Hot Topics in Acute Care Surgery and Trauma

Rifat Latifi
Fausto Catena
Federico Coccolini *Editors*

Emergency General Surgery in Geriatrics

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WORLD SOCIETY OF EMERGENCY SURGERY

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Emergency General Surgery in Geriatrics

Springer

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Preface

The book *Emergency General Surgery in Geriatrics*, part of the Hot Topics in Acute Care Surgery and Trauma Series, is a timely one for many reasons. One of the most important is that the world is getting older, and therefore the elderly need and will increasingly need major surgical interventions. This trend is evident not only in emergency general surgery, but more in general in surgery involving all systems and organs.

In our role of editors, we had the great honor and pleasure of designing and creating a book that in our mind should reflect the most important aspects of emergency general surgery in this population of patients. Their care is complex beyond any imagination and should be led by common sense, evidence-based practice, and by a patient-centered approach. Advanced technologies should not only be used to grant older patients the longer possible life, but also to improve its quality. While this book is being completed, the world is dealing with the COVID-19 pandemic, and many elderly unfortunately succumbed to this terrible disease.

We are grateful to all authors for devoting their time to this publication and for sharing their expertise with the readers. We also wish to acknowledge the precious help of Geena George, MPH, research coordinator at the Department of Surgery Clinical Research Unit, Westchester Medical Center, Valhalla, NY, for her fundamental administrative support. In addition, we wish to thank the whole Springer team for its assistance.

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Foreword to the Series

Research is fundamentally altering the daily practice of acute care surgery (Trauma, Surgical Critical Care, and Emergency General Surgery) for the betterment of patients around the world. Management for many diseases and conditions is radically different than it was just a few years previously. For this reason, concise up-to-date information is required to inform busy clinicians. Therefore, since 2011 World Society of Emergency Surgery (WSES), in a partnership with the American Association for the Surgery of Trauma (AAST), endorse the development and publication of the *Hot Topics in Acute Care Surgery and Trauma*, realizing the need to provide more educational tools for young in-training surgeons and for general physicians and other surgical specialists. These new forthcoming titles have been selected and prepared with this philosophy in mind. The books will cover the basics of pathophysiology and clinical management, framed with the reference that recent advances in the science of resuscitation, surgery, and critical care medicine have the potential to profoundly alter the epidemiology and subsequent outcomes of severe surgical illnesses and trauma.

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Part I

General Consideration in the Management of Elderly Surgical Patients

1 Emergency General Surgery in the Elderly: An Introduction to the Research Base

Rifat Latifi, David J. Samson, and Sharika Kaul

1.1 Introduction

Our impression is that emergency general surgery (EGS) in the elderly is common; however, in order to better understand this important topic, we must understand what constitutes EGS. The American Association for Surgery of Trauma (AAST) Committee on Severity Assessment and Patient Outcomes has proposed a list of EGS conditions [1]. This initiative also identified procedure codes relevant to EGS [2]. Application of the AAST definition requires not just diagnoses and procedures but the timing of surgical intervention soon after presentation [3]. Using the AAST definition, frequently performed EGS procedures include partial colectomy, small bowel resection, cholecystectomy, operative management of peptic ulcer disease, lysis of peritoneal adhesions, appendectomy, and laparotomy.

Emergency general surgery in the elderly population represents a significant, and likely growing, societal burden in the US. What constitutes "elderly" is controversial; researchers apply a variety of age cutoffs. Regarding EGS burden, Gale and colleagues reported an analysis of 10 years (2001–2010) of data from the Agency for Healthcare Research and Quality Healthcare Cost and Utilization Project Nationwide Inpatient Sample (AHRQ HCUP NIS). During the study period, there

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were 13,720,962 patients undergoing EGS admissions, of which 49.6% were age 60 years and older. Trends across time were not analyzed for specific age strata, but for all ages there was a significant rise in the number of admissions between 2001 and 2010. Also, EGS admission numbers included both those who underwent surgery during that admission and those who did not; however, the proportion of EGS patients who underwent surgery during the admission significantly increased from 27.7% in 2001 to 28.7% in 2010. It is unclear if the proportion of elderly patients undergoing surgery differs from that of all ages; although, if we assume that it is the same, and if we conservatively use the 2001 surgery rate, we can use Gale's report to estimate that approximately 3.8 million patients aged ≥60 underwent EGS procedures in the first decade of this century.

The main question that needs to be answered is: among elderly EGS patient samples, what factors predict adverse outcomes such as mortality, morbidity, and readmission rate? This question is not easily answered from the current evidence base, but we postulate that it depends on comorbidities, surgical decision-making, and many other factors [4–8].

1.2 Review

1.2.1 Scope of the Review

We reviewed articles that appeared in PubMed between January 2000 and December 2019 (see Table 1.1 for key to abbreviations of studies summarized in subsequent tables). We included articles that performed multivariable regression analyses of mortality or morbidity outcomes for at least 100 elderly EGS participants. These analyses were sought because the results of purely univariable analyses could be influenced by confounding; whereas, multivariable analyses have the potential to control for confounding and produce relatively unbiased results. Studies used several age cutoffs to define advanced age. We included US studies as well as reports from non-US high-income countries. We evaluated the methodologic quality and risk of bias of the studies using a tool developed by Hayden et al. [9]. Domains included in this tool are study participation, study attrition, prognostic factor measurement, outcome measurement, study confounding, and statistical analysis and reporting. To assess confounding, we required that studies presented information about age; sex; race/ethnicity; a severity of illness (SOI) measure, such as ASA class [10]; at least two comorbidities (CMs); and EGS procedure type. Within each domain, a summary risk of bias rating was assigned (low, moderate, or high risk of bias).

Out of 33 studies we reviewed, we selected three homogeneous samples with respect to EGS procedure type (Table 1.2). Two of these studies focused solely on emergent colon resection [11, 12]; one study addressed only emergent colorectal resection [13]. Twenty-two studies presented data on a mix of EGS procedure types and provided percentages of patients by specific procedure types [14–35]. Five studies were heterogeneous regarding EGS procedure type, but no patient

Table 1.1 Key to abbreviations

ACS NSQIP	American College of Surgeons National Surgical Quality Improvement Project
AHA ASHD	American Hospital Association Annual Survey of Hospitals Database
ASA	American Society of Anesthesiologists
AZ	Arizona
BMI	Body Mass Index
Ca	Cancer
CA SID	California State Inpatient Database
CAD	Coronary artery disease
CAN	Canada
CHF	Congestive heart failure
COPD	Chronic obstructive pulmonary disease
CSHA	Canadian Study of Health and Ageing
Cx	Complications
DEU	Germany
DM	Denmark
ECOG	Eastern Cooperative Oncology Group
EGS	Emergency general surgery
ESP	Spain
Fem	Female
FIN	Finland
FRA	France
fTRST	Fleming Triage Risk Screening Tool
FunctD	Functional dependence
GBR	Great Britain
H	Hospital
Hisp	Hispanic ethnicity
HRS	Health and Retirement Study
HTN	Hypertension
IH	In-hospital
IRL	Ireland
ITA	Italy
JHU CAG	Johns Hopkins University Adjusted Clinical Groups
LiverD	Liver disease
MC	Medical center
MD HSCRC	Maryland Health Services Cost Review Commission
MedPAR	Medicare Provider Analysis and Review
MetCa	Metastatic cancer
NHS HES	National Health Service Hospital Episode Statistics
NIS	National Inpatient Sample
NS	Nonsignificant
P-POSSUM	Portsmouth-Physiological and Operative Severity Score
Pro	Prospective
Retro	Retrospective
RF	Renal failure
SGP	Singapore
SWE	Sweden
U	University
UK	United Kingdom
USA	United States of America

Table 1.2 Study characteristics

References	Design	Participants	Country	Data source	Period	*n*	Procedures
Abdelsattar 2016 [11]	Retro	Emergent colon resection, age 65–99	USA	MedPAR	2008–2010	122,604	100% Colon resection
Kwok 2011 [12]	Retro	Emergent colectomy, age ≥ 80	USA	ACS NSQIP	2005–2008	1730	100% Colon resection
Mamidanna 2012 [13]	Retro	Nonelective, colorectal resection, age ≥ 70	GBR	NHS HES	Apr 2001–Mar 2008	36,767	100% Colorectal resection
Ah 2019 [14]	Retro	EGS, age ≥ 65	SWE	Orebro U H	2015–2016	209	39.2% Intestinal resection, 18.2% lysis of adhesions, 1.9% vascular surgery, 22% stoma creation/intestinal deviation, 6.7% bowel repair
Becher 2019 [15]	Retro	425 ACHs, 10 EGS procedures, age ≥ 65	USA	CA SID, AHA ASHD	2010–2011	61,330	11.6% Appendectomy, 41.6% cholecystectomy, 16.1% colectomy, 4.7% inguinal/femoral herniorrhaphy, 9.3% lysis of adhesions, 1.1% NSTI excision, 2.1% repair of perforated pelvic ulcer disease, 9.6% small bowel resection, 0.6% umbilical herniorrhaphy, 2.7% ventral herniorrhaphy
Ho 2019 [16]	Retro	EGS, age ≥ 65	USA	NIS	2011	280,885	13.7% Colon surgery, 9.6% small bowel surgery, 29.2% gallbladder surgery, 18.5% ulcer disease, 18.1% lysis of adhesions, 6.5% appendectomy, 4.4% laparotomy
Parmar 2019 [17]	Pro	Abdominal EGS, age ≥ 65	GBR	49 UK hospitals	03/20/17–06/19/17	956	18.5% Adhesiolysis, 15.5% small bowel resection, 12.2% stoma formation, 11.3% right colectomy, 10.9% Hartmann's, 4.9% other colorectal resection, 4.4% abdominal wall closure, 3.6% enterotomy, 3.3% peptic ulcer suture or repair, 2.9% drainage of abscess/collection, 2.6% left colectomy, 1.7% washout only, 1.4% gastric surgery, 1.4% repair of intestinal perforation, 1.2% laparostomy formation, 1.1% stoma revision, 1.0% intestinal bypass, 0.9% hemostasis, 0.8% reduction of volvulus, 0.5% peptic ulcer oversew of bleed

Smith 2019 [18]	Retro	High acuity EGS, age ≥ 65	USA	MedPAR	2015	3319	3.2% Herniorrhaphy, 1.2% NSTI, 26.6% surgery for perforated viscus, 12.4% resection of ischemic tissue, 56.6% surgery for colorectal emergency
Zattoni 2019 [19]	Pro	Abdominal EGS, age ≥ 70	ITA	Policlinico S Orsola-Malpighi	Dec 2015–May 2016	110	31.8% Colon resection, 10% small bowel resection, 20% small bowel surgery without resection, 11.8% cholecystectomy, 3.6% appendectomy,11.8% herniorrhaphy, 1.8% gastric resection, 0.9% splenectomy, 3.6% peptic ulcer repair, 2.7% abdominal lavage, 1.8% stoma creation/intestinal deviation
Bolger 2018 [20]	Retro	EGS, age ≥ 80	IRL	U H Kerry	2008–2015	128	35% Exploratory laparotomy-colon, 25–32.8% bowel resection, 10.2% diversion, 10.9% lysis of adhesions, 11.7% other laparotomy, 18.0% hernia repair, 9.4% laparoscopy ± resection, 3.9% appendectomy, 3.1% cholecystectomy
Hentati 2018 [21]	Retro	EGS, age ≥ 65	FRA	Henri Mondor U H	2011–2013	185	14.6% Hernia repair, 10.3% cholecystectomy, 7.6% small bowel resection with primary anastomosis, 2.7% small bowel resection with stoma diversion, 8.6% small bowel adhesiolysis, 9.7% gastrointestinal oversewing, 5.9% colon resection with primary anastomosis, 24.9% colon resection with stoma diversion, 5.4% other laparotomy, 10.3% appendectomy, 29.2% malignancy
Mehta 2018 [22]	Retro	12 EGS procedures, age ≥ 65	USA	MD HSCRC	Jul 2012–Sep 2014	3832	27.7% Cholecystectomy, 14.2% open large intestine excision, 14.2% peritoneal adhesiolysis, 12.9% appendectomy, 7.1% small intestine excision, 5.4% unilateral inguinal hernia repair, 4.9% excision of lesion, tissue, or subcutaneous tissue, 3.4% umbilical hernia repair, 3.3% control of stomach or duodenum ulcer and hemorrhage, 3.2% anterior abdominal wall hernia repair, 2.6% laparotomy, 1.0% perirectal tissue incision or excision
McIsaac 2017 [23]	Retro	EGS, age ≥ 65	CAN	Ontario	Apr 2002–Mar 2014	77,184	33.8% Colon resection, 11.2% small bowel resection, 9.7% appendectomy, 1.1% laparotomy, 19.5% lysis of adhesions, 20% cholecystectomy, 4.6% repair of perforated pelvic ulcer disease

(continued)

Table 1.2 (continued)

References	Design	Participants	Country	Data source	Period	*n*	Procedures
Rangel 2017 [24]	Retro	Acute abdomen EGS, age ≥ 70	USA	Brigham & Women's H	2006–2011	297	41.8% Gastrointestinal resection, 15.2% cholecystectomy, 12.4% herniorrhaphy, 9.1% lysis of adhesions, 5.7% appendectomy, 2.7% repair of perforated pelvic ulcer disease, 2% intestinal bypass for malignancy, 1% mesenteric revascularization, 3% palliative stoma for malignancy
Zogg 2017 [25]	Retro	EGS, age ≥ 65	USA	CA SID	2007–2011	552,845	20.1% Gastrointestinal bleed, 15.2% soft tissue, 10.9% intestinal obstruction, 10.0% biliary disorder, 9.4% colorectal disorder, 6.2% gastrointestinal cancer, 5.4% hernia, 4.2% vascular, 4.2% enteritis, 4.1% pancreatic, 3.3% abdominal pain, 1.6% appendiceal, 1.2% cardiothoracic, 1.2% peptic ulcer disease, 0.9% gastrostomy, 0.8% other gi, 0.5% peritonitis, 0.4% fistula, 0.2% need for resuscitation, 0.2% hepatic, 0.1% tracheostomy, 0.1% retroperitoneal, 0.0% genitourinary
Joseph 2016 [26]	Pro	EGS, age ≥ 65	USA	U Arizona MC	Oct 2012–Mar 2014	220	9.5% Appendectomy, 22.7% cholecystectomy, 10.9% herniorrhaphy, 37.2% bowel resection,
Lees 2015 [27]	Retro	EGS, age 65–80	CAN	U Alberta H	2009–2010	257	12.1% Cholecystectomy, 10.1% colon resection with primary anastomosis, 8.9% colon resection with ostomy, 7.0% gastric resection/gastrostomy, 5.8% exploratory laparotomy, 13.6% other
Ong 2015 [28]	Retro	Abdominal EGS, age ≥ 65	SGP	Khoo Teck Puat H	2010–2013	120	2.1% Inguinal hernia, 1.4% obturator hernia, 0.7% periumbilical hernia, 0.7% perforated esophagus, 27.1% perforated gastric ulcer, 9.0% perforated duodenal ulcer, 1.4% perforated gallbladder, 8.3% perforated small bowel, 5.6% perforated colonic malignancy, 4.2% perforated colonic diverticulitis, 25.7% perforated appendix, 6.9% small bowel gangrene, 2.1% large bowel gangrene, 4.9% empyema gallbladder

