgeries.

Conversely, the identification of postoperative complications after primary bariatric surgery requiring reoperation is much easier to identify. The postoperative complications can be further classified based on the time of onset: acute (7 days), early (7 days to 6 weeks), late (6–12 weeks), and chronic (12 weeks or more). Postoperative complications are also classified based on type: surgical/anatomical versus nutritional/metabolic.

It is also highly relevant to consider the complications attributable to the surgeon's level of expertise, as well as the patient's compliance and progression of the associated comorbidities. By doing so, not only will the arbitrary decision-making on how to approach conversion become systematic and standardized, but patient compliance and progression of associated comorbidities will also show better outcomes.

Due to the lack of societal consensus on indications for reoperation, candidates should be individualized in accordance to the intended goal. Nevertheless, after failure of a primary LSG, conversion to LRYGB has achieved effective weight loss management. A systematic review on revisional bariatric surgery following failed primary LSG assessed the efficacy of currently available revisional procedures between three different groups: laparoscopic resleeve gastrectomy (LRSG), LRYGB, and other surgical interventions. After conversion to LRYGB, body mass index (BMI) decreased to 33.7 and 35.7 kg/m^2 at 12 and 24 months of follow-up, respectively [17]. Excess weight loss (EWL) was 60% and 48% over the same periods. It was concluded that both LSG and LRYGB appear to be practical options after failure of primary LSG [17]. Moreover, in high-volume, specialized centers, where strict criteria for patient selection for primary LSG is performed, conversion to LRYGB was effective for further weight loss and GERD remission at 2-year follow-up [19]. Similarly, Shimon and colleagues reported similar effective results for both LRYGB and BPD-DS. Conversion to either LRYGB or BPD-DS after failure of primary LSG is an efficient and effective treatment for inadequate weight loss and resolution of comorbidities [20].

Further long-term evidence is needed to properly determine the validity of LRYGB as a conversion procedure after primary LSG has failed. More so, randomized control trials (RTC) should be considered in order to establish the most appropriate alternative for conversion.

28.2.2 Patient Selection

Laparoscopic sleeve gastrectomy has reported superb short- and medium-term outcomes yielding low complication rates and overall safety, making it the procedure of choice for primary bariatric surgery [21]. Despite its evident popularity and effectiveness, reports of long-term follow-up are heterogeneous, thus inferring the possibility of higher than expected non-responder rates. For example, follow-ups after 5 and 10 years of primary LSG have reported poor response rates of 21% and 38.5%, respectively [22, 23]. Regardless of the type of primary rapid weight loss surgery, patient selection mandates careful evaluation in order to identify the possible mechanism leading to poor response or complication. Furthermore, understanding the etiology of primary failure will reflect better conversional outcomes.

Similar to other surgical procedures, the conversion of LSG to RYGB requires the appropriate counseling about the risks, benefits, and necessary lifestyle modifications. The patient selection must also include a comprehensive evaluation to identify the reason(s) for the failure of the primary LSG. Prior to deeming necessary said reoperation, the following must be thoroughly reviewed and assessed:

- Review of prior bariatric-related operative reports
- Imaging studies
- Nutritional assessment and patient education
- Psychological evaluation
- Preoperative clearance

28.2.2.1 Surgical History

Because of the variability of the techniques, it is important to carefully review the original operation. This helps not only to determine the best strategy, but also to avoid possible complications. The potential history of additional operations might also influence the choice of the procedure. In the presence of a large sleeve with retained gastric fundus and for the indication of weight regain, a resleeve can be considered. Other than the supporting evidence regarding the safety and efficacy, the conversion from LSG to LRYGB is a relatively intuitive operation. Recall that the type of primary procedure will inevitably have an influence on the weight loss of the secondary one. Such is the case, that revisions of primary restrictive operations will result in higher weight loss than revisions of malabsorptive ones [24]. Due to the aforementioned, it is highly suggestible to consider the conversion of a failed primary LSG to a LRYGB as the standard approach.

28.2.2.2 Imaging Studies

The anatomical and functional assessment of the gastrointestinal tract prior to reoperation is essential. To better evaluate the anatomy and transit of the primary performed LSG, a preoperative contrast upper GI (UGI) is the best approach. This study provides anatomical (size of the sleeve, presence of hiatal hernias) but also functional (presence of reflux) information. The surgeon performing the conversion should personally evaluate the image to identify any relevant finding(s) associated to the failure. An upper endoscopy is also key to confirming the presence of hiatal hernias, evaluating mucosal abnormalities (Barrett's), and evaluating the duodenum prior to its exclusion from the gastrointestinal tract. Finally, computed tomography (CT) scan should be considered only when there is a high suspicion of a staple line leak as it entails high sensitivity and can identify secondary changes related to the leak, such as extraluminal collections, fat stranding, pleural effusion, and free air [25].

28.2.2.3 Patient Education

Roughly 6% of patients undergoing primary LSG will present with poor response of weight loss or weight regain. Equally, patients with gastric outlet obstruction are potential candidates for conversion to LRYGB. The poor response of the patient to achieve or maintain long-term weight loss is not a marker of patient noncompliance or surgical technique alone. Hence, a thorough preoperative education and fair assessment of the patient's expectations is paramount for a positive outcome. In fact, a study showed that only 50% of patients were noted to have a good satisfaction index postoperatively [26]. Moreover, the failure of a primary LSG is granted to be multifactorial, hence the mentioned variability of the results.

28.2.2.4 Psychological Evaluation

The psychological evaluation of a bariatric reoperation candidate is also relevant for the uncovering of how possible maladaptive eating behaviors that developed during the primary operation can be managed after the reintervention. The psychological profile is not only limited to the patient's eating behaviors, but rather to a mixture of changes in environment and psychosocial stress [27]. There are several mechanisms that contribute to the failure of a primary LSG. Due to the fact that LSG is mainly a restrictive procedure, the patient's adherence to a strict diet is significantly determinant for weight loss. This is a well-known behavior that was firstly described in patients who underwent vertical banded gastroplasty (VBG) and who compensated limited volume intake with high calorie intake [28]. Overall, when it comes to dietary and nutritional assessment and counseling, eating disorders (i.e., binge eating, high caloric liquid intake) and low energy expenditure should be addressed and corrected prior to conversion.

Ignoring the psychological aspects of a bariatric patient might lead to the patient's unnecessary exposure to a higher risk in morbidity and mortality [10]. The psychological assessment should not be underestimated as this, along with psychiatric comorbidities, and lack of patient compliance, affects weight loss surgery outcomes [29].

28.3 Treatment

As previously mentioned, based on a BMI > 35, the modified Reinhold criteria (<50% excessive weight loss) represent a criterion used to define the primary procedure as non-responding [30].

If the criteria for no response are controversial for primary operations, an even greater lack of agreement exists for the definition of failure of the reoperative procedures, especially the conversion of LSG to LRYGB. Obviously, the revisional procedure should address the reason for failure of the primary operation [27]. Also, initial responders to primary LSG can potentially develop weight regain, often associated with the return of associated comorbidities [27]. The conversion to LRYGB has been associated with a higher success rate in terms of reflux symptoms resolution and diabetes control with equal benefits in weight loss at 1-year follow-up [31].

28.3.1 Surgical Technique

Access to the abdominal cavity is done through the supraumbilical region, left to the midline, using an optical trocar. Following the exploration of the abdominal cavity, two subsequent 5-mm trocars are placed for liver retraction just below the xiphoid process and along the anterior axillary line below the 12th rib for assisting maneuverability. The optical entry trocar is often positioned away from prior surgical incisions to minimize potential, inadvertent visceral injury during reoperation [12].

One of the reasons for weight regain after primary LSG is an incomplete resection of the fundus and an antral dilation or a high-volume capacitance antrum [15, 32, 33]. Disputably, there is controversy on whether the weight regain following primary LSG is related to the complete primary dilation of the pouch or an inadvertently created large sleeve, both of which could fundamentally be the root cause for failure [34]. The conversion of a failed sleeve into a gastric bypass requires trimming of the gastric pouch for removal of any retained or neo-fundus and subsequent ascend and anastomosis of the distal limb [35]. When there is an intention to perform said conversion, the presence of dense adhesions and corresponding vascular supply warrants gentle handling of the tissue, as well as the upsizing of all staple heights, oversewing of staple lines, and the assessment for circumferential reinforcement of the gastrojejunal anastomosis [10].

Adhesions between sleeve and left hepatic lobe are common and should be promptly identified and dissected to allow placement of the liver retractor.

The sleeve is to be divided distal to the left gastric artery as to create a gastric pouch with a standard 30–50 mL volume. As for the biliopancreatic and Roux limbs, they should be a length of 50 and 150 cm, respectively. The length of the Roux limb can be determined preoperatively based on the patient's current BMI and can be lengthened accordingly to achieve greater postoperative weight loss. The jejunojejunostomy is performed with a linear stapled technique, the mesenteric defects are closed, and the Roux limb is positioned in an antecolic fashion. Generally, a retrocolic positioning is reserved for a short jejunogastric anastomosis. The rest of the procedure will continue as would be done on a primary surgery basis.

In the conversion of SG to BPD-DS, the distal ileum is divided at about 250–300 cm proximal to the ileocecal valve, with the proximal loop becoming the biliopancreatic limb and the distal loop becoming the alimentary limb. A study on the long-term effectiveness of laparoscopic conversion of LSG to BPD-DS or RYGB demonstrated that both procedures are equally effective for the treatment for both inadequate weight loss and improvement of comorbidities [20]. Carmeli and colleagues compared outcomes of conversion from a failed primary LSG to a LRYGB or a BPD-DS. Patients who underwent conversion to BPD-DS showed greater %EWL (80% vs. 65.5%) yet required longer operative times and length of stay [36]. Alsabah et al. showed similar outcomes when comparing resleeving and conversion to RYGB with a 1-year %EWL of 57% and 61%, respectively [37].

An alternative, the conversion to a mini-gastric bypass (single anastomosis bypass or omega loop bypass), is becoming a rather popular alternative for non-responding primary LSG. Despite having the singularity of possessing one anastomosis rather than two, recent positive outcomes support this alternative therapy. Moskowicz and colleagues reported their experience with a 23 patient cohort achieving an excess BMI loss over 51% at 24 months of follow-up [38]. However, there is insufficient evidence to determine the safety and feasibility of the mini-gastric bypass with standard LRYGB for the conversion after failure of primary LSG.

Even with superior weight loss and comorbidity resolution outcomes rendered by conversion from primary LSG to BPD-DS, this procedure in particular is considered to be too aggressive with high morbidity rates including malnutrition [35]. Also, considering the technical simplicity of the LSG, bariatric surgeons should reconsider resleeving a non-responding primary LSG due to a high probability of recurrent poor response, and the decision should be case-dependent following the patient's best interests. This rationale suggests that LRYGB should be the optimal procedure when considering converting a primary LSG.

28.4 Outcomes

As previously mentioned, many revisional procedures have been proposed for the non-responding primary LSG. In a comparison between RLSG and DS, a greater percentage of excessive weight loss (%EWL) was reported in the DS group (74% vs. 44%), yet the cohorts were seemingly small to determine it as substantial evidence [39]. Similarly, Carmeli and colleagues compared postoperative outcomes of conversion after non-responding sleeve to a LRYGB or a BPD-DS. Their results showed a greater %EWL after BPD-DS, yet required longer operative time and length of stay [36]. In accordance to Carmeli's group findings, a comparison of RLSG and conversion to LRYGB reported a 1-year %EWL improvement of 57% and 61%, respectively [37].

As with any other surgical procedure, LSG holds the potential for technically related complications. Despite the relative ease of this approach, there are several pitfalls entailed. These complications include hemorrhage, leakage, and stenosis. Other postoperative complications, although relevant, remain independent to the surgery's technical aspects. Due to the lack of evidence related to outcomes following conversion of failed primary LSG to LRYGB, it is uncertain to determine the actual postoperative complications related directly to procedural technicalities. Nevertheless, contemporary literature has suggested similar postoperative complications after conversion [12, 19, 20]. Overall the conversion from LSG to LRYGB has the advantage of maintaining a low-pressure system. Hence, the potential higher likelihood of anastomotic complications is mitigated by the lack of distal obstruction.

Considering the increased longevity associated with bariatric procedures, complications are not relegated to 30 postoperative days as in most surgeries [27]. Rapid weight loss operations have both short- and long-term complications and may require the same type of intervention as would be necessary after a primary procedure complication. To further elaborate, a multicenter retrospective study on the short-term outcomes of LSG conversion to LRYGB reported a 10% complication rate from a 1325 patient cohort. The complications were limited to early anastomotic leak due to persistent GERD, early proximal leak from the gastric pouch due to thermal injury, and hemorrhage from the jejunojejunal anastomosis, which was refractory to conventional treatment. All complications showed good recovery after standard of care management [19].

Altered gastric anatomy following primary LSG is crucial prior to conversional operation. Conversional surgery is reserved for failed LSG due to IWL, weight regain, and severe GERD (worsening of preoperative or de novo) refractory to medical treatment [40]. Hence, RYGB further extends as the most suitable candidate for conversion after non-responding primary LSG, especially for exacerbated GERD and for weight regain [17, 35, 41, 42]. More so, LRYGB holds its long-term efficacy regarding weight loss maintenance [40]. A Canadian study reported a 6.6% conversion rate to LRYGB as a safe option for LSG non-response and resulted in significant benefits from the comorbidity resolution in the presence of additional non-significant weight loss [43]. More recently, the 3-year interim analysis of the prospective randomized Swiss multicenter bypass or sleeve study (SM-BOSS) showed a 3.8% need of LSG conversion due to severe GERD and insufficient weight loss [43]. Regardless of the presented evidence, there are still no strict criteria for patients' selection to convert from a LSG to a LRYGB, yet there is consensus on LRYGB as the best option in case of conversion [17, 35, 41].

28.5 Conclusions

With the growing popularity of minimally invasive bariatric surgery, maintenance of long-term outcomes and adequate management of early non-response should be prioritized. As more primary LSGs are being performed, so will there continue to be a rise in revisional surgeries. Bariatric surgeons and high-volume centers must understand the pathophysiology of primary non-response to LSG in order to offer the most proper approach. Similarly, a thorough understanding of the relevant surgical history should be highlighted to ensure resolution of the etiology of non-response and the avoidance of potential postoperative complications. Future studies should focus on long-term outcomes after bariatric reoperation (specifically conversion) and ensure patient follow-up to set societal and consented criteria for conversion after non-responding primary LSG.

References

1. WHO. Obesity and overweight. 2018. Available at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight.Accessed 15 Jan 2019.
2. Welbourn R, et al. Bariatric surgery worldwide: baseline demographic description and one-year outcomes from the fourth IFSO global registry report 2018. Obes Surg. 2019;29:782–95. https://doi.org/10.1007/s11695-018-3593-1.
3. Trastulli S, et al. Laparoscopic sleeve gastrectomy compared with other bariatric surgical procedures: a systematic review of randomized trials. Surg Obes Relat Dis. 2013;9:816–29.
4. Diamantis T, et al. Review of long-term weight loss results after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2014;10:177–83.
5. van Rutte PWJ, Luyer MDP, de Hingh IHJT, Nienhuijs SW. To sleeve or NOT to sleeve in bariatric surgery? ISRN Surg. 2012;2012:674042.
6. Våge V, et al. Changes in obesity-related diseases and biochemical variables after laparoscopic sleeve gastrectomy: a two-year follow-up study. BMC Surg. 2014;14:8.
7. Li J-F, et al. Comparison of the long-term results of Roux-en-Y gastric bypass and sleeve gastrectomy for morbid obesity: a systematic review and meta-analysis of randomized and nonrandomized trials. Surg Laparosc Endosc Percutan Tech. 2014;24:1–11.
8. Lim CSH, Liew V, Talbot ML, Jorgensen JO, Loi KW. Revisional bariatric surgery. Obes Surg. 2009;19:827–32.
9. Lacy A, et al. Revisional surgery after sleeve gastrectomy. Surg Laparosc Endosc Percutan Tech. 2010;20:351–6.

10. Lo Menzo EL, Szomstein S, Rosenthal RJ. Reoperative bariatric surgery. In: Nguyen NT, Blackstone RP, Morton JM, Ponce J, Rosenthal RJ, editors. The ASMBS textbook of bariatric surgery. New York: Springer; 2015. p. 269–82. https://doi.org/10.1007/978-1-4939-1206-3_24.
11. Mittermair R, Sucher R, Perathoner A. Results and complications after laparoscopic sleeve gastrectomy. Surg Today. 2013;44:1307–12.
12. Landreneau JP, et al. Conversion of sleeve gastrectomy to Roux-en-Y gastric bypass. Obes Surg. 2018;28:3843–50.
13. Homan J, et al. Secondary surgery after sleeve gastrectomy: Roux-en-Y gastric bypass or biliopancreatic diversion with duodenal switch. Surg Obes Relat Dis. 2015;11:771–7.
14. Sánchez-Pernaute A, et al. Single-anastomosis duodenoileal bypass with sleeve gastrectomy (SADI-S) for obese diabetic patients. Surg Obes Relat Dis. 2015;11:1092–8.
15. Noel P, et al. Revised sleeve gastrectomy: another option for weight loss failure after sleeve gastrectomy. Surg Endosc. 2014;28:1096–102.
16. Bruzzi M, et al. Revisional single-anastomosis gastric bypass for a failed restrictive procedure: 5-year results. Surg Obes Relat Dis. 2016;12:240–5.
17. Cheung D, Switzer NJ, Gill RS, Shi X, Karmali S. Revisional bariatric surgery following failed primary laparoscopic sleeve gastrectomy: a systematic review. Obes Surg. 2014;24:1757–63.
18. Hall JC, et al. Gastric surgery for morbid obesity. The Adelaide Study. Ann Surg. 1990;211:419–27.
19. Boru CE, Greco F, Giustacchini P, Raffaelli M, Silecchia G. Short-term outcomes of sleeve gastrectomy conversion to R-Y gastric bypass: multi-center retrospective study. Langenbeck's Arch Surg. 2018;403:473–9.
20. Shimon O, Keidar A, Orgad R, Yemini R, Carmeli I. Long-term effectiveness of laparoscopic conversion of sleeve gastrectomy to a biliopancreatic diversion with a duodenal switch or a Roux-en-Y gastric bypass due to weight loss failure. Obes Surg. 2018;28:1724–30.
21. Brethauer SA, Hammel JP, Schauer PR. Systematic review of sleeve gastrectomy as staging and primary bariatric procedure. Surg Obes Relat Dis. 2009;5:469–75.
22. Golomb I, Ben David M, Glass A, Kolitz T, Keidar A. Long-term metabolic effects of laparoscopic sleeve gastrectomy. JAMA Surg. 2015;150:1051.
23. Felsenreich DM, et al. Weight loss, weight regain, and conversions to Roux-en-Y gastric bypass: 10-year results of laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2016;12:1655–62.
24. Brolin RE, Cody RP. Weight loss outcome of revisional bariatric operations varies according to the primary procedure. Ann Surg. 2008;248:227–32.
25. Aurora AR, Khaitan L, Saber AA. Sleeve gastrectomy and the risk of leak: a systematic analysis of 4,888 patients. Surg Endosc. 2012;26:1509–15.
26. Edholm D, Ottosson J, Sundbom M. Importance of pouch size in laparoscopic Roux-en-Y gastric bypass: a cohort study of 14,168 patients. Surg Endosc. 2016;30:2011–5.
27. Ma P, Reddy S, Higa KD. Revisional bariatric/metabolic surgery: what dictates its indications? Curr Atheroscler Rep. 2016;18:42.
28. Brolin RE, Robertson LB, Kenler HA, Cody RP. Weight loss and dietary intake after vertical banded gastroplasty and Roux-en-Y gastric bypass. Ann Surg. 1994;220:782–90.
29. Rutledge T, Groesz LM, Savu M. Psychiatric factors and weight loss patterns following gastric bypass surgery in a veteran population. Obes Surg. 2011;21:29–35.
30. Gastrointestinal surgery for severe obesity: National Institutes of Health Consensus Development Conference Statement. Am J Clin Nutr.1992;55:615S–19S.
31. Brethauer SA, et al. Standardized outcomes reporting in metabolic and bariatric surgery. Surg Obes Relat Dis. 2015;11:489–506.
32. Braghetto I, et al. Evaluation of the radiological gastric capacity and evolution of the BMI 2–3 years after sleeve gastrectomy. Obes Surg. 2009;19:1262–9.
33. Silecchia G, et al. Residual fundus or neofundus after laparoscopic sleeve gastrectomy: is fundectomy safe and effective as revision surgery? Surg Endosc. 2015;29:2899–903.
34. Nedelcu M, Noel P, Iannelli A, Gagner M. Revised sleeve gastrectomy (re-sleeve). Surg Obes Relat Dis. 2015;11:1282–8.

35. Nevo N, Abu-Abeid S, Lahat G, Klausner J, Eldar SM. Converting a sleeve gastrectomy to a gastric bypass for weight loss failure-is it worth it? Obes Surg. 2018;28:364–8.
36. Carmeli I, Golomb I, Sadot E, Kashtan H, Keidar A. Laparoscopic conversion of sleeve gastrectomy to a biliopancreatic diversion with duodenal switch or a Roux-en-Y gastric bypass due to weight loss failure: our algorithm. Surg Obes Relat Dis. 2015;11:79–85.
37. AlSabah S, et al. Approach to poor weight loss after laparoscopic sleeve gastrectomy: re-sleeve vs. gastric bypass. Obes Surg. 2016;26:2302–7.
38. Moszkowicz D, et al. Laparoscopic omega-loop gastric bypass for the conversion of failed sleeve gastrectomy: early experience. J Visc Surg. 2013;150:373–8.
39. Dapri G, Cadière GB, Himpens J. Laparoscopic repeat sleeve gastrectomy versus duodenal switch after isolated sleeve gastrectomy for obesity. Surg Obes Relat Dis. 2011;7:38–43.
40. Iannelli A, et al. Laparoscopic conversion of sleeve gastrectomy to Roux-en-Y gastric bypass: indications and preliminary results. Surg Obes Relat Dis. 2016;12:1533–8.
41. Parmar CD, et al. Conversion of sleeve gastrectomy to Roux-en-Y gastric bypass is effective for gastro-oesophageal reflux disease but not for further weight loss. Obes Surg. 2017;27:1651–8.
42. Mahawar KK, Jennings N, Balupuri S, Small PK. Sleeve gastrectomy and gastro-oesophageal reflux disease: a complex relationship. Obes Surg. 2013;23:987–91.
43. Yorke E, et al. Revision of sleeve gastrectomy to Roux-en-Y gastric bypass: a Canadian experience. Am J Surg. 2017;213:970–4.

Chapter 29
Conversion from Sleeve Gastrectomy to MGB/OAGB

Rudolf Alfred Weiner, Sylvia Weiner, and Sonja Chiappetta

Abbreviations

BMI	Body mass index
BPD/DS	Biliopancreatic diversion with duodenal switch
BPL	Biliopancreatic limb
EWL	Excess weight loss
FU	Follow-up
GERD	Gastroesophageal reflux disease
GERD-HRQL	GERD Health-related quality of life questionnaire
MGB/OAGB	Mini/one anastomosis gastric bypass
PPI	Proton pump inhibitor
RSI	Reflux symptom index
RYGB	Roux-en-Y gastric bypass
SD	Standard deviation
SG	Sleeve gastrectomy
TWL	Total weight loss

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-28936-2_29) contains supplementary material, which is available to authorized users.

R. A. Weiner (✉)
Sana-Klinikum Offenbach, Department for Obesity Surgery and Metabolic Surgery, Offenbach, Germany

S. Weiner
Krankenhaus Nordwest, Department for Obesity Surgery, Metabolic Surgery and MIC Surgery, Frankfurt, Germany

S. Chiappetta
Department of Obesity and Metabolic Surgery, Ospedale Evangelico Betania, Naples, Italy

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_29

29.1 Introduction

Sleeve gastrectomy (SG) is the most commonly performed bariatric procedure around the world, and studies have shown its relative safety and effectiveness in the short- and long-term [1–4]. However, increasing evidence has shown that SG may fail as a bariatric procedure [5–7]. Failure of SG leading to revision results predominantly from insufficient weight loss, weight regain, and intractable gastroesophageal reflux disease (GERD) including Barrett's esophagus [5–7]. Redo and revisional surgeries in the form of re-sleeve or gastric bypass (Roux-en-Y gastric bypass [RYGB], mini/one anastomosis gastric bypass [MGB/OAGB], biliopancreatic diversion with duodenal switch [BPD/DS], and single anastomosis duodeno-ileostomy with sleeve gastrectomy [SADI-S]) are described in the current literature [8].

Recurrence of weight and associated diseases is not a failure of the procedure itself. All procedures are not able to offer a causal treatment of obesity. Recurrence is therefore in the same way an open problem, like in cancer treatment.

The ideal revision operation of failed SG remains unclear. Suggestions include conversion to RYGB in the case of reflux and BPD/DS in the case of weight regain after SG [9–11]. Arman et al. reported that 25% of failed SGs (20/110 patients) involved conversion to another construction, including ten BPD/DS, four RYGB, and three re-sleeve procedures for weight issues, increasing the percentage of excess BMI loss (%EBMIL) from 62.5% to 81.7% ($p = 0.015$) with BPD/DS as the preferred procedure for weight regain [6]. Felsenreich et al. described a conversion rate of 36% (19/56 patients) at a median of 36 months after SG. Those patients were converted to RYGB ($n = 18$) owing to significant weight regain ($n = 10$), reflux ($n = 6$), or acute revision ($n = 2$) [5].

Insufficient weight loss/regain remains an important long-term complication. A mean EWL of 50–60% [1–4, 12] can be achieved in the long-term after SG, but many have had less positive results. In addition to failed weight loss/regain, GERD is another long-term complication that occurs in about 20–30% of patients, and the long-term incidence and impact of Barrett's esophagus are still unclear [4, 7, 13, 14].

MGB/OAGB as a primary and second-stage rescue procedure is growing in adoption around the world [15, 16]. MGB/OAGB links the effect of RYGB as a low-pressure system and a less dangerous malabsorptive procedure than BPD/DS [17, 18]. Thus, it associates the positive effects of BPD/DS and RYGB with further excess weight loss (EWL) and the treatment of GERD. The current literature confirms the safety and long-term effectiveness of MGB/OAGB as a primary procedure [19–21] as well as a revisional surgery for failed gastric-restrictive procedures [17, 18, 22, 23, 24].

Whether re-sleeve, RYGB, MGB/OAGB, SADI, SASI, SAGI, or BPD/DS remains the surgery of choice after failed SG is unclear. Our own results published in 2011 and 2019 [8, 24]. The results of conversions to RYGB and MGB during 2014–2018 in comparison will be shown more detail later. The current literature shows varying results, and no comparisons between revisional RYGB and revisional MGB/OAGB after failed SG have been performed. Thus, the aim of the present study is to analyze the results of RYGB and MGB/OAGB as revisional surgery after failed SG from a single center.

29.2 Definition of the Procedures and Historic Background

The name of MGB/OAGB or OAGB alone is still under discussion. Finally, there are two types of the procedure:

1. Originally mini-gastric bypass (MGB, named as the first minimal-invasive gastric bypass in 1997 or called also as malabsorptive gastric bypass) was devised by Rutledge in the USA in 1997 [20]. As a trauma surgeon, he was faced with an abdominal gunshot wound, where duodenal exclusion with a Billroth II anastomosis was an appropriate reconstruction. This was the inspiration for the MGB, constructing a *long* lesser curvature channel which inhibits gastroesophageal reflux (GERD).
2. OAGB/BUGA. Because of suspected GERD, in 2002 a variant of the MGB, named one anastomosis gastric bypass (OAGB) or BAGUA (bypass gastrico de una anastomosis), originated in Spain by Miguel Carbajo and Manoel Garcia-Caballero [25, 32]. Previously, they had performed the Roux-en-Y gastric bypass operation (RYGB) for >10 years.

The MGB and OAGB have been increasing throughout the world [26–33] and in 2015 became the third most common bariatric operation internationally [33].

Annual conferences on MGB and OAGB had been held in Paris, India, Montreal, Vienna, and London, where the MGB/OAGB Club was formed [34]. The first IFSO Consensus Conference on MGB/OAGB was in July 2019.

29.3 Personal Experiences

The ranking of primary bariatric procedures is changing from the beginning of obesity surgery. The periods become shorter and shorter. There is no era of "gold standard procedures" anymore. There is in the USA a long period with the RYGB as the "gold standard." The SG is the most popular procedure worldwide. After M. Gagner in the USA, we started with single-alone SG in 2001 in Europe together with Jacques Himpens in Belgium. After a slow start in the first 4 years, the SG became a rising popularity. The number of full BPD/DS decreased, and RYGB and SG became the most performed procedures. In our practice the SG became the leading procedure in 2006. The rise of the SG is shown in Fig. 29.1.

Worldwide MGB/OAGB is gaining popularity as a primary surgical treatment for morbid obesity due to reduced operation time, a shorter learning curve, better

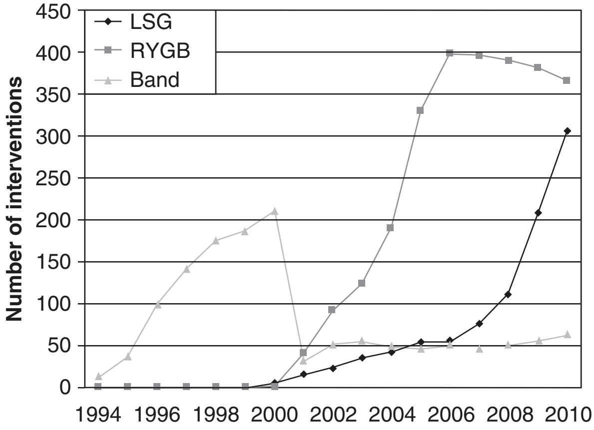


Fig. 29.1 Number of standard procedures (gastric banding, gastric bypass, sleeve gastrectomy) between 1994 and 2011

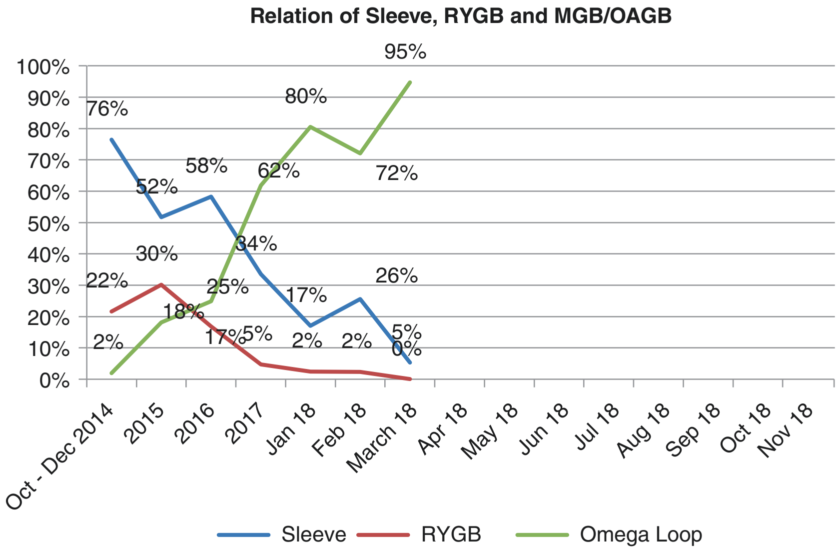


Fig. 29.2 Number of standard procedures (RYGB, SG, and MGB/OAGB) between 2014 and 2018

weight loss, and fewer major complications compared to RYGB. The MGB/OAGB became also in our practice the first choice in primary procedures (Fig. 29.2). These advantages of primary surgery could be transferred to revisional surgery after SG. Thus, the aim of our study was to compare MGB/OAGB and RYGB as revisional surgery after SG (s. below). As a primary, but not as a revisional procedure, it is the easiest reversible procedure, comparable with LAGB in the past.

29.4 Indications for Conversions from Sleeve Gastrectomy to MGB/OAGB

Revisional surgery from SG to RYGB or MGB/OAGB can be performed because of:

(a) Insufficient weight loss (EWL < 50%)
(b) Weight regain after successful weight loss (>15% regain of lost weight)
(c) Intractable GERD

Preoperative existing GERD resolved in the majority (>70%) after primary MGB (Table 29.1), explained by the decrease in gastroesophageal pressure gradient after MGB [35]. The same will happen after conversion from SG to MGB.

Indication for conversion in the case of intractable GERD included esophagitis ≥ grade B according to the Los Angeles classification. GERD-HRQL scores ≥ 12 in

Table 29.1 Postoperative changes reported after MGB and OAGB

	MGB	OAGB[a]
Mean 1 year post-op T2D resolution	85.9%	91.5%
Mean 5 years T2D resolution	79.8%	90.1%
Resolution of sleep apnea – 1 year	87.0%	95.4%
Resolution of sleep apnea – 5 years	86.7%	93.2%
Resolution of hypertension – 1 year	76.8%	80.6%
Resolution of hypertension – 5 years	69.0%	78.6%
Resolved elevated cholesterol – 1 year	82.1%	90.6%
Resolved elevated cholesterol – 5 years	73.0%	84.9%
Mean pre-op GER	**21.2%**	**22.0%**
Mean post-op GER	**0.07%**	**0%**
Post-op nausea, vomiting, and dyspepsia	8.0%	7.6%
Marginal ulcer	1.7%	1.4%
Diarrhea (>4 BMs/day)	2.3% ± 5.2	2.6% ± 4.4
Anemia	4.7%	6.3%
Severe anemia (<8 g/dl)	1.1% ± 3.1	2.1% ± 2.2
Major low serum albumin	0.4%	0.8%
Major nutritional complications requiring hospitalization	0.6%	1.2%
No. of post-op internal hernias	8 (0.02%)	3 (0.03%)
Revisions[b]	334 (0.9%)	126 (1.4%)

Total: 37,094 MGBs and 9203 OAGBs
T2D: type 2 diabetes
[a]No differences statistically between MGB and OAGB. *Source*. Deitel M., Kuldeepak S Kular. Consensus survey on mini-gastric bypass and one-anastomosis gastric bypass. Annals of Bariatrics & Metabolic Surgery. Online edition: http://meddocsonline.org/
[b]After MGB, revisions included 150 patients for EWL and 80 patients for inadequate wt loss. After OAGB, revisions included 82 patients for EWL and 19 patients for inadequate wt loss

proton pump inhibitor (PPI) treatment [36]. There are many reports and studies about de novo GERD. In the study of Kowalewski et al. [37], 60% of patients after SG reported recurring GERD symptoms, and 44% were treated with PPI. Only four participants complained of reflux before the surgery, which means that 93% of the cases developed de novo GERD. There is no statistically significant correlation between GERD symptoms and weight loss effect. Further is the impairment of "Quality of Life" one of the leading arguments [38, 39, 40].

Barrett The incidence in the literature has a wide range. In our experiences we have not seen the prevalence of >16–17% after 5–10 years [5, 14]. A submitted paper with FU of 15 years and more in 56 cases was not accepted, because the number of cases was mentioned to be too low. The abdominal esophagus is the shortest part of the organ (1–2 cm in length), crosses the diaphragm through the esophageal aperture, descends to the left of the midline, and ends at the esophagogastric junction. The phrenic-esophageal ligament keeps the esophagus in the diaphragmatic orifice and is divided in an ascending limb, up to the diaphragm, which is an extension of subpleural fascia, and a descending limb, often rich in adipose tissue, which is in continuity with the fascia transversalis. This adipose tissue in the inferior portion of the phrenic-esophageal ligament is a constant report and may be useful to individuate the esophagogastric junction. As an effect of the postoperative weight loss, the fat disappears, and the lower esophageal sphincter will be influenced, and a sleeve migration can happen.

Recommendation We decided to choose the RYGB reconstruction in cases of Barrett to have a guarantee for preventing any reflux.

Recurrence of comorbities after remission oder missing remission The resolution and the remission of diabetes type 2 plays an important role in the indication for revisonal surgery. The definition of diabetes resolution and remission was provided by the ASMBS outcome reporting standards [41]. The worsening of the EOSS score is an indication for revisional bariatric surgery as well.

29.5 Differential Indications for MGB/OAG Versus RYGB

In our department, the indication for MGB/OAGB is given in a failed SG when weight issues are the principal patient problem, while the indication for RYGB is given in a failed SG when GERD is the principal patient problem. Coexisting weight problems or metabolic disorders led us to choose a longer biliopancreatic limb length.

The metabolic syndrome is treated more powerful with a longer length of the biliopancreatic limb. This is independent from surgical reconstruction (one or two anastomoses). Biliopancreatic limb length more than 150 cm is associated with nutritional complication.

In patients with a biliopancreatic limb length of 200 cm, the incidence is 2–3% but is rapidly increasing with longer limb length. The discussion of total limb length measurement is not finished yet. In our experiences with all available procedures, we can state:

1. With a biliopancreatic limb length of 150 cm, the risk for malnutrition is low.
2. The length of the BL is more important than the length of the common channel (CC).

Ahuja et al. (2018) [42] published a comparative study. One hundred and one patients who underwent MGB/OAGB were divided into three groups of 150 cm, 180 cm, and 250 cm depending on the length of BPL bypassed. The nutritional parameters (vitamin D3, vitamin B12, serum iron, serum ferritin, total protein, serum albumin, serum globulin), anthropometric measurements (weight, BMI), and comorbidity resolution (T2DM, hypertension) were compared between the three groups at 1-year follow-up. There was statistically significant difference in number of patients having deficiencies in all the nutritional parameters except globulin between 150 cm and 250 cm groups($p < 0.05$). While on comparing 180 cm and 250 cm group, a statistically significant difference was present in vitamin D3, vitamin B12, and total protein ($p < 0.05$) only. The difference was statistically insignificant between the three groups on T2DM, hypertension resolution, and %EWL, but TWL between 150 cm vs 180 cm and 150 cm vs 250 cm showed significant difference. The authors concluded a 150 cm BPL length is adequate with very minimal nutritional complications and good results. A 180 cm BPL can be used in super obese, while a 250 cm BPL should be used with utmost care as it results in significant nutritional deficiencies. The same consequences have been expected after secondary MGB/OAGB after SG.

29.6 Contraindications

The classic contraindications *for all types of gastric bypass surgery* are:

1. Frozen abdomen (after peritonitis)
2. Smoker (recurrent ulcerations and perforations)
3. Chronic inflammatory bowel disease (Morbus Crohn)
4. Severe iron deficiencies

29.7 Informed Consent

RBS needs a very detailed explanation of risks and benefits. The evidence-based medicine should be the basis. The personal experience of the surgeon has to be explained as well.

29.8 Preoperative Diagnostic

All patients had to undergo full preoperative evaluation. Upper endoscopy is mandatory.

X-ray: In cases of potential use of metal clips in the primary SG

Attention! You must be sure that no metal clips were used during the primary SG. Metal clips were (unfortunately) often used for control of staple-line bleedings. If during the process of dividing the sleeve to create a gastric pouch only one clip will be in the staple line, a dysfunction will happen. If the primary SG was not done by yourself, then an X-ray can detect the number of clips and their location.

29.8.1 Surgical Steps

MGB/OAGB was performed starting with lysis of the typical adhesions after SG. The lesser curvature was skeletonized in the avascular zone of the angulus opening the omental bursa. A long gastric pouch was started beginning below the crow's foot with a horizontal 60 mm linear stapler. In the case of a dilated sleeve, re-sleeve was performed using a gastric tube (42 Ch). In a case of a giant hiatal hernia (>5 cm), we performed dissection of the angle of His and the hiatus and posterior closure of the crura using a gastric tube (42 Ch).