Rangel 2015 [29]	Retro	Acute abdomen EGS, age ≥ 70	USA	Brigham & Women's H	2006–2011	390	24.4% Colon resection, 15.6% small bowel resection, 12.8% herniorrhaphy, 10.0% laparoscopic cholecystectomy, 8.2% open cholecystectomy, 7.9% laparotomy, adhesiolysis, 5.4% appendectomy, 2.6% repair of perforated pelvic ulcer disease, 1.8% intestinal bypass for malignancy, 1.8% mesenteric revascularization, 2.6% palliative stoma for malignancy,
Ukkonen 2015 [30]	Retro	Abdominal EGS, age > 65	FIN	Central H	2007–2009	430	32.3% Acute cholecystitis, 13.9% incarcerated hernia, 5.6% inguinal, 4.2% femoral, 4.2% other, 11.6% malignancies, 5.8% large bowel, 4.7% palliative, 10.7% acute appendicitis, 6.0% intestinal obstruction caused by adhesions, 5.1% acute diverticulitis, 2.3% gastro-duodenal ulcer, 1.9% volvulus, 0.9% mesentery artery thrombosis, 15.1% miscellaneous
Merani 2014 [31]	Retro	EGS, age ≥ 80	CAN	U Alberta H	2008–2010	170	22.9% Colon surgery, 19.4% small bowel surgery, 15.9% other laparotomy, 10.6% cholecystectomy, 8.8% herniorrhaphy, 5.3% duodenal bleed/perforation
Farhat 2012 [32]	Retro	11 EGS procedures, age ≥ 60	USA	ACS NSQIP	2005–2009	35,334	16.7% Partial colon resection, 10.1% small bowel resection, 9.5% laparoscopic appendectomy, 5.9% exploratory laparotomy, 5.4% colectomy, 4.7% lysis of adhesions, 3.5% cholecystectomy, 2.9% cholecystectomy, 2.5% repair of stomach, 1.9% ventral herniorrhaphy
McGillicuddy 2009 [33]	Retro	Colorectal EGS, age ≥ 65	USA	Yale New Haven H	2000–2006	292	29.8% Obstructing or perforated colorectal carcinoma, 25.3% perforated diverticulitis, 8.9% lower gastrointestinal tract hemorrhage, 8.6% colorectal ischemia, 4.5% sigmoid volvulus, 4.5% incarcerated hernia, 4.1% noncolorectal metastatic disease, 3.4% endoscopic perforation, 3.4% atony, 1.7% c difficile colitis/toxic megacolon, 9.2% other

(continued)

Table 1.2 (continued)

References	Design	Participants	Country	Data source	Period	*n*	Procedures
Rubinfeld 2009 [34]	Retro	Major abdominal EGS, age ≥ 80	USA	Henry Ford H	Jul 2000–Nov 2006	440	35% Exploratory laparotomy-colon, 25% exploratory laparotomy-small bowel, 8.0% inguinal/femoral herniorrhaphy, 5.9% cholecystectomy, 5.9% incisional herniorrhaphy, 5.0% perforated ulcer repair, 4.1% appendectomy, 3.0% cholecystectomy gastric, 8.0% miscellaneous
Arenal 2003 [35]	Retro/pro	EGS, age ≥ 70	ESP	H U Rio Hortega	1986–1995	710	19.3% Gastrointestinal resection, 19.4% herniorrhaphy, 15.4% cholecystectomy, 10.4% appendectomy, 9.3% intestinal bypass and defunctioning stoma, 8.2% gastrointestinal oversewing 5.6% laparotomy
Cooper 2018 [36]	Retro	Major abdominal EGS, age ≥ 65	USA	Medicare HRS	2000–2012	349	colon resection, small bowel resection, appendectomy, laparotomy, lysis of adhesions, cholecystectomy, gastrectomy, herniorrhaphy, pancreatectomy
Khan 2018 [37]	Retro	Urgent/emergent surgery, age > 65	USA	U Arizona MC	2013–2015	725	Appendectomy, 31% cholecystectomy, hernia repair, 22.6% bowel resection, bowel diversion
Olufajo 2017 [38]	Retro	Urgent/emergent surgery, age ≥ 70	USA	Brigham & Women's H	2006–2011	421	Appendectomy, cholecystectomy, herniorrhaphy
Orouji Jokar 2016 [39]	Pro	EGS, age ≥ 65	USA	U Arizona MC	2013–2014	260	Appendectomy, cholecystectomy, hernia repair, bowel resection, incision and drainage, and wound debridement
Cooper 2015 [40]	Retro	Major abdominal urgent/emergent surgery, age ≥ 65	USA	Medicare HRS	2000–2010	400	Colon resection, small bowel resection, appendectomy, laparotomy, lysis of adhesions, cholecystectomy, gastrectomy, herniorrhaphy, pancreatectomy
Brandt 2019 [41]	Retro	Abdominal EGS, age ≥ 75	DNK	Hvidovre U H	Jan 2014–Mar 2015	150	
Khan 2019 [42]	Pro	EGS, age ≥ 65	USA	U Arizona MC	2014–2016	326	
Kongwibulwut 2019 [43]	Retro	EGS, age ≥ 90	USA	ACS NSQIP	2007–2015	4,456,809	

percentages were given for specific types [36–40]. Finally, three studies made no mention of either specific EGS procedure types or patient distributions [41–43]. We assume studies in this group were heterogeneous on procedure type.

1.2.2 Demographics and ASA Classes

As depicted in Table 1.3, average age was noted in most studies and was reported between 70.5 and 85.3 years. A bit less than half of the studies described the percentage of patients aged 85 or older, and it ranged between 0.0% and approximately 50%. These studies were heterogeneous on the percentage of female patients, running between 31.6% and 67.3%. Less than half of the studies gave data on race and ethnicity; non-US studies did not report on this variable. The majority of the participants in the studies reporting race were white patients and consisted of 61.9% and 88.4%. Hispanic ethnicity was mentioned in six of the studies and ranged from 1.2% to 19.4%. Of 13 studies that provided data on ASA class, the percentage in class 3 or higher was between 29.1% and 92.1%.

1.2.3 Comorbidities

Information on comorbidities was sparse (Table 1.4). Among studies that described specific comorbidities, the most common specific conditions were hypertension, cancer, diabetes mellitus, coronary artery disease, COPD, obesity, functional dependence, and congestive heart failure.

1.2.4 **Outcomes** (Table 1.5)

1.2.4.1 Mortality

Fourteen studies reported in-hospital mortality (IHM) with rates between 3.2% and 23.2% [15, 16, 22, 24, 26–28, 31, 33–37, 42]. The lowest IHM rate was reported by Joseph et al. [26], who used an age cutoff of 65; the highest rate was from the 2017 Rangel study [24], which selected patients 70 and older. Merani [31] and Rubinfeld [34] had a minimum age cutoff of 80 years, yet found intermediate IHM rates of 14.7% and 15.0%, respectively. There were ten studies that performed multivariable regression analyses [15, 16, 22, 27, 31, 33–36, 42], and age was a significant independent predictor of IHM in two of the studies [16, 22]. Additionally, four studies found ASA class to be an important predictor [27, 31, 34, 35]. Other significant factors were not discovered by more than two studies.

Twelve studies assessed 30 dM [12–14, 17, 19, 20, 25, 29, 30, 32, 36, 43]. The low outlier 30 dM rate of 1.1% was reported by Zogg [25]. The other 11 studies reported 30 dM rates of 14.2–31.1%. Rate did not appear related to sample age cutoff. Two studies that were homogeneous with respect to procedure type had higher 30 dM rates: Kwok [12] (colon resection, 28.3%) and Mamidanna [13]

Table 1.3 Demographics and ASA classes

References	*n*	Age	≥85	Fem	White	Black	Asian	Other	Hisp	ASA1	ASA2	ASA3	ASA4	ASA5	ASA3+
Abdelsattar 2016 [11]	122,604	77.3		59.9	85.3										
Kwok 2011 [12]	1730	85.3		65.3											92.1
Mamidanna 2012 [13]	36,767			58.3											
Ah 2019 [14]	209	75.6		49.8						2.0	27.1	53.3	16.1	1.5	70.9
Becher 2019 [15]	61,330	76.5		55.1	61.9	4.4		10.7	19.4						
Ho 2019 [16]	280,885		17.4	60.0	76.9	6.5		10.2	6.4						
Parmar 2019 [17]	956		13.2	57.6						3.3	30.3	45.1	18.9	2.4	66.4
Smith 2019 [18]	3319		19.0	60.0	88.4	7.0	1.1	2.3	1.2						
Zattoni 2019 [19]	110	81	40.0	57.3						0.0	11.8	62.7	24.5	0.9	29.1
Bolger 2018 [20]	128	84.4		46.1						0.0	15.6	42.2	42.2		84.4
Hentati 2018 [21]	185	79.9		57.3						3.2	66.4	24.9	5.4		30.3
Mehta 2018 [22]	3832		15.3	53.6	71.4	17.0		97.0	2.0						
McIsaac 2017 [23]	77,184	77		54.7											
Rangel 2017 [24]	297	78		57.2	82.4	8.1	2.4				17.2	58.6	16.4		
Zogg 2017 [25]	552,845	78.0		58.4	66.7	6.1	8.8	2.5	16.8						
Joseph 2016 [26]	220	75.5		44.1											
Lees 2015 [27]	257	71.5	0.0	47.9						1.5	19.3	37.1	33.2	3.9	74.2
Ong 2015 [28]	120	70.5		39.6											
Rangel 2015 [29]	390		17.9	55.6	81.0	8.4		10.5		0.3	20.0	60.8	17.2	0.5	>17
Ukkonen 2015 [30]	430	76.4		50.9											
Merani 2014 [31]	170		38.2	48.8						0.7	8.2	58.2	32.8		91.0
Farhat 2012 [32]	35,334			54.4	77.1	8.9				1.4		44.8			>45
McGillicuddy 2009 [33]	292	78.1		59.2											
Rubinfeld 2009 [34]	440	84.2	~50	62.0											
Arenal 2003 [35]	710	79.4		53.2							<41	25.4	31.1	2.7	
Cooper 2018 [36]	349		23.6	59.6	78.6	16.8		4.6							
Khan 2018 [37]	725		<22	37.7	72.1										
Olufajo 2017 [38]	421		17.9	56.0	81.0	89.0		10.1							>67
Orouji Jokar 2016 [39]	260	74.8		66.5	40.0										
Cooper 2015 [40]	400		24.0	60.0	78.0	14.5		1.8	5.8						
Brandt 2019 [41]	150	81.5		60.7							<41	45.3	<13		58.6
Khan 2019 [42]	326	73.9		42.6	81.3										
Kongwibulwut 2019 [43]	4,456,809		100.0	67.3						0.3	8.9	51.8	36.1	2.9	90.8

Table 1.4 Comorbidities

References	*n*	BMI	Obese	Smoker	DM	HTN	COPD	CAD	CHF	CVA/TIA	FunctlD	LiverD	RF	Ca	MetCa
Abdelsattar 2016 [11]	122,604					42.3			11.2			0.9	5.2		16.2
Kwok 2011 [12]	1730													18.3	
Mamidanna 2012 [13]	36,767				4.7					0.6			1.2	47.4	
Ah 2019 [14]	209	24.9												46.9	
Becher 2019 [15]	61,330														
Ho 2019 [16]	280,885				28.4	72.1			15.9			4.7	18.5	8.1	4.9
Parmar 2019 [17]	956										16.0				
Smith 2019 [18]	3319														
Zattoni 2019 [19]	110										29.1				
Bolger 2018 [20]	128				21.9										
Hentati 2018 [21]	185	24.5			15.1			13.0		4.9		3.2		29.2	
Mehta 2018 [22]	3832														
McIsaac 2017 [23]	77,184														
Rangel 2017 [24]	297		24.6											44.8	
Zogg 2017 [25]	552,845														
Joseph 2016 [26]	220														
Lees 2015 [27]	257		27.7	14.0	22.5	59.5		29.2							
Ong 2015 [28]	120														
Rangel 2015 [29]	390		20.5							0.5	25.4		1.8		
Ukkonen 2015 [30]	430	26.4	20.5		15.1									17.0	
Merani 2014 [31]	170		11.2	11.2	20.0	65.9			17.1	4.1					
Farhat 2012 [32]	35,334														
McGillicuddy 2009 [33]	292				17.8	57.2	8.9	23.3	13.0				2.4		
Rubinfeld 2009 [34]	440				22.0	81.0		34.0	25.0				23.0		
Arenal 2003 [35]	710														
Cooper 2018 [36]	349										18.2				
Khan 2018 [37]	725				37.4		28.3		25.5	16.3		14.6	21.2	10.8	
Olufajo 2017 [38]	421		20.8												
Orouji Jokar 2016 [39]	260														
Cooper 2015 [40]	400				34.0			49.8	32.8				19.3	47.5	
Brandt 2019 [41]	150														
Khan 2019 [42]	326					30.1	20.2	18.4		9.8		10.1			
Kongwibulwut 2019 [43]	4,456,809		13.3		11.2	75.9	8.9		5.3		30.3		2.3		2.4

Table 1.5 Outcomes

Study	Participants	Data source	*n*	Independent multivariable predictors	Outcome(s)	Period	%
Becher 2019 [15]	425 Acute care hospitals, 10 EGS procedures, age ≥ 65	CA SID, AHA ASHD 2010–2011	425	Hospital volume, procedure	Mortality	IH	
Ho 2019 [16]	EGS, age ≥ 65	NIS 2011	280,885	Age, coagulopathy, fluid, and electrolyte disorders, liver diseases, combinations	Mortality	IH	5.6
Mehta 2018 [22]	12 EGS procedures, age ≥ 65	MD HSCRC Jul 2012–Sep 2014	3832	Low volume surgery, age ≥ 75, 5+ comorbidities	Mortality	IH	4.7
Rangel 2017 [24]	EGS, acute abdomen, age ≥ 70	Brigham & Women's H 2006–2011	297		Mortality	IHI	23.2
Joseph 2016 [26]	EGS, age ≥ 65	U AZ MC Oct 2012–Mar 2014	220		Mortality	IH	3.2
Lees 2015 [27]	EGS, age 65–80	U Alberta H 2009–2010	257	ASA class, number of complications	Mortality	IH	12.0
Ong 2015 [28]	Abdominal EGS, age ≥ 65	Khoo Teck Puat H 2010–2013	120		Mortality	IH	10.0
Merani 2014 [31]	EGS, age ≥ 80	U Alberta H 2008–2010	170	ASA class, complications	Mortality	IH	14.7
McGillicuddy 2009 [33]	Colorectal EGS, age ≥ 65	Yale New Haven H 2000–2006	292	Complications, septic shock, time in operating room, age, estimated blood loss >1000 mL	Mortality	IH	15.0
Rubinfeld 2009 [34]	Major abdominal EGS, age ≥ 80	Henry Ford H Jul 2000–Nov 2006	440	ASA score, female	Mortality	IH	15.0
Arenal 2003 [35]	EGS, age ≥ 70	H U Rio Hortega 1986–1995	710	ASA grade, mesenteric infarction, defunctioning stoma, exploratory laparotomy, time from symptom onset to admission	Mortality	IH	21.5
Cooper 2018 [36]	Major abdominal EGS, age ≥ 65	Medicare HRS 2000–2012	349	High illness burden	Mortality	IH	15.0

Khan 2018 [37]	Urgent/emergent surgery, age > 65	U AZ MC 2013–2015	725		Mortality	IH	15.3
Khan 2019 [42]	EGS, age ≥ 65	U AZ MC 2014–2016	347	EGS Frailty Index ≥0.325	Mortality	IH	8.9
Kwok 2011 [12]	Emerg colectomy, age ≥ 80	ACS NSQIP 2005–2008	1730	Age 80–89, functional dependence, COPD, CHF, metastatic cancer, steroids, SIRS, creatinine >1.5	Mortality	30 d	28.3
Mamidanna 2012 [13]	Nonelective colorectal resection, age ≥ 70	NHS EHS Apr 2001–Mar 2008	36,767	Age > 76, diagnosis, resection type, respiratory comorbidity, renal failure, reoperation	Mortality	30 d	24.1
Ah 2019 [14]	EGS, age ≥ 65	Orebro U H 2015–2016	209	Age, log morbidity P-POSSUM, log mortality P-POSSUM, packed red blood cells transfusion, cancer, ischemia	Mortality	30 d	31.1
Parmar 2019 [17]	Abdominal EGS, age ≥ 65	49 UK hospitals 03/20/17–06/19/17	956	CSHA Clinical Frailty Score	Mortality	30 d	14.6
Zattoni 2019 [19]	Abdominal EGS, age ≥ 70	Policlinico S Orsola-Malphghi 2015–May 2016	110		Mortality	30 d	19.1
Bolger 2018 [20]	EGS, age ≥ 80	U H Kerry 2008–2015	128	ICU admission, ASA 3/4	Mortality	30 d	22.6
Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	Race, ethnicity	Mortality	30 d	1.1
Rangel 2015 [29]	EGS, acute abdomen, age ≥ 70	Brigham & Women's H 2006–2011	390	Acute kidney injury, ASA class ≥IV, CS ≥4, major operative severity	Mortality	30 d	16.2
Ukkonen 2015 [30]	Abdominal EGS, age > 65	Central H 2007–2009	430	Age, atrial fibrillation, malignancies, BMI ≤18.5, open surgery	Mortality	30 d	14.2
Farhat 2012 [32]	EGS, age ≥ 60	ACS NSQIP 2005–2009	35,334	Wound class, ASA class, Modified Frailty Index, age	Mortality	30 d	
Cooper 2015 [40]	Major abdominal urgent/emergent surgery, age ≥ 65	Medicare HRS 2000–2010	400	dementia, postoperative complications, hospitalization ≤6 mo preoperative	Mortality	30 d	19.8