Then, the ligament of Treitz was located and identified. Starting at the ligament of Treitz, a 200 cm length of the small intestine was measured in 5 cm increments and then brought up and sutured to the gastric stump. A termino-lateral gastroenterostomy was created with a 60 mm linear stapler after a small incision was made with an ultrasound dissector at the anterior wall of the stomach and jejunum (Fig. 29.3). A gastric tube (24 Ch) was guided to the jejunum, and a double hand-sewn suture on the front wall (Vicryl 0) was performed and tested for leaks with methylene blue. A drainage tube was placed in the left upper abdomen. Patients received PPI treatment for 6 months after surgery.

29.8.2 Potential Surgical Mistakes

There are a number of potential mistakes. We can divide these mistakes in three groups:

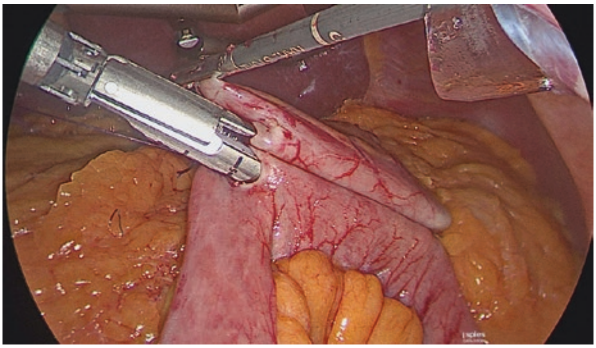


Fig. 29.3 Wide anastomosis as crucial principle of MGB. The linear stapler has a length of 60 mm

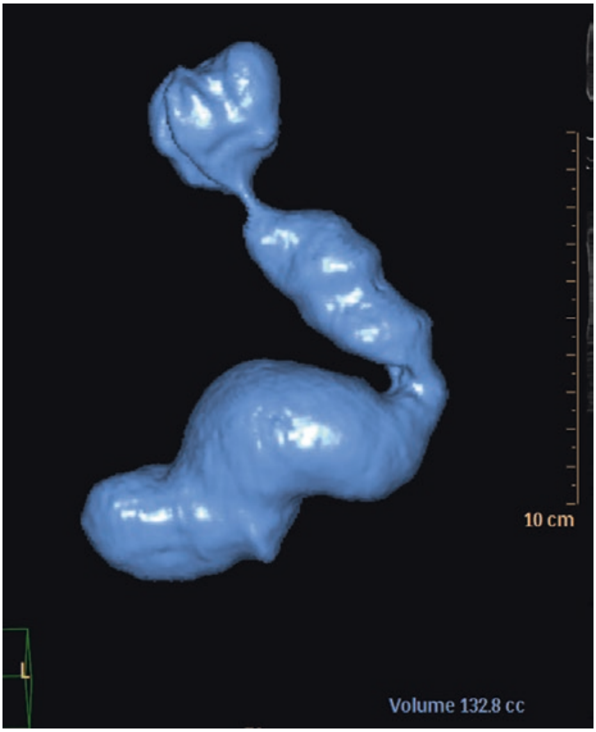


Fig. 29.4 Sleeve migration in the virtual CT scan

1. Level of diaphragm. A sleeve migration was not recognized (Fig. 29.4).
2. Level of dividing the stomach. If a functional or morphological stenosis of the sleeve indicated a revision (GERD), then short proximal gastric pouches do not allow an MGB/OAGB revision (Figs. 29.5 and 29.6). See Video 29.1 to prevent surgical mistakes. The grasper marked the wrong position for dividing the sleeve. The result is severe bile gastritis (Fig. 29.7) and bile reflux (Video 29.2).
3. Intestine lengths. Limb length more than 150 cm is associated with risks for malnutrition. More than 200 cm limb length increases the nutritional risks markable.

29.8.3 Early Postoperative Complications

Staple-line bleedings are the most common but rare early complications. Leaks of the gastroileostomy are less than in RYGB, because the anastomosis is directly in front of the camera and be controlled very well. Methylene blue test or bubble test is what we recommend in all cases.

Complications of the entero-entero anastomosis were missing, but tears in the intestine during the process of limb length measuring can happen.

Attention If you feel there was a defect of the intestinal mucosa, then have a second look during the procedure and not 2–4 days within a peritonitis.

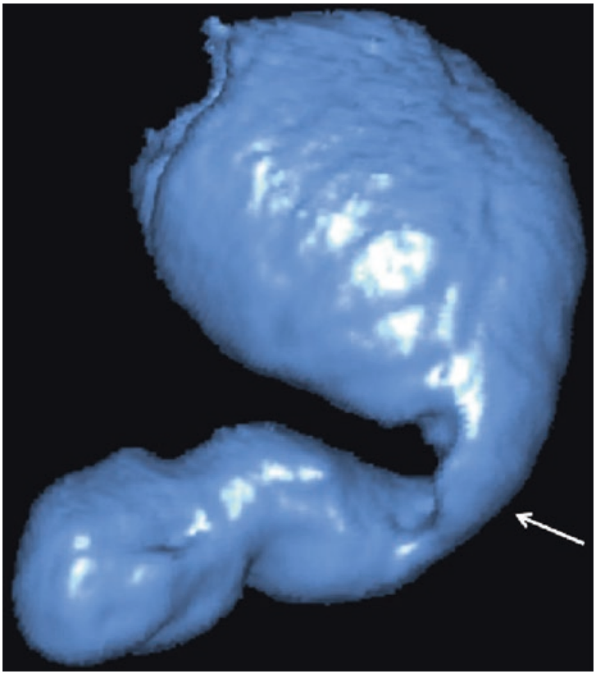


Fig. 29.5 CT imaging of sleeve stenosis. A conversion to MGB/OAGB is not possible, because the GE will be too proximal

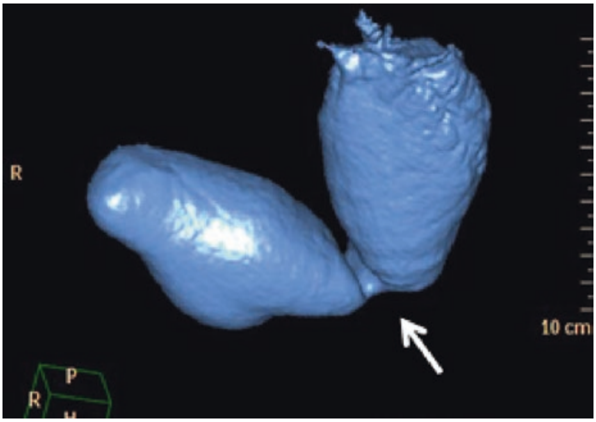


Fig. 29.6 CT imaging of sleeve stenosis. A conversion to MGB/OAGB is not possible, because the GE will be too proximal

29.8.4 Late Postoperative Complications

(a) *Ulcerations*. With the extension of the postoperative PPI medication up to 6 months and more, the number of ulcerations is markably decreased.
(b) *Internal hernias* (*rotation*). After all Roux reconstructions (RYGB, BPD, PBPD-DS), the risk for internal herniations with bowel obstructions exists (Fig. 29.8). The inci-

Fig. 29.7 Bile gastritis with reactive mucosal proliferations in the SG after conversion

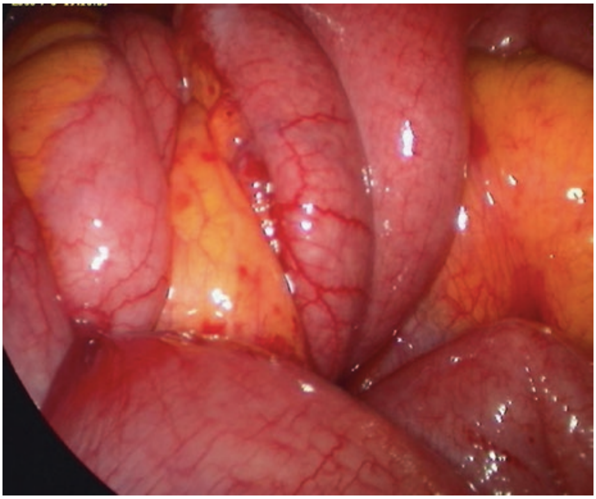


Fig. 29.8 Rotation of the intestine with twisted mesenterium. It is a kind of internal hernia, but not a Petersen hernia

dence of internal herniation can be lowered by surgical closure with nonabsorbable material. After MGB/OAGB is the calssic Petersen hernia not possible, but we can observe in a much lower incidence a rotation of the intestine with intermittent or complete obstruction. A small number of cases were published.

(c) *Cancer*. In general, the discussion about incidence of esophageal and gastric carcinoma after bariatric surgery is running. Many studies have shown that obesity is related with a higher incidence of many different carcinomas. After weight loss and reduction of the chronic inflammation in the body, the incidence of many cancers can be lowered. The data about the incidence of gastric carcinoma and esophageal carcinomas after bariatric surgery are not unique. Especially for MGB/OAGB, an increased risk for anastomotic cancer is discussed. The procedure is performed since more than 20 years, but only one case of cancer is reported.

(d) *Protein malnutrition*. This is one of the most challenging nutritional complications, because protein cannot be supplemented orally in an efficient way. Although if the weight loss was good, we did experience some patients who developed protein malnutrition and required revision surgery [13, 14]. We found that these patients had relative short bowel length which resulted in a short common channel or relative too long biliopancreatic limb.

(e) *Vitamin deficiencies A*, *D*, and *K*. Fat-soluble vitamins have to be supplemented, but also after regular intake of A, D, and K, deficiencies were seen. Night blindness is a symptom of vitamin A deficiency. Spontaneous hematoma is an alarming symptom of vitamin K deficiency; especially lacking K2 levels were seen in our practice very often. The supplementation of both is easy to handle by oral supplementation. The need for parenteral application is rare [46].

29.8.5 Results in Comparison to Conversions into MGB and RYGB (Study)

We performed a retrospective analysis of prospectively collected data. From October 2014 to December 2016, 55 patients underwent revisional surgery after failed SG with conversion to RYGB ($n = 21$) and MGB/OAGB ($n = 34$) at a center of excellence for obesity and metabolic surgery.

Figure 29.9 shows our current treatment algorithm in failed SG.

Data collected included the following: gender, age, body mass index (BMI), excess weight loss (EWL), total weight loss (TWL), time, indication for revisional surgery, and postoperative morbidity. Patients underwent follow-up (FU) at 1, 3, and 6 months and 1 year after surgery up to December 2017. Patients filled out the StuDoQ-German quality control questionnaire, which is the official questionnaire of the national German register for obesity and metabolic surgery, at 3 and 12 months after surgery. The eligibility criteria failed SG with indication for revisional surgery owing to weight regain/insufficient weight loss or intractable GERD. Continuous variables were presented as mean ± standard deviation (SD). Categorical variables were summarized with the use of frequencies and analyzed with the χÇ test. Continuous variables, when normally distributed, were reported as mean, SD, and range. Intergroup differences were tested by a two-sample t-test for normally distributed data. A p-value <0.05 was considered significant. Statistical analysis was performed using SPSS 25.0 for Windows (SPSS Inc., Chicago, IL, USA). Informed consent was obtained from all participants. All procedures involving human participants were performed in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. This work has been reported in line with the STROCSS (Strengthening the Reporting of Cohort Studies in Surgery) criteria [24]. Ethical approval was obtained from the local ethics committee (Landesärztekammer Hessen, Germany, reference number FF 3/2018), and all participants provided written informed consent for data sharing. The National Clinical Trials number is NCT03526783.

29.9 Study Design

29.9.1 Laparoscopic Roux-en-Y Gastric Bypass (RYGB)

RYGB was performed starting with lysis of the typical adhesions after SG. The lesser curvature was skeletonized at the level of the second to the third vascular arcade, opening the omental bursa. A gastric pouch was created with one or two horizontal (45 mm linear stapler) staple lines. In the case of a dilated sleeve, re-sleeve was performed using a gastric tube (24 Ch). In a case of a giant hiatal hernia (>5 cm), we performed a dissection of the angle of His and the hiatus and posterior closure of the crura using a gastric tube (42 Ch). Then, the ligament of Treitz was located and identified. Starting at the ligament of Treitz, a 50 cm length (200 cm

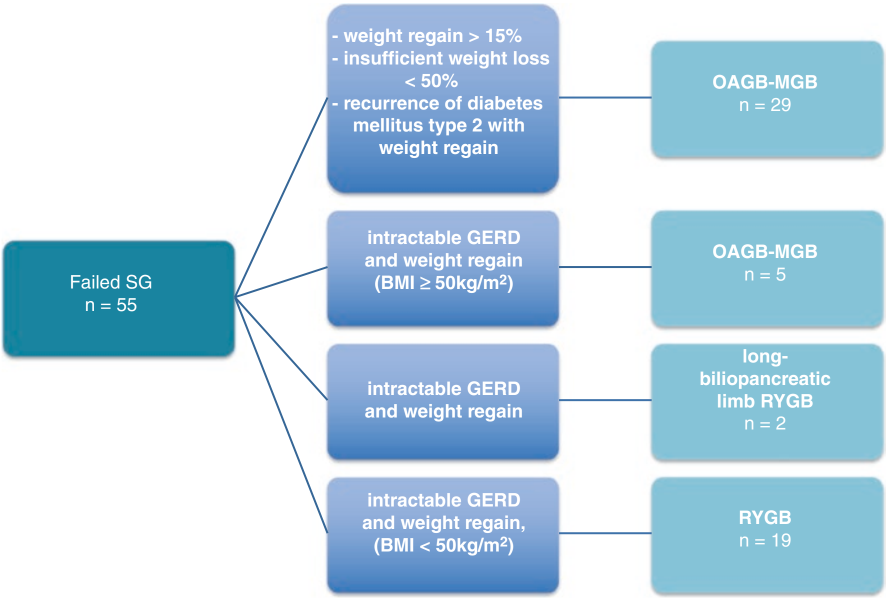


Fig. 29.9 Current internal treatment algorithm in failed sleeve gastrectomy. SG, sleeve gastrectomy; MGB/OAGB, mini/one anastomosis gastric bypass; RYGB, Roux-en-Y gastric bypass; GERD, gastroesophageal reflux disease

length in the case of a long BPL-RYGB) of the small intestine was measured in 5 cm increments and divided with a 45 mm linear stapler. The detached afferent limb of the jejunum was brought up and sutured to the gastric pouch. A termino-lateral gastroenterostomy was created with a 45 mm linear stapler after a small incision was made with an ultrasound dissector at the anterior wall of the stomach and jejunum. A gastric tube (24 Ch) was guided to the jejunum, and a double hand-sewn suture on the front wall (Vicryl 0) was performed and tested for leaks with methylene blue. A 150 cm alimentary limb (70 cm length in the case of a long BPL-RYGB) was measured in 5 cm increments to perform latero-lateral enteroenterostomy. The jejunal limbs were incised with an ultrasound dissector, and an anastomosis was created with two 45 mm linear staplers. The resulting defect was closed with a running suture (Vicryl 0). Brolin stitch was performed and mesenterial defects were closed. A drainage tube was placed in the left upper abdomen. Patients received PPI treatment for 6 weeks after surgery.

29.9.2 Laparoscopic Mini/One Anastomosis Gastric Bypass (MGB/OAGB)

MGB/OAGB was performed starting with lysis of the typical adhesions after SG. The lesser curvature was skeletonized in the avascular zone of the angulus opening the omental bursa. A long gastric pouch was started beginning below the crow's foot with a horizontal 60 mm linear stapler. In the case of a dilated sleeve, re-sleeve was performed using a gastric tube (42 Ch). In a case of a giant hiatal hernia (>5 cm), we performed dissection of the angle of His and the hiatus and posterior closure of the crura using a gastric tube (42 Ch). Then, the ligament of Treitz was located and identified. Starting at the ligament of Treitz, a 200 cm length of the small intestine was measured in 5 cm increments and then brought up and sutured to the gastric stump. A termino-lateral gastroenterostomy was created with a 45 mm linear stapler after a small incision was made with an ultrasound dissector at the anterior wall of the stomach and jejunum. A gastric tube (24 Ch) was guided to the jejunum, and a double hand-sewn suture on the front wall (Vicryl 0) was performed and tested for leaks with methylene blue. A drainage tube was placed in the left upper abdomen. Patients received PPI treatment for 6 months after surgery.

29.9.3 Results

A total of 55 patients were included. Conversion to RYGB was performed in 21 patients (2 males, 19 females) and conversion to MGB/OAGB in 34 (11 males, 23 females). Indications for revisional surgery included weight regain/insufficient

Table 29.2 Patient's data prior to revisional surgery ($n = 55$)

	$n = 55$	RYGB ($n = 21$)	MGB/OAGB ($n = 34$)	p-value
Age (years)	46.5 ± 11.1 (22–68)	46.14 ± 10.8 (22–61)	46.76 ± 11.48 (25–68)	$p = 0.84$
BMI before SG (kg/m^2)	53.4 ± 9.5 (36.3–72.6)	49.8 ± 9.3 (36.3–68.6)	56.5 ± 8.8 (38.4–72.6)	$p = 0.0097$
BMI at conversion (kg/m^2)	42.2 ± 8.7 (22.3–62.7)	36.6 ± 6.9 (22.2–51.9)	45.7 ± 8 (30.1–62.9)	$p = 0.0001$
BMI drop at 12 months (kg/m^2)		3.6 ± 3.3 (−3.3–9.3)	9.7 ± 5.8 (1.9–23.3)	$p = 0.0001$
Time after SG (months)	45.5 ± 22.3 (2–91)	35.59 ± 24.73 (2–84)	38.53 ± 22.02 (3–91)	$p = 0.6481$
EWL after SG (%)	42 ± 23 (0–124)	54 ± 28 (11–124)	35 ± 15 (0–76)	$p = 0.0018$
Nadir EWL after SG (%)	48 ± 23 (24–144)	61 ± 9 (24–144)	41 ± 15 (26–106)	$p = 0.0001$
Weight regain after nadir weight after SG (kg)	4.9 ± 4.09 (0–19)	4.2 ± 6.9 (0–9)	5.2 ± 4.7 (0.4–19)	$p = 0.5251$
TWL after SG (%)	21.5 ± 10.4 (0–47.2)	25.7 ± 12.8 (4.9–47.2)	18.9 ± 7.8 (0–35.5)	$p = 0.0175$

SG sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass, *FU* follow-up, *EWL* excess weight loss, *TWL* total weight loss, *BMI* body mass index

weight loss ($n = 37$, 67%) and intractable GERD ($n = 18$, 33%; 13/18 patients underwent RYGB and 5/18 underwent MGB/OAGB). Due to a giant hiatal hernia, additional hiatoplasty was performed in eight patients during RYGB and in four during MGB/OAGB. Patient data are listed in Table 29.2. Mean preoperative sleeve volume was measured by computed tomography volumetry in 52 patients with a mean volume of 182.12 ± 59.15 ml (80–370).

The average GERD-HRQL score was 12.9 ± 9.12 (range 0–35) in the RYGB group and 4.59 ± 5.02 (range 0–17) in the MGB/OAGB group. The average RSI score was 9.95 ± 8.6 (range 0–32) in the RYGB group and 4.97 ± 5.71 (range 0–19) in the MGB/OAGB group. At 1-year FU, the average RSI score was 2.9 ± 9.69 (range 0–45) in the RYGB group and 4.21 ± 5.8 (range 0–32) in the MGB/OAGB group.

FU at 1 year (December 2017) was 100% (55/55 patients).

29.10 RYGB Group

In the RYGB group ($n = 21$) prior to SG, mean BMI was 49.8 ± 9.3 kg/mÇ (range 36.3–68.6). Conversion was performed 33.3 ± 22.8 months (range 2–84) after SG with a mean EWL of 54% ± 28% (range 11–124) after SG.

Table 29.3 RYGB group ($n = 21$)

	Prior to SG	Prior to RYGB	3 months FU ($n = 21$)	12 months FU ($n = 21$)
Weight in kg	137.9 ± 28.5	101.6 ± 23.5	94.6 ± 21.6	87.1 ± 183
	(85–189)	(52.5–160)	(54–152)	(52–129)
BMI in kg/m²	49.8 ± 93	36.6 ± 6 9	34.1 ± 63	33.5 ± 5.6
	(36.3–68.6)	(22.2–51.9)	(23.1–48 7)	(22.2–44.8)
EWL in % since SG	–	54 ± 28	65 ± 23	76 ± 23
		01–124)	(23–117)	(35–125)
EWL in % since RYOT	–	–	11 ± 12	22 ± 18
			(−7–41)	(1–67)
TWL in % since SG	–	25.7 ± 12.8	30.8 ± 10.9	36 ± 10.8
		(4.9–473)	(10.8–50.6)	(16–54.4)
TWL in % since RYGB		–	5.1 ± 5.2	10.3 ± 7.6
			(−2.1–20)	(24–33.1)

SG sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass, *FU* follow-up, *EWL* excess weight loss, *TWL* total weight loss, *BMI* body mass index

The mean operation time of conversion of SG in RYGB was 98.2 ± 24.3 min (range 39–150). All conversions were performed laparoscopically. No intraoperative complications were seen. Blood loss was <10 ml in all patients. Length of hospital stay was 5 days in all patients, following our internal protocol. Within the first 30 postoperative days, three patients (three women) developed postoperative complications. An anastomotic ulcer was diagnosed via upper endoscopy at postoperative day 27 and was treated conservatively by intravenous PPI therapy and per oral aluminum complex (sucralfate 1–1–1–1) (Clavien–Dindo classification Grade II). One patient developed a postoperative ileus due to stenosis of the enteroenterostomy site, and reoperation was performed on the third postoperative day by revision of the entero-entero anastomosis (Clavien–Dindo classification Grade IIIb). Elevated inflammation signs, elevated lipase, and signs of mild postoperative pancreatitis on the computed tomography scan of the abdomen were treated conservatively in the third patient (Clavien–Dindo classification Grade II). The progression of weight, BMI, EWL, and TWL is listed in Table 29.3.

29.10.1 MGB/OAGB Group

In the MGB group prior to SG ($n = 34$), mean BMI was 56.5 ± 8.8 kg/mÇ (range 38.4–72.6). Conversion was performed 38.5 ± 22 months (range 3–91) after SG with a mean EWL of 35% ± 15 (range 0–76).

The mean operation time of conversion of SG in MGB was 78.7 ± 35.7 min (range 25–183). All conversions were performed laparoscopically. No intraoperative complications were seen. Blood loss was <10 ml in all patients. Length of stay was 5 days in all patients, following our protocol. During the first 30 postoperative

Table 29.4 MGB/OAGB group ($n = 34$)

	Prior to SG	Prior to MGB/OAGB	3 months FU ($n = 34$)	12 months FU ($n = 34$)
Weight in kg	164.4 ± 33 (110–233)	133.2 ± 28.6 (80–214.7)	119 ± 24.3 (74.5–183)	106.3 ± 21.2 (72.5–158)
BMI in kg/m^2	56.5 ± 8.8 (38.4–72.6)	45.7 ± 8 (30.1–62.9)	40.9 ± 6.8 (28.9–53.5)	36.6 ± 6.3 (25.7–47.8)
EWL in % since SG	–	35 ± 15 (0–76)	50 ± 16 (7–82)	64 ± 16 (42–97)
EWL in % since MGB/OAGB	–	–	15 ± 10 (3–45)	29 ± 13 (9–69)
TWL in % since SG	–	18.9 ± 7.8 (0–35.5)	27.2 ± 8.7 (3.5–45.4)	34.7 ± 9.3 (19.1–60.5)
TWL in % since MGB/OAGB	–	–	8.3 ± 5.6 (1.6–27.7)	15.8 ± 7.8 (4–43.1)

SG sleeve gastrectomy, *MGB/OAGB* mini/one anastomosis gastric bypass, *FU* follow-up, *EWL* excess weight loss, *TWL* total weight loss, *BMI* body mass index

days, no patient had a surgical complication. The progression of weight, BMI, EWL, and TWL is listed in Table 29.4.

29.10.2 RYGB Group Versus MGB/OAGB Group

Both groups were similar in age ($p = 0.84$) at conversion and time of conversion ($p = 0.6481$) after SG. The MGB group had a higher BMI prior to conversion (45.7 kg/mÇ in the MGB/OAGB group vs 36.6 kg/mÇ in the RYGB group) ($p = 0.0001$). At 12 months, mean additional %TWL post-revision was 10.3% ± 7.6% in the RYGB group and 15.8% ± 7.8% in the MGB/OAGB group ($p = 0.0132$, Fig. 29.10). Figure 29.11 shows the trend of EWL over time.

Comparing conversion of failed SG to RYGB or MGB/OAGB showed a significantly favorable operation time. MGB/OAGB was performed in 79 ± 36 min (range 25–183) vs RYGB in 98 ± 24 min (range 39–150) ($p = 0.03$).

At preoperative assessment, 18 (32.7%) patients were being treated for 1 or more comorbidities:

12 (21.8%) had type 2 diabetes mellitus (8 by insulin), 21 (38.2%) had oral treatment for dyslipidemia, 7 (12.7%) were on continuous positive airway pressure, and 12 (21.8%) were under medical treatment for hypertension. In addition, 26 patients (47.3%) took PPIs for GERD.

FU was protocolled up to 1 year after surgery. Table 29.5 shows the different symptoms and complications as asked in the official questionnaire of the national German register for obesity and metabolic surgery (StuDoQ|Metabolische & Bariatrische Erkrankungen-Questionnaire) at 12 months. Readmission due to gastrointestinal problems was 7/21 (58%) in the RYGB and 3/12 (25 %) in the MGB/

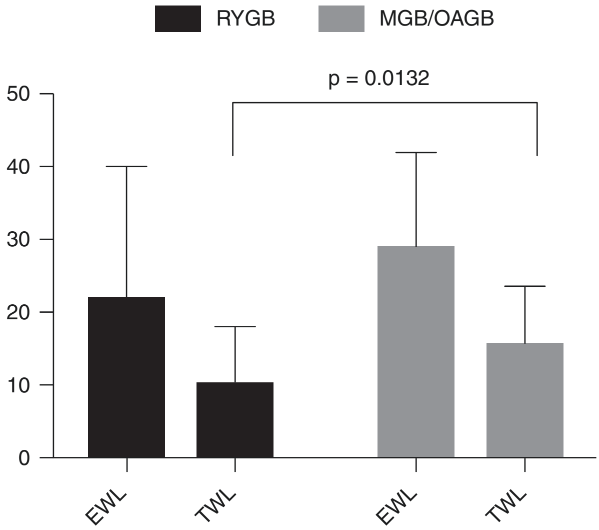


Fig. 29.10 Excess weight loss (EWL)% and total weight loss (TWL)% 12 months after RYGB and MGB/OAGB. A statistic significant difference was seen regarding weight loss. MGB/OAGB, mini/one anastomosis gastric bypass; RYGB, Roux-en-Y gastric bypass

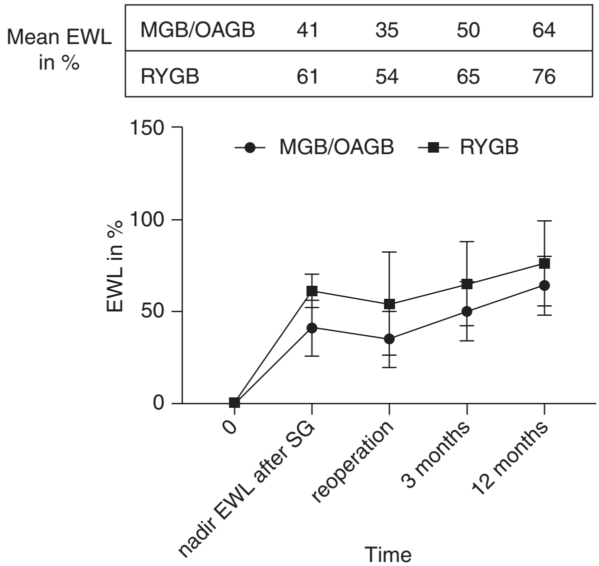


Fig. 29.11 Trend of excess weight loss. EWL in % in the MGB/OAGB and RYGB group with the sleeve procedure, the nadir weight reached after SG, EWL at the time of reoperation, and the progression of EWL after the second-step operation at 3 and 12 months. Means are expressed in the upper box. SG, sleeve gastrectomy; MGB/OAGB, mini/one anastomosis gastric bypass; RYGB, Roux-en-Y gastric bypass; EWL, excess weight loss

OAGB group during the first postoperative year. Diagnostics included upper endoscopy and a glucose tolerance test. Upper abdominal pain was mostly related to anastomotic ulcers, bile reflux, and dumping syndrome. Lower abdominal pain was mostly related to flatulence, diarrhea, and obstipation. All complications seen up to 1 year were Clavien–Dindo I and II complications, and pharmacological treatment (Clavien–Dindo II) was given in GERD (PPI per os), bile reflux (cholestyramine per os), dumping (dietary changes, acarbose), and anastomotic ulcers (high dosage of intravenous PPI for 1 week). All symptoms resolved with this

Table 29.5 Comparison of 1-year FU complications (Clavien–Dindo Classification I–II)

	RYGB (*n* = 21)	MGB/OAGB (*n* = 34)
Upper GI symptoms		
Nausea	5/21 (23.8%)	4.34 (11.8%)
Vomiting	4/21 (19%)	3/34 (5.9%)
Upper abdominal pain	3/21 (14.3%)	4/34 (11.8%)
Lower abdominal pain	2/21 (9.5%)	4/34 (11.8%)
Anastomotic ulcers		
Symptomatic bile reflux	2/21 (9.5%)	6/34 (17.6%)
Lower GI symptoms		2.34 (5.9%)
Foul smelling bowels	2/21 (9.5%)	12/34 (35.3%)
Flatulence	3/21 (14.3%)	12/34 (35.3%)
Diarrhea	3/21 (14.3%)	12/34 (35.3%)
Obstipation	1/21 (4.8%)	1/34 (2.9%)
Dermatologic symptoms		
Dystrophic nails	1/21 (4.8%)	3/34 (8.8%)
Dermatitis	0/21 (0%)	3/34 (8.8%)
Glossitis	0/21 (0%)	0/34 (0%)
Neurologic symptoms		
Muscle pain	0/21 (0%)	3/34 (8.8%)
Ataxia	0/21 (0%)	0/34 (0%)
Paresthesia	2/21 (9.5%)	5/34 (14.7%)
Hair loss	4/21 (19%)	7/34 (20.6%)
Fatigue	5/21 (23.8%)	5/34 (14.7%)
Dumping syndrome	4/21 (19%)	1/34 (2.9%)
GERD	1/21 (4.8%)	4/34 (11.8%)

Table 29.6 Resolution of comorbidities at 1-year FU

	RYGB (*n* = 21)	MGB/OAGB (*n* = 34)
Resolution of comorbidities		
Diabetes mellitus	−3/5 (60%)	−7/7 (100%)
Hypertension	−0/3 (0%)	−6/9 (66.7%)
Dyslipidemia	−2/8 (25%)	−8/13 (61.5%)
Sleep apnea	−0/2 (0%)	−4/5 (80%)

RYGB Roux-en-Y gastric bypass, *MGB/OAGB* one/mini anastomosis gastric bypass

treatment. No revisional surgery was performed during the first year of FU, and mortality was 0%. No significant differences were seen between the bypass groups. One-year FU showed more upper gastrointestinal symptoms in the RYGB and more lower gastrointestinal symptoms in the MGB/OAGB group, but without any statistical significance between groups.

Table 29.6 shows the metabolic changes. Twelve patients had type 2 diabetes mellitus, two of whom reported a recurrence of type 2 diabetes mellitus after SG. In these two patients, MGB/OAGB was performed. Percentages of comorbidities resolved were type 2 diabetes mellitus, 100%; hypertension, 66.7%; dyslipidemia, 61.5%; and obstructive sleep apnea, 80%. One-year FU showed greater metabolic improvement after MGB/OAGB.

29.11 Discussion

Redo and revisional surgeries after SG are increasing due to insufficient weight loss, weight regain, and intractable GERD. Whether re-sleeve, RYGB, MGB/OAGB, or BPD/DS is the best second-step procedure remains under debate.

MGB/OAGB is gaining popularity as a primary surgical treatment for morbid obesity because of its reduced operation time, shorter learning curve, better weight loss, and fewer major complications compared with RYGB [18, 21, 29, 30]. A summary of comparisons between both types of gastric bypass was shown in Table 29.1.

The advantages of MGB/OAGB include the technical simplicity to handle revisional surgery, the low-pressure system of MGB/OAGB, the additional weight loss, and the metabolic answer of this procedure that adds fatty food intolerance/fat malabsorption [23, 29, 30, 43, 44, 54]. While SG induces a significant elevation in intragastric pressures and gastroesophageal pressure gradient, MGB/OAGB statistically diminishes both parameters [31]. Furthermore, MGB/OAGB is believed to cause marked fatty food and sweet intolerance and is more malabsorptive than the standard RYGB owing to its longer BPL 30, without reaching the malabsorptive dangers of BPD/DS with its disadvantageous side effects [32, 33], thereby resulting in additional weight loss. These advantages of primary surgery could be transferred to revisional surgery after failed SG.

The heterogeneity of the current studies with different revisional procedures and exanimated parameters makes it difficult to compare revisional surgeries after failed SG. In 2014, Cheung et al. [47] performed a systematic review of 11 primary studies (218 patients) on revisional bariatric surgery following failed primary SG and found only limited evidence for selecting the appropriate revisional operation. Both RYGB and re-sleeve achieved effective weight loss following failed SG. They concluded that the less technically challenging nature of re-sleeve may be more widely applicable and that further research is required to elicit the sustainability of long-term weight loss benefits [34]. The negative effects of re-sleeve in the form of the risk of leakage, the high-pressure system, and the absence of an additional malabsorptive effect must be kept in mind when choosing this type of revisional surgery.

The most common mistake is the division of the sleeve in a too proximal level, as shown in the Video 29.1. Severe bile reflux will be a potential result. Correctly, the resection of the sleeve should start in the middle part of the antrum. With a super long sleeve and a wide anastomosis below the transverse colon, the patient could expect the best outcome.

Summarizing the current literature, revisional MGB/OAGB for a failed restrictive procedure was found to be safe and effective for 5 years. However, quality of life and upper gastrointestinal function seem to be lower compared with primary MGB/OAGB [19]. Furthermore, RYGB was found to be a feasible, effective, and well-tolerated alternative in selected patients with failed SG with improved secondary weight loss and GERD. Quezeda et al. [48] reported that over 90% of GERD patients had resolved or improved symptoms [35], but Poghosyan et al. [49] underlined the high-cost morbidity (11.7%) of revisional RYGB [24]. At least, BPD/DS yielded greater weight loss compared with RYGB, and Carmeli et al. concluded that the mechanism of failure should guide the selection of the second procedure [37–45].

However, BPD/DS involves an important risk of complications such as severe protein-calorie malnutrition and micronutrient and vitamin deficiencies [50].

A novel study with a concomitant literature review by Parmar et al. demonstrated that the conversion of SG to RYGB is effective for GERD symptoms, but not for further weight loss. The conversion to RYGB is very effective for GERD, with 100% of patients reporting improvement in symptoms and 80% reporting being able to stop their antacid medications; however, the study group concluded that future studies need to examine the best revisional procedure for insufficient weight loss or weight regain after SG [51].

In our study [24], weight loss was better ($p = 0.0132$), operation time was faster ($p = 0.03$), and early surgical complications were lower in the MGB/OAGB compared with the RYGB group. After 1-year FU, no statistical significance was seen in regard to postoperative complications. At 1-year FU, 4.8% of the RYGB and 11.8% of the MGB/OAGB patients had still reflux symptoms ($p = 0.6$).

The addition of further weight loss and technical facilities in our study underlines the positive effects of MGB/OAGB as a second-step procedure after failed SG compared with RYGB.

Since revisional procedures are associated with higher rates of readmission and overall morbidity [52], it is important to choose a safe and straightforward technical surgical procedure for revisional surgery to maintain the best effects on further weight loss and existing GERD.

Some limitations of the present study must be mentioned:

First, the study had a FU of only 1 year. Long-term FU is needed to point out the positive and negative effects of MGB/OAGB in the long term.

Second, a selection bias could attenuate the study results. In our department, the indication for MGB/OAGB is given in failed SG due to weight issues and that for RYGB is given in failed SG due to GERD. Thus, the MGB/OAGB group had a higher BMI prior to conversion (45.7 kg/mÇ in the MGB/OAGB group vs 36.6 kg/mÇ in the RYGB group, $p = 0.0001$).

Third, since RYGB and MGB/OAGB are malabsorptive procedures, the nutritional parameters for each group would have been interesting but are missing due to outpatient laboratory examinations.

29.12 Conclusion from our Study and the Literature

At 1-year FU, MGB/OAGB after failed SG was found to be safe, technically easier, and effective as a second-step procedure compared with RYGB.

Thus, MGB/OAGB should be considered as a second-step surgery after failed SG.

Further data are necessary to highlight the positive effects of MGB/OAGB in the long term.

With biliopancreatic limb (BL) lengths of 150 cm, the weight loss and metabolic effects are powerful. The BL should not extend 200 cm. Also with 200 cm limb length, up to 3% cases with severe malnutrition can be expected. The limb length can be changed easily.

In cases of severe GERD and bile gastritis, the conversion into an RYGB can be performed. The alimentary limb length should be at least between 60 and 70 cm to prevent any bile reflux into the sleeve-like gastric pouch.

Compliance with Ethical Standards

Conflict of Interest: All authors have no conflicts of interest or financial ties to disclose.
Informed consent: Informed consent was obtained from all the individual participants included in the study.
Ethical Approval: All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

References

1. Sarela AI, Dexter SP, O'Kane M, Menon A, McMahon MJ. Long-term follow-up after laparoscopic sleeve gastrectomy: 8-9-year results. Surg Obes Relat Dis. 2012;8:679–84.
2. Diamantis T, Apostolou KG, Alexandrou A, Griniatsos J, Felekouras E, Tsigris C. Review of long-term weight loss results after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2014;10:177–83.
3. Gadiot RP, Biter LU, van Mil S, Zengerink HF, Apers J, Mannaerts GH. Long-term results of laparoscopic sleeve gastrectomy for morbid obesity: 5 to 8-year results. Obes Surg. 2017;27:59–63.
4. Himpens J, Dobbeleir J, Peeters G. Long-term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252:319–24.
5. Felsenreich DM, Langer FB, Kefurt R, et al. Weight loss, weight regain, and conversions to Roux-en-Y gastric bypass: 10-year results of laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2016;12:1655–62.
6. Arman GA, Himpens J, Dhaenens J, Ballet T, Vilallonga R, Leman G. Long-term (11+ years) outcomes in weight, patient satisfaction, comorbidities, and gastroesophageal reflux treatment after laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2016;12:1778–86.
7. Braghetto I, Csendes A. Prevalence of Barrett's esophagus in bariatric patients undergoing sleeve gastrectomy. Obes Surg. 2016;26:710–4.
8. Weiner RA, Theodoridou S, Weiner S. Failure of laparoscopic sleeve gastrectomy--further procedure? Obes Facts. 2011;4(Suppl 1):42–6.
9. El Chaar M, Stoltzfus J, Claros L, Miletics M. Indications for revisions following 630 consecutive laparoscopic sleeve gastrectomy cases: experience in a single accredited center. J Gastrointest Surg. 2017;21:12–6.
10. Homan J, Betzel B, Aarts EO, van Laarhoven KJ, Janssen IM, Berends FJ. Secondary surgery after sleeve gastrectomy: Roux-en-Y gastric bypass or biliopancreatic diversion with duodenal switch. Surg Obes Relat Dis. 2015;11:771–7.
11. Casillas RA, Um SS, Zelada Getty JL, Sachs S, Kim BB. Revision of primary sleeve gastrectomy to Roux-en-Y gastric bypass: indications and outcomes from a high-volume center. Surg Obes Relat Dis. 2016;12:1817–25.
12. Bohdjalian A, Langer FB, Shakeri-Leidenmuhler S, et al. Sleeve gastrectomy as sole and definitive bariatric procedure: 5-year results for weight loss and ghrelin. Obes Surg. 2010;20:535–40.

13. Lauti M, Kularatna M, Hill AG, MacCormick AD. Weight regain following sleeve gastrectomy: a systematic review. Obes Surg. 2016;26:1326–34.
14. Genco A, Soricelli E, Casella G, et al. Gastroesophageal reflux disease and Barrett's esophagus after laparoscopic sleeve gastrectomy: a possible, underestimated long-term complication. Surg Obes Relat Dis. 2017;13:568–74.
15. Jammu GS, Sharma R. A 7-year clinical audit of 1107 cases comparing sleeve gastrectomy, Roux-En-Y gastric bypass, and mini-gastric bypass, to determine an effective and safe bariatric and metabolic procedure. Obes Surg. 2016;26:926–32.
16. Plamper A, Lingohr P, Nadal J, Rheinwalt KP. Comparison of mini-gastric bypass with sleeve gastrectomy in a mainly super-obese patient group: first results. Surg Endosc. 2017;31:1156–62.
17. Disse E, Pasquer A, Espalieu P, Poncet G, Gouillat C, Robert M. Greater weight loss with the omega loop bypass compared to the Roux-en-Y gastric bypass: a comparative study. Obes Surg. 2014;24:841–6.
18. Cavin JB, Voitellier E, Cluzeaud F, et al. Malabsorption and intestinal adaptation after one anastomosis gastric bypass compared with Roux-en-Y gastric bypass in rats. Am J Physiol Gastrointest Liver Physiol. 2016;311:G492–500.
19. Noun R, Zeidan S, Riachi E, Abboud B, Chalhoub V, Yazigi A. Mini-gastric bypass for revision of failed primary restrictive procedures: a valuable option. Obes Surg. 2007;17:684–8.
20. Rutledge R, Walsh TR. Continued excellent results with the mini-gastric bypass: sixyear study in 2,410 patients. Obes Surg. 2005;15:1304–8.
21. Musella M, Susa A, Manno E, et al. Complications following the mini/one anastomosis gastric bypass (MGB/OAGB): a multi-institutional survey on 2678 patients with a mid-term (5 years) follow-up. Obes Surg. 2017;27:2956–67.
22. Bruzzi M, Voron T, Zinzindohoue F, Berger A, Douard R, Chevallier JM. Revisional single-anastomosis gastric bypass for a failed restrictive procedure: 5-year results. Surg Obes Relat Dis. 2016;12:240–5.
23. Moszkowicz D, Rau C, Guenzi M, Zinzindohoue F, Berger A, Chevallier JM. Laparoscopic omega-loop gastric bypass for the conversion of failed sleeve gastrectomy: early experience. J Visc Surg. 2013;150:373–8.
24. Chiappetta S, Stier C, Scheffel O, Squillante S, Weiner RA. Mini/one anastomosis gastric bypass versus Roux-en-Y gastric bypass as a second step procedure after sleeve gastrectomy—a retrospective cohort study. Obes Surg. 2019;29(3):819–27. https://doi.org/10.1007/s11695-018-03629-y.
25. Garcia-Caballero M, Carbajo MA. One anastomosis gastric bypass: a simple, safe and efficient procedure for treating morbid obesity. Nutr Hosp. 2004;19:372–5.
26. Lee WJ, Yu PJ, Wang W, Chen TC, Wei PL, Huang MT. Laparoscopic Roux-en-Y versus mini-gastric bypass for the treatment of morbid obesity: a prospective randomized controlled clinical trial. Ann Surg. 2005;42:20–8.
27. Rutledge R. Revision of failed gastric banding to mini-gastric bypass. Obes Surg. 2006;16:521–3.
28. Chevallier J-M, Chakhtoura G, Zinzindohoue F. Laparoscopic mini-gastric bypass. In: Deitel M, Gagner M, Dixon JB, Himpens J, editors. Handbook of obesity surgery. Toronto: FD-Communications; 2010. p. 78–84.
29. Noun R, Skaff J, Riachi E, Daher R, Antoun NA, Nasr M. One thousand consecutive mini-gastric bypass: short and long-term outcome. Obes Surg. 2012;22:697–703.
30. Musella M, Sousa A, Greco F, De Luca M, Manno E, Di Stefano C, et al. The laparoscopic mini-gastric bypass: the Italian experience: outcomes from 974 consecutive cases in a multi-center review. Surg Endosc. 2014;28:156–63.
31. Kular KS, Manchanda N, Rutledge R. A 6-year experience with 1,054 mini-gastric bypasses – first study from Indian subcontinent. Obes Surg. 2014;24:1430–5.
32. Carbajo MA, Luque-de-Leon E, Jiminez JM, Ortiz-de-Solorzano J, Perez-Miranda M, Castro-Alija MJ. Laparoscopic one-anastomosis gastric bypass: technique, results, and long-term follow-up in 1200 patients. Obes Surg. 2017;27:1153–67.
33. Deitel M. Letter to the editor: bariatric surgery worldwide 2013 reveals a rise in mini gastric bypass. Obes Surg. 2015;25:2165.

34. Deitel M, Kular KS, Musella M, Carbajo M, Luque-de-Lyon E. A new organization – The MGB-OAGB Club. Bariatr News. 2016;26:10.
35. Tolone S, Cristiano S, Savarino E, Lucido FS, Fico DI, Docimo L. Effects of omega-loop bypass on esophagogastric junction function. Surg Obes Relat Dis. 2016;12:62–9.
36. Agha RA, Borrelli MR, Vella-Baldacchino M, Thavayogan R, Orgill DP, STROCSS Group. The STROCSS statement: strengthening the reporting of cohort studies in surgery. Int J Surg. 2017;46:198–202.
37. Kowalewski PK, Olszewski R, Walędziak MS, Janik MR, Kwiatkowski K, Gałązka-Świderek N, Cichoń K, Brągoszewski J, Paśnik K. Long-term outcomes of laparoscopic sleeve gastrectomy—a single-center, retrospective study. Obes Surg. 2018;28:130–4.
38. Velanovich V. The development of the GERD-HRQL symptom severity instrument. Dis Esophagus. 2007;20:130–4.
39. Belafsky PC, Postma GN, Koufman JA. Validity and reliability of the reflux symptom index (RSI). J Voice. 2002;16:274–7.
40. Shantavasinkul PC, Omotosho P, Corsino L, Portenier D, Torquati A. Predictors of weight regain in patients who underwent Roux-en-Y gastric bypass surgery. Surg Obes Relat Dis. 2016;12:1640–5.
41. Brethauer SA, Kim J, el Chaar M, et al. Standardized outcomes reporting in metabolic and bariatric surgery. Surg Obes Relat Dis. 2015;11:489–506.
42. Ahuja A, Tantia O, Goyal G, Chaudhuri T, Khanna S, Poddar A, Gupta S, Majumdar K. MGB-OAGB: Effect of Biliopancreatic Limb Length on Nutritional Deficiency, Weight Loss, and Comorbidity Resolution.Obes Surg. 2018 Nov;28(11):3439–45. https://doi.org/10.1007/s11695-018-3405-7.
43. Lee WJ, Ser KH, Lee YC, Tsou JJ, Chen SC, Chen JC. Laparoscopic Roux-en-Y vs. mini-gastric bypass for the treatment of morbid obesity: a 10-year experience. Obes Surg. 2012;22:1827–34
44. Lee WJ, Yu PJ, Wang W, Chen TC, Wei PL, Huang MT. Laparoscopic Roux-en-Y versus mini-gastric bypass for the treatment of morbid obesity: a prospective randomized controlled clinical trial. Ann Surg. 2005;242:20–8.
45. Dolan K, Hatzifotis M, Newbury L, Lowe N, Fielding G. A clinical and nutritional comparison of biliopancreatic diversion with and without duodenal switch. Ann Surg. 2004;240:51–6.
46. Slater GH, Ren CJ, Siegel N, et al. Serum fat-soluble vitamin deficiency and abnormal calcium metabolism after malabsorptive bariatric surgery. J Gastrointest Surg. 2004;8:48–55; discussion 54–5.
47. Cheung D, Switzer NJ, Gill RS, Shi X, Karmali S. Revisional bariatric surgery following failed primary laparoscopic sleeve gastrectomy: a systematic review. Obes Surg. 2014;24:1757–63.
48. Quezada N, Hernandez J, Perez G, Gabrielli M, Raddatz A, Crovari F. Laparoscopic sleeve gastrectomy conversion to Roux-en-Y gastric bypass: experience in 50 patients after 1 to 3 years of follow-up. Surg Obes Relat Dis. 2016;12:1611–5.
49. Poghosyan T, Lazzati A, Moszkowicz D, et al. Conversion of sleeve gastrectomy to Roux-en-Y gastric bypass: an audit of 34 patients. Surg Obes Relat Dis. 2016;12:1646–51.
50. Carmeli I, Golomb I, Sadot E, Kashtan H, Keidar A. Laparoscopic conversion of sleeve gastrectomy to a biliopancreatic diversion with duodenal switch or a Roux-en-Y gastric bypass due to weight loss failure: our algorithm. Surg Obes Relat Dis. 2015;11:79–85.
51. Parmar CD, Mahawar KK, Boyle M, Schroeder N, Balupuri S, Small PK. Conversion of sleeve gastrectomy to Roux-en-Y gastric bypass is effective for gastro-oesophageal reflux disease but not for further weight loss. Obes Surg. 2017;27:1651–8.
52. Stefanidis D, Malireddy K, Kuwada T, Phillips R, Zoog E, Gersin KS. Revisional bariatric surgery: perioperative morbidity is determined by type of procedure. Surg Endosc. 2013;27:4504–10.
53. Chen CY, Lee WJ, Lee HM, et al. Laparoscopic conversion of gastric bypass complicationto sleeve gastrectomy: technique and early results. Obes Surg. 2016;26:2014–21.
54. Lee WJ, Lee YC, Ser KH, Chen SC, Chen JC, Su YH. Revisional surgery for laparoscopic minigastric bypass. Surg Obes Relat Dis. 2011;7(4):486–91.

Chapter 30
Conversion of Sleeve Gastrectomy to Duodenal Switch

Andrew Luhrs and Ranjan Sudan

30.1 Introduction

After nearly 20 years, laparoscopic sleeve gastrectomy (SG) has become a well-established stand-alone procedure for the treatment of morbid obesity. Originally devised as a component of a biliopancreatic diversion and duodenal switch (BPD/DS), many patients who underwent SG as the first stage of the BPD/DS achieved adequate weight loss and therefore did not require the second stage. Since 2013 SG has been the most commonly performed weight loss surgery in the United States and as of 2017 represented over 59% of all cases performed [1]. The proponents of SG cite low complication rates, respectable percent excess weight loss (60% EWL at 5 years), and resolution of the comorbidities associated with obesity [2].

However, despite the seeming successes of SG as a primary bariatric procedure, long-term data suggests a non-responder (defined as failing to achieve or maintain >50%EWL) rate as high as 50% at 6–8 years with between 6.8% and 30% ultimately undergoing a revision surgery [3–5]. The vast majority of SG patients requiring revision are due to inadequate weight loss or weight regain [4]. Other common causes of SG revisions include severe gastroesophageal reflux and sleeve stricture.

A number of surgical options have been described to aid patients who have been unable to lose adequate weight after SG including resleeve of the initial sleeve gastrectomy (reSG) and conversion to another bariatric operation, including adjustable gastric banding (AGB), Roux-en-Y gastric bypass (RNYGB), or biliopancreatic diversion and duodenal switch (BPD/DS). When considering primary bariatric surgery, the BPD/DS has been shown to have superior weight loss and results in greater

A. Luhrs · R. Sudan (✉)
Department of Surgery, Brown University, Providence, RI, USA
e-mail: Ranjan.Sudan@duke.edu

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_30

than 70% EWL (compared to 45% EWL for AGB and approximately 60% EWL for SG and RNYGB) [6]. This fact should be taken into account when considering the otherwise healthy patient requiring revision. Converting a SG to an operation that has similar or even inferior performance and durability seems unlikely to garner the desired results.

This idea has been borne out in the literature. When comparing SG patients undergoing revisional surgery, the duodenal switch has significantly greater excess weight loss when compared to those who underwent RNYGB and reSG (80%EWL as compared to 66%EWL and 47%EWL, respectively) [7].

Expanding beyond solely weight loss, there are technical challenges which are avoided with conversion to BPD/DS. For revision to RNYGB and reSG, the procedure requires entering a re-operative field and an anastomosis or staple line on a stomach wall, which may be thickened and scarred. Entrance into this high-risk area of scarred stomach is avoided with the BPD/DS.

Finally, after a failed SG, many patients have one last opportunity to undergo an operation, which will produce the desired results. Given the efficacy and durability of the BPD/DS, this may make it the most logical option for revising a SG patient. However, the BPD/DS is not without complications and the decision regarding the choice of revisional procedure is a complex one. Decisions should only be made after involving the complete multidisciplinary team.

30.2 History of Biliopancreatic Diversion and Duodenal Switch

The biliopancreatic diversion (BPD) was originally described by Nicola Scopinaro. Scopinaro sought to maintain malabsorption seen with the JIB while eliminating many of the complications that presumably stemmed from its long blind limb. The original BPD involved a distal gastrectomy, creating a 200–500 mL pouch, followed by a gastrojejunal anastomosis with a 200 cm Roux limb anastomosed to the proximal stomach. The enteroenterostomy was created 50 cm from the ileocecal valve, which created a short common channel. This technique avoided the complications seen with the jejunoileal bypass (JIB) by eliminating a long blind small bowel limb [8].

While the BPD had sustainable weight loss, it was associated with a high rate of protein malnutrition; post gastrectomy symptoms, such as dumping syndrome; and the development of marginal ulcers. The duodenal switch modification or the biliopancreatic diversion and duodenal switch (BPD/DS) has become popular because it is associated with a low incidence of the post gastrectomy syndrome. The BPD/DS reduces ulcer formation by decreasing parietal cell mass, and therefore, acid production decreases via a sleeve gastrectomy and by performing a post pyloric duodeno-ileal anastomosis. The modern-day BPD/DS was first described by Hess and Hess in 1998. This was followed by the first description of a laparoscopic technique for BPD/DS by Gagner et al. in 2000, and in the same year, Sudan et al. performed the first robotic BPD/DS [9–11].

Table 30.1 Common reasons for inadequate weight loss after SG

Patient factors
Dietary noncompliance
Inadequate follow-up
Inadequate preoperative education
Preoperative BMI > 55 kg/m^2
Anatomic factors
Enlarged sleeve (>40 French bougie)
Retained antrum/fundus
Progressive sleeve dilation

30.3 Preoperative Evaluation and Patient Selection

Revisional surgery carries added risk; in fact, one-third of patients undergoing a revision weight loss procedure will have a major complication [12]. Therefore, patient selection and the preoperative workup are of paramount importance. There are numerous factors leading to poor response after SG, and each should be carefully considered when evaluating a patient for revision surgery (Table 30.1).

Ideally patients are compliant with dietary and exercise recommendations and have been regularly evaluated during long-term follow-up appointments. If this is not the case, then early identification of maladaptive behaviors may allow for minor non-operative interventions obviating the need for surgical intervention. Behaviors which may have led to poor response of the index procedure should be identified and addressed in a multidisciplinary setting. Evaluations by the bariatric surgeon, psychologist, nutritionist, bariatrician, social worker, and financial advocates are all valuable portions of the preoperative assessment. It is imperative to ensure that a patient who has had a poor response after SG is compliant. The noncompliant patient will not likely derive optimal benefit from subsequent revision to BPD/DS and will be more likely to develop nutritional complications. Patients should understand that revision to BPD/DS mandates life-long follow-up with the weight loss team to assess for the development of long-term complication and nutritional deficiencies as well as weight maintenance.

Once a patient has been identified as being a non-responder after a SG, a full history and physical exam should be conducted. The history should focus on factors which may have contributed to suboptimal response including reflux or obstructive symptoms, weight trends before and after surgery, exercise regimen, and dietary habits. The patient should be queried for any symptoms of malnutrition or micronutrient deficiencies. In addition, a detailed surgical history is necessary and all prior operative notes should be reviewed. In particular, it is important to note if the patient has had prior abdominal wall hernia repair with mesh, bowel resections, or a cholecystectomy. A complete physical exam should be performed with particular attention to the abdomen. Any physical evidence of malnutrition or micronutrient deficiency should be identified and remediated as it is more difficult to do so after conversion to a BPD/DS.

30.3.1 Imaging Assessment

Following the initial evaluation, patients should undergo an upper gastrointestinal (UGI) contrast study and upper endoscopy to evaluate for anatomical causes for failure or contraindications to duodenal switch. An appropriate UGI study should assess the overall anatomy of the sleeve as well as any irregularities such as hiatal hernia, dilation, retained fundus or antrum, stricture, or fistula. The rate of sleeve emptying and the presence of any reflux should be assessed. It is important to note that slight sleeve dilation in this setting is considered acceptable as a larger sleeve (40–60 French) is desirable with the BPD/DS as compared to the stand-alone SG. In addition, the surgeon should perform an upper endoscopy to assess for esophagitis and hiatal hernia as well as to assess the anatomy of the sleeve. In our experience, computed tomography, pH studies, and esophageal manometry studies are rarely needed but may be individualized for a particular patient.

30.3.2 Psychology Assessment

Just as for the index operation, patients seeking a revision surgery are submitted to a thorough psychological assessment. There are a number of psychological conditions that should be identified and managed prior to proceeding with surgery. Failing to recognize these comorbidities may lead to poor results of a subsequent revision surgery or even be a source of preventable morbidity and mortality.

30.3.3 Nutritional Assessment

A thorough and complete dietary evaluation should be required of all patients seeking a revision procedure. Patients with maladaptive eating behavior such as binge eating and grazing should be expected to show proof of dietary modifications and compliance through the use of a food journal or similar device. Additionally, a complete biochemical nutritional assessment, including vitamins and minerals, should be performed (Table 30.2). Patients may present with varying degrees of a malnourishment, and any nutrient deficiencies should be corrected prior to surgical intervention.

30.3.4 Final Preoperative Assessment

Prior to scheduling surgery, it is imperative that all portions of the preoperative evaluation be reviewed by the surgeon with emphasis on patient compliance with

Table 30.2 Preoperative nutrition labs assessed

Minerals	Vitamins	Macronutrients
Copper	Vitamin A	Lipid panel
Zinc	Thiamine	Hemoglobin A1C
Iron and TIBC	Vitamin B 12	Homocysteine
Ferritin	25-hydroxy vitamin D	*Other*
Transferrin	Vitamin K	CBC with differential
Magnesium	Folate	CMP
Phosphorus		LDH
		PTH
		TSH and free T4

Table 30.3 Contraindications to BPD/DS

Medical
Inability to tolerate general anesthesia
Cirrhosis with portal hypertension
Severe coagulopathy
Malignancy
Pre-existing malabsorptive disorder
Massive abdominal wall hernia
Social
Inability to understand potential complications
Documented history of poor compliance
Inability to afford Vitamins
Poor social support
Inability to follow-up regularly
Active substance abuse

dietary and behavioral interventions. Additionally, it is essential that all members of the multidisciplinary team have an opportunity to express any concerns that may have arisen in the preoperative evaluation. Patients who have raised red flags with team members should be reviewed in a multidisciplinary fashion prior to recommending surgery.

30.3.5 Contraindications

Contraindications to revision to BPD/DS are similar to contraindications to a primary BPD/DS and are listed in Table 30.3.

30.4 Operative Technique

30.4.1 Laparoscopic Biliopancreatic Diversion and Duodenal Switch

Immediately prior to surgery, the patient should receive appropriately dosed antibiotic and venous thromboembolism prophylaxis, and these should be re-dosed at appropriate intervals. The patient should be brought to an appropriately provisioned operating suite, staffed with a team who is familiar with complex minimally invasive bariatric surgery.

Some surgeons advocate for a split legged positioning; however, we place the patient in a supine position. Pneumatic compression stockings and a Foley catheter are placed. Arms are placed at right angles and secured to arm boards. A foot board is placed and the legs are secured above and below the knee to allow for extreme Reverse Trendelenburg. Patient positioning is critical to avoid pressure injury to the body or traction injury to the brachial plexus.

Peritoneal access can be performed using a Veress needle entry at Palmer's point and insufflating the abdomen to 15 mmHg using CO_2. A 12-mm optical port with a 10-mm zero-degree laparoscope is then used to enter the abdomen under direct visualization in the supraumbilical position. Alternatively, the Hasson technique may be used. After entering the abdomen, the absence of any unintentional injury from the Veress needle or the initial trocar is confirmed, and a general inspection of the abdomen is performed noting any significant adhesions, hernia, pathology of the liver, or any unrecognized complications stemming from the index operation. From here on, the operation may be performed either laparoscopically or robotically. A similar port configuration is used for either technique (Fig. 30.1).

The patient is then placed in Trendelenburg positioning and the bowel is run from the ileocecal valve proximally. Distal and proximal marking sutures are placed at 100 cm to aid in maintaining orientation. A marking suture is then placed at 250 cm from the ileocecal valve. The bowel at the 250 cm mark is then approximated and loosely fixed with a tacking suture to the transverse mesocolon in the right upper quadrant (Fig. 30.2).

A liver retractor is then placed through a subxiphoid incision, and the liver is retracted away from the first portion of the duodenum anteriorly and caudally. At this stage, if employing the robot, it is docked or one can proceed with conventional laparoscopy. Any adhesions of the duodenum to the liver are taken down at this time. If the gallbladder has not been previously removed, a cholecystectomy is optional at this time. The gallbladder specimen is placed in a laparoscopic retrieval bag and placed in the left upper quadrant for later retrieval.

The sleeve is visually inspected to confirm preoperative findings. It is then mobilized by entering the lesser sac at the level of the antrum. This dissection is carried along the greater curvature of the stomach past the pylorus and along the inferior boarder of the duodenum. Care must be taken while mobilizing the duodenum as there are a number of pancreaticoduodenal branches which can cause troublesome

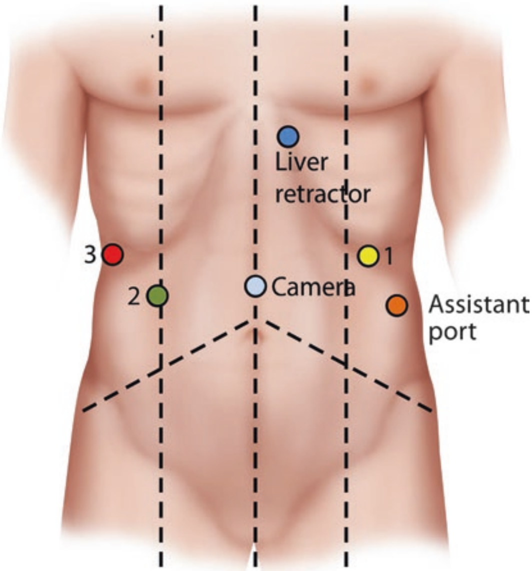


Fig. 30.1 Standard port placement for robot-assisted laparoscopic biliopancreatic diversion and duodenal switch. C-Camera; LR-Liver retractor. (With permissions from Springer Nature)

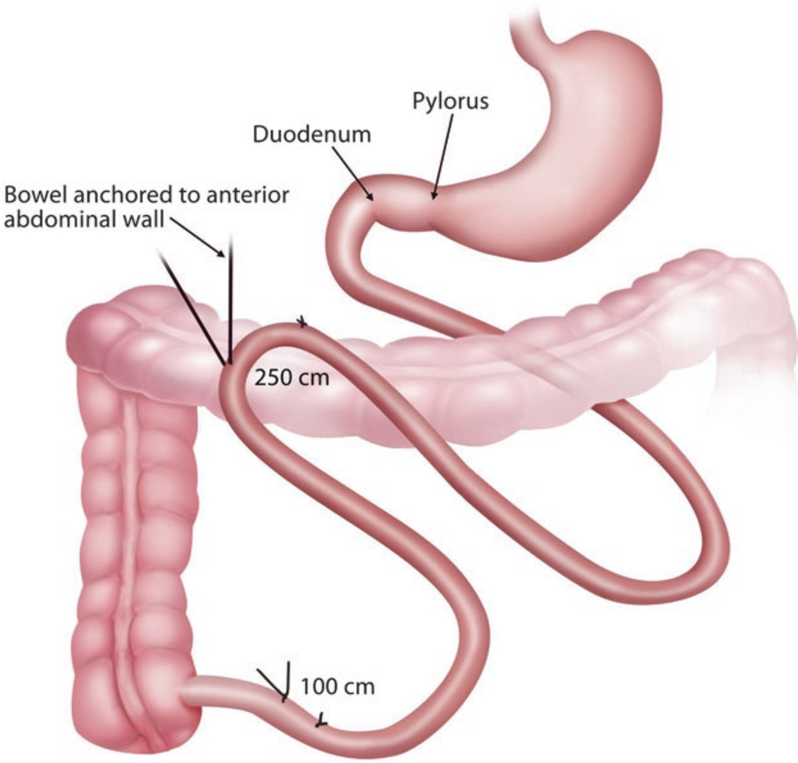


Fig. 30.2 Placement of marking sutures. (With permissions from Springer Nature)

bleeding, and it is critical to avoid excessive devascularization of the duodenum or cause injury to the pancreas. The dissection is carried just anterior to the gastroduodenal artery (GDA), which is approximately 3–4 cm distal to the pylorus. The retroduodenal dissection is performed using blunt dissection and judicious use of energy source such as the harmonic scalpel. A band passer or right-angle dissector may be used to complete a tunnel allowing the passage of a linear cutting stapling device to divide the first portion of the duodenum. Again, care must be taken with this portion of the dissection as injury to the duodenum, portal structures, pancreas, or GDA is possible if excessive force or inappropriate use of energy source is employed.

Next the bowel that was previously marked at 250 cm from the ileocecal valve is approximated to the transected portion of the duodenum using a 3-0 barbed absorbable suture in a loop configuration. Opposing enterotomies are made, and a hand-sewn two-layer anastomosis is performed (Fig. 30.3). Upon completion of the

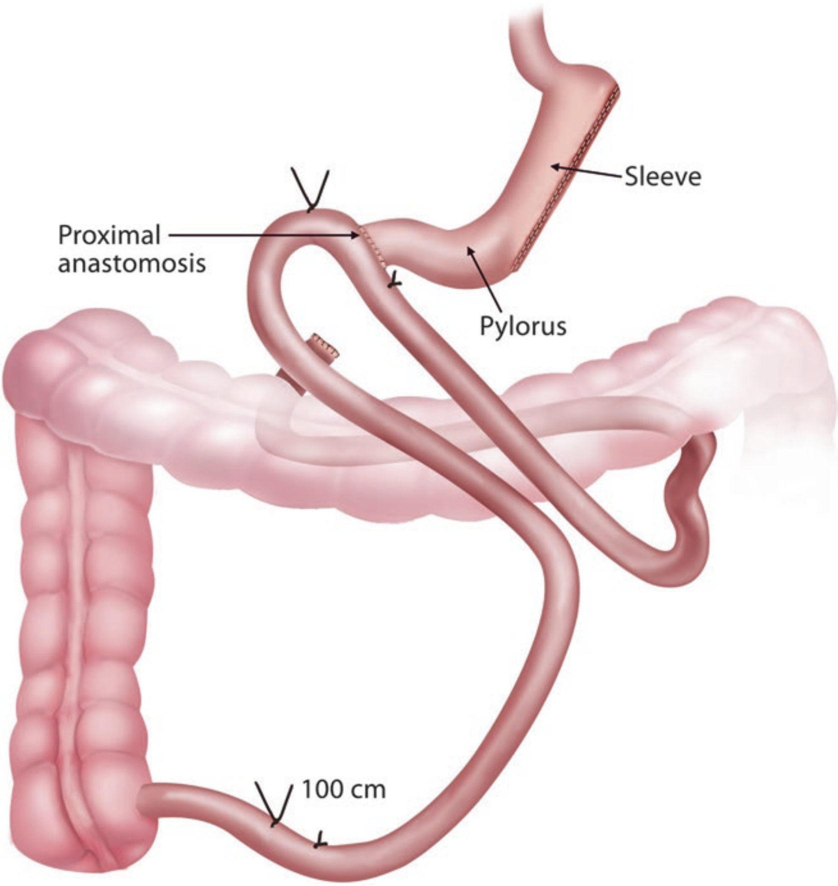


Fig. 30.3 Completion of sleeve gastrectomy and duodeno-ileostomy. (With permissions from Springer Nature)

anastomosis, a leak test is performed using methylene blue. The bowel is then run to the 100 cm mark and is anastomosed to the distal end of the biliopancreatic limb just proximal to the duodeno-ileostomy. This is performed using a 60-mm linear cutter stapler with medium leg length, and the common enterotomy is closed in a hand-sewn fashion with 3-0 barbed absorbable suture. The mesenteric defect is then closed with a non-absorbable 3-0 suture. The proximal portion of the loop that was anastomosed with the duodenum is then divided with a medium leg-length stapler separating the biliary limb from duodeno-ileal anastomosis (Fig. 30.4).

The abdomen is then inspected and gallbladder specimen removed. The 12-mm port site is closed using a transfascial closure device and all port sites closed in standard fashion.

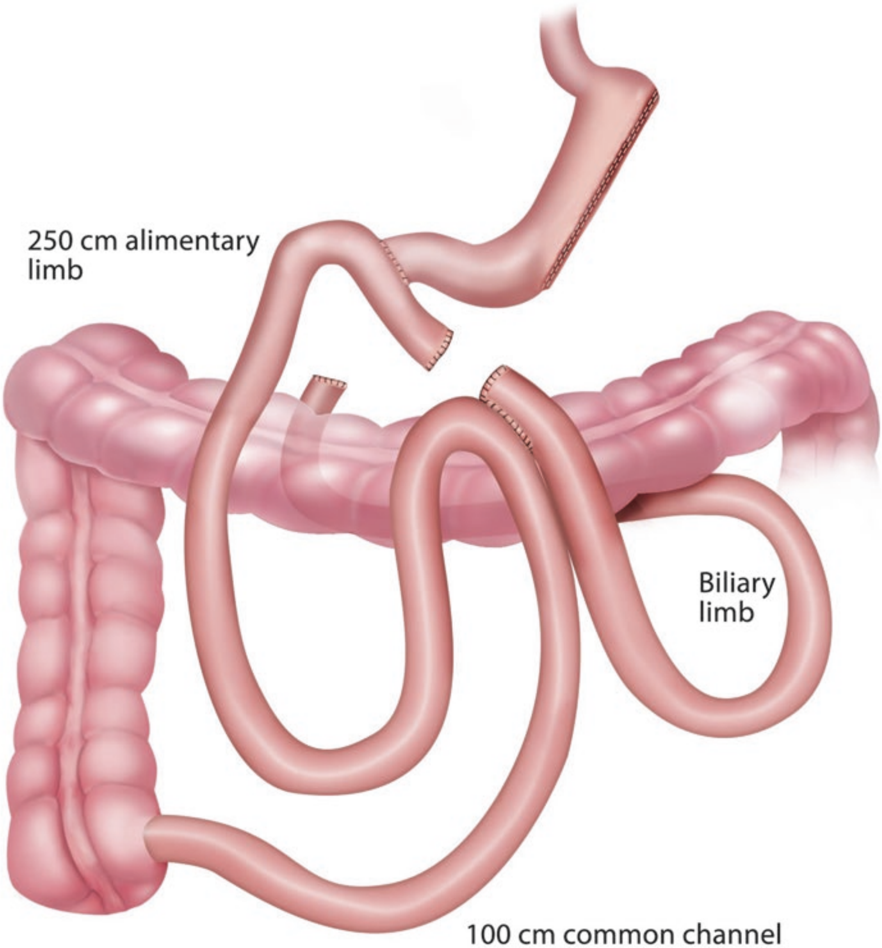


Fig. 30.4 Final anatomy of biliopancreatic diversion and duodenal switch. (With permissions from Springer Nature)

30.5 Postoperative Care

Immediate postoperative care is similar to primary bariatric patients. A Foley catheter is not routinely left in place. The patient is transported from the operating room using equipment specialized for the bariatric patient. After a suitable stay in the post-anesthesia care unit, the patient is transferred to a nursing unit with staff trained in the care of the bariatric patient. Routine use of cardiac telemetry and continuous pulse oximetry is important as a means to detect early postoperative complications. The patient remains nil per os (NPO) with intravenous hydration until postoperative day one.

In an effort to limit the use of narcotics, multimodality non-narcotic adjunctive analgesic agents are used. At the time of surgery, a transverse abdominis plane block is performed using liposomal bupivacaine. This provides 72 hours of local analgesic effect. Additionally, routine use of scheduled acetaminophen, ketorolac, and gabapentin significantly decreases postoperative narcotic requirements. Antiemetics including transdermal scopolamine, ondansetron, and promethazine are provided to the patient on an as needed basis. Typically, patients are only supplied with low-dose narcotics on request. The patient should ambulate within 6 hours of surgery and frequently thereafter. Routine use of pneumatic compression stockings and chemical venous thromboembolism prophylaxis is employed.

On postoperative day one, the patient is advanced to a clear liquid diet, if there are no clinical concerns for a leak. Should any concern exist, a CT scan with oral contrast or an UGI study is performed prior to advancing the patient's diet. On postoperative day two, if the patient is tolerating clear liquids, the patient is advanced to a full liquid diet including dietary protein supplements, and intravenous fluids are discontinued. A significant number of patients are discharged on the second postoperative day. However, due to the complexity of revisional BPD/DS, if any deviations from the standard recovery pathway are encountered, patients should be observed for a longer duration.

Patients are discharged with minimal narcotics and are prescribed a proton pump inhibitor for at least a month. The patient is brought to clinic 3 weeks after discharge. At this time the patient meets with a dietician and the diet is advanced from full liquids to an appropriate post-surgical diet slowly transitioning to more solid foods. Patients will be required to take lifelong multivitamins with specific formulations for the BPD/DS patient. Additionally, patients are required to track their protein intake and are instructed to consume at least 80 grams of protein daily.

Patients are brought for follow-up appointments regularly at 3, 6, and 12 months during the first year and then annually afterward. The frequency of follow-up depends on patient progress and results of nutritional studies. They are seen more frequently if needed. During follow-up appointments, patients meet with the psychologist, dietician, and surgeon.

30.6 Long-Term Outcomes

BPD/DS as a primary bariatric procedure has been clearly demonstrated to have superior long-term weight loss. While long-term outcomes after revision to BPD/DS are not well described in the literature, of all the revision options, it appears that BPD/DS has the greatest weight loss. Two years after revision, BPD/DS patients have 73% EWL as compared to 44%EWL after reSG and 48% after conversation to RNYGB [7, 13]. However, little data exists on weight loss benefits beyond 2 years.

In addition to superior weight loss, the BPD/DS has significantly greater rates of remission of comorbidities. Buchwald noted in his landmark meta-analysis that 98% of BPD/DS patients had resolution of diabetes as compared to 84% of RNYGB [6]. While revision to BPD/DS was not included in Buchwald's analysis, it seems intuitive that this trend would hold for revision procedures.

Finally, quality of life after BPD/DS receives much attention and is an area in which many surgeons are misinformed. Many bariatric surgeons council their patients that after BPD/DS frequent malodorous stools are unavoidable. However, in our experience this is modifiable based on a patient's diet. Most often patients having frequent stools can be sufficiently managed by reducing or eliminating dietary fats and sugars. While the BPD/DS patient may have loose stools in the immediate postoperative period, by 6–12 months after surgery, the majority of patients have 2–3 bowel movements a day.

30.7 Complications

BPD/DS is the most technically challenging bariatric procedure, and it requires a high level of technical skill and clinical expertise to perform safely and select patients who are appropriate candidates. Complication rates after primary laparoscopic BPD/DS are similar to other bariatric procedures when performed in high-volume centers by experienced surgeons [14]. However, there is only limited data on complication rates after revision to BPD/DS.

The data on a staged approach to BPD/DS suggests complication rates are halved in those undergoing a staged approach [15]. However, this data is not likely to extrapolate to the patient undergoing revision to BPD/DS after a poor response to SG because much of the benefit of derived from the initial weight loss may not be present in this population. In fact, complication rates ranging from 10% to 50% have been described [12].

Perioperative mortality remains a rare complication in the era of laparoscopic BPD/DS; reported mortality rates after primary laparoscopic BPD/DS range from 0% to 2.3% and are commonly associated with anastomotic leak, pulmonary embolism, and respiratory failure [6]. Anastomotic leak remains the most feared complication with reported rates ranging between 1% and 3%. Anastomotic leak is evidenced by tachycardia, fever, low urine output, or leukocytosis. If anastomotic leak is suspected, stable patients should undergo CT of the abdomen and pelvis with oral and intravenous contrast. If the patient is unstable or becomes unstable, the patient should proceed directly to the operating room for exploration. Small contained leaks can often be managed by placing a radiology guided percutaneous drain, NPO, and maintaining the patient with parenteral nutrition. This should be continued until radiographic evidence of resolution of the anastomotic leak has been obtained.

Perioperative malnutrition remains a significant concern after BPD/DS. Patients should all be maintained on micronutrient supplementation for life according to published nutritional guidelines [16]. Unfortunately, protein calorie malnutrition, deficiencies of fat-soluble vitamins, hypocalcemia, and iron-deficiency anemia are common in the non-compliant or poorly managed patient. These deficiencies can lead to a host of problems including night blindness, peripheral neuropathies, osteoporosis, Wernicke's encephalopathy, and death. Therefore, micronutrient surveillance and compliance with supplementation is of paramount importance.

30.8 Conclusions

The biliopancreatic diversion and duodenal switch is a safe and effective option for revision after a failed sleeve gastrectomy. BPD/DS has the most significant percent of postoperative excess weight loss. For a non-responder to SG, electing to proceed with BPD/DS provides the best long-term outcomes for weight loss and comorbidity resolution. In experienced centers the BPD/DS has an acceptable complication rate.

References

1. Estimate of bariatric surgery numbers: American Society of Metabolic and Weight Loss Surgeons; 2018. Available from: https://asmbs.org/resources/estimate-of-bariatric-surgery-numbers.
2. Deitel M, Gagner M, Erickson AL, Crosby RD. Third International Summit: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2011;7(6):749–59.
3. Himpens J, Dobbeleir J, Peeters G. Long-term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252(2):319–24.
4. Fischer L, Hildebrandt C, Bruckner T, Kenngott H, Linke GR, Gehrig T, et al. Excessive weight loss after sleeve gastrectomy: a systematic review. Obes Surg. 2012;22(5):721–31.
5. Eid GM, Brethauer S, Mattar SG, Titchner RL, Gourash W, Schauer PR. Laparoscopic sleeve gastrectomy for super obese patients: forty-eight percent excess weight loss after 6 to 8 years with 93% follow-up. Ann Surg. 2012;256(2):262–5.
6. Buchwald H, Avidor Y, Braunwald E, Jensen MD, Pories W, Fahrbach K, et al. Bariatric surgery: a systematic review and meta-analysis. JAMA. 2004;292(14):1724–37.
7. Dapri G, Cadiere GB, Himpens J. Laparoscopic repeat sleeve gastrectomy versus duodenal switch after isolated sleeve gastrectomy for obesity. Surg Obes Relat Dis. 2011;7(1):38–43.