(continued)

Table 1.5 (continued)

Study	Participants	Data source	*n*	Independent multivariable predictors	Outcome(s)	Period	%
Kongwibulwut 2019 [43]	EGS, age ≥ 90	ACS NSQIP 2007–2015	4,456,809	Preoperative septic shock, preoperative sepsis, current smoking, weight loss >10% ≤6 mo, systemic inflammatory response syndrome, steroids, creatinine >1.2, functional dependence, SGOT >40, albumin <3.0, transfer from outside hospital	Mortality	30 d	21.0
Parmar 2019 [17]	Abdominal EGS, age ≥ 65	49 UK hospitals 03/20/17–06/19/17	956	CSHA Clinical Frailty Score	Mortality	90 d	19.5
Zattoni 2019 [19]	Abdominal EGS, age ≥ 70	Policlinico S Orsola-Malphghi 2015–May 2016	110	Age ≥ 85 NS, fTRST score ≥ 2, CACI≥6	Mortality	90 d	22.7
Hentati 2018 [21]	EGS, age ≥ 65	Henri Mondor U H 2011–2013	185	Bowel ischemia, ICU admission, postoperative complications	Mortality	90 d	23.2
Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	race, ethnicity	Mortality	90 d	7.1
Brandt 2019 [41]	Abdominal EGS, age ≥ 75	Hvidovre U H Jan 2014–Mar 2015	150	Age, sarcopenia, ECOG 4 performance status, ASA 4–5	Mortality	90 d	42.7
Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	Race, ethnicity	Mortality	180 d	15.7
Cooper 2015 [40]	Major abdominal urgent/emergent surgery, age ≥ 65	Medicare HRS 2000–2010	400		Mortality	180 d	31.0
Mamidanna 2012 [13]	Nonelective colorectal resection, age ≥ 70	NHS EHS Apr 2001–Mar 2008	36,767	Age > 75, diagnosis, resection type, cardiac comorbidity, respiratory comorbidity, renal failure, reoperation	Mortality	1 yr	42.9
McIsaac 2017 [23]	EGS, age ≥ 65	Ontario Apr 2002–Mar 2014	77,184	JHU ACG Frailty indicator, frailty by postoperative survival days, frailty by procedure	Mortality	1 yr	23.3
Rangel 2015 [29]	EGS, acute abdomen, age ≥ 70	Brigham & Women's H 2006–2011	390	ASA class ≥IV, BMI <18.5, BMI ≥30, CS ≥4, albumin <3.5, ventilator days	Mortality	1 yr	32.5

Cooper 2018 [36]	Major abdominal EGS, age ≥ 65	Medicare HRS 2000–2012	349	High illness burden	Mortality	1 yr	
Rangel 2017 [24]	EGS, acute abdomen, age ≥ 70	Brigham & Women's H 2006–2011	297	Sarcopenia, Charlton Comorbidity Index ≥2, major operative severity, ASA 3–4	Mortality	1 yr	32.0
Olufajo 2017 [38]	Urgent/emergent surgery, age ≥ 70	Brigham & Women's H 2006–2011	421	Acute kidney injury, ASA class ≥IV, BMI <18.5, BMI ≥30, Charlson score ≥ 4, major operative severity, albumin <3.5	Mortality	1 yr	32.5
Cooper 2015 [40]	Urgent/emergent major abdominal surgery, age ≥ 65	Medicare HRS 2000–2010	400		Mortality	1 yr	34.3
Parmar 2019 [17]	Abdominal EGS, age ≥ 65	49 UK hospitals 03/20/17–06/19/17	956	CSHA Clinical Frailty Score	Complications	IH	
Mehta 2018 [22]	12 EGS procedures, age ≥ 65	MD HSCRC Jul 2012–Sep 2014	3832	Age ≥ 75, black race, 2+ comorbidities	Complications	IH	37.0
Joseph 2016 [26]	EGS, age ≥ 65	U AZ MC Oct 2012–Mar 2014	220	Modified Frailty Index ≥0.25	Complications	IH	35.0
Lees 2015 [27]	EGS, age 65–80	U Alberta H 2009–2010	257		Complications	IH	52.9
Merani 2014 [31]	EGS, age ≥ 80	U Alberta H 2008–2010	170		Complications	IH	20.6
McGillicuddy 2009 [33]	Colorectal EGS, age ≥ 65	Yale New Haven H 2000–2006	292	Contamination, shock, chronic renal insufficiency, time in operating room	Complications	IH	34.6
Arenal 2003 [35]	EGS, age ≥ 70	H U Rio Hortega 1986–1995	710		Morbidity	IH	41.2
Cooper 2018 [36]	Major abdominal EGS, age ≥ 65	Medicare HRS 2000–2012	349	High illness burden	Complications	IH	38.0
Orouji Jokar 2016 [39]	EGS, age ≥ 65	U AZ MC 2013–2014	260	EGSFI: cancer, hypertension, coronary heart disease, dementia, need help with activities of daily living, adverse health attitude, albumin <3	Complications	IH	33.3

(continued)

Table 1.5 (continued)

Study	Participants	Data source	*n*	Independent multivariable predictors	Outcome(s)	Period	%
Khan 2019 [42]	EGS, age ≥ 65	U AZ MC 2014–2016	347	EGS Frailty Index ≥0.325	Complications	IH	26.7
Smith 2019 [18]	Admitted urgently/ emergently, HA-EGS, age ≥ 65	MEDPAR 2015	3319		Major systemic complications	IH	40.6
Smith 2019 [18]			3319		Major surgical complications	IH	45.5
Joseph 2016 [26]	EGS, age ≥ 65	U AZ MC Oct 2012–Mar 2014	220	Modified Frailty Index ≥0.25	Major complications	IH	9.1
Khan 2018 [37]	Urgent/emergent surgery, age > 65	U AZ MC 2013–2015	725		Major complications	IH	44.6
Hentati 2018 [21]	EGS, age ≥ 65	Henri Mondor U H 2011–2013	185		CD G3/4 complications	IH	28.6
Ong 2015 [28]	Abdominal EGS, age ≥ 65	Khoo Teck Puat H 2010–2013	120	Surgery delay >24 h	CD G3+ complications	IH	13.1
Ukkonen 2015 [30]	Abdominal EGS, age > 65	Central H 2007–2009	430		CD G3+ complications	IH	31.9
Kongwibulwut 2019 [43]	EGS, age ≥ 90	ACS NSQIP 2007–2015	4,456,809		Morbidity	30 d	45.0
Zattoni 2019 [19]	Abdominal EGS, age ≥ 70	Policlinico S Orsola-Malphghi 2015–May 2016	110	Age ≥ 85 NS, ASA class ≥4, Charlson Age Comorbidity Index ≥6, major surgery	CD G3+ complications	30 d	28.2
Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	Race, ethnicity	Major morbidity	30 d	1.7
Zattoni 2019 [19]	Abdominal EGS, age ≥ 70	Policlinico S Orsola-Malphghi 2015–May 2016	110	Age ≥ 85 NS, ASA class ≥4, Charlson Age Comorbidity Index ≥6	CD G3+ complications	90 d	5.4

Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	Race, ethnicity	Major morbidity	90 d	12.5
Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	Race, ethnicity	Major morbidity	180 d	26.6
Mehta 2018 [22]	12 EGS procedures, age ≥ 65	MD HSCRC Jul 2012–Sep 2014	3832	Low volume surgery, age ≥ 85, hospital ≤200 beds	Failure to rescue	IH	15.0
Khan 2018 [37]	Urgent/emergent surgery, age > 65	U AZ MC 2013–2015	725	Age ≥ 80, ASA class >3, s albumin <3.5, CHF, chronic renal failure, COPD, malignancy	Failure to rescue	IH	11.5
Khan 2019 [42]	EGS, age ≥ 65	U AZ MC 2014–2016	347		Failure to rescue	IH	11.5
Mehta 2018 [22]	12 EGS procedures, age ≥ 65	MD HSCRC Jul 2012–Sep 2014	3832	Female, age ≥ 75, 2+ comorbidities, hospital ≤200 beds	Readmission	30 d	11.5
Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	Race, ethnicity	Unplanned readmission	30 d	2.1
Khan 2019 [42]	EGS, age ≥ 65	U AZ MC 2014–2016	347	EGS Frailty Index ≥0.325	Readmission	30 d	10.1
Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	Race, ethnicity	Unplanned readmission	90 d	15.9
Zogg 2017 [25]	EGS conditions, age ≥ 65	CA SID 2007–2011	552,845	Race, ethnicity	Unplanned readmission	180 d	35.6
Ho 2019 [16]	EGS, age ≥ 65	NIS 2011	280,885		Discharge to home	IH	26.4
Smith 2019 [18]	Admitted urgently/emergently, HA-EGS, age ≥ 65	MEDPAR 2015	3319		Discharge home	IH	49.8
Hentati 2018 [21]	EGS, age ≥ 65	Henri Mondor U H 2011–2013	185		Discharge home	IH	45.7

(continued)

Table 1.5 (continued)

Study	Participants	Data source	n	Independent multivariable predictors	Outcome(s)	Period	%
Rangel 2017 [24]	EGS, acute abdomen, age ≥ 70	Brigham & Women's H 2006–2011	297		Discharge home	IH	52.2
Abdelsattar 2016 [11]	Emerg colon resection, age 65–99	MedPAR 2008–2010	122,604	Age, sex, race/ethnicity, surgical aspects, comorbidities	Nonhome discharge	IH	46.7
Lees 2015 [27]	EGS, age 65–80	U Alberta H 2009–2010	257	ASA class, age, number of complications	Nonhome discharge	IH	39.8
Merani 2014 [31]	EGS, age ≥ 80	U Alberta H 2008–2010	170		Nonhome discharge	IH	46.2
Khan 2019 [42]	EGS, age ≥ 65	U AZ MC 2014–2016	347	EGS Frailty Index ≥0.325	Adverse discharge disposition	IH	37.7
McIsaac 2017 [23]	EGS, age ≥ 65	Ontario Apr 2002–Mar 2014	77,184	JHU CAG Frailty indicator	Institutional discharge	IH	
Joseph 2016 [26]	EGS, age ≥ 65	U AZ MC Oct 2012–Mar 2014	220		Discharge rehab	IH	30.9
Joseph 2016 [26]	EGS, age ≥ 65	U AZ MC Oct 2012–Mar 2014	220		Discharge SNF	IH	12.3

(colorectal resection, 24.1%). Moreover, 11 of 12 studies [12–14, 17, 20, 25, 29, 30, 32, 40, 43] conducted multivariable analyses and age was a significant independent predictor of 30dM in four studies [12–14, 30]. ASA class was also a multivariable predictor in three studies [20, 29, 32]. Pulmonary comorbidities were significant in three studies [12, 13, 43]. No other variable was a significant predictor in more than two studies.

Five studies analyzed 90-day mortality, which ranged between 7.1% and 42.7% [17, 19, 21, 25, 41]. The highest rate was from a study that selected patients aged ≥75 [41]. All of these studies reported multivariable analyses on this outcome. Age was significant in two studies; [19, 41] all other variables were significant in only one study. Two studies that mentioned 180-day mortality reported rates of 15.7% and 31.0% [25, 40]. One-year mortality ranged between 23.3% and 42.9% in seven studies [13, 23, 24, 29, 36, 38, 40]. Moreover, six studies did multivariable regressions. ASA class was a significant independent predictor of 1-year mortality in three studies [24, 29]. BMI and albumin levels were significant in two studies each [24, 38]. No other factors were significant in more than one study.

1.2.4.2 Complications

There were ten studies which reported on in-hospital complications (IHCx), with rates between 20.6% and 52.9% [17, 22, 26, 27, 31, 33, 35, 36, 39, 42]. The lowest rate came from a study with a lower age cutoff of 80 years [31]. The rate generally was not related to the minimum age of the sample. Additionally, seven studies analyzed complications by multivariable regression [17, 22, 26, 33, 36, 39, 42]. Frailty was the only variable significant in two studies [26, 42].

Six studies presented results on major complications, ranging between 9.1% and 45.5% [18, 21, 26, 28, 30, 37]. Only two of six studies performed multivariable analyses [26, 28], both with differing results.

Thirty-day complications were reported by three studies [19, 25, 43], two of which were limited to major complications [19, 25]. This pair of studies both conducted multivariable analyses of 30-day and 90 day complications and yielded different results for each outcome. Zogg et al. [25] was the only study that produced findings on 180-day morbidity.

FTR rates were presented in three studies with estimates between 11.5% and 15.0% [22, 37, 42]. Two of these studies did multivariable analyses and both found age to be a significant independent predictor [22, 37].

There were three studies that reported on 30-day readmissions, with rates occurring between 2.1% and 11.5% [22, 25, 42]. While all of these studies performed multivariable regressions on this outcome, no variable was significant in more than one study. Zogg et al. [25] was the only study that presented data on 90-day and 180-day readmission rates.

1.2.4.3 Other Outcomes

Discharge disposition was addressed in 10 studies [11, 16, 18, 21, 23, 24, 26, 27, 31, 42]. Discharge to home was studied in four articles [16, 18, 21, 24], and occurred in 26.4–52.2% with no multivariable analyses. In six studies, data on nonhome discharge was given [11, 23, 26, 27, 31, 42], and included rates between 37.7% and 46.7%. Of the four studies with multivariable regressions, two [11, 27] found age to be a significant independent predictor, and two [23, 42] conveyed that frailty was important.

1.3 Summary

Designs of 33 elderly sample studies were prospective in five, retrospective in 27, and mixed retrospective/prospective in one. Three studies were homogeneous on procedure type and 30 were heterogeneous. Studies were based in the US and other high-income countries. The data source for 14 studies were administrative databases, and 19 articles reported experience from individual medical centers.

All studies were rated low risk of bias on attrition, prognostic factor measurement, and outcome measurement. High risks of bias ratings were assigned to 15 studies on participation, 21 studies on confounding, and 5 studies on analysis and reporting. When we rated studies as being at high risk of bias for participation, selection bias is likely; hence, the relationship between a prognostic factor and outcomes is different between participants and nonparticipants. Frequent specific problems with this literature include inadequate description of the source population on key characteristics and inadequate description of the study sample on these characteristics. High risk of bias on study confounding means that there is a strong likelihood that the effect of a prognostic factor is distorted by another factor related to both the index prognostic factor and the outcome. Frequently, studies were missing information for key characteristics. Similarly, studies repeatedly did not account for all important confounders in the design or analysis. Regarding the statistical analysis and reporting, studies had important shortcomings. In particular, the model development strategy was usually unclear. Specifically, methods were often unclear in which candidate variables were identified for entry into multivariable models and rules for selecting the final model. Future research should use a standard set of variables that are measured to describe study samples, and to be used as prognostic factors and potential confounders in analyses.

The most frequent procedure types were gastrointestinal resection, appendectomy, gall bladder surgery, lysis of adhesions, and herniorrhaphy. The definition of advanced age was ≥65 in most studies, but other minimum age cutoffs were used. The proportion of females ranged from 31.6% to 67.3%. Among less than half of the studies reporting racial distribution, the large majority were white. ASA class distributions were heterogeneous across the studies. The comorbidities most often described included: hypertension, cancer, diabetes mellitus, coronary artery disease, COPD, obesity, functional dependence, and congestive heart failure.