8. Scopinaro N, Gianetta E, Adami GF, Friedman D, Traverso E, Marinari GM, et al. Biliopancreatic diversion for obesity at eighteen years. Surgery. 1996;119(3):261–8.
9. Ren CJ, Patterson E, Gagner M. Early results of laparoscopic biliopancreatic diversion with duodenal switch: a case series of 40 consecutive patients. Obes Surg. 2000;10(6):514–23; discussion 24.
10. Hess DS, Hess DW. Biliopancreatic diversion with a duodenal switch. Obes Surg. 1998;8(3):267–82.
11. Sudan R, Puri V, Sudan D. Robotically assisted biliary pancreatic diversion with a duodenal switch: a new technique. Surg Endosc. 2007;21(5):729–33.
12. Spyropoulos C, Kehagias I, Panagiotopoulos S, Mead N, Kalfarentzos F. Revisional bariatric surgery: 13-year experience from a tertiary institution. Arch Surg. 2010;145(2):173–7.
13. Cheung D, Switzer NJ, Gill RS, Shi X, Karmali S. Revisional bariatric surgery following failed primary laparoscopic sleeve gastrectomy: a systematic review. Obes Surg. 2014;24(10):1757–63.
14. Biertho L, Simon-Hould F, Marceau S, Lebel S, Lescelleur O, Biron S. Current outcomes of laparoscopic duodenal switch. Ann Surg Innov Res. 2016;10(1):1–5.
15. Iannelli A, Schneck AS, Topart P, Carles M, Hebuterne X, Gugenheim J. Laparoscopic sleeve gastrectomy followed by duodenal switch in selected patients versus single-stage duodenal switch for superobesity: case-control study. Surg Obes Relat Dis. 2013;9(4):531–8.
16. Parrott J, Frank L, Rabena R, Craggs-Dino L, Isom KA, Greiman L. American society for metabolic and bariatric surgery integrated health nutritional guidelines for the surgical weight loss patient 2016 update: micronutrients. Surg Obes Relat Dis. 2017;13(5):727–41.

Chapter 31
Conversion from Sleeve Gastrectomy to OADS

Miguel Josa, Andrés Sánchez-Pernaute, and Antonio Torres

Sleeve gastrectomy (SG) is a highly effective stand-alone surgical procedure for many morbidly obese patients and an adequate operation as a first step for super-obese (SO) patients or high-risk patients [1, 2].

However, long-term results indicate that up to 64 and 70% of patient present insufficient weight loss and weight regain, respectively, despite proper preoperative management and selection [1]. Moreover, SG is often performed in high-risk [3, 4], extreme age [5, 6] patients, or it is included in a two-step sequential strategies in super-obese individuals [7].

If weight loss after SG is inadequate, or if there is weight regain, different surgical options are available as a second step: resleeve, sleeve plication, banding of the sleeve, gastric bypass (GB), or duodenal switch (BPD-DS) [2]. For insufficient weight loss in a patient with a correct sleeve anatomy, we usually choose a malabsorptive procedure, especially if the patient was initially SO, as it offers the best weight loss for this subset of patients [8]. Twelve years ago, we introduced the single-anastomosis duodenoileal bypass with sleeve gastrectomy (SADI-S), a modified and simplified DS that has demonstrated satisfactory short- and long-term results [9]. Two years later, after demonstrating the good results of SADI-S as a primary bariatric and metabolic operation, we decided to introduce single-anastomosis duodenoileal bypass (SADI) as a second step after SG for insufficient weight loss or for a programed second-step surgery.

A second step was offered when less than 50% excess weight loss was achieved, if the patient began to regain weight after reaching an adequate weight

---

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-28936-2_31) contains supplementary material, which is available to authorized users.

M. Josa · A. Sánchez-Pernaute · A. Torres (✉)
Department of Surgery, Hospital Clínico San Carlos, Madrid, Spain

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_31

nadir, and to every SO patient regardless of satisfactory weight loss usually at 12 months from the sleeve gastrectomy. SADI was performed as a second step in those patients without problems derived from the SG, which could indicate dismantling of the sleeve (gastric stricture with severe gastroesophageal reflux), and without any accompanying conditions contraindicating a malabsorptive operation.

31.1 Technique

The first operation was a standard SG performed over a 42–54-French gastric bougie. For SADI, patients were placed in the supine position with legs closed and the surgeon standing at the left-hand side of the patient, unless a remodeling of the sleeve was planned; in that case, a standard French position was adopted. After a complete evaluation of the abdomen, the distal end of the previous sleeve was identified, and with the stomach held upwards, dissection of the greater curvature was completed down to the first segment of the duodenum, 2- or 3-cm distal to the pylorus. The posterior wall of the duodenum was separated from the pancreas, usually after identifying the course of the gastroduodenal artery. After opening the peritoneum at the right margin of the duodenum with care not to damage the right gastric artery, hepatic or bile duct, the duodenum was encircled and divided with a 60-mm blue cartridge linear stapler. The ileocecal junction was located, and 250 cm was measured proximally at 10-cm intervals. The selected ileal loop was ascended antecolically and isoperistaltically anastomosed to the proximal duodenal stump with a 2-layer running suture hand-sewn anastomosis.

31.2 Patients

In the last 10 years, 49 patients have been submitted to SADI as a second step after a sleeve gastrectomy. They were 34 women and 15 men, with a mean age at the sleeve of 42 years. The mean initial weight was 141 kg (99–216), and the mean initial BMI was 52 kg/m^2 (36–71). The mean maximum excess weight loss after the sleeve was 63% (34–113), and it was achieved as an average at the first postoperative year (4–24 months). The mean time for the second operation was 34 months (11–111), and at the second step, the mean excess weight loss was 43% (20–70). In 70% of the cases, the common limb was 250 cm long, and in the other 30% it was 300 cm. All duodeno-ileostomies were completed in a double-layer hand-sewn technique, with 3/0 PDS (Johnson & Johnson) or 3/0 VLoc (Medtronic). Methylene blue test was performed in all cases, and a vacuum drain left behind the anastomosis. In three cases, resleeve over a 54-French bougie was made at the second step. No postoperative complications were registered; and mean hospital stay was 4 days, the same as after all bariatric procedures in our institution.

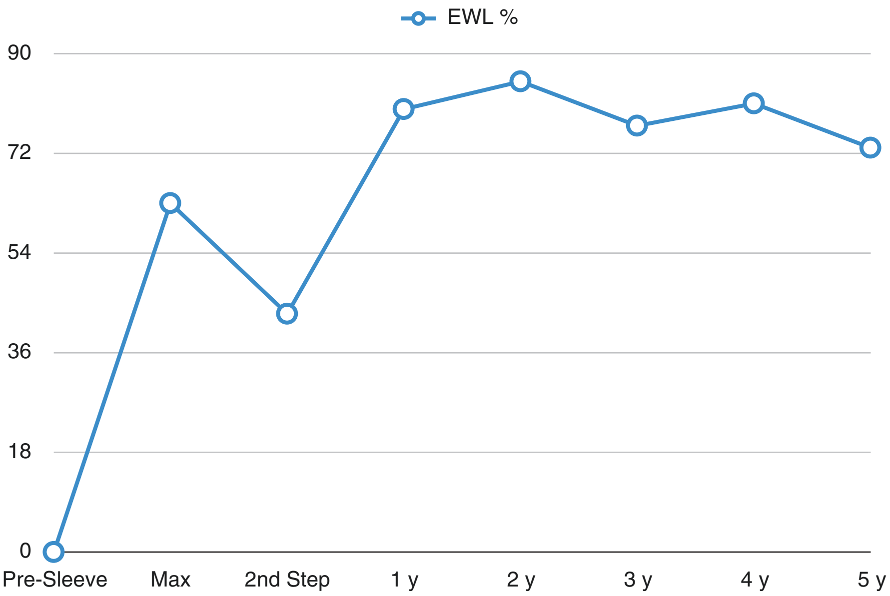


Fig.31.1 Excess weight loss percentage after sleeve gastrectomy and after SADI as a revisional surgery

Table 31.1 Evolution of type 2 diabetes after sleeve gastrectomy and after SADI. A 30% further improvement is achieved in the control of the disease after completing the revisional surgery

	Pre-sleeve	After sleeve	After SADI
Glycemia (mg/dl)	171	140	92,7
HbA1c (%)	8,15	7,2	5,2
Off therapy (%)	26	60	92

Excess weight loss was 80% at 1 year from the second step, 85% at 2 years, 77% at 3 years, 81% at 4 years, and 73% at 5 years (Fig. 31.1). In the follow-up, one patient was reoperated to undergo reversion of the procedure because of a liver failure; she had an underlying liver cirrhosis due to HVC infection. Two patients were submitted to a trimming of the sleeve in a third procedure due to insufficient weight loss.

Forty-five percent of our patients had type-2 diabetes, 30% of them under insulin therapy. Diabetes was improved after the sleeve with an important reduction of mean glycemia and HbA1c; however, a greater improvement was observed after the second step, with normalization of mean levels of HbA1c and glycemia (Table 31.1).

All patients after SADI received different postoperative supplements, but still the blood tests performed in the follow-up demonstrated deficiencies in the red series, iron, vitamin D, and some micronutrients (Table 31.2).

Table 31.2 Comparison between lab tests in the preoperative period after the sleeve gastrectomy and after SADI. It is remarkable how most of the values analyzed are normal after the sleeve gastrectomy, sometimes even better than preoperatively because of the control of the patient by the endocrinologist, and many of them worsen after SADI in spite of a correct supplementation

	Preoperative		After sleeve		After SADI	
	Mean	% Abnormal	Mean	% Abnormal	Mean	% Abnormal
Hemoglobin	13,8	18	14,3	3	12,5	39
Hematocrit	41,9	9	41,7	0	38,1	35
Iron	67,7	5,5	89,3	11	65	32
Calcium	9,5	5	9,5	0	8,9	0
Parathormone	74,6	50	62,4	39	95,7	57
Vitamin D	16,8	73	21,4	52	24,9	62
Copper	140	0	129	0	99	20
Zinc	85	0	83	0	59	52
Selenium	83	0	78	0	99	20
Proteins	7,2	5	7,08	0	6,4	9
Albumin	4,1	9	4,1	3	3,8	41

31.3 Discussion

In our series we demonstrate good definitive weight loss after the second procedure, increasing from an initial 43% EWL after the sleeve procedure to a final 73% EWL after the duodenal bypass. This number is of particular importance because the initial mean BMI of our series was over 52 kg/m^2, and 75% of the patients were initially SO patients. Comorbidities were successfully controlled after the second operation. These results are similar to those published in other series, such as Balibrea et al. [10]; they have an %EWL and a BMI at 24 months of 78.93% and 28.64 kg/m^2, respectively.

BPD-DS was the initial option for a second step after SG as SG was born as the staging of BPD-DS. BPD-DS has also been the recommendation of many surgeons because most of the patients completing the second stage after SG had initially been SO patients, and BPD-DS and BPD-like operations exhibit better long-term results in this subset. Sovik et al. [11] observed a 26% failure rate after GB versus a 0% after BPD-DS, and Prachand et al. [8] reported a 40% failure rate after GB in SO patients and a 16% failure rate after BPD-DS.

Our weight loss is comparable, or slightly better, to those obtained 1 and 2 years after resleeve (57 and 44%EWL, respectively) or RYGBP (61 and 48%EWL, respectively) [12, 13]. In addition, similar outcomes (55%EWL after 12 months) have been reported when RYGBP is performed in super-obese patients in a two-step strategy [14], or when indicated in poor comorbidity control, or even in severe gastroesophageal reflux (61.7%EWL after 16 months) [15].

Nonetheless, the secondary effects associated with BPD and BPD-DS may sometimes, in some authors' opinions, outweigh the beneficial weight loss of malabsorptive surgery [11, 16]. Problems secondary to malabsorptive surgery have likely been exaggerated as when exhaustive comparisons between GB and BPD-DS are performed, significant differences are only observed in serum calcium levels and bowel movements [17]. In our series, decreased levels of vitamin D, iron, and some micronutrients (selenium and zinc) were detected, but these abnormalities were not severe and have also been reported after standard GB [18, 19]. On the other hand, the rates of comorbidities resolution, especially type 2 diabetes mellitus, were more than satisfactory.

This has been stated by Balibrea et al. [10]: 71.4% patients showed complete remission of DM2, all patients presented normal blood glucose, and glycated hemoglobin levels with only 14% patients (2) received a daily dose of metformin. However, 24 months after SADI, two patients had elevated insulin and HOMA index values without clinical consequences. Dyslipidemia remitted in 31.2% patients and improved in 25%. Hypertension complete remission and improvement rates were 27.7 and 22.2%, respectively.

Another concern associated with malabsorptive procedures, such as a SADI, is an increase in the occurrence of nutritional deficiencies. In the multicenter cohort study of Dijkhorst et al. [20], the similarity of postoperative deficiencies found in SADI and RYGB groups is likely related to sufficient supplementation as every patient is advised to take specialized multivitamins to meet their daily requisite of vitamins after surgery and to prevent nutritional deficiencies from occurring; it is important to take into account in an adequate follow-up.

BPD-DS has been traditionally considered a difficult operation to perform, with more frequent postoperative complications. Highly experienced groups have not reported this for the traditional BPD-DS [21]. Technically, BPD-DS exhibits some advantages over other techniques as a second step after SG; the operation is directed toward a “nontouched” area, the duodenum, and this simplifies dissection and decreases anastomotic problems. This has been stated by Dapri et al. [22], which demonstrate a similar rate of postoperative complications between BPD-DS and resleeve gastrectomy as second step; in addition, complications after BPD-DS are easier to manage than those affecting the higher part of the gastric staple line. Furthermore, our technique with reduction to 1 anastomosis helps in this reduction of potential postoperative short- and long-term complications. The elimination of the mesenteric defect reduces the probability of internal herniation; there remains a huge defect below the ascended ileal loop, which could act as a hernia ring provoking obstruction or even volvulation of the small bowel along the anastomotic loop axis.

31.4 Conclusion

SADI offers a satisfactory weight loss for those patients submitted previously to a SG. It is a simplified technique, with a low postoperative complication rate and an acceptable rate of nutritional deficiencies, and should be considered as a good option as a second step after SG. Although there is no consensus about which technique should be performed after SG as a second-step procedure, BPD, Roux-en-Y gastric bypass (RYGBP), and resleeve are commonly considered.

References

1. Himpens J, Dobbeleir J, Peeters G. Long-term results of laparoscopic sleeve gastrectomy for obesity. Ann Surg. 2010;252:319–24.
2. Deitel M, Gagner M, Erickson AL, Crosby RD. Third International Summit: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2011;7:749–59.
3. Chaudhry UI, Kanji A, Sai-Sudhakar CB, et al. Laparoscopic sleeve gastrectomy in morbidly obese patients with end-stage heart failure and left ventricular assist device: medium-term results. Surg Obes Relat Dis. 2015;11(1):88–93.
4. Magee CJ, Barry J, Arumugasamy M, et al. Laparoscopic sleeve gastrectomy for high-risk patients: weight loss and comorbidity improvement—short-term results. Obes Surg. 2011;21(5):547–05.
5. Yoon J, Sherman J, Argiroff A, Chin E, Herron D, Inabnet W, Kini S, Nguyen S. Laparoscopic sleeve gastrectomy and gastric bypass for the aging population. Obes Surg. 2016;26(11):2611–15.
6. Inge TH, Courcoulas AP, Jenkins TM, et al. Weight loss and health status 3 years after bariatric surgery in adolescents. N Engl J Med. 2016;374(2):113–23.
7. Silecchia G, Boru C, Pecchia A, et al. Effectiveness of laparoscopic sleeve gastrectomy (first stage of biliopancreatic diversion with duodenal switch) on co-morbidities in super-obese high-risk patients. Obes Surg. 2006;16(9):1138–44.
8. Prachand VN, DaVee RT, Alverdy JC. Duodenal switch provides superior weight loss in the super-obese (BMI > 50 kg/m2) compared with gastric bypass. Ann Surg. 2006;244:611–9.
9. Sánchez-Pernaute A, Rubio MA, Pérez Aguirre E, Barabash A, Cabrerizo L, Torres A. Single-anastomosis duodenoileal bypass with sleeve gastrectomy: metabolic improvement and weight loss in first 100 patients. Surg Obes Relat Dis. 2013;9:731–5.
10. Balibrea JM, Vilallonga R, Hidalgo M, Ciudin A, González Ó, Caubet E, et al. Mid-term results and responsiveness predictors after two-step single-anastomosis duodeno-ileal bypass with sleeve gastrectomy. Obes Surg. 2016;27(5):1302–8.
11. Sovik TT, Taha O, Aasheim ET, et al. Randomized clinical trial of laparoscopic gastric bypass versus laparoscopic duodenal switch for superobesity. Brit J Surg. 2010;97:160–6.
12. AlSabah S, Alsharqawi N, Almulla A, Akrof S, Alenezi K, Buhaimed W, Al-Subaie S, Al Haddad M. Approach to poor weight loss after laparoscopic sleeve gastrectomy: re-sleeve vs. gastric by-pass. Obes Surg. 2016;
13. Cheung D, Switzer NJ, Gill RS, et al. Revisional bariatric surgery following failed primary laparoscopic sleeve gastrectomy: a systematic review. Obes Surg. 2014;24(10):1757–63.
14. Alexandrou A, Felekouras E, Giannopoulos A, et al. What is the actual fate of super-morbid-obese patients who undergo laparoscopic sleeve gastrectomy as the first step of a two-stage weight-reduction operative strategy? Obes Surg. 2012;22(10):1623–8.
15. Gautier T, Sarcher T, Contival N, et al. Indications and mid-term results of conversion from sleeve gastrectomy to Roux-en-Y gastric bypass. Obes Surg. 2013;23(2):212–5.
16. Sovik TT, Aasheim ET, Taha O, et al. Weight loss, cardiovascular risk factors, and quality of life after gastric bypass and duodenal switch. A randomized trial. Ann Intern Med. 2011;155:281–91.
17. Laurenis A, Taha O, Maleckas A, Lönroth H, Olbers T. Laparoscopic biliopancreatic diversion/duodenal switch or laparoscopic Roux-en-Y gastric bypass for super-obesity - weight loss versus side effects. Surg Obes Relat Dis. 2010;6:408–16.

18. Higa K, Ho T, Tercero F, Yunus T, Boone KB. Laparoscopic Roux-en-Y gastric bypass: 10-year follow-up. Surg Obes Relat Dis. 2011;7:516–25.
19. John S, Hoegerl C. Nutritional deficiencies after gastric bypass surgery. J Am Osteopath Assoc. 2009;109:601–4.
20. Dijkhorst PJ, Boerboom AB, Janssen IMC. Failed sleeve gastrectomy: single anastomosis duodenoileal bypass or Roux-en-Y gastric bypass? A multicenter cohort study. Obes Surg. 2018;28:3834–42.
21. Biertho L, Lebel S, Marceau S, et al. Perioperative complications in a consecutive series of 1000 duodenal switches. Surg Obes Relat Dis. 2013;9:63–8.
22. Dapri G, Cadière GB, Himpens J. Laparoscopic repeat sleeve gastrectomy versus duodenal switch after isolated sleeve gastrectomy for obesity. Surg Obes Relat Dis. 2011;7:38–44.

Chapter 32
Resleeve Gastrectomy

Patrick Noel, Marius Nedelcu, and Michel Gagner

32.1 Introduction

Laparoscopic sleeve gastrectomy (LSG) has evolved into a primary surgical treatment modality for morbid obesity. It has gained wide popularity as a sole bariatric procedure, now established as the most frequent bariatric procedure in France since 2011 and in the US since 2013 [1, 2]. This growth can be explained by several advantages that LSG carries over more complex bariatric procedures, such as Roux-en-Y gastric bypass (RYGBP) or duodenal switch (DS), including lower morbidity such as dumping syndrome, hypoglycemia and glycemic dysregulation, marginal ulcers, malnutrition, bone demineralization (falls and fractures), substance abuse (suicides), small bowel obstruction, and internal hernia. Similar results were achieved at 5 years in randomized studies [3, 4].

With an increasing number of LSG performed, the significant issue of weight regain is becoming more prevalent and it will represent a major issue that revisional bariatric surgery will need to address in the upcoming years. The long-term weight loss results following LSG are extremely variable between 40% and 86% EWL [5, 6]. The majority of these reports have analyzed their initial experience, and some authors incriminate the learning curve as one of the factors for weight loss failure.

A second intervention such as revisional sleeve gastrectomy (ReSG) [7–9], LRYGB [10], or biliopancreatic diversion with DS (BPD-DS) [11] or its variant single-anastomosis duodenoileal bypass (SADI) [12] can be proposed. It is also

P. Noel (✉)
Emirates Specialty Hospital, Dubai, United Arab Emirates

M. Nedelcu
Centre de Chirurgie de l'Obesite (CCO), Clinique Saint Michel, Toulon, France

M. Gagner
Department of Surgery, Sacré-Coeur Hospital, Montréal, QC, Canada

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_32

necessary to know the extent and causes of failures of LSG as well as the indications and outcomes of revision after LSG. Each team should use a specific algorithm in order to evaluate their results. Our algorithm used for failed LSG was previously described [7].

The results of the revisional surgery after LSG may be expected to be inferior compared to the primary surgery. The purpose of this study was to evaluate our initial case series regarding the medium-term (5 years) weight outcomes of ReSG.

32.2 Methods

All consecutive ReSG performed between October 2008 to January 2013 were studied. A prospectively maintained database was analyzed for the patients' demographic, preoperative weight and status of comorbid conditions, prior surgeries, postoperative weight, and postoperative status of comorbid conditions at different points of the follow-up (1 and 5 years, respectively). The complications were not analyzed in this study as they have been reported in our previous manuscript [7]. A multidisciplinary team consisting of a surgeon, a physician/endocrinologist, a psychiatrist, and a clinical nutritionist evaluated all patients preoperatively.

All patients underwent ReSG by the same surgeon (P.N.). The posterior approach with the three-port technique remained constant from the beginning of the experience, and it has previously been described [7]. Any intraperitoneal attachment between the left lobe of the liver and the anterior gastric surface was carefully dissected. The greater curvature was dissected next to expose the previous staple line. All adhesions were divided between the stomach and the pancreas, taking care not to injure the splenic artery. Once the mobilization of the stomach was completed, the anesthesiologist inserted a 36F orogastric bougie (MidSleeve®) to reach the pylorus, and different applications of a linear stapler Echelon 60–4.1 mm (Ethicon Endo-Surgery Inc., Cincinnati, OH) were fired. In the study period, no reinforcement of staple line was performed. Systematic drain and nasogastric tubes were not used in the postoperative period.

All patients were followed up on an outpatient basis regularly over the entire period. The follow-up consisted of a careful documentation of changes in weight and comorbidities. Patients who were unavailable for office follow-up visits were interviewed by telephone regarding their current weight and comorbid conditions. The follow-up is presented as the number of patients followed up divided by the total number of patients eligible for follow-up during each postoperative year. The radiological studies were reviewed and the dilatation was classified as primary or secondary. A primary dilation was defined as an upper posterior gastric pouch incompletely dissected during the initial procedure due to learning curve or difficult cases (super-super-obesity) with poor posterior exposure and incomplete visualization of the left crus of the diaphragm. A secondary dilation was defined as a homogeneous dilated gastric tube of more than 250–300 mL in volume at CT scan volumetry, seen later during follow-up. The probable mechanisms involved are natural history of LSG, a patient's eating habits, the use of a large calibration bougie with a planned second procedure, narrowing of the gastric incisura during the primary operation with consequent gastric upstream dilation of the remnant stomach, or a combination of these mechanisms.

Weight loss was reported as the percentage of excess BMI loss (% EBMIL), surgical success was defined as % EBMIL >50%, and inadequate weight loss was defined using the criteria of Halverson and Koehler of <50% EBMIL. A clear distinction was done for the entire cohort between the two forms that define the weight loss failure. The inadequate weight loss at 12 months after the surgery represents % EBMIL of less than 50%. The progressive weight regain occurred with a greater than 25% EBMIL regain with respect to the minimal weight following ReSG is occurring when an initial successful weight loss (defined as % EBMIL >50%) was achieved.

We used the following definitions for comorbidities: hypertension (systolic blood pressure ≥ 140 and/or diastolic blood pressure ≥90 mmHg, or antihypertensive drug therapy), type 2 diabetes mellitus (T2DM, fasting plasma glucose ≥126 mg/dL or 2-hour plasma glucose ≥200 mg/dL during oral glucose tolerance test or antidiabetic drug with or without insulin therapy), and obstructive sleep apnea (OSA, repeated upper airway occlusions during sleep with or without sleepiness and high apnea/hypopnea index and need for continuous positive airway pressure during sleep). The remission of a comorbidity was defined when a patient no longer needed a drug therapy and had normal blood pressure and lab values. For diabetes, remission was defined as patients with normal fasting glucose, without medication for 1 year, and a glycosylated hemoglobin (HbA1c) <6%. Improvement was defined as changing from insulin to oral antidiabetic drugs, lowering the dose or number of drugs needed, or improvement of HbA1c with the same treatment. The reflux was defined for patients with persistent clinical symptomatology despite double dose of proton pump inhibitors associated with different grades of esophagitis found during preoperative upper endoscopy.

For the statistical analysis, continuous demographic variables were expressed as mean ± standard deviation, and range; categorical variables as well as complications were reported as number and percentage. Continuous outcome variables were generally reported as mean ± standard deviation, and range. Statistical analysis was performed using Statistical Package for Social Sciences, version 17 (SPSS, Chicago, IL).

32.3 Results

From October 2008 to January 2013, 31 patients underwent ReSG, and their outcomes after 5-year follow-up are illustrated in Fig. 32.1. The mean BMI was 38.6 kg/m^2 for 29 women, and the mean age was 41.6 years. The mean interval time from the primary LSG to ReSG was of 29.6 months (11–67 months). The indication for

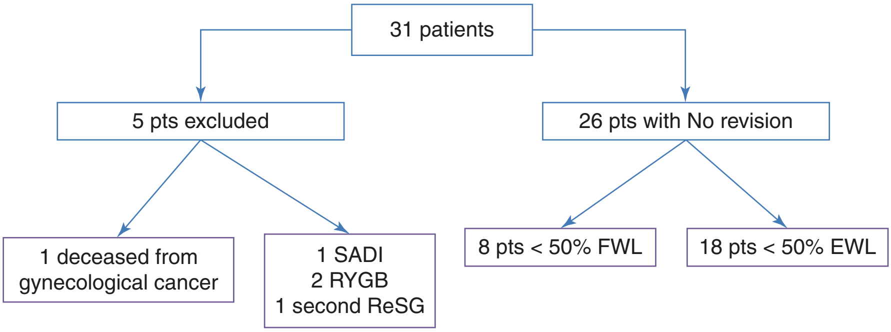


Fig. 32.1 Patients' outcomes following ReSG at 5 years' follow-up

ReSG was inadequate weight loss - 17 patients (54.8%), weight regain - 12 patients (38.7%), and gastroesophageal reflux disease (GERD) - 2 patients.

The analysis of barium swallow indicated primary dilation (upper gastric pouch) in 21 cases, and in the remaining 10 cases, the radiologic findings were compatible with a secondary dilation (gastric tube dilation). The CT scan volumetry (27 cases) revealed a mean gastric volume of 394.3 cc (range, 275–1056 cc).

32.3.1 Five-Year Follow-Up

Five patients were excluded from the weight loss analysis. One patient died from gynecological cancer. Of the remainder, four patients underwent different bariatric revisional surgery as follows:

- One patient underwent SADI at 33 months after ReSG for a BMI of 39.2 kg/m^2.
- Two patients underwent an RYGB for reflux at 36 months and 64 months, respectively.
- One patient underwent a second ReSG for reflux.

All the 26 patients without reoperation had available data at 5-year follow-up. The mean % EBMIL was 58.2% (range, 3.3–100%). Eighteen patients (70% of patients) had > 50% EBMIL at 5 years. All the eight patients (30% of patients) with failure of % EBMIL (< 50%) were the first three cases of our series, and six out of them had secondary dilatation. Analyzing the group of patients with EBMIL > 50%, there were 17 out of 18 patients with primary dilatation and only one with secondary dilatation. The BMI evolution before and after primary LSG followed by ReSG is summarized in Fig. 32.2.

All cases were completed by laparoscopy with no intraoperative incidents. One case of gastric stenosis was recorded treated successfully with two endoscopic dilations. One perigastric hematoma has been drained postoperatively by radiology. No other complications or mortality were recorded.

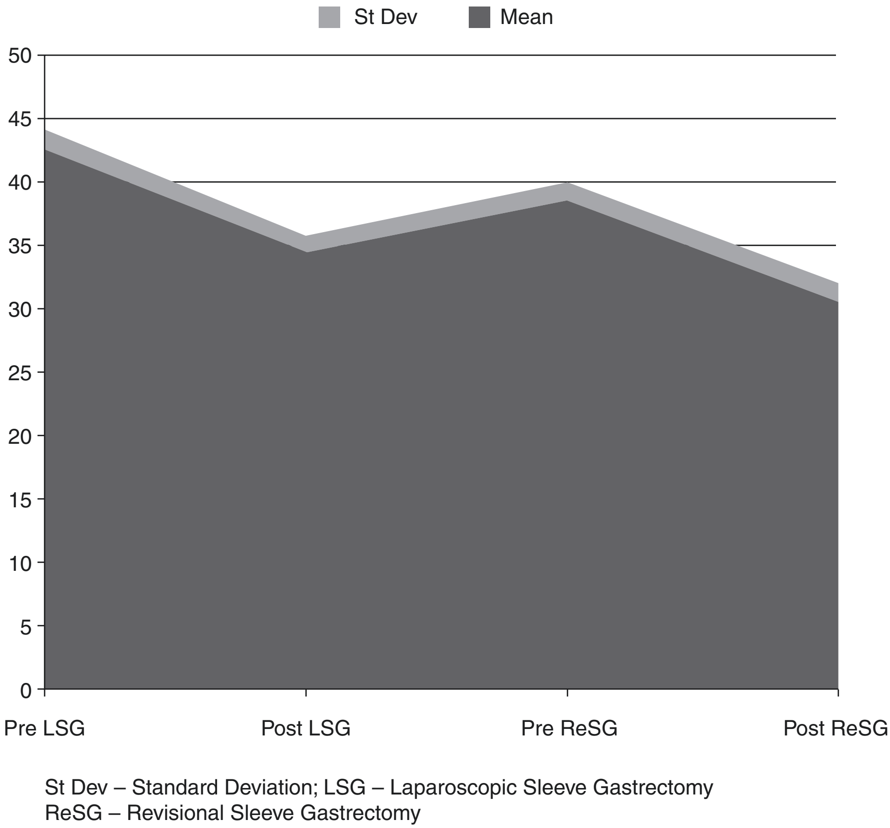


Fig. 32.2 Weight loss (mean and standard deviation) – before and after primary laparoscopic sleeve gastrectomy (LSG) and before and after resleeve (ReSG)

32.4 Discussions

LSG is considered to be a technically straightforward procedure, but the surgical technique is one of the major determinants of the success of this procedure. Removal of the entire gastric fundus is a key point. The left crus of the diaphragm must be systematically visualized. Our technique includes the following: The posterior aspect of the fundus is grasped repeatedly with forceps operated by the right hand, while the left hand releases the stapler and pulls laterally before the stapler is definitively clamped and fired [13].

As bariatric procedures are performed more frequently, the number of revisions will also rise. We found that the best way to approach these patients is to first perform a full history, and then to assess their BMI and their alimentary habits. All patients with a history suggestive of maladaptive eating disorders because of their bariatric surgery underwent further psychological evaluation and were treated prior to consideration for surgical revision. The next step was to document their anatomy with a barium swallow to look for evidence of primary or secondary dilatation of the gastric sleeve. For nonconclusive results on upper GI series, a volumetric CT scan was done. The sensitivity of CT scan volumetry is limited and sometimes operator dependent, but the reading of CT scan can show us the presence of the short gastric vessels which can indicate an incomplete dissection of the gastric fundus during the primary procedure.

Revisional bariatric surgery after LSG is becoming more common due to the rapid increase of number of patients undergoing this procedure as treatment for morbid obesity. The problem of the inadequate weight loss and weight regain after LSG is an issue as for other bariatric procedures. Weight regain after gastric bypass is equally prevalent, but not often performed due to lack of successful options, except for conversion to DS. Hence, LSG is more frequently revised, giving the impression that this procedure fails more frequently. Also it is often performed as a two-stage procedure, and when the second stage is performed, it is often considered as a failure, when it is not.

A systematic review of weight regain following bariatric surgery identified five principal etiologies: nutritional noncompliance, hormonal/metabolic imbalance, mental health, physical inactivity, and anatomical/surgical factors [14]. For the latter one, Deguines et al. [15] have demonstrated a correlation between residual gastric volume and LSG success as defined by %EWL > 50%, BAROS > 3, BMI < 35 kg/m^2, and/or the Biron criteria. Possible explanations for other anatomical LSG failures include the following: dilatation of the residual stomach, calibration of the stomach with an excessively large gastric bougie [16], and incomplete section of the gastric fundus (from where ghrelin is secreted) [17].

For the LSG, the risk of dilatation in time with weight loss failure was a constant source of debate. Facing 42 patients with primary dilatation (upper gastric pouch), this question came up rapidly among the authors: Has this part of the stomach undergone secondary dilatation or was it incompletely dissected from the beginning? The answer remains unknown; a prospective randomized study based on CT scan volumetry would be needed. With the development of CT scan gastric volumetry, it will be easier to differentiate between secondary and primary dilation, as the former provides useful details such as the position of the staple line and the integrity of the angle of His that are in favor of a primary dilation.

Braghetto et al. [18] reported data on 15 LSG patients undergoing CT scan gastric volumetry on POD 3 and, repeatedly, at 24–36 months after surgery, they found that the mean gastric volume had increased from 108 to 250 mL. None of these patients experienced weight regain, and the authors concluded that the gastric capacity increased after LSG sleeve gastrectomy even when a narrow gastric tubulization was performed. Langer et al. [19] prospectively studied 23 patients (15 morbidly obese, 8 super-obese) via Upper Gastro Intestinal (UGI) contrast studies and found that the dilation occurred in only one patient, while weight regain after initial successful weight loss occurred in three more patients, at a mean follow-up of 20 months.

Yehoshua et al. [20] investigated the role of the intraluminal pressure in the process of dilation of the gastric tube. The preoperative mean volume of the entire stomach was 1553 cc (600–2000 cc) and that of the sleeved stomach was 129 cc (90–220 cc). Results showed that the sleeve has a higher mean pressure of 43 mmHg when filled with saline (range = 32–58 mmHg) compared to the removed stomach that had a mean pressure of 26 mmHg (range = 12–47 mmHg). The study concluded that the notably higher pressure in the sleeve reflects its markedly lesser distensibility compared to that of the whole stomach and that of the removed fundus.

Unfortunately, there is a paucity of significant data (summarized in Table 32.1) to help the surgeon decide which revisional procedure to choose. Nonetheless, in the setting of weight loss failure after LSG, many bariatric centers advocate LRYGB as standard revisional procedure despite no long-term follow-up data. DS or more recent SADI represents other promising options in this patient population. Because of the superior weight loss seen with the DS when compared to other bariatric procedures, interest has grown in using this procedure in the treatment of morbidly obese patients who fail in other surgical therapy [25, 26].

Table 32.1 Literature review of revisional surgery following LSG

Study	Journal/Year	Number of patients	Revisional procedure	Weight loss results
Yorke et al. [21]	Am J Surg./2017	18	RYGBP	Mean BMI dropped from 40.5 to 36.4
Kim et al. [22]	SOARD/2016	48	RYGBP	Percentage total weight loss at 36 Mo was 6.5%
Crovari et al. [23]	SOARD/2016	28	RYGBP	Percentage total weight loss at 36 Mo was 19.3%
Prager et al. [24]	SOARD/2016	11	RYGBP	Mean BMI dropped from 40.6 to 34.7
Berends et al. [25]	SOARD/2015	43	25 DS vs 18 RYGBP	EWL greater for DS (59%) compared to LRYGB (23%)
Keidar et al. [26]	SOARD/2015	19	9 DS vs 10 RYGBP	EWL greater for DS (80%) compared to LRYGB (65%)
Torres et al. [12]	SOARD/2015	16	SADI	Mean EWL was 72%
AlSabah et al. [27]	Obes Surg/2016	36	12 RYGBP vs 24 ReSG	At 1 year, EWL was 61.3% for RYGBP and 57% for ReSG
Noel et al.	Current series	31	ReSG	58% achieved > 50% EWL at 5-year follow-up

LSG laparoscopic sleeve gastrectomy, *RYGBP* Roux-en-Y gastric bypass, *DS* duodenal switch, *SADI* single-anastomosis duodenoileal bypass, *ReSG* resleeve gastrectomy, *BMI* body mass index, *EWL* excess weight loss, *Mo* months

32.5 Conclusions

At 5 years' postoperative, the ReSG as a definitive bariatric procedure remained effective for 58%. The results appear to be more favorable especially for the non-super-obese patients and for primary dilatation. ReSG is a well-tolerated bariatric procedure with low long-term complication rate. Further prospective clinical trials are required to compare the outcomes of ReSG with those of LRYGB or DS for weight loss failure after LSG.