IHM rates varied from 3.2% to 23.2%. Age was not generally found to be a significant independent predictor of IHM in 10 studies. ASA class was an important predictor in four studies. Rates of 30 dM ranged from 1.1% to 31.1%. On a study level basis, studies that homogeneously selected patients for colon resection, colorectal resection, and cardiothoracic surgery had high 30 dM rates. Age and ASA class were each found to be significant independent predictors of 30 dM in four of twelve studies. Pulmonary comorbidities were significant in three studies. Age was also a significant predictor in two of five studies assessing 90-day mortality. IHCx rates were between 20.6% and 52.9%. Frailty was found to be a significant predictor of IHCx in two of seven studies. Age was a significant predictor of FTR in two studies. In two studies each, nonhome discharge was predicted by age and frailty.

1.4 Conclusions

We reviewed studies limited to elderly patients undergoing EGS procedures. ASA class was a fairly consistent significant predictor of in-hospital mortality. Age and ASA class predict 30-day mortality in elderly samples. Consistent predictors of complications after EGS in the elderly have not emerged.

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Geriatric Decision-Making in the Emergency Department: A Surgeon's Perspective

2

James Feeney and Rifat Latifi

2.1 Introduction

As the population of older patients increases, geriatric emergency surgery becomes more and more common. An estimated 46.3 million persons (14.5% of the US population) are aged 65 or older in 2014, and that number is expected to increase to 98 million, or 23.5%, by 2060 [1]. This fact alone portends increased contact with the medical community, and a concomitant increase in surgical emergencies.

Operative intervention on the geriatric population is technically similar to surgery on younger patients: the anatomy does not change, and the principles of surgery are the same; however, the physiology does change, and so does the ability to withstand major surgery. For these reasons, the perioperative and postoperative courses, complications, and pitfalls can be wildly different. The decrease in physiologic reserve experienced by geriatric patients also obviously changes the risk and benefit analysis behind different surgical interventions for different disease and injury processes.

This chapter will deal with geriatric surgical decision-making as considered from several different vantage points. We will consider physiologic and pharmacologic issues, as well as perioperative risk mitigation and stratification strategies; we

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will consider behavioral, cultural, and legal facets, as they pertain particularly to geriatric patients. In summation, the goal is to care for geriatric patients in a manner consistent with their desires and to be thoughtful about all of the complicating factors that may influence the decision to operate. This approach does not guarantee a good outcome, but it does guarantee a thoughtful and thorough approach to marrying the right level of intervention to each patient, consistent with her or his clinical condition and, perhaps more importantly, wishes.

2.2 Physiologic and Pharmacologic Factors in Geriatric Surgery

As people age, they experience increasing rates of serious comorbidity and frailty, and these factors complicate the performance of surgery in this population. Patients' experiences in the elective surgery realm mean that time to plan medication use on the day of surgery, multispecialty and multidisciplinary collaboration in the preoperative and postoperative phases, and close follow-up in the postsurgical phase. However, in the emergent setting, there is often not sufficient time to alter preoperative medication use or to mitigate chronic conditions optimally. This means that disordered and deranged organ function, worsened by the acute, presumably surgical untreated disease, shock, surgery, or anesthesia physiologically stresses further the geriatric patient. Some of the more common comorbidities that directly impact the perioperative care of the surgical patient include: Coronary Artery Disease (CAD), Chronic Obstructive Pulmonary Disease (COPD), Chronic Kidney Disease (CKD), liver dysfunction, malnutrition, neurologic and psychiatric disease, musculoskeletal atrophy and frailty, and Adrenal Insufficiency (AI).

Coronary Artery Disease (CAD) is extremely common despite advances in diagnosis and treatment, a leading cause of morbidity and mortality [2]. Approximately 40% of patients >80 years of age have evidence of severe CAD at necropsy. Additionally, a greater percentage (60%) has evidence of obstructive CAD [3]. Coronary disease in the octogenarian is, therefore, more the rule than the exception.

Unlike in the elective surgical population, there is little time to intervene or even sometimes fully assess the geriatric emergency surgical patient. However, age itself is only a minor contributor to overall perioperative risk in the latest American College of Cardiology guidelines. For example, preexisting hypertension, diabetes mellitus, or renal failure contributes to a higher incidence of perioperative myocardial infarction (MI) (5.1%), cardiac death (5.7%), or ischemia (12–17.7%) [4]. Additional risk factors in the elderly include the need for emergency surgery, major surgical procedures, ASA physical status III or IV, and poor nutritional status.

Cardiovascular disease and arrhythmia, often a result of ischemic heart disease, have several pharmacologic implications that may complicate or protect in times of emergent surgery. There is some data that Statins are protective in both hemorrhages and septic shock, and beta-adrenergic receptor blockade may confer some benefit in vasculopathic patients [3]. However, the anticoagulated or platelet inhibited patient confers immediate, serious added risk for the emergent surgical patient.

Anticoagulation with warfarin should be addressed prior to surgery with Prothrombin Complex Concentrate, Factor VII, Vitamin K, and/or Fresh Frozen Plasma, as available [2–4]. Direct oral anticoagulants (DOACs) have reversal agents currently available, but they have not been demonstrated to improve outcomes when administered and should be evaluated on a case-by-case basis [2].

Electrocardiographic evaluation is essential in all geriatric patients, because of the incidence of underlying cardiac disease that may be previously clinically silent [4]. An echocardiogram might be indicated in the presence of cardiac murmur, new arrhythmia, or concern for aortic stenosis. A person experiencing a myocardial infarction may require emergent intervention, which is fraught with complications if stenting is indicated, because of the requirement for antiplatelet use [5]. Additionally, if a patient is experiencing malignant arrhythmias, cardioversion or medical management may be necessary. Similarly, if Mobitz II or III heart block is identified on EKG, or other arrhythmias which may require pacing and emergency transvenous pacer prior to induction may be required [6]. Aside from this limited evaluation and intervention, cardiac status should not impact true emergency surgical decision-making.

Chronic Obstructive Pulmonary Disease and other chronic lung conditions are an infrequent cause of perioperative mortality, although the complication rates are higher in the perioperative period. The respiratory mortality ranged from 0–0.6% depending on the surgical sites and the presence of pulmonary risk factors. Aspiration during anesthesia had a high mortality of 5% [5]. Risk factors for developing pulmonary embolism include age, malignancy, obesity, and the type of surgery performed. Recent studies demonstrated that prophylactic low-dose aspirin or low-dose low-molecular weight heparin in high risk elderly surgical patients are effective and safe to prevent or decrease the risk of DVT and pulmonary embolism. Advanced age is, therefore, a significant risk factor for morbidity or mortality of deep venous thrombosis (DVT) and pulmonary embolism. Neuraxial block can reduce the odds of pulmonary embolism by 55% and deep vein thrombosis by 44% [6, 7]. The Pulmonary Embolism Prevention Trial Collaborative Group recently reported that aspirin reduced the morbidity and mortality of DVT and pulmonary embolism by 30% with a slight increase in gastrointestinal bleeding of lesser severity in elderly patients undergoing surgery for hip fracture [7].

Chronic Kidney Disease (CKD) is a risk factor for perioperative morbidity and mortality. Patients experience changes to perioperative drug metabolism and clearance, CKD is a risk factor for serious postoperative complications, such as acute renal failure and cardiovascular complications which are associated with increased morbidity and mortality [8]. Much of the increased risk is due to the fact that greater than 40% of the population with CKD has Diabetes Mellitus as the cause of their renal disease [7, 8]. A preoperative serum creatinine >2 mg dL^{-1} was found to be an independent predictor of cardiac complications, and was associated with major cardiac complications in 9% of cases [8]. Serum creatinine should be evaluated preoperatively and monitored postoperatively along with markers for renal failure, including acid-base status, potassium and phosphate metabolism, and total body fluid status [6–8]. If feasible, hemodialysis before and immediately after surgery should be effected; however, in the true surgical emergency, this is rarely possible or prudent. In the postoperative phase, Renal Replacement Therapy (RRT) with Continuous Veno-Venous Hemofiltration (CVVH) or hemodialysis results in less hemodynamic instability and should be instituted as soon as possible, even without fluid removal [8, 9]. Finally, in the postoperative period, attention should be given to the development of secondary hyperparathyroidism [9] and calcium monitored in the perioperative period frequently.

Chronic Liver Disease, especially in its end-stage, confers extremely high risk on the surgical patient, largely due to sepsis and hepatic failure. In a systematic review conducted by de Goede et al., the overall risk of perioperative morbidity and mortality were 30.1% and 11.6%, respectively and the coexistence of portal hypertension was found to be associated with a twofold increase in mortality [10]. The Child-Turcotte classification system was initially proposed in 1964 to predict mortality after portosystemic shunt surgery. It was then modified in 1972 by Pugh et al. The Child-Pugh classification relies on three objective laboratory (albumin level, bilirubin level, and prothrombin time) and two subjective clinical (severity of ascites and encephalopathy) criteria to stratify patients into three classes. It is easy to remember and apply, and the data is typically readily available, making it convenient, and fairly accurate. Predicted mortality varies from 10% for Child-Pugh A, 30% for Child-Pugh B, and up to 80% for Child-Pugh C [10].

The Model of End-Stage Liver Disease (MELD), published in 2000, represented a more specific scoring system designed to better predict mortality after transjugular intrahepatic portosystemic shunt (TIPS) procedures. It is based on bilirubin, creatinine, and international normalized ratio (INR) values. In the original publication, a MELD score < 8 was predictive of good post-TIPS survival, whereas a MELD score > 18 translated into significantly greater mortality [10]. Since then, several data have validated the MELD system for myriad surgical procedures, with only slightly variable cutoff values used to stratify expected patients with poor outcomes. In a recent review of the available literature, Hanje et al. concluded that elective general surgery in the abdominal cavity could be recommended for MELD scores <10, but should be discouraged with MELD scores >15 [10]. Unfortunately, and similar to the limitations associated with the Child-Pugh score, the MELD is not specific to patients with surgical emergencies [11].

Malnutrition is extremely important to surgical healing and confers an increase in perioperative morbidity and mortality, including increases in surgical infections, delirium, and prolonged lengths of stay. Obviously underweight patients, patients with temporalis or truncal muscle wasting, or patients with sequelae of malnutrition, such as pressure ulcers, should be identified preoperatively so that appropriate mitigation steps can be taken in the early postoperative phase [12]. There is little that can be done to mitigate the perioperative risks associated with malnutrition in the emergent surgical patient preoperatively; however, placement of surgical feeding access, either transnasaly or surgically at the time of surgery, improves outcomes and reduces the number of days without nutrition in the surgical patient [12, 13]. Enteral feeding is preferred and should be started as soon as feasible. Total Parenteral Nutrition is less desirable and is associated with increases in wound infection, urinary tract infection, Central Venous Catheter infections, and deep space infections, as well as electrolyte abnormalities, hyperglycemia, lengths of stay, and costs [13].

Neurologic and psychiatric diseases most commonly afflicting emergent geriatric surgical patients include dementia, substance withdrawal, and deliriuim. Dementia confers added risk for delirium and typically worsens with critical illness and surgical intervention. Delirium is defined as an acutely altered and fluctuating mental status, with an altered level of consciousness and disorientation [14]. It is quite common and often undiagnosed in the geriatric population, with an incidence ranging from 9% to 87% [14]. Risk factors for the development of delirium include older age, dementia, psychopathological symptoms, medical comorbidities, frailty, and functional impairment. The risk factors are additive, and, therefore, patients can be assessed and identified as having a higher risk for delirium postoperatively so that supportive and environmental steps can be taken to mitigate the delirium, as much as possible [15].

Substance abuse increases the risk of delirium in the postoperative period up to threefold [16]. The management of delirium is supportive, therefore, a high index of suspicion for withdrawal and delirium is indicated when geriatric patients screen positive for substance abuse. Withdrawal from chronic use is problematic for alcohol abuse, which is fairly common and typically treated with benzodiazepines or ethanol, and for benzodiazepine use particularly. Approximately 30–100% of patients on long-term benzodiazepines become dependent [17], with withdrawal symptoms including formication, anxiety and panic attacks, insomnia, hallucinations, seizures, fasiculations, psychosis, and delirium [17]. Treatment of benzodiazepine dose is usually effected with gradually decreasing doses or through the use of antiepileptic medications including carbamazepine [17].

The diagnosis of delirium is usually established with the use of assessment scales or tools, one of the most common being the Confusion Assessment Method-Intensive Care Unit (CAM-ICU) tool. This scoring system has well-established reliability and validity for assessing delirium [18]. Other popular tools include the Mini-Mental Status Exam, Informant Questionnaire on Cognitive Decline in the Elderly, and the Memorial Delirium Assessment Scale [15].

Many common medications may cause or exacerbate delirium in elderly patients, including H2 blockers, corticosteroids, diphenhydramine, belladonna, promethazine, warfarin, opiates, benzodiazepines, and antiparkinsonian medications. If possible these should be discontinued when delirium is a factor in postoperative care. Also, ethanol withdrawal or withdrawal from other substances may often be confused with or exacerbate delirium. Careful history should identify patients at risk for ethanol withdrawal, and treatment for withdrawal should be accompanied by treatment with thiamine, to reduce the effects of Korsakoff's psychosis [18].

Treatment of delirium consists firstly in addressing routine metabolic causes, including electrolyte abnormalities, glucose, oxygenation, and ventilation. Additionally, routine sources of sepsis should be sought and ruled out, including urosepsis, pneumonia, line sepsis, and surgical site infection. If found, these should be addressed quickly. Besides optimizing environmental support, pharmacological treatment is sometimes necessary in addition to optimizing environmental and supportive measures. Environmental supports, such as hearing and vision aids nearby, attention to early resumption of enteral nutrition, sleep hygiene, patients being helped out of bed, tubes and catheters removal, avoidance of dehydration and hypovolemia, family involvement and interaction, and attention to electrolyte abnormalities, have been demonstrated to reduce delirium from 15% to 10% [19].

Pharmacologic management includes haloperidol, which is the treatment of choice for delirium [19], and is considered superior to benzodiazepines both for the avoidance of side effects attributed to benzodiazepines as well as superior outcomes in symptom management. Atypical antipsychotics are not superior to haloperidol but may be preferred for ease of administration, preferred route, or length of half-life [20]. Usually, loading doses of 2–5 mg are repeated every 15 min while agitation persists. After the delirium is controlled, scheduled antipsychotic medication is prescribed over the next few days to prevent relapses [20].

Potential side effects of treatment of delirium that require monitoring include extrapyramidal side effects and prolonged QT syndrome. Daily EKC should be obtained to follow corrected QT (cQT) intervals, and if found to be greater than 440 ms in males and 460 ms in females, the haloperidol should be discontinued. Corrected QT interval is used because it is heart rate independent [19]. Extrapyramidal side effects include acute dystonia, akathisia, drug-induced Parkinsonism, and Tardive Dyskinesia. Acute dystonia typically occurs within minutes of atypical antipsychotic medication administration. It is characterized by painful convulsive movements of the neck, tongue, and body [20]. Usual treatment is anticholinergic drugs, including Benzhexol or benztropine intramuscularly. Akathisia is a very distressing side effect that occurs usually days to weeks after taking antipsychotic drugs and is characterized by difficulty in keeping one's legs in place. Treatment includes reducing antipsychotic dose or beta-adrenergic receptor blockers such as Propranolol. Drug-induced Parkinsonism presents identically to Parkinson's disease. It includes muscle stiffness, pill-rolling tremor, and Bradykinesia. It typically begins several months after antipsychotic drug treatment. It is treated with Benzhexol or other anticholinergic medications. Tardive dyskinesia is the most difficult side effect of atypical antipsychotics to treat. It typically begins years after chronic treatment with antipsychotic drugs. It is characterized by irregular movements of the tongue and face. The prognosis is usually poor [19].

Adrenal insufficiency is a difficult problem to diagnose and is often not immediately obvious to treating physicians. Estimates are that up to 20–30% of patients admitted to the ICU are adrenally insufficient [20–22]. The benefits of treating relative adrenal insufficiency in septic shock, sepsis, subarachnoid hemorrhage, and critical illness are well documented [20–22]. Especially well studied is the effect of treating relative adrenal insufficiency in cardiac surgery patients. Patients have less dependence of vasopressors and improved clinical outcome [21, 22]. In sepsis, the Surviving Sepsis campaign recommends treating vasopressor dependence after fluid resuscitation with empiric corticosteroids [22]. This represents a paradigm shift over decades ago when steroids were thought to be universally detrimental.

Patients chronically taking corticosteroids as outpatients should be suspected of relative adrenal insufficiency, even without biochemical proof of glandular dysfunction. These patients should be treated for relative adrenal insufficiency as a matter of routine [23, 24]. Early treatment with steroids clearly reduces mortality and decreases vasopressor use [23, 24], and in patients with hemodynamic instability, shock, and vasopressor requirement, adrenal insufficiency should be considered and treated empirically, preferably within the first hour after vasopressor use is required [20].

Etomidate is a popular drug for the induction of anesthesia, especially in the cardiac surgery population, because it does not depress myocardial activity [24]. Patients requiring vasopressors who were induced using etomidate should be strongly suspected of having adrenal insufficiency and should be treated empirically [24]. Many authors historically have raised concerns with the use of corticosteroids in the postoperative setting, due to the negative effects of corticosteroids on wound healing. However, the doses used in the postoperative setting are usually physiologic (not more than normal secretory levels), compared with large doses used when the negative wound healing effects were first described [20–29]. Additionally, the effects of corticosteroids are minimal when compared to the effects of persistent hypotension, shock, poor oxygen delivery, and acidosis that proceeds from untreated adrenal insufficiency. Considering that adrenal insufficiency is present in nearly 20% of ICU patients, it is important to attune ourselves to the diagnosis and treatment of this comorbidity, because the consequences of untreated adrenal insufficiency are disastrous [26–30].

2.3 Perioperative Risk Stratification

For the purposes of prognostication, the National Surgical Quality Improvement Project (NSQIP) calculator is an excellent, evidence-based tool to use, in real-time, with easily available data, to help families and patients weigh risks and benefits of emergency surgical intervention [6]. It has 21 variables that can be placed into an internet online interface and provide a reasonably accurate estimate of perioperative morbidity and mortality. As the scoring system requires a CPT code for which operative procedure was selected, there is no capability to estimate nonoperative risk [27]. Other scoring systems exist, including Goldman Cardiac Risk, Revised Cardiac Risk Index, APACHE series (II, III), SOFA, and POSSUM scores, to name a few. The ease of use and excellent r statistic for the NSQIP calculator make it more reliable and easy to utilize. The ability to quantify the risks of surgery, as with a reproducible score, makes the discussion of risks and benefits more straightforward and empiric [27].

Delaying emergent surgery in favor of perioperative risk stratification worsens outcomes [28]. In several studies, delay to pursue cardiac or other functional testing led to worsening of the initial surgical emergency. In the true emergency, perioperative testing should be minimized, as mentioned above, and except for active cardiac ischemia, dealt with after the acute emergency is addressed definitively [27, 28].

2.4 Cultural, Legal, and Social Factors in Operative Decision-Making

There are several cultural and societal factors that become immediately important in the emergency surgical patient. Initially, the discussion of a patient's end of life wishes and values regarding catastrophic medical conditions becomes of paramount importance when assessing a geriatric, or really any, patient with life-threatening illness or injury. The discussion of how, or if, to proceed is immediately apparent, and may need to occur with a surrogate if the patient herself or himself is incapacitated.

The discussion of end of life wishes centers around several factors, including patient factors, surrogate factors, provider factors, and system factors [29]. Patient factors include a willingness to document or communicate advance directives, the ability to locate important documents, including living wills and medical powers of attorney, and thorough discussions of wishes with surrogates [29]. Even in the face of terminal illness, caregivers and patients tend to feel unprepared for end of life discussions, and rely on vague or inaccurate assessments of likely patient outcome [30]. Surgeons feel as if they do not have adequate time to discuss the end of life issues, and that the issues tend not to be raised prior to critical or serious illnesses. When they do occur, the discussions are typically held in lawyers' offices, and the forms are boilerplate, leaving little room for individual expression of values and wishes [29, 30]. Patients and surrogates, therefore, feel that patients' wishes are unknown, may be misrepresented, or do not apply to the written instructions [30].

Surgeons can improve the communication with patient families through improving their own education, using available resources [30], and through involvement of palliative care specialists [29]. Surgeons can set realistic and open expectations for the operation, and discuss with family members who should be the point person for communication and surrogacy, if possible, before the operation begins and in the presence of the patient, whose wishes should be heard if possible [29]. Additionally, many patients and physicians misunderstand the role of palliative care consultation services [30]. Patients can be offered palliation even if they accept surgical intervention, to facilitate improved pain control, and agreement for that consultation preoperatively helps ameliorate some of the misunderstandings in the sometimes fraught postoperative state [30]. Standardized approaches and treatment pathways, including quantitative risk estimation (e.g., NSQIP) can also help to reduce rates of non-beneficial surgery and intervention.

Incapacitated patients not in immediate life-threatening situations may need conservation, guardianship, or surrogates appointed through legal proceedings. Patients with chronic illnesses, including dementia and psychiatric impairment, may need court-appointed guardians or conservators to ensure that their rights, property, and wishes are being protected. The laws differ from state-to-state and country-to-country, so a comprehensive accounting of the policies and procedures is impractical; however, suffice to say that particular attention to the expressed wishes of the incapacitated, demented, or delirious patient is essential to providing care to the emergent surgical patient [31].

Finally, there is the legal question of elder abuse. Elder abuse is extremely difficult to determine, diagnose with any certainty, or to identify with a high degree of certainty. Several studies have estimated the rate of elder abuse at between 7.6% and 10%, although each study represents these rates as underestimates [32, 33]. Risk factors include younger age, female gender, dementia, functional impairment, and poor physical health, and the perpetrators are more often male, children or spouses, have a history of substance abuse or mental health problems of their own.

Diagnosis is particularly difficult. Geriatric patients may conceal their circumstances or be unable to articulate them. Injuries sustained may not be the result of abuse; elderly patients are more prone to falls, bruising, cuts and scrapes, malnutrition, injury, and may not remember events to give a correct accounting of the events. Patients with dementia may confabulate abuse allegations, or not, may confuse the perpetrators, or not, and may say one thing 1 day and another thing the next [33]. Cultural norms may dictate withholding information from the medical community and language barriers may make communication more difficult [32].

Assessment of abuse should be done alone with the patient and should be done, if possible, by persons with particular expertise in interviewing elder abuse patients. If suspected, a multiprofessional approach may be beneficial [32] and the physician may not have time for necessary activities, such as interviews of family members or home visits.

In the emergent surgical patient, these activities are complicated by the need for surrogacy for surgical consent, for family involvement in decision-making, and by the time constraints imposed by emergent surgical conditions. There are several different community organizations that may be of help, including district attorney offices, police department, adult protective services, centers for aging, home health agencies, and hospital resources [32]. Any or all of these can be marshaled if there is suspicion of elder abuse.

2.5 Conclusion

As the world's population ages, especially in developed nations, we come to be faced with the problem of patients at extremes of age with emergent surgical needs. To us, as disinterested strangers, these patients become one in a string of daily chores. They become another in a line of interruptions in our days. However, these patients are also the centers of someone's universe, a parent, aunt, uncle, sibling, and in emergent situations, the reality and gravity of a true threat to life can be overwhelming to family members. A physician who cares for geriatric patients with serious illness or injury has the same responsibilities as always, to shepherd families and patients through the decisions that need to be made, to offer clear and accurate information free of our own judgments and biases as much as possible, and to treat the patients the way they want to be treated in as much as those facts may be ascertained. This becomes difficult in emergency surgery, and unpacking the elements of the decisions can expose our own psychological baggage behind caring for elderly patients. Truth in representing the data, and separating it from opinion may be the best course for the ethical treatment of geriatric patients, remembering that patient autonomy persists even at the extremes of age. With our long white coats comes great responsibility and power, power to clarify or obfuscate, to terrify or console, to facilitate or impede and the power to be accurate or to misrepresent. These powers should be wielded ethically and thoughtfully, as their impact may be much more profound in the geriatric patient.

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3 Radiologic Evaluation of Elderly Surgical Patients Undergoing Major Emergency Surgeries

Timothy Diestelkamp and Anthony Gilet

3.1 CT in Geriatric Emergency Evaluation

Prompt and accurate evaluation and assessment of patients is vital to the successful treatment of patients in the emergency setting. When evaluating the elderly in an emergency setting, medical imaging plays a crucial role in diagnosis, determining the extent of injury, and triage. This is especially true in the elderly population, where because of potential comorbidities patients may present with a confounding medical picture or have less intrinsic ability to compensate for an insult, necessitating a quick and accurate diagnosis. One of the most useful imaging modalities to complete this evaluation, particularly in the elderly population, is computed tomography (CT). CT has a number of advantages over other modalities that make it the first-line imaging modality for the majority of emergency imaging needs when caring for the elderly.

First, CT is able to provide a tremendous amount of information very quickly. Whereas plain film radiography is quick and easily accessible, it lacks the sensitivity and specificity of CT, and only provides a two-dimensional representation.

Another advantage of CT in the emergency setting is its speed and accessibility. A CT examination of the chest, abdomen, and pelvis on current generation scanners can be acquired in under 10 s. Not only does this supply rapid results, but it is very well tolerated by patients. Elderly patients are at greater risk of inability to lie still for a scan, and motion degradation (artifact) is minimized the faster the scan is acquired. This is in contradistinction to MRI, where the same volume of imaging would take orders of magnitude longer to acquire, and is much more susceptible to patient motion artifact. CT also offers the benefit of data reconstruction, including multiplanar reformatting (MPR). This allows a clinician to reorient the images to follow an anatomic rather than cardinal axis. By allowing the capability, a clinician

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may be able to orient images to view the arch of the aorta in a single image, whereas it would normally fall out of the conventional viewing planes.

A potential negative aspect of CT is the associated ionizing radiation. Radiologists and clinicians should always be mindful and follow the ALARA principle (as low as reasonably achievable), weighing the clinical necessity of the test versus the clinical harm of the radiation. It is important to be aware of the fact the risk of additional radiation-induced cancer is negligible in the elderly population, approaching the point of "zero-risk" as a person ages. After the age of 40, the risk of radiation-induced cancer drops exponentially, and after the age of 60 the line approaches zero. The speed, accessibility, accuracy, tolerability, and general safety profile of CT far outweigh the risks and the time that may delay necessary surgery [1].

3.2 Concerns of Iodinated Contrast in the Elderly Population

One historical concern regarding CT examinations is the use of iodinated intravenous (IV) contrast agent's concern over nephrotoxicity. This matter arises more frequently in the elderly population secondary to greater rate of underlying renal function impairment. The literature indicating evidence of nephrotoxicity is based on older, higher osmolarity agents predominantly used intra-arterially during cardiac and arterial catheterization. Notably, recent research indicates that nephrotoxicity associate with the current generation of low-osmolar contrast agents, given IV, has minimal to zero-risk of nephrotoxicity, especially in patients with chronic renal insufficiency. In January 2020, the American College of Radiology and the National Kidney Foundation released a consensus statement with the following findings [2]:

- The putative risk of administering modern intravenous iodinated contrast media in patients with reduced kidney function has been overstated.
- Although the true risk of contrast-induced acute kidney injury remains unknown, prophylaxis with intravenous normal saline is indicated for patients without contraindication (e.g., heart failure) who have acute kidney injury (AKI) or an estimated glomerular filtration rate (eGFR) less than 30 mL/min/1.73 m^2 who are not undergoing maintenance dialysis.
- In individual high-risk circumstances, prophylaxis may be considered in patients with an eGFR of 30–44 mL/min/1.73 m^2 at the discretion of the ordering clinician.
- The presence of a solitary kidney should not independently influence decision-making regarding the risk of contrast-induced acute kidney injury.
- Ad hoc lowering of contrast media dose below a known diagnostic threshold should be avoided due to the risk of lowering diagnostic accuracy.
- When feasible, nephrotoxic medications should be withheld by the referring clinician in patients at high risk.
- Renal replacement therapy should not be initiated or altered solely based on contrast media administration.

3.3 Mesenteric Ischemia

Mesenteric ischemia is hypoperfusion to the intestine when the blood supply fails to meet the demands of the tissue, and hence depriving the tissue of required oxygen required to maintain viability [3]. The clinical presentation is often nonspecific (especially in the pediatric and elderly population) and the imaging findings may suggest a number of possible disease processes if the constellation of findings are not all evident on initial examination, and thus early identification may be difficult. However, if the present imaging findings and clinical presentation are accurately synthesized together, the diagnosis can still be made with high sensitivity and specificity. Another difficulty in determining the presence of mesenteric ischemia is that the diagnosis of mesenteric ischemia encompasses a spectrum of varying severities from mild decreased perfusion of the mesentery to full-fledged infarction and chronicities as there may be chronic or acute ischemia of the bowel. This variance in the severity and chronicity contributes to the variable and nonspecific clinical presentation and imaging characteristics. Additionally, mesenteric ischemia can be secondary to arterial (occlusion, embolic, dissection, vasoconstriction), venous (portal and mesenteric vein thrombosis), or systemic (hypotension, shock) etiology. Lastly, it is important to consider that the entirety of the intestine must be evaluated when imaging to properly assess for mesenteric ischemia as it can be present in one portion of the bowel while the other regions appear unaffected. Due to this large field of view that must be accounted for, as well as the emergent necessity for evaluation as the intestines may be in the process of failing, makes CT the modality of choice for its evaluation.

3.3.1 Imaging Findings

CT examination of the bowel is ideal for evaluating mesenteric ischemia [1]. The addition of oral and intravenous contrast is necessary whenever able to aid in this examination as well. Intravenous contrast can be of tremendous value as this can demonstrate any vascular occlusion or stenosis that may be the cause of the ongoing ischemia. Sharp cutoff of the vessel may suggest embolic causation, whereas, in contrast, thrombus formation often demonstrates a tapering, irregular cutoff of the vessel. Occluding thrombus is often depicted with a hyperattenuating rim, representing the vascular wall, which outlines the thrombus. Additionally, upstream from the occlusion, the artery may be dilated.

3.3.1.1 Wall Thickening

The most common finding of mesenteric ischemia on CT is a circumferential thickening of the bowel wall [3]. This thickening often does not exceed 1.5 cm in thickness [4]. This thickening is caused by edema, inflammation, and hemorrhage within the wall of the intestine [5]. This can often be seen in the attenuation of the wall on CT. Sometimes the wall is homogenously hypoattenuating with edema and inflammation. It also may have a target-like or circular pattern of enhancement often representing limited blood flow that is able to perfuse portions of the bowel wall, but not the entirety. Also, areas of high-attenuation representing hemorrhage within the hypoattenuated infarcted wall can be seen.

3.3.1.2 Enhancement

Reduced enhancement of the bowel is the only direct sign to indicate that there is absence of blood flow. This finding was found to have 100% specificity for intestinal ischemia in 24 patients with small bowel obstructions [5]. Though it is important to note that the absence of mesenteric enhancement can be difficult to identify on CT examination if one is not specifically searching for it as discussed by Marcari et al. [6].

3.3.1.3 Shock Bowel

When discussing the enhancement pattern of ischemic bowel wall, it is important to mention “shock bowel”. “Shock bowel” is when the small bowel demonstrates prolonged hyperenhancement in a patient with hypovolemic shock [7]. Additionally, it may demonstrate wall thickening, luminal dilatation, and fluid-filled loops of small bowel while the colon appears normally. These findings resolve with volume resuscitation indicative of reversible ischemic changes. Thus, it is believed that these findings result from splanchnic vasoconstriction caused by hypovolemia.