References

1. Lazzati A, Guy-Lachuer R, Delaunay V, Szwarcensztein K. Azoulay D Bariatric surgery trends in France: 2005-2011. Surg ObesRelat Dis. 2014;10(2):328–34.
2. Ponce J, DeMaria EJ, Nguyen NT, Hutter M, Sudan R, Morton JM. American Society for Metabolic and Bariatric Surgery estimation of bariatric surgery procedures in 2015 and surgeon workforce in the United States. SurgObesRelat Dis. 2016;12(9):1637–9.
3. Salminen P, Helmiö M, Ovaska J, et al. Effect of laparoscopic sleeve gastrectomy vs laparoscopic Roux-en-Y gastric bypass on weight loss at 5 years among patients with morbid obesity: the SLEEVEPASS randomized clinical trial. JAMA. 2018;319(3):241–54.
4. Peterli R, Wölnerhanssen BK, Peters T, et al. Effect of laparoscopic sleeve gastrectomy vs laparoscopic Roux-en-Y gastric bypass on weight loss in patients with morbid obesity: the SM-BOSS randomized clinical trial. JAMA. 2018;319(3):255–65.
5. Rawlins L, Rawlins MP, Brown CC, Schumacher DL. Sleeve gastrectomy: 5-year outcomes of a single institution. SurgObesRelat Dis. 2013;9:21–5.
6. Lemanu DP, Singh PP, Rahman H, Hill AG, Babor R, MacCormick AD. Five-year results after laparoscopic sleeve gastrectomy: a prospective study. SurgObesRelat Dis. 2015;11(3):518–24.
7. Nedelcu M, Noel P, Iannelli A, Gagner M. Revised sleeve gastrectomy (re-sleeve). SurgObesRelat Dis. 2015;11(6):1282–8.
8. Gagner M, Rogula T. Laparoscopic reoperative sleeve gastrectomy for poor weight loss after biliopancreatic diversion with duodenal switch. ObesSurg. 2003;13:649–54.
9. Rebibo L, Fuks D, Verhaeghe P, Deguines JB, Dhahri A, Regimbeau JM. Repeat sleeve gastrectomy compared with primary sleeve gastrectomy: a single-center, matched case study. ObesSurg. 2012;22(12):1909–15.
10. Regan JP, Inabnet WB, Gagner M, Pomp A. Early experience with two-staged laparoscopic Roux-en-Y gastric bypass as an alternative in the super-super obese patient. ObesSurg. 2003;13:861–4.
11. Dapri G, Cadière GB, Himpens J. Laparoscopic repeat sleeve gastrectomy versus duodenal switch after isolated sleeve gastrectomy for obesity. SurgObesRelat Dis. 2011;7(1):38–43.
12. Sánchez-Pernaute A, Rubio MÁ, Conde M, Arrue E, Pérez-Aguirre E, Torres A. Single-anastomosis duodenoileal bypass as a second step after sleeve gastrectomy. SurgObesRelat Dis. 2015;11(2):351–5.
13. Nedelcu M, Eddbali I, Noel P. Three-port sleeve gastrectomy: complete posterior approach. SurgObesRelat Dis. 2016;12(4):925–7.
14. Karmali S, Brar B, Shi X, Sharma AM, de Gara C, Birch DW. Weight recidivism post-bariatric surgery: a systematic review. ObesSurg. 2013;23(11):1922–33.
15. Deguines JB, Verhaeghe P, Yzet T, Robert B, Cosse C, Regimbeau JM. Is the residual gastric volume after laparoscopic sleeve gastrectomy an objective criterion for adapting the treatment strategy after failure? SurgObesRelat Dis. 2013;9(5):660–6.

16. Weiner RA, Weiner S, Pomhoff I, et al. Laparoscopic sleeve gastrectomy—influence of sleeve size and 120 resected gastric volume. ObesSurg. 2007;17:1297–305.
17. Lin E, Gletsu N, Fugate K, et al. The effects of gastric surgery on systemic ghrelin levels in the morbidly obese. Arch Surg. 2004;139:780–4.
18. Braghetto I, Cortes C, Herquiñigo D, et al. Evaluation of the radiological gastric capacity and evolution of the BMI 2–3 years after sleeve gastrectomy. ObesSurg. 2009;19:1262–9.
19. Langer FB, Bohdjalian A, Falbervawer FX, et al. Does gastric dilatation limit the success of sleeve gastrectomy as a sole operation for morbid obesity? ObesSurg. 2006;16:166–71.
20. Yehoshua RT, Eidelman LA, Stein M, et al. Laparoscopic sleeve gastrectomy—volume and pressure assessment. ObesSurg. 2008;18:1083–8.
21. Yorke E, Sheppard C, Switzer NJ, et al. Revision of sleeve gastrectomy to Roux-en-Y gastric bypass: a Canadian experience. Am J Surg. 2017;213(5):970–4.
22. Casillas RA, Um SS, Zelada Getty JL, Sachs S, Kim BB. Revision of primary sleeve gastrectomy to Roux-en-Y gastric bypass: indications and outcomes from a high-volume center. SurgObesRelat Dis. 2016;12(10):1817–25.
23. Quezada N, Hernández J, Pérez G, Gabrielli M, Raddatz A, Crovari F. Laparoscopic sleeve gastrectomy conversion to Roux-en-Y gastric bypass: experience in 50 patients after 1 to 3 years of follow-up. SurgObesRelat Dis. 2016;12(8):1611–5.
24. Felsenreich DM, Langer FB, Kefurt R, et al. Weight loss, weight regain, and conversions to Roux-en-Y gastric bypass: 10-year results of laparoscopic sleeve gastrectomy. SurgObesRelat Dis. 2016;12:1655–62.
25. Homan J, Betzel B, Aarts EO, van Laarhoven KJ, Janssen IM, Berends FJ. Secondary surgery after sleeve gastrectomy: Roux-en-Y gastric bypass or biliopancreatic diversion with duodenal switch. SurgObesRelat Dis. 2015;11(4):771–7.
26. Carmeli I, Golomb I, Sadot E, Kashtan H, Keidar A. Laparoscopic conversion of sleeve gastrectomy to a biliopancreatic diversion with duodenal switch or a Roux-en-Y gastric bypass due to weight loss failure: our algorithm. SurgObesRelat Dis. 2015;11(1):79–85.
27. AlSabah S, Alsharqawi N, Almulla A, Akrof S, Alenezi K, Buhaimed W, Al-Subaie S, Al Haddad M. Approach to poor weight loss after laparoscopic sleeve gastrectomy: re-sleeve vs. gastric bypass. ObesSurg. 2016;26(10):2302–7.

Chapter 33
Conversion from Adjustable Band to Sleeve

Brittany Nowak and Marina Kurian

33.1 Introduction

Adjustable gastric banding (AGB) is a surgery that quickly became popular internationally due to its less drastic nature, reversibility, and adjustability. On an IFSO survey, it reached its peak as 42.3% of bariatric surgeries performed worldwide in 2008 [1] and subsequently declined to 3% of bariatric surgeries performed in 2016 [2]. Now many surgeons have abandoned the band, while a select few continue to offer it to patients.

Many patients who have undergone AGB require reoperation either due to a device-related complication such as slip, pouch dilation, erosion, band, or tubing leak; due to band intolerance, reflux, or dysmotility; or due to inadequate weight loss or weight regain (Table 33.1). Rates in the literature have been quoted as high as 40–50% over long term follow-up [3–5]. Patients who have the band removed will regain weight and should be offered conversion surgery in order to maintain weight loss [6].

Even those surgeons who do not currently offer AGB must be comfortable managing patients with a band and be able to identify and counsel patients who will require conversion to sleeve gastrectomy (SG) or Roux-en-Y gastric bypass (RYGB).

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-28936-2_33) contains supplementary material, which is available to authorized users.

B. Nowak (✉) · M. Kurian
Department of Surgery, NYU Langone Heath, New York, NY, USA
e-mail: Marina.kurian@nyumc.org

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_33

Table 33.1 Reasons for band removal

Device related	Patient related	Weight related
Band disconnect	Band intolerance	Inadequate weight loss
Band erosion	Dysphagia	Weight regain
Band or port infection	Esophageal dilation	
Band slip (gastric prolapse)	Esophageal dysmotility	
Gastric pouch formation	Gastroesophageal reflux	
Leak in system	Intractable nausea or vomiting	
Tubing break	Pain	
	Pseudoachalasia	
	Psychologic intolerance	

33.2 Indications for Conversion from AGB

In the acute setting, patients can require urgent surgery for band slip, gastric perforation, and band erosion with free perforation. Most of the other reasons for band removal are more insidious and are the result of an ongoing discussion and workup. These include band or tubing leak, pouch dilation, dysphagia, pseudoachalasia, gastroesophageal reflux, band intolerance, weight regain, and inadequate weight loss. Patients who experience band slip or pouch dilation can be offered band repositioning or conversion surgery. Those who have had good weight loss with the band that halts after device leak can have their bands replaced. With band erosion, the band can be removed and replaced at an interval surgery, but conversion is recommended as erosion can occur again. For all the other indications, patients should be converted to another surgery.

33.3 Reasons to Convert to Sleeve

Patients who had successful weight loss with AGB but subsequently encounter difficulties with band intolerance in some form are good candidates for conversion to SG as they have already been to shown to respond a solely restrictive surgery [3]. There are two scenarios where patients should be encouraged toward RYGB. First, if the patient never tolerated band fills, AGB may have precipitated or uncovered an underlying esophageal dysmotility disorder, and those patients should undergo RYGB as it is a lower pressure system without the pylorus. If a patient still wants to be considered for SG, they should undergo preoperative esophageal manometry to assess esophageal motility. Second, if a patient does not lose weight with a band, this is concerning for maladaptive eating behavior, and they should undergo further dietary counseling and conversion to a surgery with a malabsorptive component, either RYGB or biliopancreatic diversion with or without DS (BPD/DS).

The data varies somewhat in the current literature with regards to conversion to SG or RYGB. Several studies have shown that patients converted to SG have fewer post-op complications than those converted to RYGB in either one or two steps [7–11]. Angrisani et al. found no statistically significant difference in percent excess weight loss in patients converted to SG or RYGB [2].

Other studies have shown less weight loss with conversion to SG when compared with RYGB [7, 8], and less weight loss than primary SG, which was worse in those who failed AGB due to weight loss failure or weight regain [3]. In those patients the concern is that SG still will not provide adequate weight loss and they will require another conversion surgery. Similar to primary bariatric surgery, during the preoperative discussion patients should be counseled on the potential for greater weight loss with conversion to RYGB, but that there is potentially an increased risk of postoperative complications.

33.4 Preoperative Evaluation

As always, a thorough history should be taken from the patient including their weight loss after AGB, symptoms of gastroesophageal reflux or dysphagia, complications from AGB, and prior surgeries. The operative report from AGB should be reviewed to anticipate band placement (pars flaccida versus perigastric), as well as any plication sutures.

Every patient should undergo esophagram and esophagoduodenoscopy (EGD) prior to surgery. The esophagram will help determine the presence of a hiatal hernia, give an idea of band placement, gastric pouch formation, band slip, and possibly evidence of band erosion. Of note, hiatal hernia is more prevalent in conversion surgery, possibly due to prior hiatal dissection and increased intra-abdominal pressure from vomiting if the band had been too tight [12]. Esophagram is not as predictive of hiatal hernia in conversion surgery as it is in primary surgery, so the hiatus must always be critically inspected in the operating room [12]. EGD is a second way to evaluate for band erosion and will also reveal any additional esophageal and gastric pathology. Esophageal manometry can be selectively utilized in patients with vomiting or band intolerance to evaluate for dysmotility prior to subjecting them to a high-pressure SG.

Two weeks prior to surgery, patients are placed on a very low calorie diet to decrease the size and fat content of the liver in order to optimize liver retraction, visualization of the hiatus, and to decrease liver bleeding [13].

33.5 One Versus Two-Step

One of the ongoing discussions with approach to conversion surgery from AGB, is whether it is best performed in a single step with simultaneous band removal and conversion. Or two steps with band removal and then an interval conversion surgery. The theoretical benefit of doing a two-step operation is to allow for decreased inflammation near where the band had been, but studies have shown that one-step conversion has comparable safety to primary LSG [14], and comparable safety to two-step conversion [15]. The efficacy is similar to primary SG as long as the capsule is disrupted during conversion [16]. The safety profile may be due to fewer comorbidities and lower baseline BMI in patients who are undergoing AGB to SG, when compared with those undergoing primary SG [14, 17]. Performing conversion in one step also offers the benefit to the patient of only one hospitalization and surgery, and avoids weight gain while waiting for second step [18]. Other studies have shown lower complication rates for two-step surgeries [19]. It is the author's practice to perform a one-step conversion, unless the band is being removed in the acute setting, the patient has band erosion, or presents after the band has already been removed.

33.6 Operative Technique

First the periumbilical incision that contains the AGB port is opened, and the port is extracted. Two trocars are inserted here and the abdomen is insufflated. Additional trocars should be placed through prior scars, when possible, in order to have the port placement the surgeon prefers for their SG. A liver retractor is used to lift the left lobe and expose the hiatus. The band is exposed by dissecting through the anterior portion of the capsule using electrocautery (Fig.33.1). This fibrous capsule surrounding the band is opened further toward the right crus, and then on the left, any gastric plication sutures from the fundus are taken down (Fig.33.2). Adhesions anteriorly of the capsule to the liver may be encountered and should be taken down in order to expose the phrenoesophageal membrane for anterior hiatal dissection. The band is unbuckled, or endoscopic shears can be used to divide the band clasp, and the band is then dislodged and removed from the abdomen.

A critical portion of the surgery is dividing the fibrin capsule (Fig. 33.3) and dissecting this off the stomach (Fig. 33.4). This is done to minimize the thickness of the tissue within the stapler fire during SG, as well as to unfurl the stomach puckered in

Fig. 33.1 Beginning of dissection of capsule surrounding band

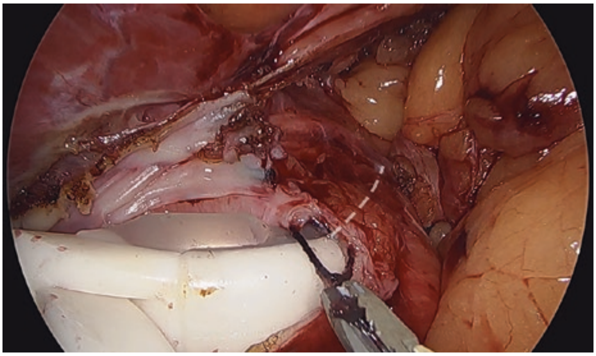


Fig. 33.2 Gastrogastric plication suture, continued dissection plane indicated by dashed line indicates dissection plane

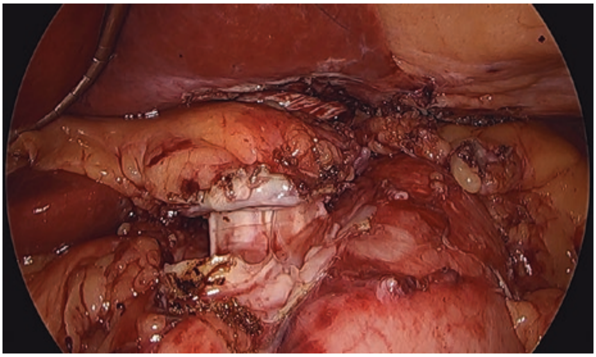


Fig. 33.3 Fibrin capsule after removal of gastric band

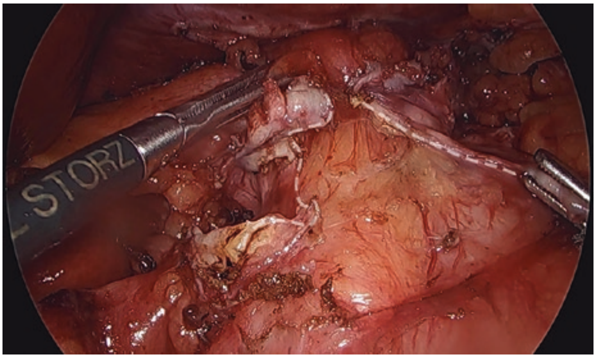


Fig. 33.4 Fibrin capsule split along anterior stomach, dashed white lines indicate edges of split capsule

the capsule. The hiatus is explored, and any hiatal hernia encountered should be repaired over a bougie. During posterior hiatal dissection, the crura are found after dissecting off the posterior fibrin capsule. Adequate hiatal dissection is important as scarring from prior surgery and inadequate esophageal dissection can lead to a malformed sleeve with inadequate restriction. A bougie is used to size the SG, and the rest of the operation is performed similar to a standard SG. Stapler selection should account for thicker tissue near the location of the prior gastric band, and it is the author's practice to use the thick black Endo-GIA staple loads (Medtronic, Minneapolis, MN) for the whole sleeve (Fig. 33.5) and imbricate the apical staple line with PDS or equivalent suture (Fig. 33.6) as this is the area most likely to develop a leak postoperatively. The cut edge of the greater omentum is then sutured to the posterior aspect of the sleeve at the apical staple line, between the second and third staple lines, and at the incisura to prevent rotation of the sleeve (Fig. 33.7).

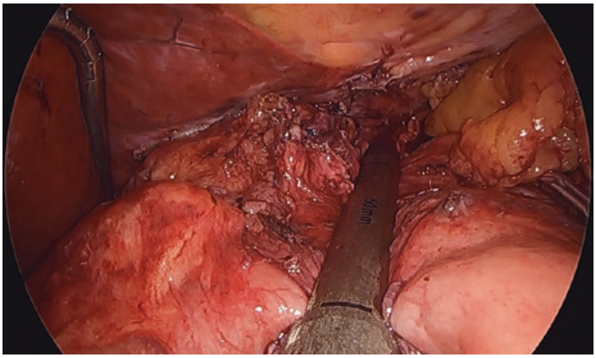


Fig. 33.5 Stapler across thickened stomach where fibrin capsule had been dissected off

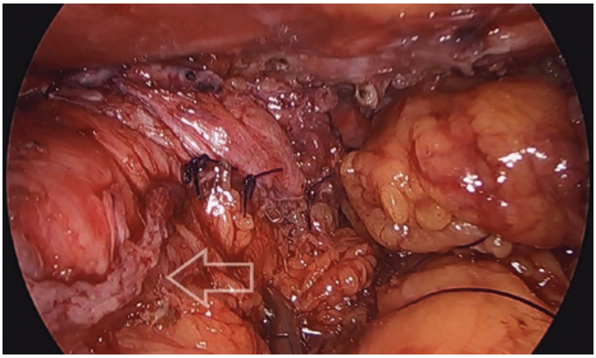


Fig. 33.6 Imbricated apical staple line, arrow outline indicates sleeve staple line inferior to imbricated portion

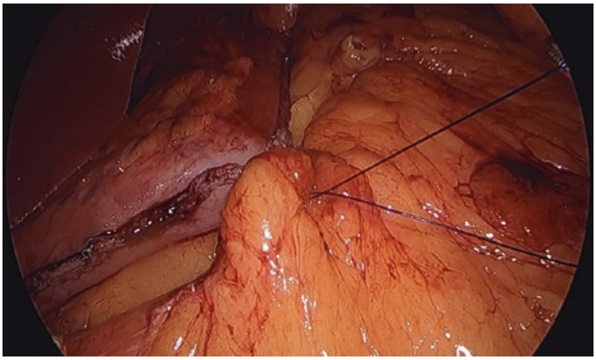


Fig. 33.7 Omentopexy of cut edge of omentum and greater curve vessels to posterior aspect of sleeve to help prevent rotation of sleeve

Fibrin sealant is applied to the entirety of the staple line. If the dissection is particularly difficult and there is concern for a possible leak, a leak test can be performed with methylene blue or endoscopic insufflation, but it is not the author's practice to do this routinely. A drain is not routinely left in place.

33.7 Postoperative Management

An esophagram is not routinely performed, and patients are started on a clear liquid diet on postoperative day 0. They are discharged typically on postoperative day 1 or 2 when they have demonstrated the ability to tolerate adequate intake. Leak is always a feared complication of SG, and rates after AGB to SG range from 0.5% to 5.6% [3, 15, 16, 20]. Mortality after this surgery is very low as many papers report zero mortality, and others show a rate comparable to primary SG [3, 14–16]. Patients can be expected to have weight loss similar with that of primary SG [16]. Conversion from AGB to SG is a safe and efficacious option in well-selected patients.

References

1. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2008. ObesSurg. 2009;19:1605–11. https://doi.org/10.1007/s11695-009-0014-5.
2. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J, Buchwald H, Scopinaro N. IFSO worldwide survey 2016: primary, endoluminal, and revisionalprocedures. ObesSurg. 2018;28:3783–94. https://doi.org/10.1007/s11695-018-3450-2.
3. Carandina S, Tabbara M, Galiay L, Polliand C, Azoulay D, Barrat C, Lazzati A. Long-term outcomes of the laparoscopic adjustable gastric banding: weight loss and removal rate. A single center experience on 301 patients with a minimum follow-up of 10 years. ObesSurg. 2017;27:889–95. https://doi.org/10.1007/s11695-016-2391-x.
4. Lazzati A, De Antonio M, Paolino L, Martini F, Azoulay D, Iannelli A, Katsahian S. Natural history of adjustable gastric banding: lifespan and revisional rate: a Nationwide study on administrative data on 53,000 patients. Ann Surg. 2017;265:439–45. https://doi.org/10.1097/SLA.0000000000001879.
5. Tammaro P, Hansel B, Police A, Kousouri M, Magnan C, Marmuse JP, Arapis K. Laparoscopic adjustable gastric banding: predictive factors for weight loss and band removal after more than 10 years' follow-up in a single university unit. World J Surg. 2017;41:2078–86. https://doi.org/10.1007/s00268-017-3922-x.
6. Aarts EO, Dogan K, Koehestanie P, Janssen IM, Berends FJ. What happens after gastric band removal without additional bariatric surgery? SurgObesRelat Dis. 2014;10:1092–6. https://doi.org/10.1016/j.soard.2013.10.014.
7. Carandina S, Maldonado PS, Tabbara M, Valenti A, Rivkine E, Polliand C, Barrat C. Two-step conversion surgery after failed laparoscopic adjustable gastric banding. Comparison between laparoscopic Roux-en-Y gastric bypass and laparoscopic gastric sleeve. SurgObesRelat Dis. 2014;10:1085–91. https://doi.org/10.1016/j.soard.2014.03.017.
8. Creange C, Jenkins M, Pergamo M, Fielding G, Ren-Fielding C, Schwack B. Gastric band conversion to Roux-en-Y gastric bypass shows greater weight loss than conversion to sleeve

gastrectomy: 5-year outcomes. SurgObesRelat Dis. 2018;14:1531–6. https://doi.org/10.1016/j.soard.2018.06.002.
9. Janik MR, Rogula TG, Mustafa RR, Alhaj Saleh A, Khaitan L. Safety of revision sleeve gastrectomy compared to Roux-Y Gastric bypass after failed gastric banding: analysis of the MBSAQIP. Ann Surg. 2019;269:299–303. https://doi.org/10.1097/SLA.0000000000002559.
10. Khan OA, McGlone ER, Maynard W, Hopkins J, Dexter S, Finlay I, Hewin D, Sedman P, Walton P, Somers S, Reddy M, Small P, Adamo M, Welbourn R. Single-step conversions from failed gastric band to sleeve gastrectomy versus Roux-en-Y gastric bypass: results from the United Kingdom National Bariatric Surgical Registry. SurgObesRelat Dis. 2018;14:1516–20. https://doi.org/10.1016/j.soard.2018.06.017.
11. Spaniolas K, Bates AT, Docimo S Jr, Obeid NR, Talamini MA, Pryor AD. Single step conversion from adjustable gastric banding to sleeve gastrectomy or Roux-en-Y gastric bypass: an analysis of 4875 patients. SurgObesRelat Dis. 2017;13:1880–4. https://doi.org/10.1016/j.soard.2017.07.014.
12. Rayman S, Goldenshluger M, Goitein O, Dux J, Sakran N, Raziel A, Goitein D. Conversion for failed adjustable gastric banding warrants hiatal scrutiny for hiatal hernia. SurgEndosc. 2018;33:2231. https://doi.org/10.1007/s00464-018-6509-1.
13. Fris RJ. Preoperative low energy diet diminishes liver size. ObesSurg. 2004;14:1165–70.
14. Aminian A, Shoar S, Khorgami Z, Augustin T, Schauer PR, Brethauer SA. Safety of one-step conversion of gastric band to sleeve: a comparative analysis of ACS-NSQIP data. SurgObesRelat Dis. 2015;11:386–91. https://doi.org/10.1016/j.soard.2014.08.018.
15. Dang JT, Switzer NJ, Wu J, Gill RS, Shi X, Thereaux J, Birch DW, de Gara C, Karmali S. Gastric band removal in revisional bariatric surgery, one-step versus two-step: a systematic review and meta-analysis. ObesSurg. 2016;26:866–73. https://doi.org/10.1007/s11695-016-2082-7.
16. Alqahtani AR, Elahmedi MO, Al Qahtani AR, Yousefan A, Al-Zuhair AR. 5-year outcomes of 1-step gastric band removal and sleeve gastrectomy. SurgObesRelat Dis. 2016;12:1769–76. https://doi.org/10.1016/j.soard.2016.05.017.
17. Dietch ZC, Schirmer BD, Hallowell PT. Simultaneous conversion of gastric band to sleeve gastrectomy is associated with increased postoperative complications: an analysis of the American College of Surgeons National Surgical Quality Improvement Program. SurgEndosc. 2017;31:5228–33. https://doi.org/10.1007/s00464-017-5591-0.
18. Moon RC, Wier J, Lind R, Teixeira AF, Jawad MA. Single-center experience in single-step conversions of gastric banding to sleeve gastrectomy: is it as safe as 2-step conversions? SurgObesRelat Dis. 2017;13:1830–4. https://doi.org/10.1016/j.soard.2017.01.013.
19. Schneck AS, Lazzati A, Audureau E, Hemery F, Gugenheim J, Azoulay D, Iannelli A. One or two steps for laparoscopic conversion of failed adjustable gastric banding to sleeve gastrectomy: a nationwide French study on 3357 morbidly obese patients. SurgObesRelat Dis. 2016;12:840–8. https://doi.org/10.1016/j.soard.2015.10.070.
20. Coblijn UK, Verveld CJ, van Wagensveld BA, Lagarde SM. Laparoscopic Roux-en-Y gastric bypass or laparoscopic sleeve gastrectomy as revisional procedure after adjustable gastric band--a systematic review. ObesSurg. 2013;23:1899–914. https://doi.org/10.1007/s11695-013-1058-0.

Chapter 34
Conversion from Gastric Plication to Sleeve Gastrectomy

Helmuth T. Billy

34.1 Introduction Gastric Plication as a Weight-Loss Operation

It is estimated that obesity affects over 500 million people worldwide [1]. Surgery remains the most effective treatment for morbidly obese patients and less aggressive, innovative procedures continue to be developed that show promise and application. The first description of gastric plication for the treatment of obesity was published by Tretbar in 1976 but remained relatively unknown until laparoscopy allowed it to be introduced as a potentially safer alternative to sleeve gastrectomy [2]. Greater curvature plication of the stomach was re-introduced by Talehpour in 2007 using a laparoscopic approach in 100 morbidly obese patients [3]. Three years later, in 2010, a group of Brazilian physicians published their findings on 52 patients undergoing greater curvature laparoscopic gastric plication. While the Tahlenpour report was a more aggressive "total vertical gastric plication," Ramos and his Brazilian colleagues described an imbrication utilizing only the greater curvature [4]. The Brazilian procedure was less aggressive and easier to perform. A shorter mean operative time and shorter hospital stay was achieved. The results were comparable to those achieved in Iran, and following the publication of their results, many authors from around the world have reported similar results using the Brazilian technique. Despite initial, encouraging short-term results, the gastric plication has generally resulted in a high rate of weight regain and often a high rate of revision when compared to other procedures. In most cases, the patients who have undergone gastric plication will achieve a consistent and measured short-term success during the initial 12–24 months post op.

H. T. Billy (✉)
Metabolic and Bariatric Surgery, St. John's Regional Medical Center, Oxnard, CA, USA

Metabolic and Bariatric Surgery, Community Memorial Hospital, Ventura, CA, USA

Bariatric Surgery, Hamad General Hospital, Doha, Qatar

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_34

The gastric plication procedure has gained popularity as a unique procedure, available to patients and bariatric programs where resources are limited or patients desire not to undergo an irreversible or anatomy-altering operation. As obesity and morbid obesity continues to remain a worldwide epidemic, less aggressive procedures that can be performed in an outpatient setting will continue to receive interest. We can expect gastric plication to continue to remain a particularly important option for patients where financial resources limit the availability of stapled procedures. As a result, bariatric surgeons should expect to see an increasing number of patients who have undergone laparoscopic plication to present for revision or conversion to other procedures. Failure rates and weight regain have been reported to increase over time with gastric plication and can reach 50% weight regain over 3–5 years following the operation. In 2018, Heidari reported on 102 of 124 patients who qualified for revisional surgery following laparoscopic greater curvature plications [5]. Weight-loss failure was defined as reaching <30% excess weight loss (EWL) during the first 12 months following plication. Weight regain was defined as reaching <30% excess weight loss at any time after the first 12 months. In all there were 39 repeat plications, 38 laparoscopic one-anastomosis gastric bypass, and 25 malabsorptive procedures performed as revisional operations. Their results demonstrated that with respect to revisional operations, OAGB and malabsorptive procedures produced the best and most consistent weight loss at 6 months, 12 months, and 24 months post op compared to re-plication. Roperation on failed laparoscopic gastric plication can be completed successfully. There were no treatment failures in the reoperation group: every patient operated on had improved weight loss following their revision.

With the large numbers of obese and morbidly obese individuals, it is doubtful that a reversal in obesity trends will be possible with stapling procedures alone. Since the advent of the laparoscopic gastric plication, a minimally invasive procedure that can be done in large numbers, at low cost, with reasonable results, the gastric plication has been widely adopted. Gastric plication does not involve gastric resection, intestinal bypass, or implantation of a foreign body (adjustable gastric band). Lower-risk alternatives to stapled procedures have traditionally appealed to patients and their referring physicians even if the overall results do not achieve the same level of success that traditional stapled bariatric procedures can achieve. Plication procedures have relatively mild complications when compared to the severity of complication that can occur with procedures such as Roux-en-Y gastric bypass and duodenal switch.

Since Telehpour initially reported his results, gastric plication has grown in popularity in various locations throughout the world. The most widely used version of gastric plication imbricates the greater curve in a two-layered approach although physicians have described and reported somewhat less favorable results utilizing an anterior plication [6]. The anterior approach allows preservation of the greater curve vessels and is generally simpler and requires less operative dissection. Gastric plication is still performed today throughout the world due primarily to its relatively low cost, the short hospitalization, and the ability to eliminate the need for expensive staplers [7]. The risk of complication is lower with gastric plication. At least 40% of patients undergoing gastric plication eventually fail to achieve their weight-loss goals within 3–5 years and as a result, surgeons performing revision surgery need to be aware of the unique technical aspects of gastric plication in order to perform a safe an effective revision operation [8].

This chapter will address the important anatomic and operative considerations that are necessary to revise a failed laparoscopic gastric plication to a laparoscopic vertical sleeve gastrectomy. With proper operative dissection and careful attention to detail, surgeons should be able to approach these patients and achieve a significant level of success with conversion to a sleeve gastrectomy. If done correctly, operative complications such as bleeding or staple-line leak should be minimal and the majority of patients should be able to achieve success without the need to revise to a malabsorptive operation.

34.2 The History of Laparoscopic Gastric Plication

The history of laparoscopic gastric plication begins in Iran when Talehpour performed total vertical gastric plication in 100 patients [2]. The average age of the patients was 32 years, and there were 76 women and 24 men in the cohort. The mean BMI was 47 (range, 36–58), and the mean weight loss achieved was as follows: 21.4% of EWL 1 month, 54% EWL at 6 months, 54% (72 cases) at 9 months, 61% EWL (56 cases) at 1 year, and 60% EWL (50 cases) at 2 years. At 3 years post op, EWL had declined and was at 57% (11 cases). The average time of follow-up was 18 months. There was weight regain in four cases comparable to their maximum weight loss, but after 3 years, and with aggressive behavioral and dietary counselling, EWL was over 50% in all of them despite some retention of the weight they had regained. Follow-up in these patients was extremely strict and exceeds the follow-up offered by most programs. Patient compliance appears to have been excellent and accounts for the impressive results obtained.

Of the 13 patients with diabetes, 8 patients achieved remission (61%). Hypertension was significantly improved in 6 of 9 cases (67%). It is easy to see how interest in the gastric plication increased following publication of these results. This early series indicated the complication rate was low and largely correctable and suggested that a gastric plication was potentially comparable to other laparoscopic procedures currently being used in the surgical treatment of morbid obesity.

Studies comparing the short- and long-term results between gastric plication and sleeve gastrectomy revealed little difference in short-term outcomes between the two procedures. After 2 years, the plication fails to achieve the same results as sleeve gastrectomy and weight regain becomes common. Grubnick et al. demonstrated that the difference in %EWL was not significant between laparoscopic gastric plication and sleeve gastrectomy at 6 months, but at 12, 24, and 36 months, there was a significant difference between the groups. Short-term follow-up did not show a significant difference in BMI between the two groups, but after

24–36 months, the difference in weight loss was 2–3 times more in LSG group [9]. Sleeve gastrectomy is a more reliable and durable operations and can serve as a revision operation following reversal of the plication.

Brethauer et all reported results on two techniques for gastric plication in a prospective nonrandomized study comparing safety and efficacy of anterior gastric plication and greater curvature gastric plication at 1 year [10]. In this 2010 publication, 15 patients were enrolled after qualifying based on the following inclusion criteria, 21–60 years old (inclusive), having a body mass index (BMI) of at least 35 but less than 50 kg/m^2; a BMI of 35–40 kg/m^2 was allowable if the patient had at least 1 or more significant medical condition related to obesity. Nine patients underwent anterior plication and six patients underwent greater curvature plication as per a standardized protocol. All patients were followed for 1 year and returned for follow-up endoscopic examination at 12 months. Four of the 9 patients undergoing anterior plication failed to return for postoperative endoscopy presumably secondary to the poor excess weight loss obtained in the anterior plication group. Brethauer's study achieved results similar to Ramos and Tahlenpour in the greater curvature plication group and was the first to report prospectively on anterior plication. Follow-up of patients undergoing anterior plication revealed mean % excess weight loss (EWL) of 17.8, 24.4, 28.4, and 23.3 at 1, 3, 6, and 12 months. Patients undergoing greater curvature plication obtained a mean %EWL of 23.3, 38.5, 49.9, and 53.4 at 1,3,6, and 12 months. There were no late complications, but early complications included one reoperation secondary to obstruction and frequent nausea, which resolved with postoperative rest, antinausea medications, and time.

34.3 Results of Gastric Plication and Expected Outcomes

34.3.1 Gastric Plication Technique

Conversion of gastric plication to sleeve gastrectomy involves careful planning and an understanding of the type and variety of plication that was initially performed. The majority of gastric plications performed involved imbrication of the greater curvature in a two-layered approach. An initial layer of interrupted sutures is placed to begin the imbrication followed by a final layer of running suture to complete the imbrication. (Illustrations 34.1 and 34.2) Understanding the technique initially used is essential to allow safe dissection, identification of each individual suture placed, and reversal of the previous imbrication to normal anatomy. Reversal of the previous imbrication allows accurate identification of key landmarks and proper positioning of the 60 mm stapler to achieve a staple line that does not cause narrowing at the angularis incisura, or twisting and kinking of the staple line of the sleeve gastrectomy. Although some surgeons have pursued a minimized operative dissection as method to avoid the time and effort required to reverse the previous imbricating sutures, this approach carries a risk unknowingly retaining folds of the gastric wall, which are still adherent as well as a risk of stapling into the actual plication.

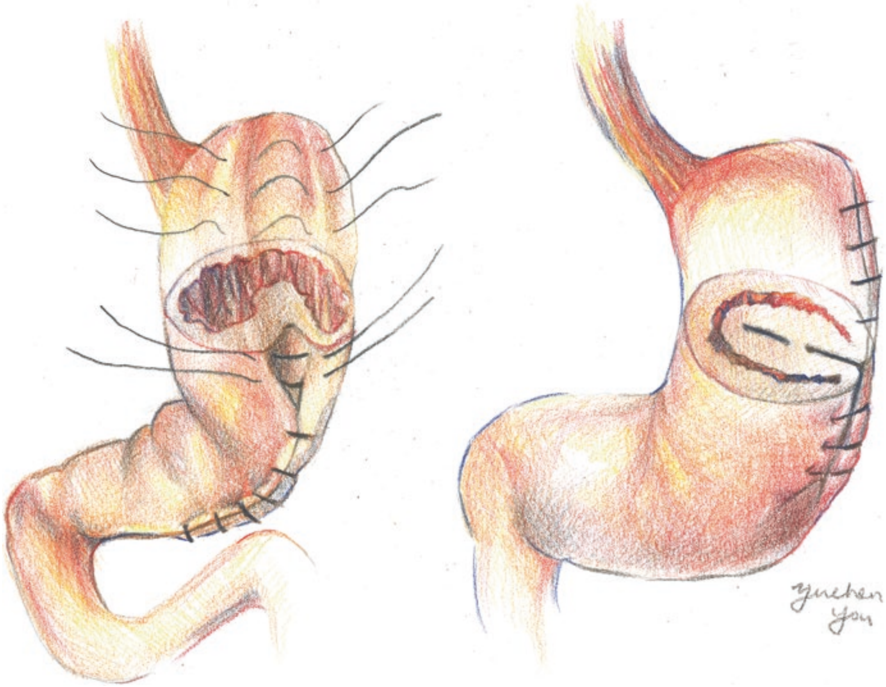


Illustration 34.1 Visualization of placement of an initial row of imbrication sutures along the greater curvature followed by placement of a second row of sutures along the greater curvature to create the two-layered greater curvature imbrication. The second layer is typically a running suture of either nonabsorbable monofilament or nonabsorbable braided suture. These are typically “0” or “2–0” sutures. (Illustration courtesy of Youchen You, DO Community Memorial Hospital Ventura California)

By completing an anatomic reversal of the previous plication, the risk of kinking and twisting of staple lines is significantly decreased as is the possibility of inadequate staple-line formation and staple-line dehiscence.

The degree and severity of scarring at the site of the plication varies. In the majority of cases, a careful dissection will reveal each individual suture used in the formation of the plication and once transected, the serosa-to-serosa approximation of the gastric wall will easily separate after which the next suture can be identified and a slow and deliberate reversal of the gastric plication can be achieved. The most common type of plication encountered is typically a greater curvature plication (GCP) although some surgeons still perform an anterior plication of the gastric wall despite the poorer weight loss reported with that approach.

Suture material ranges from nonabsorbable prolene to braided ethibond type sutures. Ethibond sutures are typically green in color and are associated with increased adhesion formation and involve a more challenging dissection. Nevertheless, each causes a different degree of scarring, which can have varying effects on the ability to perform a straight, uniform staple line unless all the plication sutures are removed.

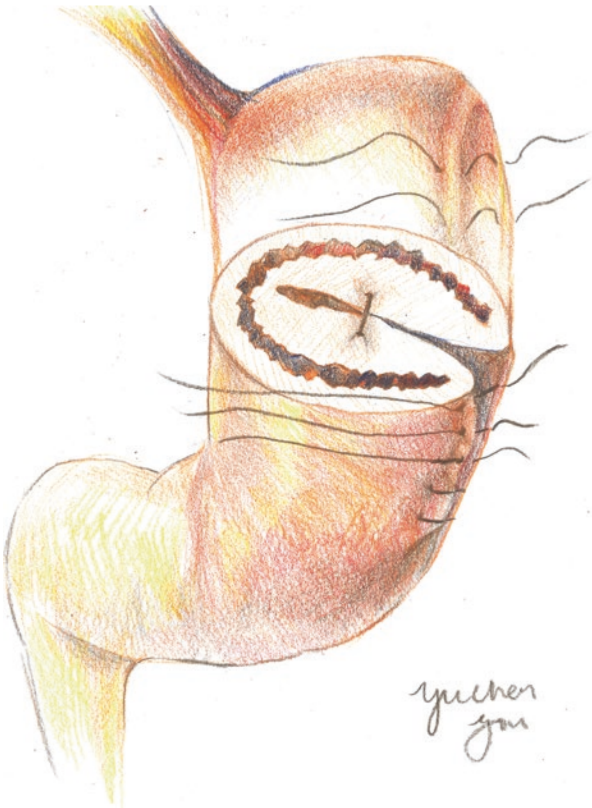


Illustration 34.2 Visualization of a two-layered greater curvature imbrication with the inner row of imbrication suture already in place. (Illustration courtesy of Youchen You, DO Community Memorial Hospital Ventura California)

Excessive scarring and inadequate dissection can contribute to obstruction at the angularis and a poor postoperative result.