3.3.1.4 Distribution

When evaluating the presence of mesenteric ischemia, it is important to consider the distribution and extent of affected bowel [1]. Even in the absence of direct visualization of the vascular interruption, one can locate the inciting injury by evaluating the location of the abnormalities. With the celiac trunk supplying much of the stomach and duodenum; the superior mesenteric artery supplying the jejunum, ileum, ascending, and proximal transverse colon; and the inferior mesenteric artery supplying the distal transverse, descending, and sigmoid colon as well as the rectum one can easily locate which arterial distribution may be compromised leading to the observed mesenteric damage. Next, based on the extent of the damage, one can determine if a major artery is involved or a distal side branch. It is important to note that collaterals are often present so the extent of affected intestine may appear somewhat different than the expected distribution. Lastly, it is imperative to remember that embolic sources of vascular interruption and ischemia will result in multiple ischemic areas that appear in a random distribution throughout the bowel.

3.3.1.5 Pneumatosis and Portal Venous Gas

Pneumatosis (intramural gas) and portal venous gas are often seen in mesenteric infarction and are highly specific for bowel necrosis [8]. Bandlike pneumatosis alone and pneumatosis in conjunction with portal venous gas are highly associated with transmural bowel infarction, whereas bubble-like pneumatosis and isolated portal venous gas are related to only partial mural bowel ischemia in one-third of cases [9].

3.3.1.6 Small Bowel Obstruction and Mesenteric Ischemia

For many patients suffering from a small bowel obstruction, mesenteric ischemia is often an unfortunate complication that arises and coexists with the obstruction. Lack of wall enhancement, ascites, and mesenteric haziness in the setting of bowel obstruction may all be indicative of ischemia and/or strangulation.

3.3.1.7 Considerations in the Elderly

The elderly population represents the majority of the cases of mesenteric ischemia, making up more than 90% of the cases [10]. This, at least in part, is due to the many comorbidities that can contribute mesenteric ischemia that is more common with age. Atherosclerosis can lead to vascular stenosis and calcification that can result in decreased blood flow to the bowel and eventual ischemia [11]. Additionally, comorbid cardiac conditions such as heart failure and atrial fibrillation can result in mesenteric ischemia in this population, either secondary to decreased cardiac output and bowel perfusion or thromboembolic phenomena. Heart failure can result in reduced cardiac output that eventually is unable to perfuse the bowel adequately and atrial fibrillation can lead to thrombus formation within the atria if adequate anticoagulation is not achieved and eventual embolization that can lead to mesenteric infarction should the clot travel to the bowel [1]. While these specific examples may be present in some patients, it is important to consider that these comorbidities, as well as many others that are not included here, can make the elderly more responsive to hemodynamic changes. Thus mesenteric ischemia may not be the initial presentation of the elderly patient; however, it may be a complication that results during an emergent situation and must be considered.

3.4 Bowel Obstruction

In similar fashion to detecting mesentery ischemia, CT is the primary imaging technique for the evaluation of the small bowel and for assessment of an obstruction [11]. This is again due to the large field of view, so the entirety of the bowel can be evaluated and an obstructive transition point, if any exists, can be identified [1]. Additionally, the quick scanning time of CT reduces the motion artifact that may limit the evaluation of the bowel. CT also allows for the characterization of a small bowel obstruction as an uncomplicated obstruction, a closed-loop obstruction, or an internal hernia. This could mean the difference between conservative management and surgical intervention for the patient.

Oral contrast may be administered to evaluate for obstruction of the bowel. Positive (bright) oral contrast, that hyperattenuates on CT examination, is often administered to assess if an obstruction is complete or partial as contrast can be seen passing the obstruction point or not. There are some downsides to the administration of oral contrast. It is important to note that oral contrast should only be administered if the patient can be monitored for a period to allow the contrast to pass into the intestines. Though administering oral contrast may be unnecessary if time cannot be afforded to wait for the contrast to reach the obstruction [12]. A special note should be made for the administration of oral contrast in the emergency setting, because if perforation is possible or the patient may be operated on, water-soluble contrast must be utilized [13] given the risk of barium peritonitis or concretions. Positive oral contrast agents can decrease sensitivity for detection of GI hemorrhage and/or ischemia. Oral contrast may limit evaluation for bowel wall thickening. If there is clinical concern for ischemia, a negative contrast agent, such as water, that will distend the bowel without hyperattenuating the lumen may be utilized. Thus, it is crucial to consider the clinical implications of administering, or not administering, oral contrast to select the examination that will provide the most information for the patient.

Intravenous contrast is routinely utilized for the evaluation of obstruction as it can highlight any changes in the bowel wall, especially those that may result if ischemia is present as well (as described in the previous section). Additionally, it may point out any inflammatory or neoplastic processes that may have contributed to the obstruction.

3.4.1 Imaging Findings

One of the subtler findings in CT examination of obstructed bowel is the gradient of oral contrast attenuation. Enteric fluid will dilute the administered oral contrast. This can be particularly useful for patients with a “gasless abdomen” on abdominal radiographs as the “gasless” appearance often indicates that the loops of bowel were filled with fluid. As the oral contrast diffuses into the fluid within the bowel, a gradient may become apparent with more concentrated contrast proximally and more dilute contrast distally. This may aid in the determination of the point of obstruction.

Small bowel obstruction appears as dilated loops of bowel proximal to the point at which the obstruction occurs [14]. These loops of bowel often appear as fluid and air-filled and measure greater than 3 cm in diameter [11]. Multiple valvulae conniventes can appear as a “stack of coins” within the obstructed bowel. Distal to the point of obstruction, there are collapsed loops of small bowel as peristalsis clears gas and contents [1]. If the terminal ileum is dilated, then obstruction of the small bowel can be excluded [15]. Because the point of obstruction marks the meeting of these opposing appearances, it is often termed the transition point. Often the dilated loops of small bowel will taper as they approach the transition point, sometimes referred to as a “bird’s beak” appearance.

One may also see the small bowel feces sign within the loops of obstructed small bowel [16]. As contents within the obstructed small bowel continue the process of digestion they begin to develop the imaging appearance of feces with air stippling. Though not specific, it is suggestive of obstruction and can aid in localizing the transition point as the contents that have been in the bowel longest typically fecalize first and appear more distally.

3.4.1.1 Closed-Loop Obstruction

A closed-loop obstruction occurs when the bowel twists upon a single point, resulting in a proximal and distal obstruction point and an intervening involved loop of bowel. Thus, there are typically two points of obstruction, one from normal bowel to the point of obstruction, and one from the involved loop of bowel to the approximate same point of twisting [11]. The small bowel is typically adhered to the posterior abdominal wall which is why closed-loop obstructions do not occur more regularly. Closed-loop obstructions often not only obstruct the luminal contents from progressing with regular peristalsis, but they may also obstruct the vascular blood flow to the incarcerated segment, resulting in ischemia and/or infarction [1]. If this strangulation of the bowel occurs, mortality rises dramatically [17]. A closed-loop obstruction appears as a cluster of the dilated, fluid-filled loops of bowel in a radial distribution (there is often a characteristic C-shaped loop of dilated bowel with two adjacent triangular-shaped collapsed loops of bowel), spiraling or convergence of vasculature to a central point, sometimes referred to as “spoke-wheel” or “whirl sign” [14]. There can also be accumulation of fluid and edema surrounding the mesentery, and signs of bowel wall ischemia, including bowel wall edema, lack of bowel wall enhancement, and pneumatosis (as discussed further in the Mesenteric Ischemia section) [1].

Since plain radiography has relatively high sensitivity for detecting small bowel obstruction, the contribution of CT lies partly in its ability to identify signs of a “surgical grade” obstruction. Mesenteric edema, bowel wall thickening in the setting of dilated bowel, bowel wall hypo- or hyperperfusion, and findings of closed-loop obstruction all increase the likelihood of surgical intervention [18–20].

3.4.1.2 Hernias

Hernias represent nearly 10% of the cases of small bowel obstruction and serve as the most common cause overall and leading cause in the developing world [17, 21]. Hernias are broadly subdivided into internal, hernias that are formed by a defect in the mesentery or omentum, or herniation around adhesions, or external, hernias that project through the abdominopelvic wall [17]. While many external hernias of clinical significance are apparent on physical examination, internal hernias are almost exclusively diagnosed radiologically. Hernias, much like closed-loop obstructions, can result in vascular occlusion at the neck of herniation [1].

3.4.1.3 Causes

Obstruction can result due to many different processes which can be easily divided into intrinsic or extrinsic causes. Extrinsic causes lie outside and separate from the bowel, whereas intrinsic causes arise as part of the bowel wall or within the lumen. The single largest cause of obstruction in the Western world is postsurgical adhesions [17]. Though rarely actually visualized radiographically, there is often a clear transition point between dilated and nondilated bowel loops with no other apparent cause of obstruction in a postoperative patient, which leads to the suggestion of adhesions. Secondary signs of adhesions leading to bowel obstruction include abrupt angulation of the bowel and the bowel adhering to surfaces nondependently, particularly when these findings correspond to transition points between dilated and normal bowel loops [11].

Neoplasms also serve as a major causative factor in the development of obstruction. However, depending on the disease process, this can be accomplished in a number of ways. Peritoneal carcinomatosis can involve the small bowel wall with serosal disease, resulting in obstruction and a transition point at the involved locations [17]. Metastatic carcinoid tumors can spread to the mesentery and result in retraction of the bowel loops with thickening of the bowel wall, ultimately resulting in obstruction much of the time [22]. Nodal metastases, when large enough such as with lymphoma, can result in extrinsic compression of the bowel and obstruction at the compression point.

Crohn's disease can serve to cause obstruction in three separate situations. First, during the initial presentation of the disease process with acute disease, patients can present with obstruction as their bowel is inflamed and serves as an intrinsic cause of obstruction. The chronic disease process can also result in obstruction, particularly during a stenotic phase. Lastly, postoperative patients with Crohn's disease who have undergone surgery may develop adhesions, resulting in obstruction.

3.5 Trauma

Trauma is a common cause of emergency surgery and there are special considerations that must be taken into account when imaging such patients. Blunt trauma often results in imaging whereas penetrating trauma often proceeds directly to surgery as evidence is often sufficient to indicate intervention [10]. The most common cause of blunt abdominal trauma is motor vehicle collision [10]. With such trauma, it is important to note that often multiple organ systems can be involved, and thus comprehensive assessment is necessary. Hollow organs, such as bowel, can suffer compression as intra-abdominal pressure often rises during the traumatic event. This can result in a number of different injuries including tears and perforation of the bowel wall. Added to this is often mechanical compression of the solid organs which can result in contusion, often of the liver and spleen. It is important to note the high speed at which many of these traumatic events occur. This can often lead to acceleration/deceleration injuries that often manifest as lacerations that occur where shear forces rip and tear at points of fixed positioning.

CT is the imaging modality of choice for blunt abdominal trauma [10]. A key component leading to CTs preference is its ability to assess for injury to the abdominal organs and to look for hemorrhage. A note should be made that extension of abdominal imaging above the diaphragm can allow for a complete examination of the abdominal organs as well as ensuring the diaphragm is intact. Additionally, CT allows for the examination of the retroperitoneum as radiographs will be limited by the soft tissue density that fills the space. Though slightly limited in its assessment of the pancreas, CT is still able to identify emergent injuries that have injured the organ and can be performed much faster than MRI examination to allow for the timely assessment of the organ. Lastly, CT is readily available for repeated examinations, allowing for follow-up of any abnormality and assessment as clinical conditions change.

3.5.1 Imaging Findings

Common signs of injury or hemorrhage can be seen on CT that are nonspecific and should be correlated with clinical symptoms or signs [10]. Often, as intravascular declines, the inferior vena cava will lack the necessary volume for proper distension, resulting in flattening and collapse. Additionally, when the intravascular volume is depleted, there may be decreased perfusion to the organs. This can be seen particularly well in the spleen as its enhancement will be delayed if intravenous contrast is present. Lastly, one can utilize the physiologic response of the vasculature to assess if vasoconstriction is present. Often the aorta and major mesenteric vessels will appear smaller in caliber than expected.

3.5.1.1 Renal Trauma

Injury to the urinary tract is a common result of trauma and injury to the urinary tract is present in 10% of trauma patients with the kidney being the most commonly injured organ within the urinary tract [11]. CT is excellent at assessing renal injury as it can characterize the damaged organ, detect any hemorrhage within the perirenal space, and identify any leakage of urine from the collecting system [3]. Determining the presence of these injuries adequately requires intravenous contrast and a nephrographic phase of imaging is often necessary for ideal characterization [23].

Renal injuries can be graded and classified based on their depth and involvement of the vasculature and collecting system, as is described by the American Association for the Surgery of Trauma [24].

Grade I renal injuries consist of renal contusions and nonexpanding subcapsular hematomas without evidence of renal laceration. Contusions are injuries to the parenchyma that result in swelling with edema and hemorrhage and appear as areas of hyperattenuation on noncontrast imaging and decreased parenchymal enhancement on postcontrast phases [11]. The affected kidney may also show persistent enhancement of the kidney on delayed phases of imaging due to lack of contrast excretion from the hypofunctioning kidney. Comparison to the contralateral kidney if not injured can help serve as a baseline. It should be noted that contusions will still enhance, though less than the unaffected parenchyma, whereas areas of renal infarction will not enhance. Subcapsular hematomas will appear as crescentic hyperattenuating collections adjacent to the kidney with mass effect distorting the contour of the kidney. Chronic hematomas may show calcifications.

Grade II renal injuries consist of nonexpanding perinephric hematomas and lacerations of the renal parenchyma that are less than 1 cm in depth of the renal cortex. Perinephric hematoma is identified as areas of hyperattenuation surrounding the renal parenchyma and may often present with mass effect on the adjacent large bowel and possible displacement of the kidney. In contrast to subcapsular hematomas, the contour of the kidney will be intact. Lacerations, or tears in the renal parenchyma, appear as irregular, linear, sometimes wedge-shaped, disruptions to the kidney parenchyma that does not enhance [11]. Resultant urinomas and hematomas may develop from lacerations and can be differentiated from one another by determining which phase of imaging contrast is seen within the collection. Contrast pooling or blush within the collection during the arterial or venous phase suggests active arterial or venous bleeding, respectively. If there is contrast 'blush' on the excretory phase, a urinary collecting system injury should be sought.

Grade III renal injuries consist of lacerations of the renal parenchyma that are greater than 1 cm in depth of the renal cortex and extending into the renal medulla. It is important to note that while Grade III lacerations are longer in depth than Grade II lacerations, they are limited to involve the renal cortex and medulla, without involving the collecting system [25].

Grade IV renal injuries consist of laceration of the renal parenchyma that include the renal cortex and medulla and extending to involve the collecting system. Lacerations that involve the collecting system are characterized on CT by visualized urine extravasation, which will appear as an opacified fluid collection on the excretory phase. Additionally, Grade IV injuries may include injury to the renal vasculature. These vascular injuries will often appear as segmental infarctions that result due to thrombus formation, laceration, or dissection of the segmental renal arteries. On CT these renal infarctions will appear as well-defined, wedge-shaped areas of nonenhancement of the renal parenchyma.

Grade V renal injuries consist of a shattered kidney, avulsion of the renal hilum, a completely devascularized kidney, and complete laceration or thrombus of the main renal artery. Shattered kidney is the most severe renal laceration that fragments the kidney into three or more separate pieces and includes injury to the collecting system [11]. Avulsion of the ureteropelvic junction is seen on CT as lack of opacified urine filling the ureter on the excretory phase. Additionally, collections of urine may be noted medially to the hilum. Renal artery occlusion is often a complication if the artery undergoes stretching, resulting in tearing of the vascular intima which can lead to dissection or thrombus formation. This occlusion of the renal artery often results in infarction of the kidney. On CT, this appears as an abrupt cutoff of contrast within the renal artery with universal lack of enhancement of the affected kidney without change to the renal contour [26]. A cortical rim sign, which is seen on CT as capsular and subcapsular enhancement, can be present due to collateral circulation; however, it takes a minimum of 8 h for this sign to become apparent due to the delayed collateral flow [27].

The ureter, though rare, can also be injured during trauma [11]. Obtaining delayed phase imaging, performed 5–7 min after contrast administration, allows for the identification and characterization of ureteral injury. These images often demonstrate the extravasation of contrast-enhanced urine from the ureter, allowing for the identification of the degree and location of the injury. On noncontrast imaging, these injuries will often present with fluid collections adjacent to the ureter and stranding of the surrounding fat.