It is our recommendation that a complete or partial reversal of the imbrication be performed to restore normal anatomy and identify the key landmarks necessary to prevent what are otherwise avoidable complications. Intraoperative endoscopy should also be immediately available on every case and identification of the intragastric plication prior to reversal should be performed. Once the plication has been reversed, a completion endoscopy should be performed to ensure that the plication has been adequately reversed. Intraoperative endoscopy will ensure that full distention of the gastric lumen can be achieved and minimal risk of incorporating the previous plication into the staple line is assured.

34.3.1.1 Greater Curvature Plication

Most surgeons that perform gastric plication prefer the approach known as a "Greater Curvature Plication." (Fig. 34.1) The operative approach used at the time of plication involves takedown and division of the greater curvature omentum and

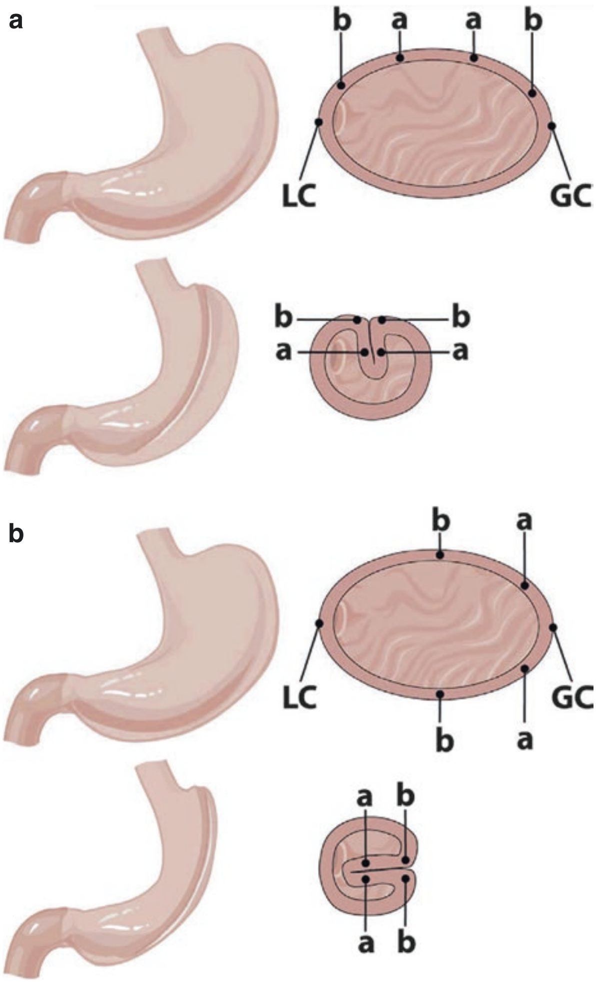


Fig. 34.1 (**a**) Illustration of anterior surface plication procedure completed with 2 rows of sutures. (**b**) Illustration of greater curvature plication procedure completed with 2 rows of sutures. Using this approach, gastric capacity could be maximally reduced. LC lesser curvature; GC greater curvature; a initial or interior row of sutures for creating imbrication b final or outer row, continuous suture row

vessels. The dissection is begun along the greater curvature opposite the angularis incisura and the omentun and greater curvature vessels are individually divided using either a ligasure device (Medtronic), a harmonic scalpel (Ethicon Endosurgery), or similar hemostatic energy device. The dissection is carried down to the level of the hilum of the spleen. The initial imbricating sutures used in the plication are placed beginning opposite the angularis incisura and are placed approximately every 10–15 mm along the greater curvature, imbricating the posterior and anterior walls of the greater curvature until the fundus is reached. Once the fundus has been imbricated, the surgeon assures the proper formation of the initial imbrication line by visualizing the gastric body, antrum, and imbrication with an endoscope. As stated by Brethauer, it is rather easy to overplicate the final suture line unless an endoscope is placed to visualize the final size and location of the imbrication created to be sure the outlet of the gastric body has not been obstructed. The final suture line is a running suture beginning at the plicated fundus and advancing proximally back, toward the angularis. Once complete, a final endoscopic examination is performed to ensure that there is no obstruction of the gastric tube or any leaks of the two-layered imbrication. If no obstruction or leaks can be identified, the operation is completed. (Image 34.A, 34.B, 34.C, 34.D, 34.E, 34.F, 34.G, 34.H).

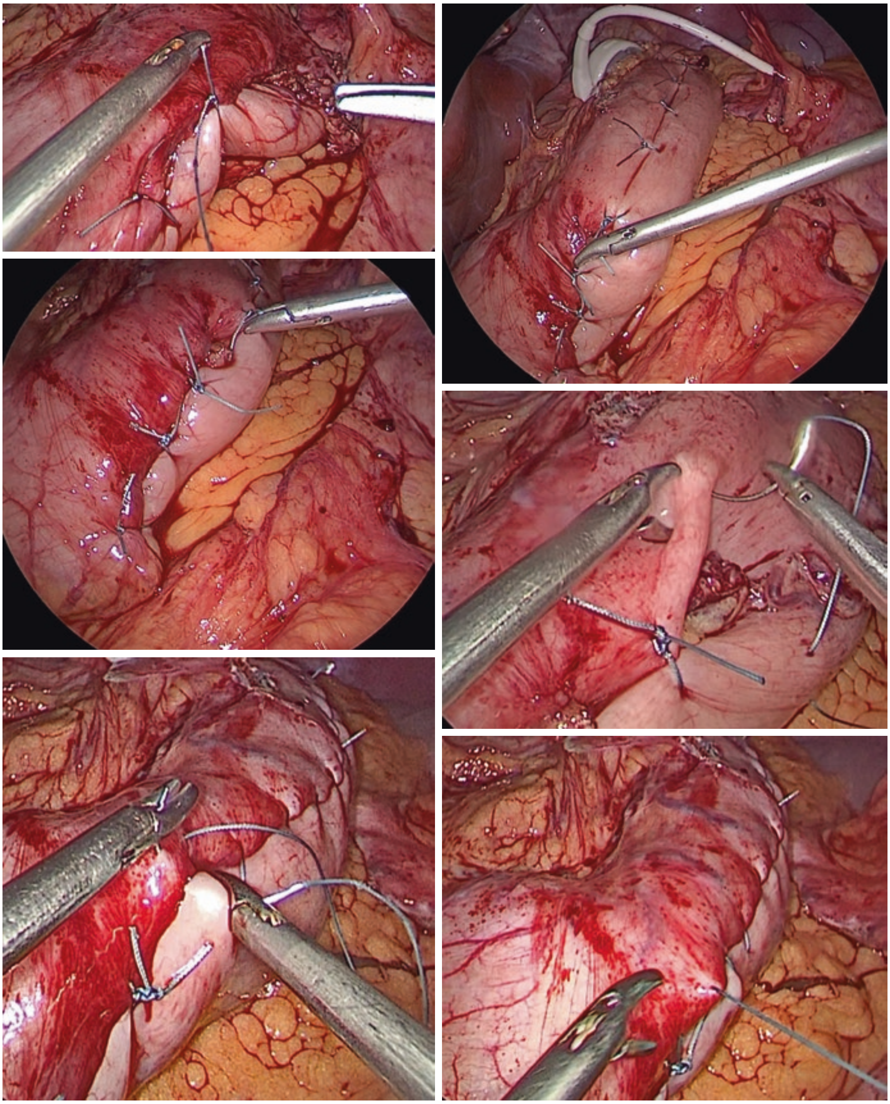


Image 34.A, 34.B, 34.C, 34.D, 34.E, 34.F, 34.G, 34.H Steps involved in the creation of the greater curvature plication involve placement of an initial row of imbricating, interrupted sutures as the first step in creation of the plication. Multiple interrupted sutures begin the process of folding the greater curve into itself. Once completed, the initial row of imbricating sutures is oversewed by a second running suture to complete the two-layered imbrication and gastric plication. In this example, 3–0 Ethibond suture was used to create the gastric plication

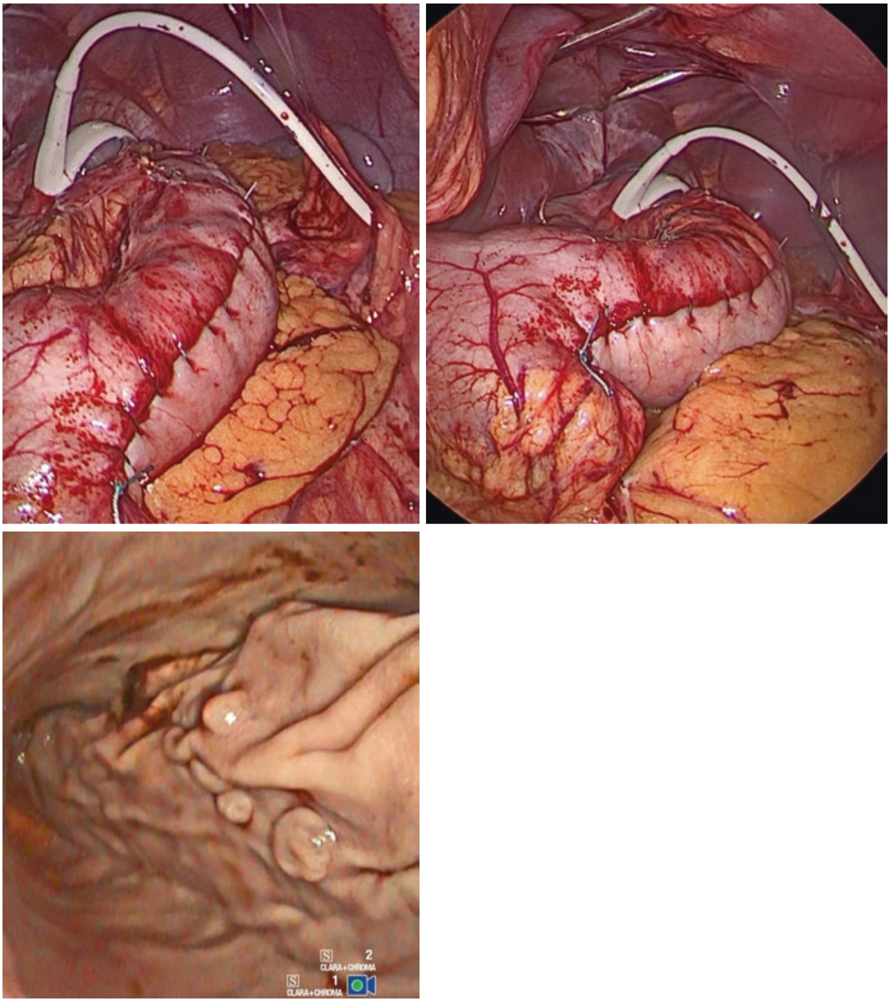


Image 34.A, 34.B, 34.C, 34.D, 34.E, 34.F, 34.G, 34.H (continued)

34.3.1.2 Anterior Gastric Plication

Anterior gastric plication is a similar operation but does not involve as complete a plication of the fundus. (Fig. 34.1) The decrease in gastric luminal volume is less than that in a GCP and overall weight-loss results are not as reliable. (Image 34.I).

34.3.2 Technique: Reversal of Gastric Plication

Reversal of gastric plication can be a tedious, time-consuming procedure. As familiarity with the operation grows, the surgeon will find that reversal can proceed very nicely as the imbricated surfaces are dependent on the plication sutures to maintain

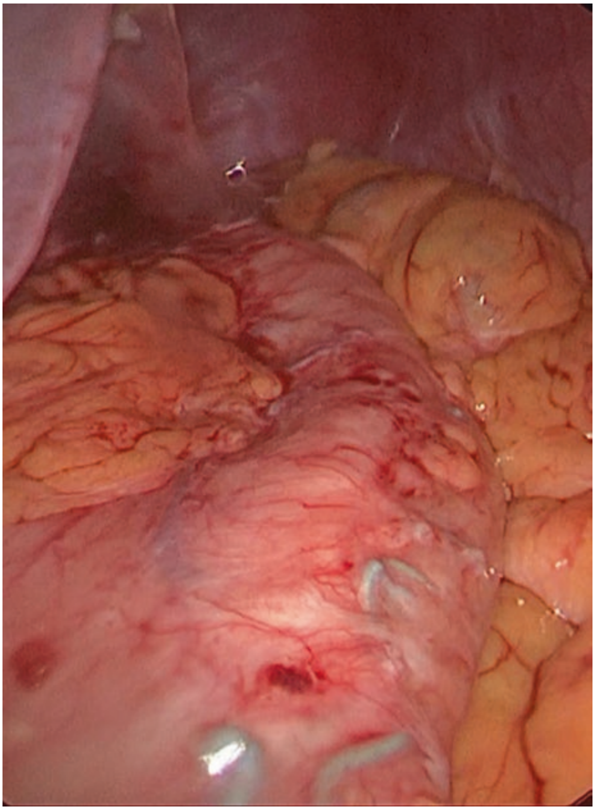


Image 34.I Completed greater curvature plication 4 years post op

the plication in the long term. The approximated serosal surfaces of the greater curvature do not form tight adhesions, and once the securing suture is divided, the operative space begins to develop and it becomes clear that the serosal fold is not tightly adherent to each other. In most cases, once the operative plane is developed, the reversal moves quickly and the restoration of normal anatomy occurs rapidly. Plications, which were performed using prolene suture, are more easily reversed than those plications, which were performed using ethibond suture. The reversal of the gastric plication occurs in the following steps

(a) Identification of the second layer running suture (Image 34.I)
(b) Transection of the second layer running suture beginning at the end of the suture line opposite the angularis incisura (Images 34.J, 34.K, 34.L, 4.M)
(c) Deliberate development of the plane of separation between the imbricated anterior and posterior serosal surfaces of the greater curvature while continuing to identify and transect additional imbrication sutures as the surgeon progresses toward the splenic hilum and fundus

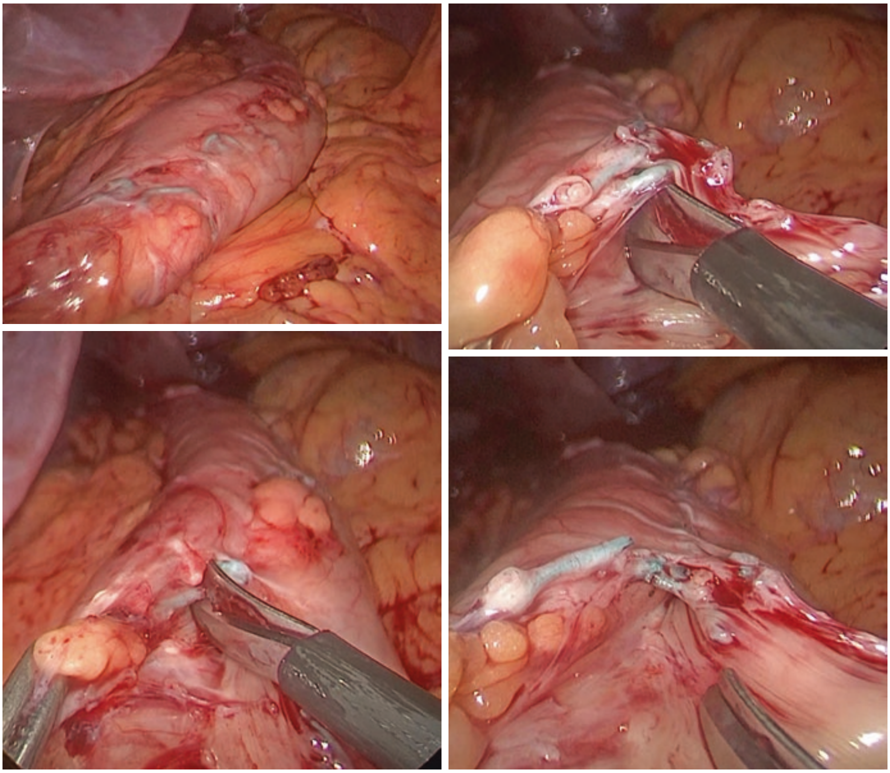


Image 34.J, 34.K, 34.L, 4.M Sequential identification and transection of imbrication sutures used to create the greater curvature plication. Creation of the space used to separate the serosal approximation is straightforward and relatively easy after removal of each imbrication suture

(d) Following complete reversal of the outer running suture, identification of each individual deep suture, transection of the suture, and continued separation of the imbricated serosal surfaces until all the deep interrupted sutures have been removed
(e) Intraoperative endoscopic examination of the gastric lumen and confirmation that the complete reversal of the greater curvature plication has occurred

Preparation for the sleeve gastrectomy can now proceed with precise measurements and marking of the distance 6 cm from the pylorus to antrum, 3 cm lateral to the angularis and 1 cm lateral to the gastroesophageal junction. Complete mobilization of the posterior stomach and visualization of the left crus and confluence of the right and left crus posteriorly to assess for any hiatal hernia.

34.3.3 Technical Pearls: Conversion to Sleeve Gastrectomy

34.3.3.1 Technical Goals of Sleeve Gastrectomy

Sleeve gastrectomy (SG) was initially conceived and first described in 1988 by Hess and Marceau as a restrictive component of the BPD-DS procedure at times when bariatric surgery was conducted via laparotomy. The sleeve gastrectomy as a modification of biliopancreatic diversion was initially described by Marceau in 1993 [11]. Marceau modified the technique, in an attempt to improve the regulation of gastric emptying and introduced the idea of a greater curvature resection. The modification was designed to retain a portion of the antrum and pylorus as well as preserving the lesser curve vagal innervation. Described as a "parietal gastrectomy," it represented a two-third reduction in gastric volume and a decrease in gastric acid production. The technique was described as consisting of a two-third gastrectomy involving only the greater curvature. "Using repeated applications of a stapling instrument, the stomach was divided from a point along the greater curvature 8 cm proximal to the pylorus, to a point just lateral to the esophagogastric junction."

Many variations exist regarding surgical technique; however, the basic tenets of LSG should be stringently followed. These include pyloric preservation with gastrectomy beginning 2 cm to 6 cm proximal to the pylorus, mobilization of the entire greater curvature with at least partial exposure and identification of the left crus and base of the right crus, avoidance of stricture at the gastric incisura, and proper apposition of the anterior and posterior aspects of the stomach when stapling to prevent a corkscrewing effect of the sleeve while at the same time paying attention to the posterior gastric wall in order to avoid a large retained fundic pouch.

Although the basic principles of sleeve gastrectomy described above are relatively straightforward, achieving these same goals following reversal of a previous gastric plication becomes more challenging. In order to maintain the same standards of a well-formed, appropriately sized sleeve gastrectomy, a complete reversal and unfolding of the previous plicated stomach is essential

34.3.4 Avoiding Complications

34.3.4.1 Indocyanine Green (ICG)

Indocyanine Green (ICG) is a form of florescent angiography that has been used to assess tissue perfusion and vascular distribution of vessels during laparoscopic surgery. ICG mapping prior to stapling allows for identification and preservation of any remaining vessels, which may be providing significant blood flow to the proximal stomach and lesser curve gastric tube of the sleeve gastrectomy. Leaks represent a significant complication following sleeve gastrectomy and can occur at a rate of 05–6% [12, 13]. Ortega et al. presents a series of sleeve gastrectomy cases where ICG mapping was used in an attempt to allow a "perfusion sparing" dissection to ensure adequate tissue perfusion of the proximal sleeve was maintained [14]. ICG is a water-soluble anionic probe with excitation and emission wavelengths in serum at 778 and 830 nm. ICG is administered in 3 cc boluses (7.5 mg) via intravenous injection followed by a 10 cc bolus of NS. The ICG can be visualized as a green florescent, which dramatically identifies arterial inflow vessels followed by tissue perfusion and finally venous outflow. ICG provides an accurate identification of the essential blood vessels remaining after greater curvature plication and can be crucial to guide the surgeon in an operative dissection to limit and avoid unnecessary dissection of critical blood flow to the upper stomach. The dye is excreted through the liver following intravenous administration, via the first-pass effect. ICG functions by binding to plasma lipoproteins, which more or less allows ICG to travel through blood vessels, revealing itself as a green florescence wherever blood flows. Poorly perfused and ischemic tissue is easily identified and becomes important in guiding the surgeon to preserve necessary arterial vessels and, at the same time, resect tissue that is poorly perfused and at risk for postoperative necrosis and leak. (Images 34.N, 34.O, and 34.P).

ICG immunoflorescent vascular mapping is used immediately following reversal of the plication sutures. The initial 3 cc (7.5 mg) bolus is used to identify important arterial inflow vessels to the upper stomach as well as to identify vascular

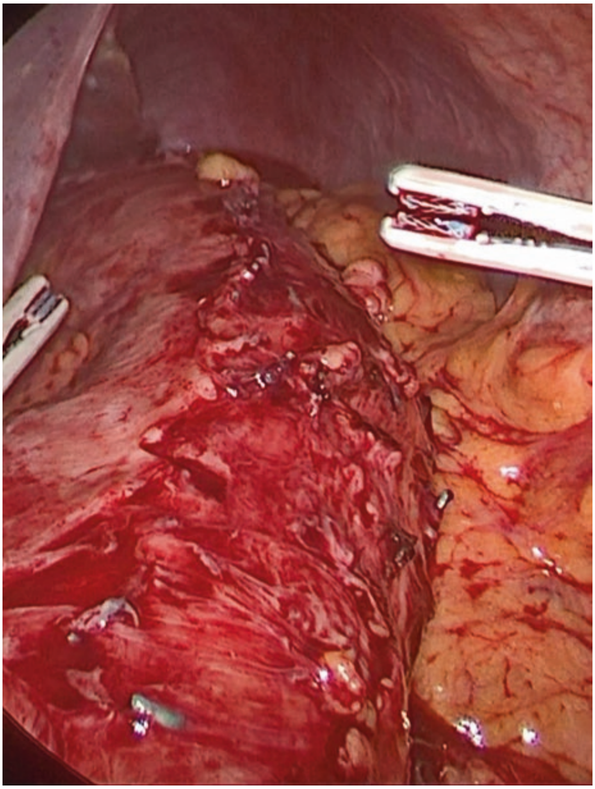


Image 34.N Completed reversal of the gastric plication prior to creation of the sleeve gastrectomy

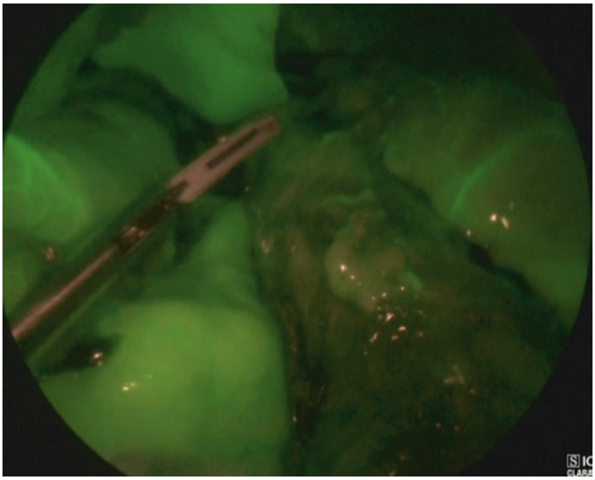


Image 34.O ICG example of well-perfused tissue and adjacent resected greater curve. Perfused tissue glows green with easy visibility of the arterial inflow, while ischemic tissue appears dark with no significant visible vessels or perfusion

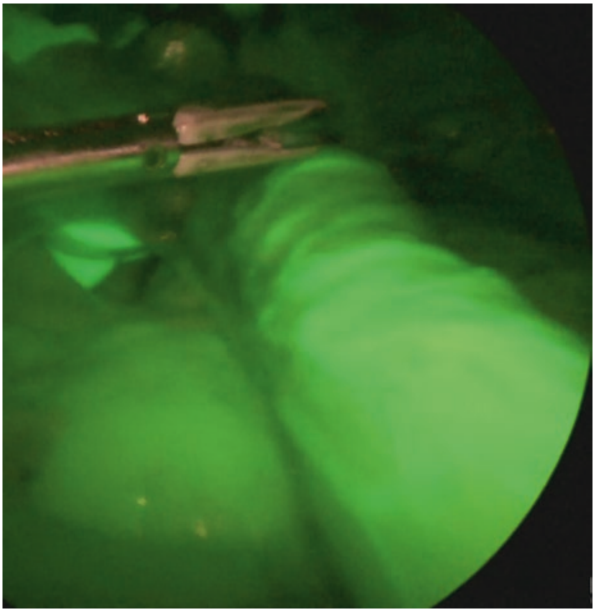


Image 34.P Well-perfused gastric sleeve following reversal of the greater curvature plication and creation of the sleeve gastrectomy

compromise of the greater curvature tissue secondary to the destruction of greater curvature inflow and chronic imbrication of the greater curve. A second bolus of 3 cc ICG is administered prior to placing and firing the stapler across the angle of Hiss and is used to guide the stapler to the best position to ensure adequate blood supply of the upper stomach. Finally, the last 3 cc bolus is used to assess overall blood supply and perfusion of the completed sleeve gastrectomy. Oversewing is avoided out of concern that it may compromise the blood supply of an already operated on gastric sleeve. If there is any question as to the tissue perfusion achieved following sleeve gastrectomy, an operative drain (19 French round) can be placed and removed following an upper GI swallow postoperative day two.

34.3.4.2 Staple-Line Consistency

An antrum-sparing sleeve gastrectomy is performed beginning 5 cm from the pylorus. Following ICG administration to identify adequate blood flow, the sleeve is created over a 40 French Bougie via sequential firings of a powered laparoscopic stapling device (Signia Medtronic) to form a sleeve with a capacity of 60–80 ml. The cartridge choice in all cases was standardized with an initial 60-mm (4.4-mm staple height) black cartridge, followed by three 60-mm purple (4.0-mm staple height) cartridges (Medtronic). All cartridges received Seam Guard staple-line reinforcement (W.L. Gore). Following placement of the 40 French bougie, measurements were taken and a proposed path of the stapler was marked at 1 cm lateral to the GE junction, 3 cm lateral to the angularis incisura, and 5 cm proximal to the pylorus. (Images 34.Q, 34.R, and 34.S). This method ensured sufficient distance from the incisura and avoided encroachment of the esophagus at the apex of the LSG, a distance of at least 1 cm from the gastroesophageal junction was maintained. It is our belief that by careful positioning of the bougie and meticulous measuring at the above-described locations, a straight staple line with little tendency to twist or kink can be created.

34.3.4.3 Repair of Hiatal Hernia

Hiatal hernia that is identified during the mobilization of the posterior gastric wall and identification of the left crus should be repaired. Ideally, the hernia defect can be identified during assessment of the left curs, but if necessary, dissection and exposure of the right crural column should be considered if a significant hiatal

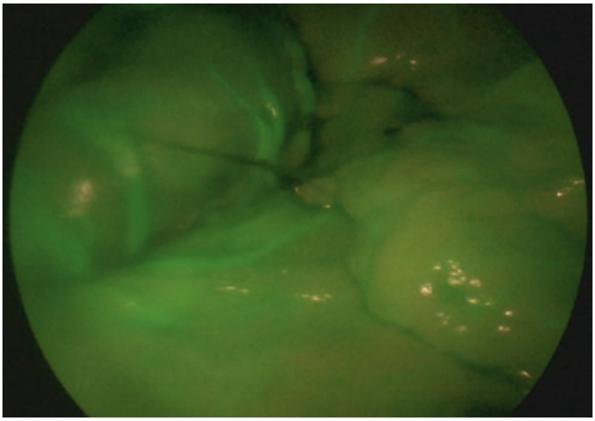


Image 34.Q ICG perfusion of the reversed gastric plication. Well-perfused view of the posterior gastric wall demonstrating adequate arterial inflow. Well-perfused tissue demonstrated a green glow, while poorly perfused tissue remains dark. In this example, the tissue glows green following reversal of the gastric plication

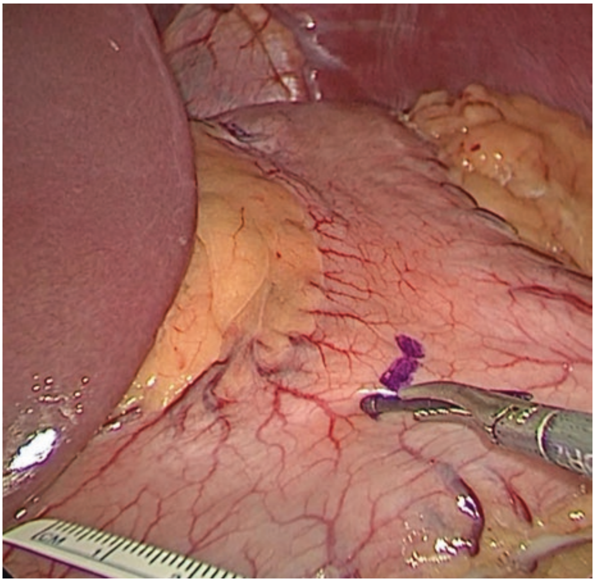


Image 34.R An example of marking the proposed staple-line path prior to performing sleeve gastrectomy. In this example, the angularis has been marked 3 cm lateral to the curve of the angularis near the location of the "crow's foot"

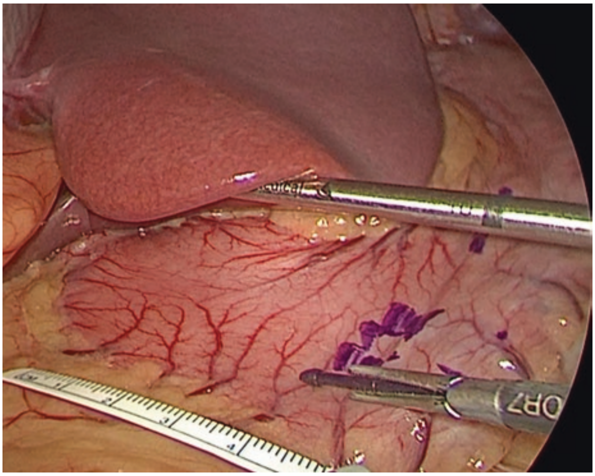


Image 34.S Example of measuring a proposed path of the staple line 5–6 cm proximal to the pylorus. The angularis has already been marked. The GE junction was also marked 1 cm lateral to the junction

hernia is identified. The effect of imbrication on the function of distal esophageal, proximal gastric cardia sling fibers is unknown and there are little reports discussing postoperative reflux after reversal of greater curvature plication. The pathophysiology of GERD following sleeve gastrectomy is unknown. Katkouda et al. studied 15 patients undergoing laparoscopic sleeve gastrectomy [15]. The mean dispensability of the LES was studied during pre-sleeve gastrectomy and post-sleeve gastrectomy. Although Katkouda was able to demonstrate a decreased dispensability of the LES following sleeve gastrectomy, that change did not correlate directly with the onset of GERD symptoms postoperatively. Katkouda's operative approach was designed to deliberately preserve the sling fibers at the gastroesophageal junction. His study is in contrast to other studies where sling fiber preservation was not a priority using a 32 French bougie. Braghetto et al. demonstrated a significant decrease in length and LES pressure when the anatomic stapling of the sleeve gastrectomy compromised the sling fibers [16]. Katkluoda's findings that the alterations in LES function did not correlate with postoperative onset of GERD suggest that the onset of GERD is multifactorial and preservation of the sling fibers could be significant. It appears that postoperative GERD following sleeve gastrectomy is not solely due to LES function. Preservation of esophagogastric sling fibers could play a role in decreasing the incidence of GERD, and as a result, we recommend using a 40 French bougie in these revision procedures and keeping the staple line a minimum of 1 cm away from the GE junction at the angle of Hiss.

34.3.4.4 Postoperative Imaging

All patients undergo postoperative upper GI to document the final outcome of the sleeve gastrectomy and to ensure against early postoperative leaks, staple-line disruption, twists, kinks, and obstruction of the sleeve gastrectomy. The final postoperative images are assessed with the goal to achieve a tubular sleeve gastrectomy with an easily identified antral pouch 5 cm from the pylorus.

34.3.4.5 Optimizing Postoperative Results

Laparoscopic plication is a minimally invasive approach to reduction of the gastric lumen. It is designed to avoid aggressive alteration of the gastric anatomy while preserving the ability to reverse the operation and restore gastric volume if needed in the future. Despite the successful reduction in gastric volume, many patients do not achieve their weight-loss goals or regain their weight in the years following the initial plication. Failure to achieve sustained weight loss following laparoscopic plication may have subselected a group of noncompliant patients who would be at risk for poor results following sleeve gastrectomy. Compliance with a postoperative regimen of dietary and behavioral changes is essential for postoperative success following minimally invasive bariatric procedures. Surgeons can further evaluate these patients with respect to the postoperative behavioral changes necessary to achieve success with the sleeve gastrectomy. Prior to sleeve gastrectomy a comprehensive preoperative educational process including a plan for postoperative aftercare should be considered for patients who fave failed laparoscopic plication operations. Preoperative careful evaluation and planning for continued postoperative follow-up may allow revision surgeons to more carefully select the most appropriate patient for sleeve gastrectomy while reserving the ability to better educate the noncompliant patient preoperatively or consider more aggressive bariatric procedures for those patients at high risk for continued noncomplaint behavior.

34.4 Summary

Laparoscopic greater curvature plication is a reversible operation that has a high degree of weight regain 2–3 years after surgery. The operation can be reversed, and sleeve gastrectomy can be performed using careful and meticulous identification of anatomy and verification of perfusion. Patients who have failed to achieve and maintain weight-loss goals with a laparoscopic gastric plication must be evaluated preoperatively, prior to revision to sleeve gastrectomy in order to identify any noncompliant behavior. Identification of specific behavior and dietary choices associated with weight regain following sleeve gastrectomy can be addressed preoperatively in patients who have failed to sustain weight loss after gastric plication. This subset of revision patients should be carefully evaluated preoperatively for noncompliant behavior. Consideration for implementation of preoperative dietary and educational support with continued postoperative follow-up may result in better long-term results after revision to sleeve gastrectomy.

References

1. World Health Organization (WHO). Obesity and over weight. Fact Sheet n 311. Revised May 2014.
2. Tretbar LL, Taylor TL, Sifers EC. Weight reduction. Gastric plication for morbid obesity. J Kans Med Soc. 1976;77(11):488–90.
3. Talebpour M, Amoli BS. Laparoscopic total gastric vertical plication in morbid obesity. J Laparoendosc Adv Surg Tech A. 2007;17:793–8.
4. Ramos A, Galvao Neto M, Galvao M, Evangelista LF, Campos JM, Ferraz A. Laparoscopic greater curvature plication: initial results of an alternative restrictive bariatric procedure. Obes Surg. 2010;20:913–8.
5. Heidari R, Talebpour M, Soleyman-jahi S, Zeinoddini A, Sanjari Moghaddam A, , Talebpour A Outcomes of reoperation after laparoscopic gastric plication failure. Obes Surg 2019;29(2):376–386.
6. Menchaca H, Harris J, Thompson S, Mootoo M, Michalek VN, Buchwald H. Gastric plication: preclinical study of durability of serosa-to-serosa apposition. Surg Obes Relat Dis. 2011;7(1):8–14.
7. Shen D, Ye H, Wang Y, Ji Y, Zhan X, Zhu J. Laparoscopic greater curvature plication: surgical techniques and early outcomes of a Chinese experience. Surg Obes Relat Dis. 2014;10(3):432–7.
8. Ji Y, Wang Y, Zhu J, Shen D. A systematic review of gastric plication for the treatment of obesity. Surg Obes Relat Dis. 2014;10(6):1226–32.
9. Grubnik VV, Ospanov OB, Namaeva KA, Medvedev OV, Kresyun MS. Randomized controlled trial comparing laparoscopic greater curvature plication versus laparoscopic sleeve gastrectomy. Surg Endosc. 2016;30(6):2186–91.
10. Brethauer SA, Harris JL, Kroh M, Schauer PL. Laparoscopic gastric plication for treatment of severe obesity. Surg Obes and Rel Dis. 2011;7:15–22.
11. Marceau P, Biron S, Bourque RA, et al. Biliopancreatic diversion with a new type of gastrectomy. Obes Surg. 1993;3:29–35.

12. Varban O, Sheetz K, Cassidy R, Stricklen A, Carlin A, Dimick J, Finks J. Evaluating the effect of operative technique on leaks after laparoscopic sleeve gastrectomy: a case-control study. Surg Obes Relat Dis. 2017;13(4):560–7.
13. Takahashi H, Strong AT, Guerron AD, Rodriguez JH, Kroh M. An odyssey of complications from band, to sleeve, to bypass; definitive laparoscopic completion gastrectomy with distal esophagectomy and esophagojejunostomy for persistent leak. Surg Endosc. 2018;32:507–10.
14. Ortega CB, Guerron AD, Yoo JS. The use of fluorescence angiography during laparoscopic sleeve gastrectomy. JSLS. 2018;22(2)
15. Reynolds J, Zehetner J, Shiraga S, Lipham J, Katkhouda N. Intraoperative assessment of the effects of laparoscopic sleeve gastrectomy on the distensibility of the lower esophageal sphincter using impedance planimetry. Surg Endosc. 2016;30(11):4904–9.
16. Braghetto I, Lanzarini E, Korn O, Valladares H, Molina JC, Henriquez A. Manometric changes of the lower esophageal sphincter after sleeve gastrectomy in obese patients. Obes Surg. 2010;20:357–62.

Chapter 35
Conversion from Endoscopic Sleeve Gastroplasty to Sleeve

Carlos Zerrweck, Manoel Galvao, Mohit Bandari, and Natan Zundel

35.1 Introduction

Bariatric surgery continues to be the most effective therapy to treat obesity and several comorbidities associated to such condition. These types of procedures are considered extremely safety, but complications have been reported in around 13% of cases (8–13% for sleeve gastrectomy) [1, 2], including bleeding, leaks, and stenosis. Mortality is a rare condition, with 0.1–0.5% rate worldwide [3]. Despite all benefits, it is estimated that less than 1% of the target population have access to bariatric surgery [4]. Another treatment options, such as diet, physical activity, and pharmacotherapy, have shown little impact in these types of patients [5]. Based on the previous study, there is a constant search for a nonsurgical, reproducible, and accessible method that promotes important and durable weight loss.

35.2 The Endoscopic Sleeve Gastroplasty

It has been an important decade for endoscopic therapies, not only to treat bariatric complications but also as primary weight loss method with the advantages of less morbidity and "simplicity." Multiple devices and techniques have been developed,

C. Zerrweck
National University of Mexico UNAM, Head of Department at The Obesity Clinic Hospital General Tláhuac, Mexico City, Mexico

M. Galvao · N. Zundel (✉)
Department of Surgery, University at Buffalo, Jackson North Medical Center, Miami, FL, USA

M. Bandari
SAIMS University, Head of Department at the Mohak Bariatric and Robotic Surgery Center, Indore, India

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_35

with different approaches to achieve weight loss. Among these, the endoscopic sleeve gastroplasty (ESG) rises as a promising technique, with an increasing popularity around the globe [6, 7]. The ESG aim is to “mimic” a sleeve gastrectomy without incisions. The technique reduces the gastric cavity to a tubular lumen, with a line of clinched plications (accordion-like) in the greater curvature [8]. It was initially described in 2013, with multiple improvements since then [6, 7, 9]. The detailed technique was previously described in Chap. 19, but the key steps are the following:

- Indications: BMI 30 kg/m^2 to 49 kg/m^2.
- Contraindications: Gastric ulcers, acute gastritis, preneoplasic findings, coagulopathy, hiatal hernia (>5 cm), prior gastric surgery, anticoagulation, pregnancy, and psychiatric disorders.
- Requirements: An endoscopic suturing system (OverStitch; Apollo Endosurgery Inc., Austin, Texas) mounted onto a specific double- or single-channel endoscope, an esophageal overtube (US Endoscopy, Mentor, Ohio), and a tissue retraction screw (Helix; Apollo Endosurgery Inc., Austin, Texas) (Fig. 35.1). The suture applied is a 2–0 polypropylene.
- Brief technique: General anesthesia with orotracheal intubation. Full-thickness sutures (aiming the muscularis propria) are delivered, starting distal (prepyloric antrum) to proximal (gastroesophageal junction), with a triangular stitch pattern

Fig. 35.1 Double-channel endoscope, OverStitch ® and Helix ®

(anterior wall – greater curvature – posterior wall). Each suture consists in around 3–6 full-thickness stitches. When all sutures are clinched together, a plication is formed. To reduce the gastric lumen, 6–8 plications are needed (Fig. 35.2). A small fundus is left in place (like a pouch) to delay gastric emptying (Fig. 35.3). Other techniques have been also described.

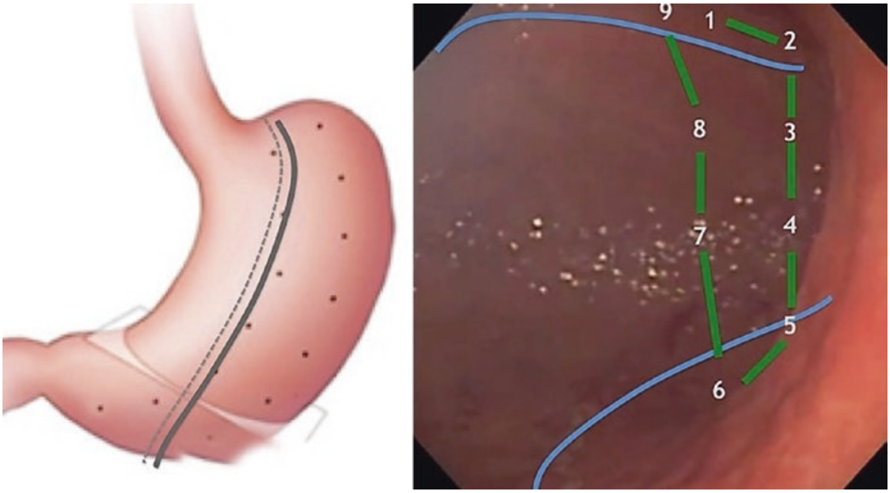


Fig. 35.2 Suture pattern direction (green lines starting from 1 to 9) to create one plication. Blue lines indicate the direction of the next plications toward the fundus

Fig. 35.3 Reconstruction in 3D of an ESG with part of the fundus left as "pouch"

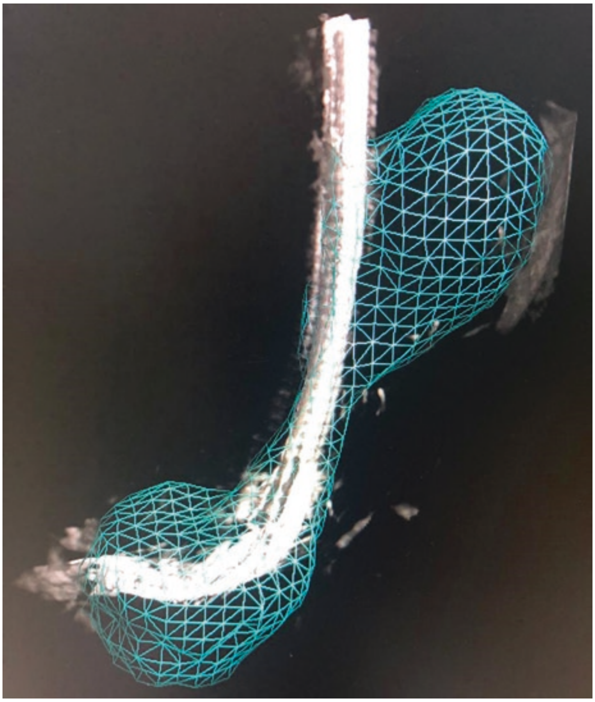


Fig. 35.4 A barium contrast study 3 months after an ESG showing a narrow gastric lumen

- Follow-up: Most of the trials do not recommend this as outpatient procedure. Liquids start normally during the first night or after 24 h. Oral contrast studies or even endoscopy can be performed during follow-up (Fig. 35.4). As any other bariatric procedure, lifestyle intervention is imperative.

35.3 Outcomes and Revisional Surgery

Post-procedure symptoms can involve epigastric/left shoulder pain, nausea, and vomiting. Complications are rare (2–2.7%) [10, 11], but bleeding, gastric perforation, perigastric collections, pleural effusion, pneumoperitoneum, or adjacent organ injury has been described. Results are limited to short-term studies, but with promising results. For example, a multicentric analysis with 248 patients that were followed at 24 months, a % of total body weight loss (%TBWL) of 18.6% (15.7–21.5%) was observed; in an intention to treat analysis, 53% of these patients achieved >10%TBWL [11].

This technique is not considered as competition to surgeries like sleeve gastrectomy or gastric bypass but an alternative for less obese patients or those not willing to accept a surgical intervention [12, 13] (Fig. 35.5).

There is no solid literature about ESG failure and subsequent revisional surgery, with only some cases available [14, 15]. A recent study with 1000 patients submitted to ESG described the need for gastroplasty reversal in 3 patients due to severe abdominal pain, 5 patients with ESG redo, and 8 revisions to sleeve gastrectomy [14]. According to the authors, the main indication for ESG revision was poor weight loss (%TBWL <5% after 6 months), but there is no information about outcomes.

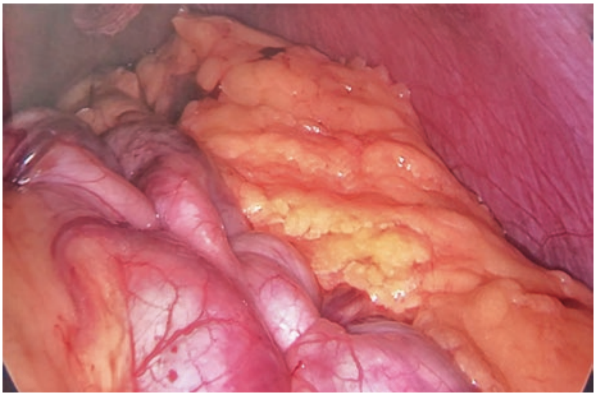


Fig. 35.5 Laparoscopic view of an ESG; clear indentations from internal stitches can be observed

35.4 Preoperative Evaluation

As every other bariatric procedure, poor weight loss is the main reason for revisional surgery after ESG. Most of these patients are included in prospective studies around the globe, so closer follow-up should be feasible, aiming to detect early failure. Professionals performing endoscopic novel techniques, such as ESG, recommend contrast studies and/or endoscopic surveillance during the first year. The intervals may vary, but a contrast study at the time of the gastroplasty and 6 months after may give important information, especially if poor weight loss is observed. Barium studies can be completed with an endoscopy to evaluate sutures status and decide if a re-ESG, or revisional surgery, can be offered. One common endoscopic finding in patients with weight regain is pouch dilation and few intact sutures [14, 15]. In patients with early procedure failure, the following assessment studies tend to show a complete reopening of the gastric lumen, without remaining sutures (Fig. 35.6). The type of revisional procedure should be a decision between the surgeon and the patient. Since most of the times there was minimal weight loss, the upcoming surgery can be planned as "primary" intervention, where the GI tract did not suffer from any real modification and subsequent adaptation (like failure after intragastric balloons). The normal "algorithm" in surgeon's daily practice for procedure selection should be applied.

35.5 Surgical Key Points

- A preoperative endoscopy is mandatory.
- If none of the sutures are in place, a "routine" sleeve gastrectomy can be offered without the need of transoperative endoscopy. Wider stapler loads are recommended all along the sleeve line (minimum height 4.1 mm).
- There should be a careful dissection of the stomach's posterior wall, since anatomic modifications are present due to sutures and anchors and adhesions related to inflammatory process (Fig. 35.7a, b).

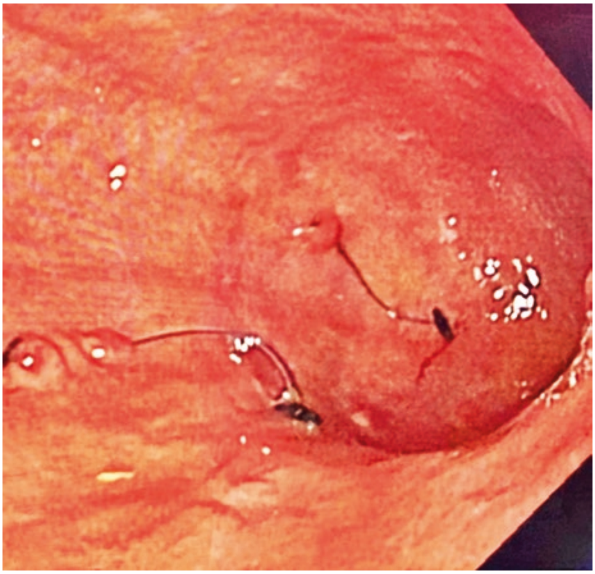


Fig. 35.6 Follow-up endoscopy 6 months after ESG in a patient with poor weight loss. A normal anatomy can be observed, with loosen up stitches

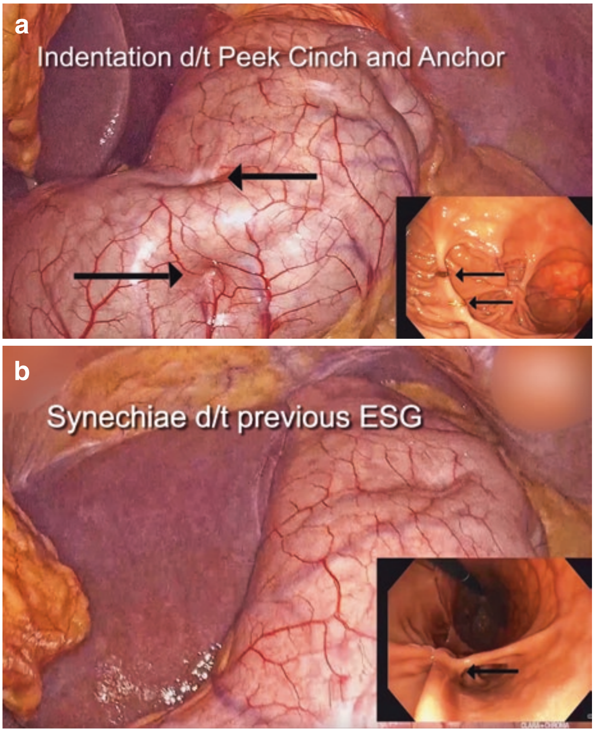


Fig. 35.7 Patient with partial weight loss after ESG. (**a**) Laparoscopic and endoscopic view of an insufflated stomach at the incisura level previously submitted to an ESG (indentation from cinches and anchors are pointed with black arrows). (**b**) Same views but at the level of the body and with retroflexion of the endoscope

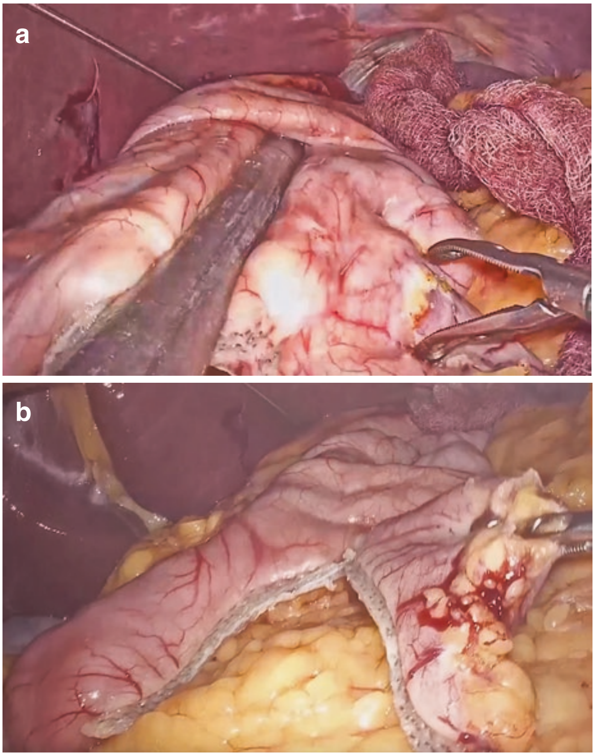


Fig. 35.8 Laparoscopic revisional surgery of a failed ESG. (**a**) Second stapler fired internal to the cinches and anchors. (**b**) After the incisura, the rest of the stomach presents more indentations

- If some sutures remain intact, a hybrid approach can be performed. The first part of the surgery will be an attempt to liberate the sutures with an endoscopy. If this is not completely possible, the endoscope will help to guide the correct placement of the stapler to avoid sutures and metal anchors (Fig. 35.8a,b).
- Intact sutures at the incisura could be dangerous during revision. If a safe stapler positioning cannot be offered to avoid an extreme sleeve narrowing, a gastric bypass should be considered instead.
- Suture-line reinforcement is advised.
- At the end of the procedure, another endoscopy could finally help to identify any foreign body within the sleeve lumen (Fig. 35.9).
- The postoperative period should be as any other sleeve.

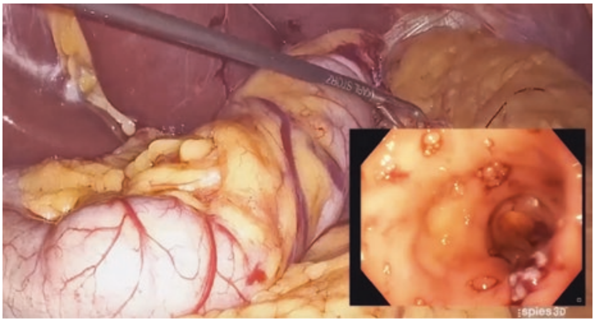


Fig. 35.9 Laparoscopic and endoscopic view of a conversion from ESG to sleeve gastrectomy

35.6 Conclusion

The endoscopic approach to weight loss is a promising tool, but there are improvements yet to come and longer follow-up of the ongoing series. Is a less invasive and less morbid technique compared with some bariatric procedures, but patient selection must be the key element to achieve better results. When the endoscopic sleeve gastroplasty fails, a complete workup has to be done before planning a revisional surgery. Conversion to sleeve gastrectomy appears safe and feasible (almost as a de novo sleeve in some cases), since complete gastroplasty dilation is often observed [6].

References

1. Chang SH, Stoll CR, Song J, Varela JE, Eagon CJ, Colditz GA. The effectiveness and risks of bariatric surgery: an updated systematic review and meta-analysis, 2003-2012. JAMA Surg. 2014;149(3):275–87.
2. Falk V, Twells L, Gregory D, Murphy R, Smith C, Boone D, et al. Laparoscopic sleeve gastrectomy at a new bariatric surgery centre in Canada: 30-day complication rates using the Clavien-Dindo classification. Can J Surg. 2016;59(2):93–7.
3. Nguyen NT, Varela JE. Bariatric surgery for obesity and metabolic disorders: state of the art. Nat Rev Gastroenterol Hepatol. 2017;14(3):160–9.
4. Buchwald H, Oien DM. Metabolic/bariatric surgery worldwide 2011. Obes Surg. 2013;23(4):427–36.
5. Middleton KM, Patidar SM, Perri MG. The impact of extended care on the long-term maintenance of weight loss: a systematic review and meta-analysis. Obes Rev. 2012;13(6):509–17.
6. Zundel N, Thompson C. Endoscopic Suturing. a compendium of current clinical experience. Bariatric Times. 2013;10(11 Suppl B):B13–5. (Editor).
7. Pena HN, Alvarado A, Wilson EB, Zundel N. Endoscopic gastroplasty as a pimary metabolic and bariatric procedure: OUS experience. Bariatric Times. 2013;10(11 Suppl B):B13–5.
8. Lopez-Nava G, Galvao MP, Bautista-Castano I, Jimenez-Banos A, Fernandez-Corbelle JP. Endoscopic sleeve gastroplasty: how I do it? Obes Surg. 2015;25(8):1534–8.
9. Abu Dayyeh BK, Rajan E, Gostout CJ. Endoscopic sleeve gastroplasty: a potential endoscopic alternative to surgical sleeve gastrectomy for treatment of obesity. Gastrointest Endosc. 2013;78(3):530–5.

10. Sartoretto A, Sui Z, Hill C, Dunlap M, Rivera AR, Khashab MA, et al. Endoscopic sleeve gastroplasty (ESG) is a reproducible and effective endoscopic bariatric therapy suitable for widespread clinical adoption: a large, International Multicenter Study. Obes Surg. 2018;28(7):1812–21.
11. Lopez-Nava G, Sharaiha RZ, Vargas EJ, Bazerbachi F, Manoel GN, Bautista-Castano I, et al. Endoscopic sleeve gastroplasty for obesity: a multicenter study of 248 patients with 24 months follow-up. Obes Surg. 2017;27(10):2649–55.
12. Galvao-Neto MD, Grecco E, Souza TF, Quadros LG, Silva LB, Campos JM. Endoscopic sleeve gastroplasty - minimally invasive therapy for primary obesity treatment. Arq Bras Cir Dig. 2016;29 Suppl 1(Suppl 1):95–7.
13. Kumar N, Abu Dayyeh BK, Lopez-Nava Breviere G, Galvao Neto MP, Sahdala NP, Shaikh SN, et al. Endoscopic sutured gastroplasty: procedure evolution from first-in-man cases through current technique. Surg Endosc. 2018;32(4):2159–64.
14. Alqahtani A, Al-Darwish A, Mahmoud AE, Alqahtani YA, Elahmedi M. Short-term outcomes of endoscopic sleeve gastroplasty in 1000 consecutive patients. Gastrointest Endosc. 2018;
15. Ferrer-Marquez M, Ferrer-Ayza M, Rubio-Gil F, Torrente-Sanchez MJ, Martinez A-GA. Revision bariatric surgery after endoscopic sleeve gastroplasty. Cir Cir. 2017;85(5):428–31.

Chapter 36
Conversion from Roux-En-Y Gastric Bypass to Sleeve Gastrectomy

Giovanni Dapri

36.1 Introduction

Laparoscopic Roux-en-Y gastric bypass (RYGB) is one of the most common bariatric procedures performed and is reported to offer at midterm percentage of excess weight loss (%EWL) of 43–68.1% [1–3], with improvement of almost all conditions related to obesity (4) Laparoscopic sleeve gastrectomy (SG) became a popular procedure for morbid obesity after the five international consensus summits [4–8], achieving a mean %EWL at year one of 59.3%, at year two of 59.0%, at year three of 54.7%, at year four of 52.3%, at year five of 52.4%, and at year six of 50.6%. SG can be considered as first step of duodenal switch (DS). The %EWL after DS is reported to be 68.9% after more than 10 years [9].

Weight loss issues (either too much weight or too little weight loss) and weight regain after initial successful weight loss are a few of the negative aspects that can affect patients after undergoing bariatric surgery.

The precise mechanisms whereby RYGB achieves sustained weight loss remain unknown, but many of the changes in gastrointestinal hormones, adipokines, and cytokines as well as in hypothalamic neuropeptides and neurotransmitters resemble the changes observed in cachexia rat model [10]. Hence, in humans, RYGB triggers a catabolic state responsible for loss of appetite and prolonged body weight reduction.

Electronic Supplementary Material The online version of this chapter (https://doi.org/10.1007/978-3-030-28936-2_36) contains supplementary material, which is available to authorized users.

G. Dapri (✉)
International School Reduced Scar Laparoscopy, Brussels, Belgium
e-mail: giovanni@dapri.net

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_36

The opposite situation of unsuccessful weight loss after RYGB can be related to technical failures or to new dietary behavior. Technical causes of weight regain can be gastric pouch dilation, gastrojejunostomy dilation, and gastro-gastric fistula's development. Patients who undergo RYGB frequently develop new alimentary habits like hyperphagia, polyphagia, or sweet eating. Hyperphagia, which means volume eating (eating too large meals), will logically be treated by increasing restriction by placement of an adjustable gastric band [11–13] or a nonadjustable ring [14] around the gastric pouch or resizing a dilated gastric pouch [15]. Polyphagia, which means grazing (eating too frequent meals), can logically be treated by conversion of RYGB to a malabsorptive procedure like distal RYGB (DRYGB), or DS performed in two steps (from RYGB to SG first and biliopancreatic diversion after). A new mixed alimentary behavior, characterized by grossly increased caloric intake, will be treated by conversion to SG, leaving the probability of adding a significant malabsorption consequence by the second step of DS. Obviously, the nutritionist's counseling constitutes an important part of the multidisciplinary consultation, since mental disorders, such as binge eating and night eating disorders, must be ruled out.

The multidisciplinary consultation is fundamental for the follow-up of obese patients and for the patients submitted to RYGB because this procedure may lead to some serious problems. One problem associated with RYGB is the dumping syndrome, which is clinically characterized by postprandial sweating, flushing, dizziness, weakness, tachycardia, palpitations, diaphoresis, and lassitude. This can be attributed to the rapid entrance of hyperosmotic foods to the jejunum, which, according to one hypothesis, causes a fall in blood volume and significant sympathetic stimulation from various pressoreceptors [16]. It is also related to the effect of hyperosmolar fluid on the argentaffin cells in the small intestinal mucosa, causing release of vasoactive serotonin and vasomotor effects. A third explanation of the syndrome is hypoglycemia provoked by excessive intake of rapid sugars or foods with high glycemic index because increased insulin sensitivity induces abrupt glucose fluctuations in the blood [17]. In bariatric surgery the dumping syndrome has been considered as a beneficial feature because patients learned to avoid calorie-dense foods and ate less at one time [18].

Despite adequate dietary counseling (small meals, little carbohydrates), patients with RYGB still can fail to comply with restriction caused by the procedure, with subsequent excessive dumping, vomiting episodes, and abdominal pain.

Furthermore, patients with symptoms of postprandial hyperinsulinemic hypoglycemia are characterized by exaggerated insulin and glucagon-like peptide-1 (GLP-1) response compared to asymptomatic operated patients [19]. The counter-regulatory mechanisms responsible for preventing hypoglycemia appear to be altered. The cause of these changes are not entirely understood, and known risk factors are female sex, longer time since surgery and lack of having prior diabetes. Treatment should begin with strict low carbohydrate diet, followed by medication therapy. Therapy with diazoxide, acarbose, calcium channel blockers, and octreotide has been proven to be beneficial, but the response apparently is highly variable and subject to fail [20].

Because of these challenges, the procedure of RYGB has not been considered as nonreversal [21], and a laparoscopic conversion of RYGB to SG can be an option. Moreover, this conversion can also constitute the first step of the DS procedure, leaving the patients in better conditions.

36.2 Surgical Technique

The patient is positioned supine with the legs and both arms in abduction (French position). The surgeon stands between the patient's legs, the camera person to the patient's right, and the assistant to the patient's left. The procedure starts by inserting the first 12-mm trocar, using the Hasson technique, on the midclavicular line in the left upper quadrant. Four additional trocars are placed under direct intraperitoneal view, usually at the same position, as for the original surgery: a 5-mm trocar on the left anterior axillary line at 5 cm distal to the costal margin, a 10-mm trocar at some 20 cm below the xiphoid process, a 12-mm trocar on the right midclavicular line on the same horizontal line, and a 5-mm trocar just distal to the xiphoid process. Another option consists into perform a reduced scar laparoscopy like represented in the video attached to this chapter. The alimentary loop is identified, and adhesions between the parietal peritoneal sheet and the greater omentum and/or small bowel, and between the left liver lobe and the gastrojejunostomy are severed. Great care is taken to prevent damage to the glissonian hepatic capsule. At this stage, both the diaphragmatic crura are clearly identified. In case of crural diastasis or incipient hernia, hiatoplasty is performed by passing 1 polypropylene one or two figure-of-eight sutures. The gastric remnant is separated from the adhesions with the gastric pouch and gastrojejunostomy by coagulating hook or thick stapling. The gastric pouch is sectioned by a firing of linear stapler, just proximal to the anastomosis in healthy tissue, and extreme care is taken not to devascularize the little stomach pouch, since it usually survives on just one or two branches of the left gastric artery (Fig. 36.1). Then, the gastrojejunostomy is separated by the proximal end of the alimentary limb by a firing of stapler. The fundus of the gastric remnant is subsequently freed from top to bottom along the greater curvature, down to the level of the body of the stomach. At this level, the body of the gastric remnant is transected from lateral to medial by firings of linear stapler (Fig. 36.2). The gastric pouch is opened on its posterior side and the remaining upper pole of gastric remnant on its anterior side (Fig. 36.3) in order to accommodate a 34-Fr orogastric bougie, pushed down at this time by the anesthesiologist. The orogastric bougie is advanced toward the pylorus, permitting to complete the SG, by stapling the antrum with multiple firings of linear stapler alongside the tube (Fig. 36.4). After this step, the continuity of the stomach is established by a manual gastrogastrostomy between the gastric pouch and the gastric remnant, using two 1 polydiaxone (PDS) running sutures (Fig. 36.5). The good

Fig. 36.1 Dismantling of the previous gastrojejunostomy

vascularization of the gastric pouch and of the distal sleeve can be checked by the contrast-enhanced indocyanine green perfusion (like in the video attached to this chapter). The jejunojejunostomy is localized, and the alimentary, biliary, and common limbs are identified. The anastomosis is dismantled by firings of linear stapler, in an attempt to duplicate the original staple line and not to impinge on the distal end of the alimentary limb (Fig. 36.6). A linear stapler anastomoses the proximal end of the alimentary limb and the distal end of the biliary limb, and the enterotomy is closed by two 2-0 PDS running sutures (Fig. 36.7). The blind loop of the biliary and alimentary limbs is resected after completion of the new jejunojejunostomy, if necessary. The mesenteric window, created at the time of RYGB, is closed using purse string of 1 polypropylene, thereby reestablishing the original anatomy. The gastrointestinal continuity is checked by insufflation of compressed air through the orogastric bougie. A drain is left in the abdominal cavity near the gastrogastrostomy and the body of the stomach. The specimens (gastric remnant, gastrojejunostomy) are retrieved from the abdomen by enlarging the left 12-mm upper quadrant trocar, which is subsequently closed in layers.

Fig. 36.2 Fundectomy of the gastric remnant

36.3 Postoperative Care

A methylene blue swallow is realized on the first postoperative day, and if negative, a liquid diet is started on the second postoperative day. The patient is discharged on a pureed diet on the fifth/sixth postoperative day, and a normal diet is started at the third postoperative month. Thereafter, the usual multidisciplinary follow-up is adopted.

36.4 Results

Despite RYGB reversal has been increasing [22], conversion of RYGB into SG remains not popular due to its difficulty and association to major complications, like anastomotic leak and stricture [23], and gastroesophageal reflux [24]. However, change in weight loss is present although it remains not high [23, 24].

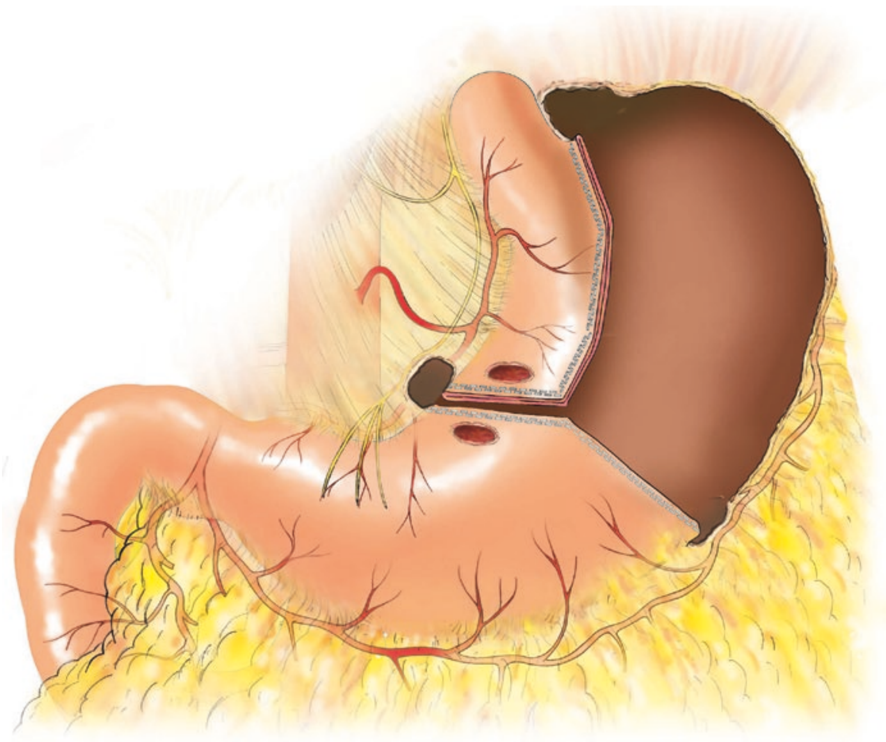


Fig. 36.3 Opening of the gastric pouch and gastric remnant to accommodate the orogastric bougie

Regarding change of hypoglycemia, deconstruction of Roux-en-Y limb and restoration of the gastrointestinal continuity remains an option to offer when the medical treatments fail [20]. Recently, a study confirmed an improvement of symptomatic hypoglycemia in RYGB reversal patients, excluding the origin of the hypoglycemia from the ß-cell hyperplasia or hyperfunction [25]. In this study, weight gain after RYGB reversal was moderate and variable; postprandial glucose, insulin, and GLP-1 excursions were significantly diminished; insulin secretion changed proportional to glucose levels and insulin clearance increased; glucagon/insulin ratios were similar.

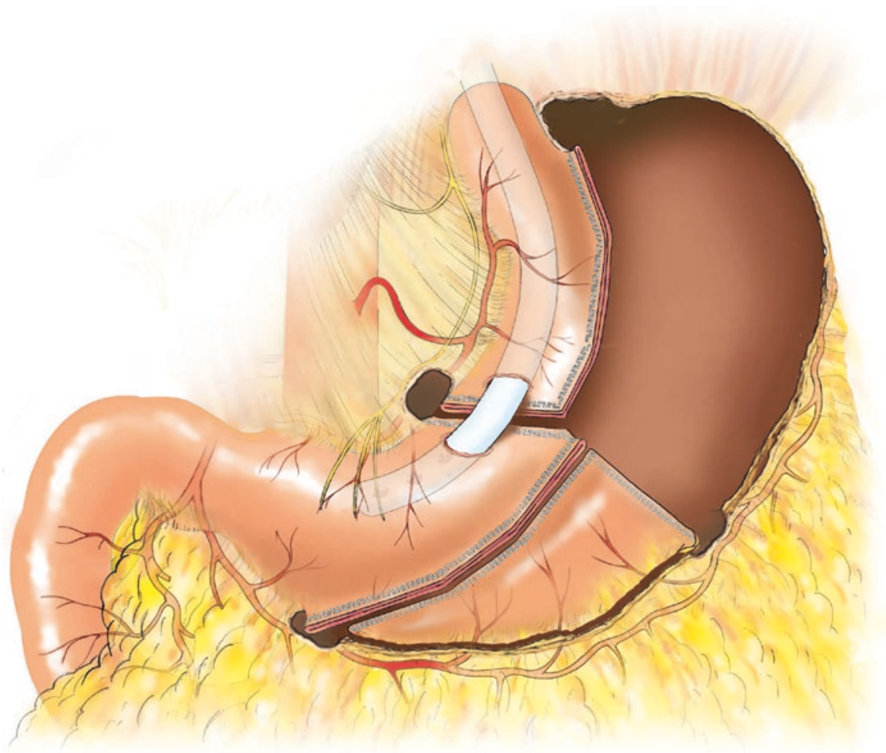


Fig. 36.4 Resection of the gastric antrum to complete the sleeve gastrectomy, after placement of an orogastric bougie and before the restoration of the gastric continuity

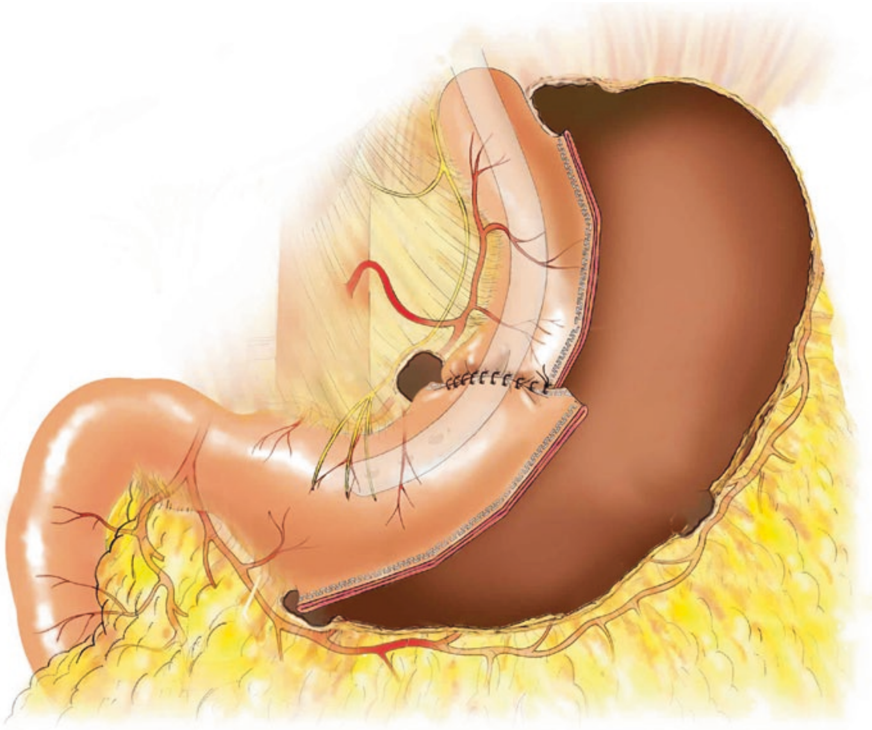


Fig. 36.5 Restoration of the gastric continuity through a manual gastrogastrostomy between the gastric pouch and the gastric remnant

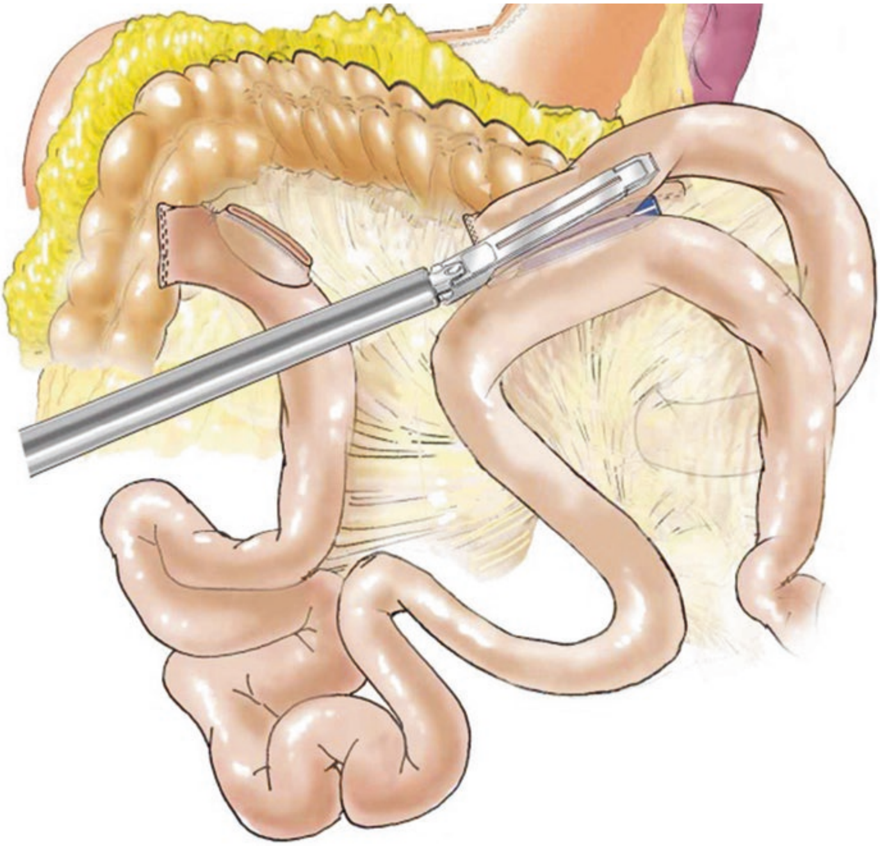


Fig. 36.6 Dismantling of the previous jejunojejunostomy

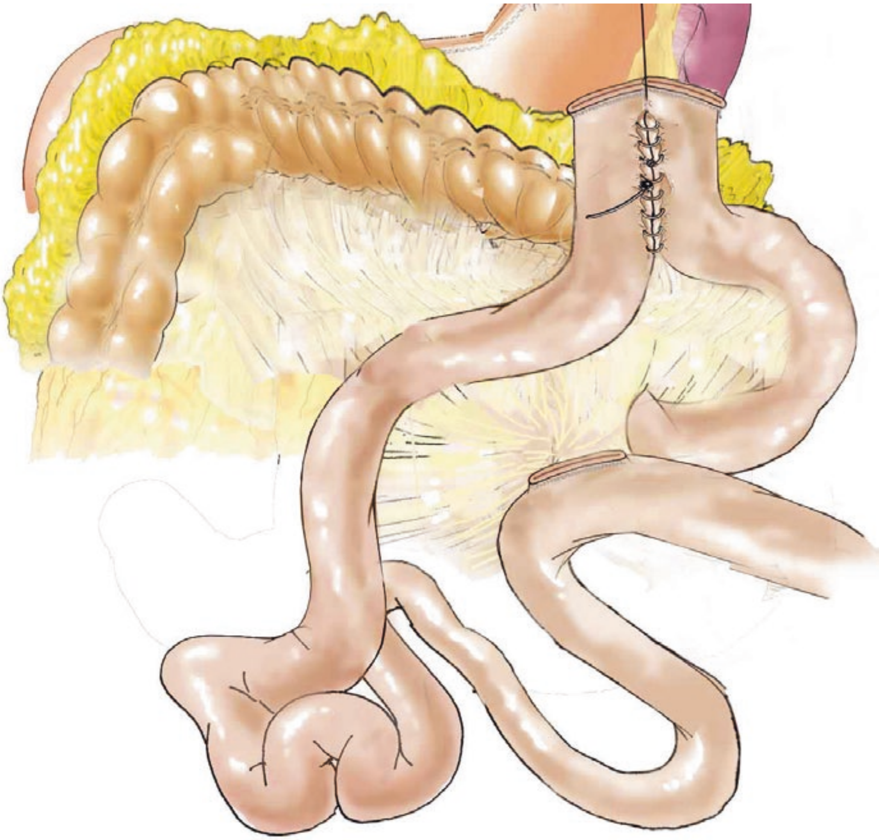


Fig. 36.7 Restoration of the small bowel continuity through a new jejunojejunostomy, performed between the previous alimentary proximal end and the previous biliary distal end

36.5 Conclusions

Laparoscopic conversion of RYGB to SG is a feasible and safe procedure to be considered in front of weight loss issues (either too much weight or too little weight loss), weight regain, dumping syndrome, or hyperinsulinemic hypoglycemia after RYGB. Moreover, this conversion can also be considered as the first step of the DS procedure, leaving the patients in better conditions.