3.5.1.2 Hepatic Trauma

The liver is one of the most commonly injured abdominal organs during blunt trauma [11]. These injuries are best detected and characterized by CT examination.

For ideal evaluation of the liver, CT performed with intravenous contrast is preferred, ideally timed during the portal venous phase of enhancement. This aids particularly in the identification of active extravasation of blood. Much like with renal trauma, hepatic injury is graded on a scale from the American Association for the Surgery of Trauma [28]. This scale divides hepatic trauma based on the presence and size of hematomas and lacerations, as well as vascular injuries of the hepatic vessels.

Grade I liver injuries consist of subcapsular hematomas that encompass less than 10% of the surface area of the liver and lacerations that disrupt the hepatic capsule and extend less than 1 cm into the hepatic parenchyma. Subcapsular hematomas are hypoenhancing elliptical collections that conform to the capsular contour of the liver. Hematomas are typically hyperdense to the liver parenchyma on noncontrast phases. Lacerations appear as linear areas of hypoattenuation that often have perihepatic blood present at the liver surface. One should always be mindful of the location of the laceration to assess for biliary duct involvement should the laceration involve the periportal region.

Grade II liver injuries consist of subcapsular hematomas that encompass 10–50% of the liver surface area, small intraparenchymal hematomas that are less than 10 cm in diameter, and lacerations that extend into the hepatic parenchyma 1–3 cm in depth and extend of less than 10 cm in length. Intraparenchymal hematomas are poorly defined regions of hypoenhancement compared to the normal liver parenchyma.

Grade III liver injuries consist of subcapsular hematomas that encompass more than 50% of the liver surface area or when these hematomas are expanding or have ruptured through the liver capsule and are actively bleeding. Extravasation of hyperattenuating blood on the portal venous phase of a contrast enhanced examination is suggestive of hemorrhage from a portal venous or hepatic arterial source. Delayed phases may show interval increase in size as the hematoma continues to grow. Intraparenchymal hematomas are also Grade III injuries when they are greater than 10 cm in diameter and are expanding or have ruptured through the liver capsule. Lastly, Grade III injuries include deeper lacerations that extend more than 3 cm into the hepatic parenchyma but are still less than 10 cm in length.

Grade IV liver injuries consist of intraparenchymal hematomas that have ruptured through the liver capsule and are actively bleeding or lacerations that result in parenchymal disruption involving 25–75% of a hepatic lobe or 1–3 Couinaud segments within a single lobe.

Grade V liver injuries consist of lacerations that disrupt more than 75% of the parenchyma of a hepatic or more than 3 Couinaud segments within a single lobe. Also Grade V liver injuries include vascular injuries to the major hepatic veins or retrohepatic vena cava. Injuries to these vascular structures can be seen on CT as abrupt cut off of these vessels on the portal venous phase. Pseudoaneuryms of the hepatic artery are often a complication of trauma and can be detected on contrast enhanced CT. They appear as arterially hyperenhancing foci that washout on the delayed phase.

3.5.1.3 Gallbladder Trauma

Gallbladder trauma can take a number of different forms and often results from blunt trauma [11]. Contusions to the gallbladder are often seen on CT examination as diffuse thickening of the gallbladder wall and may often appear with pericholecystic fluid. These often represent intramural hematomas. Hemorrhage into the gallbladder lumen or gallbladder fossa is often seen as high density fluid, however this appearance is nonspecific as high-attenuation gallbladder sludge may appear similarly. Laceration of the gallbladder wall is often seen as disruption of the gallbladder wall and can be demonstrated on post contrast imaging with disruption of the normal enhancement pattern.

3.5.1.4 Splenic Trauma

Similar to renal and hepatic injuries, splenic injury is classified according to the American Association for the Surgery of Trauma [28]. Contrast enhanced CT examination is the mainstay of evaluation of the spleen following trauma [11]. Portal venous phase imaging aids in the detection of the majority of splenic injury, and most vascular injuries are evident on arterial phase. Grade I spleen injuries consist of subcapsular hematomas that encompass less than 10% of the surface area of the spleen and lacerations that disrupt the splenic capsule and extend less than 1 cm into the splenic parenchyma. Subcapsular hematomas are hypoenhancing collections that conform to the capsular contour of the spleen. Lacerations appear as linear areas of hypoattenuation that often have perisplenic blood present. One should always be mindful of the location of the laceration to assess for involvement of the splenic hilum and the vascular structures present there.

Grade II splenic injuries consist of subcapsular hematomas that encompass 10–50% of the splenic surface area, small intraparenchymal hematomas that are less than 5 cm in diameter, and lacerations that extend into the splenic parenchyma 1–3 cm in depth and not involving a parenchymal vessel.

Grade III splenic injuries consist of subcapsular hematomas that encompass more than 50% of the splenic surface area when these hematomas are expanding or have ruptured through the splenic capsule. Intraparenchymal hematomas are also Grade III injuries when they are greater than 5 cm in diameter. Lastly, Grade III injuries include deeper lacerations that extend more than 3 cm into the hepatic parenchyma or involve trabecular vessels. Active contrast extravasation, ill defined vessel borders, irregular truncation and pseudoaneurysm formation all suggest vascular injury.

Grade IV splenic injuries consist of lacerations to the splenic vasculature that results in greater than 25% devascularization of the spleen. This may result in focal wedge-shaped areas of hypoenhancement. As the severity of the devascularization worsens, a majority of the spleen or a significant portion may hypoenhance.

Grade V splenic injuries consist of a completely shattered spleen and vascular injury with devascularization of the entire spleen.

3.5.1.5 Pancreatic Trauma

Pancreatic injury during trauma is uncommon, though very important to diagnose as it can lead to significant complications [11]. CT diagnosis of these injuries is often difficult to detect and other methods, such as MRCP and ERCP, may be necessary for further evaluation when clinical suspicion is high or CT findings are nonspecific or equivocal. When they do occur, injuries occur at the pancreatic neck and body two-thirds of the time. Particularly, this region is susceptible to crushing injury against the adjacent vertebral column. These injuries will often result in the formation of contusions or hematomas which appear as diffuse gland enlargement with areas of high and low attenuation extending through the gland. Peripancreatic fluid, stranding, and hematoma are additional signs of injury that are nonspecific but can help prompt further investigation.

Lacerations are also potential injuries to the gland in the traumatic setting. These are often characterized as focal, hypoattenuating, linear structures oriented perpendicularly to the axis of the gland. Lacerations may completely transect the pancreas. Special consideration should be paid to the main pancreatic duct as disruption leads to significant morbidity and mortality. If laceration extends greater than 50% of the AP diameter of the gland, then main pancreatic duct involvement is suggested. An uncommon CT grading system of pancreatic lacerations exists and can be applied to assist with patient management. Grade A lesions represent lacerations that extend less than 50% of the AP diameter of the gland. Grade B lesions represent pancreatic tail lacerations that extend greater than 50% of the AP diameter (B1) or completely transect the gland (B2). Grade C lesions represent pancreatic head lacerations that extend greater than 50% of the AP diameter (C1) or completely transect the gland (C2).

3.5.1.6 Adrenal Trauma

Though rare, adrenal trauma is a potential result of abdominal trauma [11]. Often it occurs with other abdominal visceral injury, and thus on its identification, other signs of injury should be searched for as well, including rib fractures. When they do occur, adrenal injuries are more commonly seen in the right adrenal gland. Possible explanations for this difference may include the constricted space of the right adrenal gland between the liver and spine. Additionally, it has been hypothesized that the direct communication of the right adrenal gland to the inferior vena cava, whereas the left adrenal gland communicates with the inferior vena cava through the left renal vein, may result in higher venous pressures when abdominal pressure increases during blunt trauma. These injuries to the adrenal gland often appear as hyperattenuating (>50 Hounsfield units) round and nodular replacement of the adrenal parenchyma and fat stranding of the surrounding fat. Delayed imaging can also be obtained to help characterize the washout pattern of adrenal lesions to differentiate them from adrenal nodules. Follow-up imaging may show regression or calcification of the hematoma and possible development of pseudocysts.

3.5.1.7 Considerations in the Elderly

An important consideration in elderly traumatic patients is distinguishing acute and chronic disease processes. This will often require the utilization of multiple phases of imaging. The time spent to acquire these phases of imaging should be weighed against the clinical information that can be gained from the information. In clinically unstable patients, the ordering physicians must determine if imaging would provide vital information that would aid in treatment decisions. If patients will require surgical intervention and imaging would only delay their necessary treatment, it may be more prudent to forego the imaging studies or limit the number or complexity of ordered imaging. This decision can often be optimized by consultation between the ordering physician and radiologist to reach the most ideal imaging result for the patient and the most timely intervention to treat their ongoing acute traumatic injury.

3.6 Vasculopathies

CT is an excellent modality for the assessment of many vasculopathies, especially due to its ability to be performed during various phases, allowing for opacification of the desired vessels [3]. For instance, the aorta and other arteries can be assessed with CT angiography. For angiography to properly evaluate the vessels, intravenous contrast will need to be administered and then scanned precisely when the contrast begins its circulation through the arteries. By utilizing this technique, abnormalities of the vasculature can become apparent. However, one must note that for patients who are unstable or cannot receive intravenous contrast, rapid noncontrast examination can be performed. Though limited, the study may be able to convey some findings relevant to the patient's condition [1].

3.6.1 Imaging Findings

Aortic aneurysm is permanent localized dilation of all three walls of the aorta by at least 50% of their regular caliber [29]. Prior to dilating to this 50% threshold, the minor dilatation greater than the accepted normal caliber of 3 cm is typically referred to as ectasia. Often, these aneurysms arise as a result of atherosclerosis from hypertension as the walls of the aorta weaken and begin to enlarge. These aneurysms typically are fusiform in shape, resulting in diffuse enlargement of the caliber, rather than saccular, which arise from a focal weakening of the vessel wall and appear as a singular outpouching from the vessel wall and often have an opening that communicates with an otherwise normal caliber vessel. Abdominal aortic aneurysms are most commonly seen below the level of the renal arteries [10]. Important aspects of these aneurysms include their maximal dilatation, their length along the aorta, and involvement of any other side branch arteries, such as the renal arteries. As aneurysms grow (typically enlarging by 0.2–0.5 cm/year), their risk of rupture grows with a five-fold 5-year rate of rupture once the aneurysm measures 6 cm in diameter [30]. Once the aneurysm ruptures, mortality rates can range from 66–95%.

3.6.1.1 Aortic Rupture

Aortic rupture occurs when the wall fails and blood is able to extravasate from the vessel and into the surrounding soft tissues. This often requires immediate surgical repair. Rupture of the aneurysm is related to the maximum diameter, the rate of expansion of the aneurysm, wall strength, and change in wall stiffness. The posterior aortic wall is the usual site of rupture [31]. Common CT appearance of this rupture usually shows a break in the rim atherosclerotic calcifications in the wall of the vessel/aneurysm. Additionally, displacement of the visceral organs is often seen. If intravenous contrast was administered, extravasation of the contrast media from the aortic lumen can serve as a direct sign of aneurysm rupture [32]. Soft tissue density can be seen surrounding the aorta and may indicate a contained rupture.

3.6.1.2 Aortic Dissection

Aortic dissection is the most common aortic emergency. Aortic dissection is characterized according to the Stanford system of classification. Type A aortic dissections include the ascending aorta and aortic arch. Type B aortic dissections are limited to only involving the descending aorta. Aortic dissection can occasionally result in aortic obstruction, resulting in organ ischemia [33]. Type B aortic dissections are typically managed conservatively; however, surgical repair is necessary if the aortic diameter enlarges [34]. For proper evaluation, CT scans must be performed before and after the administration of intravenous contrast. On the noncontrast phase, one may observe a calcified intimal layer that is displaced from the other layers of the aortic wall by the tear. On contrast-enhanced imaging, a dissection flap will be observed separating the true lumen and false lumen of the dissection. The false lumen can be determined from the true lumen as it may contain foci of hypoattenuation representing portions of the medial layer of the wall that were not completely separated during the dissection of the vessel wall, commonly referred to as the "cobweb sign". Additionally, the false lumen typically has a larger cross-sectional area than the true lumen. Another sign of the false lumen is the "beak sign" which is defined as the wedge of hematoma within the false lumen that is propagating the separation of the layers of the wall [35]. One can often visualize the connection of the undissected aorta with the true lumen.

3.6.1.3 Intramural Hematoma

Intramural hematoma is formed when spontaneous hemorrhage occurs from the vasa vasorum in the medial layer of the aortic wall. Intramural hematoma results in weakening of the wall and can predispose to aortic dissection. Because of this close relationship, intramural hematomas are commonly categorized on the same Stanford scale as aortic dissections. Intramural hematoma is typically well seen on noncontrast CT examination, as intravenous contrast may obscure the hematoma. Intramural hematomas appear as a surrounding cuff of hyperattenuation, representing the hematoma within the intimal layer, with displacement of intimal calcifications centrally towards the vessel lumen. On contrast-enhanced imaging, no dissection flap will be observed and the intramural hematoma will not enhance.

3.6.1.4 Considerations in the Elderly

The incidence and the prevalence of abdominal aortic aneurysms are increasing in the elderly [36]. Thus, screening has been suggested [37]. Screening for men aged between 65 and 75 years has been shown to decreased mortality associated with abdominal aortic aneurysms [38].

3.7 Perforation

Perforation of the bowel can occur secondary to many of the already discussed conditions, including mesenteric ischemia, obstruction, and trauma [11]. It can also be the primary presentation of a patient after perforation of a duodenal or colonic diverticulum, resulting in free intraperitoneal air [10]. CT examination is highly sensitive in the detection of this free intraperitoneal air [39]. As the patient is lying supine during the CT examination, the air often collects anterior to the liver beneath the anterior abdominal wall [14]. Additionally, air may be seen near the perforation, such as at the porta hepatis, adjacent to the duodenum, especially if a perforated duodenal ulcer is present [39]. Displaying images in the "lung window" allows the free air to contrast better against the fat and soft tissue densities within the peritoneal cavity and standout as black voids. One should note that intraperitoneal free air is not always an emergent finding as it can be expected in the postoperative setting, and thus the patient's clinical course must be considered when free air is found.

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4 Medical Comorbidities in Geriatric Patients Undergoing Major Emergency Surgeries

Merita Shehu and Rosemary L. Conigliaro

4.1 Introduction

Lifespan determined by human biology is about 120 years. As technology and medicine advance, life expectancy is slowly beginning to get closer to lifespan. Worldwide the numbers of Centenarians, people at least 100 years old, are increasing. In the US, they represent a growing minority. The number of Americans aged 100 and over increased 43.6% from 50,281 in 2000 to 72,197 in 2014 [1, 2]. Life expectancy in the last two decades has also significantly increased in western countries: it is about 82 years for women and 80 years for men. In the US, those 65 years of age and older accounted for 40 million people, or 13%, of the total population [3].

As we age, the number of chronic medical conditions requiring medical attention increases. The National Quality Forum defines multiple chronic conditions as “two or more chronic conditions that collectively have an adverse effect on health status, function, or quality of life and that require complex healthcare management, decision-making, or coordination.” Among Americans aged 65 years and older, as many as three out of four persons have multiple medical conditions [4]. Approximately 66% of total health care spending in the United States is associated with care for over one in four Americans with multiple medical conditions [4]. Society and healthcare providers should focus greater efforts on healthy optimal aging with preserved physical and cognitive function and a high level of

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independence until death. Until then, we have to face the challenges of a growing population with multiple comorbidities.

4.2 The Characteristics of the Elderly Patients: the Hospitalist Challenges

4.2.1 Pressure Ulcers

Older patients have a lower physiological reserve; they develop chronic diseases that contribute to frailty, with the inability to perform daily activities and independent living. They are less active and more dependent on others. Immobilization comes with the cost of causing pressure ulcers. In an overview of comorbidities and the development of pressure ulcers among older adults, Jaul et al. concluded that multiple chronic diseases and complicating factors associated with immobility, tissue ischemia, and undernutrition are the causes of pressure ulcers in community settings, hospitals, and facilities [5].