References

1. Pories W, Swanson M, MacDonald K. Who would have thought it? An operation to be the most effective therapy for adult-onset diabetes mellitus. Ann Surg. 1995;222:339–50.
2. Jones K. Experience with the Roux-en-Y gastric bypass, and commentary on current trends. Obes Surg. 2000;10:183–5.

3. Christou NV, Look D, MacLean LD. Weight gain after short- and long-limb gastric bypass in patients followed for longer than 10 years. Ann Surg. 2006;244:734–40.
4. Deitel M, Crosby RD, Gagner M. The first international consensus summit for sleeve gastrectomy (SG), New York City, October 25-27, 2007. Obes Surg. 2008;18:487–96.
5. Gagner M, Deitel M, Kalberer TL, Erickson AL, Crosby RD. The second international consensus summit for sleeve gastrectomy, March 19-21, 2009. Surg Obes Relat Dis. 2009;5:476–85.
6. Deitel M, Gagner M, Erickson AL, Crosby RD. Third international summit: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2011;7(6):749–59.
7. Gagner M, Deitel M, Erickson AL, Crosby RD. Survey on laparoscopic sleeve gastrectomy (LSG) at the Fourth International Consensus Summiton Sleeve Gastrectomy. Obes Surg. 2013;23(12):2013–7.
8. Gagner M, Hutchinson C, Rosenthal R. Fifth International Consensus Conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6.
9. Marceau P, Biron S, Hould FS, et al. Duodenal switch: long-term results. Obes Surg. 2007;17:1421–30.
10. Guijarro A, Kirchner H, Meguid MM. Catabolic effects of gastric bypass in a diet-induced obese rat model. Curr Opin Clin Nutr Metab Care. 2006;9:423–35.
11. Bessler M, Daud A, Digiorgi MF, et al. Adjustable gastric banding as revisional bariatric procedure after failed gastric bypass-intermediate results. Surg Obes Relat Dis. 2010;6:31–5.
12. Gobble RM, Parikh MS, Greives MR, Ren CJ, Fielding GA. Gastric banding as a savage procedure for patients with weight loss failure after Roux-en-Y gastric bypass. Surg Endosc. 2008;22:1019–22.
13. Chin PL, Ali M, Francis K, LePort PC. Adjustable gastric band placed around gastric bypass pouch as revision operation for failed gastric bypass. Surg Obes Relat Dis. 2009;5:38–42.
14. Dapri G, Cadière GB, Himpens J. Laparoscopic placement of non-adjustable silicone ring for weight regain after Roux-en-Y gastric bypass. Obes Surg. 2009;19:650–4.
15. Al-Bader I, Khoursheed M, Al Sharaf K, Mouzannar DA, Ashraf A, Fingerhut A. Revisional laparoscopic gastric pouch resizing for inadequate weight loss after Roux-en-Y gastric bypass. Obes Surg. 2015;25(7):1103–8.
16. Matthews DH, Lawrence W Jr, Poppell JW, et al. Change in effective volume during experimental dumping syndrome. Surgery. 1960;48:185–94.
17. Bikman BT, Zheng D, Pories WJ, et al. Mechanism for improved insulin sensitivity after gastric bypass surgery. J Clin Endocrinol Metab. 2008;93:4656–63.
18. Deitel M. The change in the dumping syndrome concept. Obes Surg. 2008;18:1622–4.
19. Øhrstrøm CC, Worm D, Hansen DL. Postprandial hyperinsulinemic hypoglycemia after Roux-en-Y gastric bypass: an update. Surg Obes Relat Dis. 2017;13(2):345–51.
20. Malik S, Mitchell JE, Steffen K, Engel S, Wiisanen R, Garcia L, Malik SA. Recognition and management of hyperinsulinemic hypoglycemia after bariatric surgery. Obes Res Clin Pract. 2016;10(1):1–14.
21. Himpens J, Dapri G, Cadière GB. Laparoscopic conversion of the gastric bypass into a normal anatomy. Obes Surg. 2006;16:908–12.
22. Shoar S, Nguyen T, Ona MA, Reddy M, Anand S, Alkuwari MJ, Saber AA. Roux-en-Y gastric bypass reversal: a systematic review. Surg Obes Relat Dis. 2016;12(7):1366–72.
23. Carter CO, Fernandez AZ, McNatt SS, Powell MS. Conversion from gastric bypass to sleeve gastrectomy for complications of gastric bypass. Surg Obes Relat Dis. 2016;12(3):572–6.
24. Arman GA, Himpens J, Bolckmans R, Van Compernolle D, Vilallonga R, Leman G. Medium-term outcomes after reversal of Roux-en-Y gastric bypass. Obes Surg. 2018;28(3):781–90.
25. Davis DB, Khoraki J, Ziemelis M, Sirinvaravong S, Han JY, Campos GM. Roux en Y gastric bypass hypoglycemia resolves with gastric feeding or reversal: confirming a non-pancreatic etiology. Mol Metab. 2018;9:15–27.

Part VII
Education and Future

Chapter 37
What We Have Learned After 20 Years of Sleeve Gastrectomy Regular Practice

Michel Gagner

37.1 Introduction

Sotto l'ombelico, non c'è né religione né verità.
Below the navel, there is neither religion nor truth.
Italian Proverb

37.2 Pioneering Period: 1999–2006

I encourage you to read on the history of sleeve gastrectomy and its early development, explained in detail in the first chapter of this book. Suffice to say that pioneering work is frowned upon and looked by many negatively, the "do not move my cheese" mentality has prevailed during that time. There was even the development of gastric plication, a reinventing of Tretbar from the 1970s, taken with laparoscopic techniques from Talebpour from Teheran, called the "sleeve killer" and promoted by Dr. Phil Schauer of the Cleveland Clinic, trying to kill the growth of sleeve gastrectomy, with some initial support from Ethicon Endosurgery Johnson & Johnson, as they had a special instrument developed to help in maintaining the plication in place laparoscopically. As it turned out, sleeve gastrectomy was the "plication killer," the absolute other way around! There was pressure from a certain establishment of the ASMBS mostly promoting only Roux-en-Y gastric bypass. In this context, the pioneering work of sleeve gastrectomy was difficult, with ostracizing comments in meeting and in corridors of bariatric surgery conferences. From the pioneering work that I have been engaged in the past, it takes about 10 years from the point of early presentations for a procedure to become mainstream, the exception being

M. Gagner (✉)
Department of Surgery, Sacré-Coeur Hospital, Montréal, QC, Canada
e-mail: Gagner.Michel@cliniqueMichelGagner.com

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_37

laparoscopic cholecystectomy, because it touched and jeopardized the bread and butter of all general surgeons. When I started laparoscopic adrenalectomy in 1991, it became the norm about 10 years later. It took a little bit longer for laparoscopic pancreatectomy because most HPB surgeons were not familiar with advanced suturing techniques [1, 2].

37.3 ASMBS and IFSO Roles with This Operation

ASMBS came out with a political statement in November/December 2007 issue of SOARD, in which the "ASMBS recognizes that performance of sleeve gastrectomy may be an option for carefully selected patients undergoing bariatric surgical treatment, particularly those who are high risk or super-super-obese, and that the concept of staged bariatric surgery may have value as a risk-reduction strategy in high-risk patient populations." There were many negative reactions from surgeons doing only Roux-en-Y gastric bypasses at the time, and they considered this statement too "avant-garde" and wanted to declare laparoscopic sleeve gastrectomy an experimental operation. Remember that this operation is the first part of an already-approved duodenal switch [3, 4].

This was updated in 2010 in SOARD: "Limited intermediate-term (3–5-year) data have been published in peer-reviewed studies demonstrating durable weight loss and improved medical co-morbidities in patients treated for morbid obesity using the SG procedure. The long-term follow-up data at 5 years for high-risk and super-obese patients are limited, in part because some patients undergo a planned second operation (Roux-en-Y gastric bypass or duodenal switch) within 2 years of their SG, either as part of an overall staged treatment strategy or because of weight loss failure or weight regain. Informed consent for SG used as a primary procedure should be consistent with the consent provided for other bariatric procedures and should include the risk of long-term weight gain [5].

At present, the ASMBS recognizes that the concept of staged bariatric surgery using lower risk procedures as the initial treatment appears to have value as a risk-reduction strategy for high-risk patients. SG is uniquely positioned as a bariatric procedure because of its development as a risk- reduction initial treatment strategy with the intent that it might be more easily converted to an alternative procedure after significant weight loss compared with the other available bariatric procedures. Much of the published data supporting SG as a bariatric procedure have described favourable outcomes in patients described as high risk, making it an acceptable option for this subgroup. Furthermore, a significant proportion of patients have demonstrated durable weight loss after SG and might not require conversion to another procedure. Therefore, it is justifiable to recommend SG as an ASMBS-approved bariatric procedure." This really had given the go-ahead for most American surgeons, and procedures went exponential after this. Commercial insurances and Centers for Medicare and Medicaid Services (CMS) approved the procedure in 2012 [6, 7].

In 2012, more studies had been published, and I am not sure why another position statement was required: "Substantial comparative and long-term data have now been published in peer-reviewed studies demonstrating durable weight loss, improved medical co-morbidities, long-term patient satisfaction, and improved quality of life after SG.

The ASMBS therefore recognizes SG as an acceptable option as a primary bariatric procedure and as a first-stage procedure in high-risk patients as a part of a planned staged approach. From the current published data, SG has a risk/benefit profile between LAGB and laparoscopic RYGB.

As with any bariatric procedure, long-term weight regain can occur and, in the case of SG, this can be managed effectively with reintervention. Informed consent for SG used as a primary procedure should be consistent with the consent provided for other bariatric procedures and should include the risk of long-term weight gain [8].

Surgeons performing SG are encouraged to continue to prospectively collect and report their outcome data in the peer-reviewed scientific studies."

By 2017, many opponents of the operation felt it was now important to revise prior statements to include the negative aspects of this procedure, in spite of having no position statement on Roux-en-Y gastric bypass with its associated complications: "Substantial long-term outcome data published in the peer-reviewed literature, including studies comparing outcomes of various surgical procedures, confirm that SG provides significant and durable weight loss, improvements in medical co-morbidities, improved quality of life, and low complication and mortality rates for obesity treatment. In terms of initial early weight loss and improvement of most weight-related co-morbid conditions, SG and RYGB appear similar. The effect of SG on GERD, however, is less clear, because GERD improvement is less predictable and GERD may worsen or develop de novo. Preoperative counselling specific to GERD-related outcomes is recommended for all patients undergoing SG. The ASMBS recognizes SG as an acceptable option for a primary bariatric procedure or as a first-stage procedure in high-risk patients as part of a planned, staged approach. As with any bariatric procedure, long-term weight regain can occur after SG and may require one or more of a variety of reinterventions. Informed consent for SG as a primary procedure should be consistent with the consent provided for other bariatric procedures and, as such, should include the risk of long-term weight regain. In addition, as with all currently recognized bariatric procedures, surgeons per- forming SG are encouraged to prospectively collect, analyze, and report their outcome data in peer-reviewed scientific forums [9]."

I still believe that the upper echelon of ASMBS had a bias against laparoscopic sleeve gastrectomy, and many were frankly jealous at the successes of this operation. Why? Most presidents of ASMBS nominated have been the strong supporters of Roux-en-Y gastric bypass. Also there has been NO position statement on adjustable gastric banding during this whole period of 20 years, yet this operation has fallen in disfavor considerably, where only 1% of primary procedures in the USA are now adjustable gastric banding. Also, there has never been any position statement on Roux-en-Y gastric bypass. They did one on gastric plication, to declare it an investigational procedure, as well as for single-anastomosis gastric bypass and single-anastomosis DS, commonly called SADI. It seems that they write a position statement on things they do not approve. Concerning laparoscopic sleeve gastrectomy, during its 20 years of existence, ASMBS published four position statements, and fortunately, IFSO never followed such pathway, leaving surgical clinicians with their good judgment [10].

37.4 International Consensus Period: 2007–2017

I organized the First International Consensus Summit for Sleeve Gastrectomy (SG), held in New York City, October 25–27, 2007, and subsequent five others over a decade. The 2011 conference organized by Raul Rosenthal in Florida was sponsored by Ethicon Endosurgery and had a very successful and well-cited publication, and I was a participant/coauthor.

In 2007, the first day consisted of live surgery by experts performing SG, and the second full day consisted of presentations and video case reviews by experts from around the world. The third day consisted of the International Summit Consensus of experts to determine the efficacy and current state of the art of sleeve gastrectomy, and the registration for the meeting was 325, especially international participants [11].

The interest to look back, and reflect at those, is to see how accurate we were 12 years back on the operation. The Consensus Panel assembled in Florence Gould Hall on October 27, 2007, with a series of questions, voted upon, and the very first panel consisted of 40 experts in the field.

Sleeve gastrectomy was indicated for high-risk patients by 62% of experts, and 58% thought that sleeve gastrectomy was indicated as a primary procedure with BMI > 40 or > 35 with comorbidities. Interestingly, at that time, 70% completely agreed that sleeve gastrectomy would be an excellent primary procedure in patients with BMI > 40 or > 35 with comorbidities if the % EWL at 5 years would be similar to Roux-en-Y gastric bypass. Well, the recent RCTs published in JAMA surgery, 11 years later, really showed exactly that!! Sleeve gastrectomy was indicated as a primary procedure for BMI 30–35 kg/m^2, and 31% of experts were prepared to do so, but it would take longer for more surgeons to accept this statement; in fact, it became the operation of choice later for this group, like all special groups such as adolescents, children, elderly patients, transplant candidates, cirrhotic, etc.

Are weight loss failures from sleeve gastrectomy easier to manage surgically than after other approved procedures? Eighty percent agreed. In the situation where after 3 years following a sleeve gastrectomy, a patient significantly regains weight, 21% would do a laparoscopic resleeve, 38% a laparoscopic Roux-en-Y gastric bypass, and 41% a duodenal switch. GERD was already on the radar screen, and in refractory GERD after sleeve gastrectomy, 39% would use medical treatment, and 44% would convert to a Roux-en-Y gastric bypass [12].

Thirty-two percent agreed completely that an IRB was not required to do this surgery in 2007, as it was similar to an approved duodenal switch, without its intestinal component. In 2007, results were actually pretty consistent with what is now published 10–12 years later; % EWL were as follows: 1 year, 50%; 2 years, 58%; 3 years, 56%; and > 3 years, 53%.

In March 19–21, 2009, in Miami Beach, at the new reopened famous Fontainebleau hotel, the Second International Consensus Summit for Sleeve Gastrectomy was held, with pouring rain outside. The main hall was where the rat packs, with Frank Sinatra, Dean Martin, and the others, have been singning. A questionnaire was filled out by attendees representing a total of 14,776 SGs. More technical details were discussed and permitted to come with specific details about how to perform this operation properly. During the consensus part, the audience responded that there was enough evidence published to support the use of sleeves as a primary procedure to treat morbid obesity [12, 13].

In December 2010, the Third International Summit was held back in New York City, and by then, the surgical community has been performing sleeves for morbid obesity for the past 10 years. The results of the questionnaire were based on 19,605 sleeve gastrectomy performed. In terms of complications prevalence, upper leaks occurred in 1.3% of cases, lower leaks occurred in 0.5% of cases, intraluminal bleeding occurred in 2.0% of cases, and mortality rate occurred in 0.1% of cases. It was concluded that upper gastric leaks are infrequent but problematic [14].

Two years later, in December 2012 again in New York City, the Fourth International Consensus Summit on Sleeve Gastrectomy was held. The experience of respondents had grown to a total of 46,133 sleevegastrectomies, with an average experience of nearly 5 years. Mean % EWL at year 1 was 59%; year 2, 59%; year 3, 55%; year 4, 52%; year 5, 52%; and year 6, 51%. If a second-stage operation became necessary, it was preferred to perform a gastric bypass by 46%, duodenal switch 24%, and resleeve 20%. Postoperative gastroesophageal reflux occurred in 8% but was variable. It was concluded that laparoscopic sleeve gastrectomy was safe, but further long-term surveillance is necessary [15].

I organized the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) annual meeting of 2014 and Fifth International Consensus Conference on Laparoscopic Sleeve Gastrectomy in Montreal at the end of August 2014. For the purpose of building best practice guidelines, an international expert panel was surveyed in 2014 and compared with the 2011 Sleeve Gastrectomy Consensus and with survey data taken from a general surgeon audience. The expert surgeons (based on having performed > 1000 cases) completed an online anonymous survey. The following indications were endorsed: as a stand-alone procedure, 97.5%; in high-risk patients, 92.4%; in kidney and liver transplant candidates, 91.6%; in patients with metabolic syndrome, 83.8%; body mass index 30–35 with associated comorbidities, 79.8%; in patients with inflammatory bowel disease, 87.4%; and in the elderly, 89.1%. Significant differences existed between the expert and general surgeons groups in endorsing several contraindications: Barrett's esophagus (80% versus 31% [$P < 0.001$]), gastroesophageal reflux disease (23% versus 53% [$P < 0.001$]), hiatal hernias (12% versus 54% [$P < 0.001$]), and body mass index > 60 kg/m^2 (5% versus 28% [$P < 0.001$]). Average reported weight loss outcomes 5 years' postoperative were significantly higher for the expert surgeons group (P = 0.005), as were reported stricture (P = 0.001) and leakage (P = 0.005) rates [16, 17]. This conference highlighted areas of new and improved best practices on various aspects of laparoscopic sleeve gastrectomy performance among experts and current general surgeon population.

The 6th International Consensus Conference on Sleeve Gastrectomy was held using the same format as Montreal, but in London, UK, during the IFSO conference of 2017. No publication really followed that meeting, as there was really nothing new from promulgated data in Montreal.

During those 10 years, we should note that Dr. Raul Rosenthal did a great job of organizing an International Sleeve Gastrectomy Expert Panel Consensus for the purpose of establishing best practice guidelines, based on the experience of >12,000 cases. It was supported by Ethicon Endosurgery, who I guess was interested in making standards, as a manufacturer of surgical instruments, to come up with the right tools for the operation. As a coauthor of this publication, it made a landmark on technical details, in Florida, on March 25 and 26, 2011. The panel comprised 24 centers and represented 11 countries, spanning the globe. Some of the experts invited were not doing sleeve gastrectomy; it helped to provoke the "sleevers" and move toward adoption of standardized techniques and measures. The following report was published in SOARD, certainly one of the top 10 papers ever from this journal, and its findings supported an effort toward the standardization of techniques and adoption of working recommendations [18].

37.5 Recent Prevalence of the Operation Worldwide

In 2016, the number of bariatric procedures was estimated to be 216,000 in the USA alone. Of these, 58% have been sleeve gastrectomy, but if one looks at the number of primary laparoscopic procedures, sleeve gastrectomy has reached 73% of all. But the USA was slow to fully adopt it because of private insurances. In countries where a national health system exists, like Chile or France, it has been the number one procedure before 2016 [19].

Worldwide, the total bariatric procedure numbers have been approximated to be 685,874, of which 634,897 (92.6%) were primary and 50,977 were revisional (7.4%). My estimate is that bariatric/metabolic surgeries are closer to one million procedures a year, as most countries do not have a national registry of bariatric procedures, and Angrisani et al. are counting on national societies of IFSO, whereas many countries do not participate, sending an estimate number. According to the latest IFSO survey, the most performed primary procedure was sleeve gastrectomy (N = 340,550; 53.6%), followed by Roux-en-Y gastric bypass (N = 191,326; 30.1%) and single-anastomosis gastric bypass (N = 30,563; 4.8%). In 2016, sleeve gastrectomy remained the most performed surgical procedure in the world, with probably more than half a million cases done yearly. Laparoscopic adjustable gastric banding is rapidly disappearing, and in some countries, the band is not even available, 20 years after its introduction laparoscopically in Belgium. This contrasts with laparoscopic sleeve gastrectomy, where 20 years later, it is the most performed bariatric/metabolic operation in the world. It has the potential to grow to 5–10 times those numbers if they are being embraced by national health care systems, and not limited from biases and budgetary constraints, like in Canada or the UK [19, 20].

37.6 My Take on GERD and Barrett's

Multiple publications now report a high rate of reflux and Barrett's histological changes at 5 years, such that they institute fears among surgeons and patients about the long-term risk of esophageal cancer. This is not frank dysplasia, and it does not take account of recent progress in endoscopic management and eradication of Barrett's. Genco et al. have found that in a cohort of about 110 patients, sampled of about one-third of all patients operated in their university hospital in Rome, a significant increase in the incidence and in the severity of erosive esophagitis, nondysplastic Barrett's esophagus was diagnosed in 19 patients (17.2%). According to them, no significant correlations were found between GERD symptoms and endoscopic findings. This contradicts the world expert on the subject of Barrett's oesophagus, Dr. Attila Csendes in Chile, in which he found 1% of Barrett's in sleeve gastrectomy patients. Could it be that Rome is overdiagnosing Barrett's, with sample and biopsies too low, in the stomach, misinterpreted by inexperienced staff? It is well known that there are major differences in interpretation among centers and pathologists of the same institution. Have the slides been verified with a second expert pathologist? Has the protocol of biopsies been thoroughly followed?

According to Sebastianelli et al., a study looking at "10 consecutive patients" from a select number of centers in Italy and France, the prevalence of Barrett's oesophagus was nearly 19% at 5 years. The design of the study is faulty, as this is not controlled, with possible cherry-picking, where patients most susceptible to accept a gastroscopy are those who have problems. This study has to be rejected on the basis of poor design. It has been demonstrated that the incidence of esophageal cancer after bariatric surgery has not changed when compared to control obese patients in Sweden. This raises the question about the genetic profile of morbid obese patients and their inherent risks to develop certain cancers. So far, the long-term patients with sleeve after duodenal switch have not demonstrated any higher rate of esophageal cancer, this in spite of known higher reflux disease, than in gastric bypass patients. One can argue that in duodenal switch patients, the reflux is of acid and not a mixture of bile. However, 24-hour pH studies done in the distal oesophagus of sleeve patients do not demonstrate a reflux of bile [21].

Of course, there has been a lot of speculation about the cause of reflux after sleeve; the most often quoted theory is the cut sling fibers on the left, severing the lower esophageal sphincter. I do not buy this theory. Firstly, the sleeve gastrectomy is often done 1 cm below the GE junction, leaving some fibers on the left, with intact quasi-circumferential fiber network, healing with a scar on the left. I think it is hormonally caused by the rise of GLP-1, and other hormonal changes, which in turn affect the tone of the lower esophageal sphincter, and as well lower the amplitude of the esophageal smooth muscle. It is well known that GLP-1 agonists have been proposed for the treatment of nutcracker oesophagus. Serum ghrelin remains low after 5 years in sleeve gastrectomy, and GLP-1 elevation probably causes a decrease by 2–4 mmHg in sphincter tone.

There has been demonstration of transthoracic migration of the sleeve and efforts are being done to close hiatal hernias and fix the oesophagoi-gastric junction in the abdomen. These efforts, I am sure, will decrease the incidence of reflux in the long-term. Many are doing partial and complete fundoplication, and perhaps the recent long-term study of partial fundoplication showing excellent results when compared to full fundoplication may lead us to a sleeve gastrectomy with partial fundoplication [22].

37.7 Bypass is Better than Sleeve, Really?

This is quite remarkable, when sleeve gastrectomy as a stand-alone procedure was less than 100 cases 15 years before, quite a fulgurant exponential growth. The reason for this is multifactorial, but mostly, recent RCTs published in the most prestigious journals have demonstrated a similar weight loss to Roux-en-Y gastric bypass at 5 years, similar resolution of comorbidities, except for GERD, but, most importantly, with a lower morbidity and mortality. The operation is done faster, and has fewer implications on nutritional micronutrients, and has simplified the postoperative management. This procedure is even done as an outpatient in many centers, in selected low-risk patients. Additionally, this procedure is easier to revise than Roux-en-Y gastric bypass. I call it the universal procedure because one can revise a sleeve to Roux-en-Y gastric bypass for severe reflux disease, in patients in whom Proton Pump Inhibitors (PPIs) have reached their maximum effect, and transformed to SADI, single- anastomosis gastric bypass or duodenal switch for weight regain or weight loss failures. Resleeve is also a reasonable option in selected patients without reflux, where the upper stomach has increased its volume to > 400 ml. The procedure is even done in planned stages for super- and super-super-obese patients with a time interval that can be from 6 months to 36 months. I consider the final statement on the comparison of both operations by Dr. Vidal and Lacy's team in Barcelona, where 10-year weight loss was similar in patients with morbid obesity that underwent Roux-en-Y gastric bypass or sleeve gastrectomy. RYGB was similar to SG in achieving 10-year type 2 diabetes remission and RYGB was superior to SG in achieving 10-year hypertension and dyslipidemia remission. This study suggested comparable effectiveness between SG and RYGB on weight loss [22, 23].

Sleeve gastrectomy also avoids severe complications of Roux-en-Y gastric bypass, the life-long risks of bowel obstruction. This has been well documented in long-term studies in Sweden, where patients are operated for internal hernias, or adhesive bowel obstructions, with prolonged hospital stays, some with devastating intestinal resections leading to sepsis and death [23].

It complicates the management of biliary lithiasis and pancreatic-biliary pathologies, where ERCP is needed. Risks of gastric or marginal ulcerations are diminished with sleeve, including the lifelong risks of gastric cancer, with an 80% gastrectomy. Dumping syndromes, complex hypoglycemia, and nesidioblastosis are diminished with sleeve gastrectomy. For all these reasons, rightly so, patients now choose sleeve gastrectomy [23].

References

1. Brethauer SA, Harris JL, Kroh M, Schauer PR. Laparoscopic gastric plication for treatment of severe obesity. Surg Obes Relat Dis. 2011;7(1):15–22.
2. Tretbar LL, Taylor TL, Sifers EC. Weight reduction. Gastric plication for morbid obesity. J Kans Med Soc. 1976;77:488–90.
3. Chouillard E. La plicature gastrique verticale (PGV) : serait-elle le futur Sleeve-killer? Obésité. 2011;6:253–5.
4. Piche T, des Varannes SB, Sacher-Huvelin S, Holst JJ, Cuber JC, Galmiche JP. Colonic fermentation influences lower esophageal sphincter function in gastroesophageal reflux disease. Gastroenterology. 2003;124(4):894–902.
5. Talebpour M, Amoli BS. Laparoscopic total gastric vertical plication in morbid obesity. J Laparoendosc Adv Surg Tech A. 2007;17(6):793–8.
6. English WJ, DeMaria EJ, Brethauer SA, Mattar SG, Rosenthal RJ, Morton JM. American Society for Metabolic and Bariatric Surgery estimation of metabolic and bariatric procedures performed in the United States in 2016. Surg Obes Relat Dis. 2018;14(3):259–63.
7. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J, Buchwald H, Scopinaro N. IFSO Worldwide Survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28(12):3783–94.
8. Clinical Issues Committee of American Society for Metabolic and Bariatric Surgery. Sleeve gastrectomy as a bariatric procedure. Surg Obes Relat Dis. 2007;3(6):573–6.
9. Clinical Issues Committee of theAmerican Society for Metabolic and Bariatric Surgery. Updated position statement on sleeve gastrectomy as a bariatric procedure. Surg Obes Relat Dis. 2010;6(1):1–5.
10. Mechanick JI, Youdim A, Jones DB, Garvey WT, Hurley DL, McMahon MM, Heinberg LJ, Kushner R, Adams TD, Shikora S, Dixon JB, Brethauer S, American Association of Clinical Endocrinologists, Obesity Society, American Society for Metabolic & Bariatric Surgery. Clinical practice guidelines for the perioperative nutritional,metabolic, and nonsurgical support of thebariatric surgerypatient--2013 update: cosponsored by American Association of Clinical Endocrinologists, the Obesity Society, and American Society for Metabolic & Bariatric Surgery. Endocr Pract. 2013;19(2):337–72.
11. Ali M, El Chaar M, Ghiassi S, Rogers AM, American Society for Metabolic and Bariatric Surgery Clinical Issues Committee. American Society for Metabolic and Bariatric Surgery updated position statement on sleeve gastrectomy as a bariatric procedure. Surg Obes Relat Dis. 2017;13(10):1652–7.
12. Telem DA, Gould J, Pesta C, Powers K, Majid S, Greenberg JA, Teixeira A, Brounts L, Lin H, DeMaria E, Rosenthal R. American society for metabolic and bariatric surgery: care pathway for laparoscopic sleeve gastrectomy. Surg Obes Relat Dis. 2017;13(5):742–9.
13. Chaar ME, Lundberg P, Stoltzfus J. Thirty-day outcomes of sleeve gastrectomy versus Roux-en-Y gastric bypass: first report based on metabolic and bariatric surgery accreditation and quality improvement program database. Surg Obes Relat Dis. 2018;14(5):545–51.
14. Sebastianelli L, Benois M, Vanbiervliet G, Bailly L, Robert M, Turrin N, Gizard E, Foletto M, Bisello M, Albanese A, Santonicola A, Iovino P, Piche T, Angrisani L, Turchi L, Schiavo

L, Iannelli A. Systematic endoscopy 5 years after sleeve gastrectomy results in a high rate of Barrett's esophagus: results of a multicenter study. Obes Surg. 2019. [Epub ahead of print].
15. Genco A, Soricelli E, Casella G, Maselli R, Castagneto-Gissey L, Di Lorenzo N, Basso N. Gastroesophageal reflux disease and Barrett's esophagus after laparoscopic sleeve gastrectomy: a possible, underestimated long-term complication. Surg Obes Relat Dis. 2017;13(4):568–74.
16. Jiménez A, Ibarzabal A, Moize V, Pane A, Andreu A, Molero J, de Hollanda A, Flores L, rtega E, Lacy A, Vidal J. Ten-year outcomes after Roux-en-Y gastric bypass and sleeve gastrectomy: an observational nonrandomized cohort study. Surg Obes Relat Dis. 2017;13(4):568–74.
17. Deitel M, Crosby RD, Gagner M. The first international consensus summit for sleeve gastrectomy (SG), New York City, October 25-27, 2007. Obes Surg. 2008;18(5):487–96.
18. Gagner M, Deitel M, Kalberer TL, Erickson AL, Crosby RD. The second international consensus summit for sleeve gastrectomy, march 19-21, 2009. Surg Obes Relat Dis. 2009;5(4):476–85.
19. Deitel M, Gagner M, Erickson AL, Crosby RD. Third international summit: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2011;7(6):749–59.
20. Gagner M, Deitel M, Erickson AL, Crosby RD. Survey on laparoscopic sleeve gastrectomy (LSG) at the fourth international consensus summit on sleeve gastrectomy. Obes Surg. 2013;23(12):2013–7.
21. Gagner M, Hutchinson C, Rosenthal R. Fifth international consensus conference: current status of sleeve gastrectomy. Surg Obes Relat Dis. 2016;12(4):750–6.
22. Rosenthal RJ, International Sleeve Gastrectomy Expert Panel, Diaz AA, Arvidsson D, Baker RS, Basso N, Bellanger D, Boza C, El Mourad H, France M, Gagner M, Galvao-Neto M, Higa KD, Himpens J, Hutchinson CM, Jacobs M, Jorgensen JO, Jossart G, Lakdawala M, Nguyen NT, Nocca D, Prager G, Pomp A, Ramos AC, Rosenthal RJ, Shah S, Vix M, Wittgrove A, Zundel N. International Sleeve Gastrectomy Expert Panel Consensus Statement: best practice guidelines based on experience of >12,000 cases. Surg Obes Relat Dis. 2012;8(1):8–19.
23. Gagner M. Patient preferences or surgeon-enforced preferences, when deciding between roux-en-Y gastric bypass versus sleeve gastrectomy. Surg Obes Relat Dis. 2019. pii: S1550–7289(19)30005-X. https://doi.org/10.1016/j.soard.2019.01.003. [Epub ahead of print].

Chapter 38
The Future of Sleeve Gastrectomy

Patrick Noel and David Nocca

From the first description by Michel Gagner in the 1990s as the first step of a two-step DS in super obese patients [1] to its recognition as a stand-alone procedure in bariatric surgery regardless of the BMI at the end of the 2000s [2], the laparoscopic sleeve gastrectomy is becoming the first bariatric procedure performed worldwide for almost two patients out of three [3].

Starting off as a simpler procedure than the gastric bypass but associated with higher risks of leaks difficult to heal, the laparoscopic sleeve gastrectomy has become today a more mature technique with significantly lower rates of postoperative complications that are better controlled by endoscopy [4], allowing sometimes to consider this surgery as a day procedure [5] and for the majority of us as the new gold standard of bariatric surgery.

As after all the procedures in bariatric surgery, the LSG could be complicated with time with a possibility of weight regain, mostly if the patient is not followed up properly and does not respect the postsurgical nutritional and physical guidelines.

Considering all of the above, the worsening of a preoperative GERD or a new-onset GERD seems to be the only real concern after the LSG [6, 7].

The LSG of the future will have to consider all of these statements.

The first step of a dedicated assessment will be more focused on the status of an eventual and often underestimated GERD and will include a proper investigation, with impedance-metry and pH-metry, allowing us to rank our patients regarding the potential risk of GERD.

Preoperatively, a systematic repair of a hiatal defect or the evolution to a new type of LSG associated with an anti-reflux procedure like a T or N Sleeve will become an option to limit the risk of a postoperative GERD in this group of patients at higher risk of reflux [8]. If the long-term evaluations of such a procedure are

P. Noel (✉)
Emirates Specialty Hospital, Dubai, United Arab Emirates

D. Nocca
CHU Montpellier Saint Eloi, Montpellier, France

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2_38

good, it may lead us to propose them as a first intention operation, maybe even for patients without preoperative GERD.

A technically perfect sleeve without any twist or stenosis should be at the end of the base of a LSG to limit the risk of GERD and of leak [7].

The use of a specially designed stapler will allow after a proper and complete dissection of the fundus and of the stomach a single stapling shot, which will probably decrease significantly the risk of leak and stenosis after LSG.

Besides a proper evaluation and a meticulous technique to achieve a perfect sleeve, an adequate choice of cartridges and reinforcement material is also important.

The combination of a perfect technique with an optimal stapler and an ideal choice of cartridges will give the opportunity to perform this surgery routinely as a day surgery for almost all patients. The consequences of this routine use of new materials will lead to the decrease in the operative time, which will in turn mean less use of anesthetic drugs as well for the patient.

We can today imagine using data analysis to preoperatively classify our patients in different groups and shaping our future LSG with a preoperative navigation system conducted through imaging and guided intraoperatively with AI.

This modern take in the care of the LSG candidate will be improved with AI more than with the current robotic system we have at our disposal today.

As a metabolic procedure validated for type 2 diabetes patients [9, 10], LSG will be a full stand-alone second stage in the care of this group of obese patients whatever their BMI, after a first medical line of treatment well conducted in combination with new drugs or classical ADO. This option of a regular surgical treatment will be performed early in the evolution of this chronic disease to limit the negative consequences of the disease.

These growing indications with the performance of a well-shaped and secured sleeve without any side effects will improve the quality of life and the future of our patients, whether metabolic or not, and will be a cost killer for our societies.

New sleeve-like procedures are completing this catalogue of techniques. A reversible sleeve using the BariClip will allow performing reversible procedures for some targeted patients with low BMI or for some stage of the disease in the future [11]. The absence of removal of a part of the organ will allow a broader population of obese patients to benefit from the advantages of this technique. This no-cutting, no-stapling, and reversible surgery will be more respectful of our modern conservative-centered way of life.

Despite its name being borrowed from the name of sleeve, the endoscopic sleeve gastroplasty is far from the principles of the sleeve and closer to a plication in its current realization and will probably evolve to a more appropriate shape with the arrival of new devices.

Within 15 years now the sleeve gastrectomy took the leadership as the procedure for a majority of patients and of surgeons, becoming a very efficient and secure surgery. The future technological improvements coming with a better selection of the candidates and the routine use of anti-reflux steps will make this sleeve a new therapeutic platform of metabolic and bariatric diseases. This sleeve platform will become the architecture of the treatment of the disease after a preliminary medical treatment and will improve with new algorithms of treatment, such as endoscopic or laparoscopic bypasses made on the antrum or on the duodenum or as a station of anchoring for new devices fixed there or at the duodenal level allowing the regular administration of molecules or drugs. This sleeve platform will become a real shuttle making possible local and selective escalating approaches in the future treatment of the diseases obesity and diabetes. This sleeve platform will be the regular sleeve, the N or T sleeve, or the reversible and clipped sleeve.

This will be the future of the sleeve, and this future will be our future tomorrow [8].

References

1. Feng JJ, Gagner M. Laparoscopic biliopancreatic diversion with duodenal switch. Semin Laparosc Surg. 2002;9(2):125–9.
2. Moy J, Pomp A, Dakin G, Parikh M, Gagner M. Laparoscopic sleeve gastrectomy for morbid obesity. Am J Surg. 2008;196(5):56–9.
3. Angrisani L, Santonicola A, Iovino P, Vitiello A, Higa K, Himpens J, Buchwald H, Scopinaro N. IFSO Worldwide Survey 2016: primary, endoluminal, and revisional procedures. Obes Surg. 2018;28(12):3783–94.
4. Nedelcu M, Manos T, Cotirlet A, Noel P, Gagner M. Outcome of leaks after sleeve gastrectomy based on a new algorithm addressing leak size and gastric stenosis. Obes Surg. 2015;25(3):559–63.
5. Surve A, Cottam D, Zaveri H, Cottam A, Belnap L, Richards C, Medlin W, Duncan T, Tuggle K, Zorak A, Umbach T, Apel M, Billing P, Billing J, Landerholm R, Stewart K, Kaufman J, Harris E, Williams M, Hart C, Johnson W, Lee C, Lee C, DeBarros J, Orris M, Schniederjan B, Neichoy B, Dhorepatil A, Cottam S, Horsley B. Does the future of laparoscopic sleeve gastrectomy lie in the outpatient surgery center? A retrospective study of the safety of 3162 outpatient sleeve gastrectomies. Surg Obes Relat Dis. 2018;14(10):1442–7.
6. Patti MG, Schlottmann F. Gastroesophageal reflux after sleeve gastrectomy. JAMA Surg. 2018;53(12):1147–8.
7. Stenard F, Iannelli A. Laparoscopic sleeve gastrectomy and gastroesophageal reflux. World J Gastroenterol. 2015;21(36):10348–57.
8. Gagner M. The future of sleeve gastrectomy. Eur Endocrinol. 2016;12(1):37–8. Nocca D, Skalli EM, Boulay E, Nedelcu M, Michel Fabre J, Loureiro M. Nissen Sleeve (N-Sleeve) operation: preliminary results of a pilot study. Surg Obes Relat Dis 2016;12(10):1832–1837.
9. Aminian A. Sleeve gastrectomy: metabolic surgical procedure of choice? Trends Endocrinol Metab. 2018;29(8):531–4.
10. Schauer PR, Bhatt DL, Kirwan JP, Wolski K, Aminian A, Brethauer SA, Navaneethan SD, Singh RP, Pothier CE, Nissen SE, Kashyap SR, STAMPEDE Investigators. Bariatric surgery versus intensive medical therapy for diabetes - 5-year outcomes. N Engl J Med. 2017;376(7):641–51.
11. Jacobs M, Zundel N, Plasencia G, Rodriguez-Pumarol P, Gomez E, Leithead J 3rd. A vertically placed clip for weight loss: a 39-month pilot study. Obes Surg. 2017;27(5):1174–81.

Index

M. Gagner et al. (eds.), *The Perfect Sleeve Gastrectomy*,
https://doi.org/10.1007/978-3-030-28936-2

T