In order to manage these patients, identification of the patients at the greatest risk for pressure ulcers is the first step. After identification, prevention of pressure ulcers is important for both patients and the medical team. Bedside clinical assessment, including a comprehensive history and physical examination, is an important part of risk evaluation. The standardized risk assessment tools include Braden, Cubbin and Jackson Norton, and Waterlow scales. In patients with increased risk, the American College of Physicians (ACP) recommends using advanced static mattresses or overlays, and advises against the use of alternating air mattresses based on cost and lack of data demonstrating a clinical advantage. Finally, the patients who do develop pressure ulcers will most likely require long-term facility care upon discharge.

4.2.2 Frailty

Frailty is a multifactorial geriatric syndrome characterized by unintentional weight loss, low energy and activity levels, weakness, and slow walking speed [6]. When we think of frailty, we remind ourselves that geriatric patients have lost their resilience. There are different standardized indices designed to measure frailty; the Frailty Index is the most widely used. Harrison identified that aging is universal but proceeds at highly variable rates with wide heterogeneity in the emergence of the aging phenotype [7]. Evans et al. concluded that frailty was independently associated with a higher risk of death and other adverse outcomes in older people admitted to an acute care hospital [8]. It is important not only to consider frailty but also its severity. Ideally, we would like to have the biological markers defining frailty distinguish frail patients as biologically older from the same age peers. For now, we evaluate based on clinical assessment tools such as the Comprehensive Geriatric Assessment (CGA).

Analyzing the risk of adverse outcomes in hospitalized older patients in relation to a frailty index based on a comprehensive geriatric assessment would be a helpful addition for patients, families, and physicians when making decisions regarding further care with a goal towards preventing futile care. Addressing the frailty, Baldasseroni et al. [9] emphasizes the importance of the CGA as a better predictor of survival and other outcomes than the presence of diseases or even the extent of comorbidities. CGA evaluates several domains such as comorbidity, cognitive and mood disorders, functional abilities, nutritional status, sarcopenia, and frailty. CGA is a multidisciplinary diagnostic process that takes into consideration not only the physical, psychological, and cognitive condition of the patient but also the environmental and functional abilities of the older patient. In an acute hospital setting, considering the social factors as well, the goal is developing a plan of care that will at least preserve function and maximize independence and quality of life. The CGA is done by a team including a geriatrician but in the real world an internist, social worker, nutritionist, and physiotherapist. A new study that analyzed the relationship between nutritional status and frailty in hospitalized older patients found that older patients with better nutritional status and higher level of serum transferrin, total protein, and albumin were less likely to develop frailty [10]. As health care providers, we have to use the tools we currently have until we find the "golden biomarkers" or "the golden clinical pearls" which will help us in making sound clinical decisions and avoid futile treatment.

4.2.3 Pain

Chronic pain is another reality of the geriatric patient. When hospitalized, these patients may have acute pain as well. When addressing pain in the elderly patients, characteristically seen in medicine wards, the Italian investigators [11] concluded that pain needs to be addressed properly with a focus on pharmacological treatment in order to support the elderly patient and facilitate daily activities upon discharge. They also found that elderly people with pain showed worse cognitive status, higher depression and comorbidities, and a longer duration of hospital stay compared to those without pain.

4.2.4 Delirium

Delirium is a common phenomenon of hospitalized elderly patient. Analyzing delirium and its effect on prognosis, Canadian researchers found that delirious patients have a poor outcome [12]. Insufficient recovery was associated with advanced age, lower baseline function, hypoxia, higher delirium severity score, and acute renal failure. Even lower risk delirious patients do poorly. Delirium has to be distinguished from other cognitive impairments such as dementia which sometimes is difficult because delirium can be superimposed on a patient with dementia. The differentiation is based on the acuity of the confusion; acute confusion is more likely to be delirium. Patients with dementia admitted to acute hospital settings have a higher risk of adverse outcomes as well [13]. Early comprehensive geriatric assessment and quality improvement initiatives are suggested to improve clinical outcomes in hospitalized patients with dementia.

4.2.5 Other Geriatric Syndromes

Frailty and delirium are considered geriatric syndromes that are frequently encountered in the elderly; both have a multifactorial pathophysiology. Additional geriatric syndromes include incontinence, falls, sleep disorders, depression, and problems related to eating and feeding [7]. The objective of this chapter is not to describe all the geriatric syndromes, but instead to address the treatment of major comorbidities in the elderly undergoing major emergent surgeries. The physician should consider all these syndromes when treating geriatric patients in the medical or surgical ward.

4.2.6 Evaluation

Illnesses in the elderly population often present with atypical and nonspecific symptoms. For example, a patient might develop myocardial infarction without chest pain. The lack of physiological reserve contributes to these atypical presentations, has significant debilitating consequences, and is associated with higher mortality and morbidity. Evaluation of the geriatric patient can be difficult for multiple reasons including: impaired hearing, impaired vision, cognitive impairment, underreporting of symptoms, multiple complaints which might be related to multiple coexisting diseases, or somatization of emotions and masking depression [14].

4.2.7 Polypharmacy

Treatment of the geriatric patient is challenging. Multimorbidity is associated with polypharmacy. Polypharmacy increases the risk of drug–drug interactions and the possibility of no adherence to medications. Hospitalists have to decide treatment based on clinical practical guidelines and evaluation of other factors such as patient preferences, possible treatment interactions, life expectancy, and ability to cooperate [7]. Many decisions rely on guidelines based on randomized clinical trials where elderly patients are not widely represented. ACP recommends a frequent review of each patient's medications, discontinuation of drugs that are unnecessary or should be avoided, and adjustment of drug dosages as appropriate. ACP recommends referring to the *2015 Beers Criteria for Potentially Inappropriate Medication Use in*

Older Adults from the American Geriatric Society, which provides a list of medications that are problematic for elderly patients [15]. Polypharmacy affects many aspects of care for the geriatric patient. In a report from the American College of Cardiology, American Geriatrics Society, and the National Institute on Aging Workshop, Shwartz et al. concluded that the needs and circumstances of older adults with cardiovascular disease (CVD) differ from those that the current medical system has been designed to meet [16]. Optimizing pharmacotherapy in older adults will require new data from traditional and pragmatic research to determine optimal CVD therapy, reduce polypharmacy, increase adherence, and meet person-centered goals.

4.3 Perioperative Risk Evaluation

4.3.1 The Role of the Hospitalist Before Surgery

Patients who undergo any surgical intervention are at risk for complications. These risks, especially the cardiovascular factors, are related to a patient's baseline risk characteristics and type of surgery. Emergent interventions are at increased risk independently from baseline risk. DeWane et al. identified clusters of high, average, and low performing geriatric emergency general surgery hospitals based on mortality performance [17]. He concluded that high performing hospitals outperformed the low and average performers across every operation reaching high-quality results regardless of operation type. More research is needed to identify the factors influencing this higher performance. Torrance, another author, proposes some solutions to reduce morbidity and mortality associated with emergent surgical care of the elderly, some of which relate to the hospitalist role as consultant or their involvement in comanagement care [18]. These include: careful postoperative management avoiding failure to rescue, comprehensive geriatric assessment, management of comorbidities, and avoidance of polypharmacy.

Before the surgical intervention, the consultant should try to stabilize the patient as quickly as possible; perform a medication review; document and assess the chronic medical conditions such as coronary artery disease, hypertension, diabetes mellitus, Parkinson disease, cerebrovascular accident, chronic kidney disease; possibly identify the presurgical functional status; check for the presence of delirium; and treat infection/sepsis if present. It is appropriate to have a baseline EKG, especially in patients with known cardiovascular disease as the elderly can have remote asymptomatic MI or conduction abnormalities; thus, a baseline EKG is always helpful even in asymptomatic patients. Echocardiography for evaluation of left ventricular function should not be performed routinely unless there is presence of dyspnea suggesting heart failure or physical exam findings that are suggestive of a valvular abnormality. The purpose of preoperative evaluation is to prevent hemodynamic instability and heart failure exacerbation.

4.3.2 Perioperative Management of Cardiovascular System

4.3.2.1 Cardiovascular Risk Assessment

In the case of emergent surgery, the American College of Cardiology (ACC) and American Heart Association (AHA) recommend proceeding with surgery without further evaluation. ACP recommends the use of risk calculators such as the Revised Cardiac Risk Index (RCRI) and the American College of Surgeons National Surgical Quality Improvement Program (NSQIP), myocardial infarction, and cardiac arrest calculator to determine the risk of a major cardiac event. RCRI uses six risk factors: high-risk surgery, history of ischemic heart disease, heart failure, history of cerebrovascular disease, diabetes mellitus requiring insulin therapy, and serum creatinine >2 mg dL (Table 4.1). The NSQIP calculator has many more risk factors including: age, sex, steroid use, sepsis, functional status, ASA class, COPD, ventilator dependent, ascites, smoking history, diabetes, hypertension, heart failure, dyspnea, dialysis, acute kidney injury, BMI, surgery type, and emergency surgery [19].

As per the American Society of Anesthesia, the ASA Physical Status Classification System has been in use for over 60 years. The purpose of the system is to assess and communicate a patient's pre-anesthesia medical comorbidities. The classification system alone does not predict the perioperative risks but used with other factors (type of surgery, frailty, level of deconditioning), it can be helpful in predicting perioperative risks [20]. The classification includes six classes, with class 1 signifying a healthy patient and class 6 signifying a patient who is brain dead. RCRI and NSQIP consider patient and surgery-related risk factors. In emergent surgery both low risk (<1%) and high risk (≥1%) patients will proceed with surgery. Knowing the risk is important for postoperative care of the patient and level of observation.

Table 4.1 Risks factors for a major cardiac event

Revised Cardiac Risk Index (RCRI)	American College of Surgeons National Surgical Quality Improvement Program (NSQIP)
– High-risk surgery – History of ischemic heart disease – Heart failure – History of cerebrovascular disease – Diabetes mellitus requiring insulin therapy – Serum creatinine >2 mg dL.	– Age – Sex – Steroid use – Sepsis – Functional status – ASA class – COPD – Ventilator dependent – Ascites – Smoking history – Diabetes – Hypertension – Heart failure – Dyspnea – Dialysis – Acute kidney injury – BMI – Surgery type – Emergency surgery

A recent study done in England tested the external validity of NSQIP and RCRI analyzing the perioperative cardiac biomarkers of patients ≥45 years old undergoing noncardiac surgery in a single tertiary care center. The study looked at the predictive performance of the models in terms of the occurrence of major cardiac complications defined as a composite of a nonfatal myocardial infarction, a nonfatal cardiac arrest, or a cardiac death within 30 days after surgery. The median age of the patients was 65 (59–72), and 704/870 (80.9%) subjects were male. The NSQIP and RCRI models had limited predictive performance in this at-risk population [21].

Based on NSQIP geriatric cohort, Alzrek [22] developed a new risk calculator, the Geriatric-Sensitive Perioperative Cardiac Risk Index (GSCRI). As Alzrek et al. indicate, the GSCRI is a significantly better predictor of cardiac risk in geriatric populations undergoing noncardiac surgery. The GSCRI model calculator contains seven variables: stroke, ASA class, surgical category, diabetes mellitus, functional status, elevated creatinine >1.5 mg/dL, and heart failure [23].

The Canadian Cardiovascular Society Guidelines on Perioperative Cardiac Risk Assessment and Management for Patients Undergoing Non-cardiac Surgery recommend measuring brain natriuretic peptide (BNP) or N-terminal fragment of proBNP (NT-proBNP) prior to surgery to enhance perioperative cardiac risk estimation in patients 65 years of age or older, or those with an RCRI score ≥1%. Other recommendations include measuring daily troponin for 48–72 h after surgery in patients with an elevated NT-proBNP/BNP measurement before surgery; or, if there is no NT-proBNP/BNP measurement before surgery, in those who have a Revised Cardiac Risk Index score ≥1, or are of age 65 years or older [24]. Measurement of postoperative troponin levels and EKG in asymptomatic patients is not recommended in the ACC/AHA guidelines. The ACP recommends these in patients with signs or symptoms of myocardial ischemia which often presents atypically in the postoperative period with symptoms such as delirium, hyperglycemia, pulmonary edema, and fluctuation of blood pressure.

4.3.3 Cardiovascular Risk Management

4.3.3.1 Coronary Artery Disease (CAD)

In a situation where emergent general surgery is a required treatment of CAD, revascularization will occur only if the patient has ST elevation and MI concomitantly. In patients with known CAD, ACP recommends continuation of beta-blockers and statins in patients who are already on those medications [25]. All other lipid-lowering medications should be withheld. Starting β-blockers on the day of surgery is not recommended. Postoperative use of β-blockers should be guided by a patient's clinical condition, with special attention to heart rate and blood pressure. The POISE trial studied the effects of metoprolol 2–4 h before noncardiac surgery and found that for every 1000 patients with a similar risk profile undergoing noncardiac surgery the extended-release metoprolol would prevent fifteen patients from having a myocardial infarction, three from undergoing cardiac revascularization, and seven from developing new clinically significant atrial fibrillation. Multivariate analyses of the trial suggested that clinically significant hypotension, bradycardia, and stroke explain how β-blockers increased the risk of death in this trial.

One interesting finding was that sepsis or infection was the only cause of death that was significantly more common among patients in the metoprolol group than in those in the placebo group [26]. The authors noticed that the results of POISE and of their meta-analysis provided evidence that perioperative β-blockers prevented nonfatal myocardial infarctions but increased the risk of nonfatal stroke. The POISE trial did not study the effects of beta-blockers on patients who were already on long-term therapy. There is no preference for β-blocker choice (atenolol, metoprolol, bisoprolol), so change of medication is not recommended. Patients who cannot take the oral form should receive the intravenous form of atenolol or metoprolol. Titration of medication should be considered based on clinical circumstances since hypotension and bradycardia increase the risk of death as noticed in the POISE trial. For the majority of patients receiving ACE inhibitors or ARB, ACP recommends evaluation and individualization of use before surgery. The exception to this recommendation is if large fluid shifts are expected intraoperatively (in that case, surgeon expertise is required pending type of surgical emergent intervention), if the patient is hypotensive already, has hyperkalemia, or acute kidney injury.

4.3.3.2 Antiplatelet Therapy

Patients who have stable CAD and a bare-metal stent on dual antiplatelet therapy (DAPT) should continue this regimen for 1 month. If they have a drug-eluting stent, then the duration should be a minimum of 6 months. The ACC, AHA, and ACP recommend the continuation of DAPT for at least 1 year for treatment of acute coronary syndrome whether it was managed with medical therapy or stent placement. When surgery mandates discontinuation of DAPT, aspirin should be continued when the risk of cardiac events outweighs the risk of bleeding. In cases where aspirin has been prescribed for primary or secondary prevention of cardiovascular events, it should be discontinued and restarted postoperatively after bleeding risk has decreased. This ACP recommendation is based on the POISE 2 trial [27]. The authors of POISE 2 concluded that administration of aspirin before surgery and throughout the early postsurgical period had no significant effect on the rate of a composite of death or nonfatal myocardial infarction but increased the risk of major bleeding.

A prospective multicenter observational study of patients with coronary stents undergoing noncardiac surgery in 11 hospitals in Spain analyzed the perioperative management of antiplatelet therapy in such patients. The study examined its relationship to the incidence of major adverse cardiac and cerebrovascular events and major bleeding events. The authors concluded that cardiac and cerebrovascular events are mainly related to previous medical conditions such as recent MI, DM with insulin dependence, chronic kidney disease, no preoperative antiplatelet therapy, and perioperative major bleeding events. Surgery was urgent or emergent in 22% of patients, and antiplatelet therapy was prescribed in 95% of procedures and was discontinued preoperatively in 15% [28]. A recent Italian study aimed to evaluate clinical outcomes of patients needing short DAPT therapy <3 months due to high bleeding risk or need for urgent major noncardiac surgery versus long-term dual antiplatelet therapy >6 months after PCI with biodegradable polymer sirolimus-eluting stent. They noticed that compared with patients who received long term dual antiplatelet therapy, patients on short-term dual antiplatelet therapy had similar rates of 1 year major cardiac events such as cardiac death, target vessel MI, clinically driven target lesion revascularization, and had more major bleedings but no significant differences in landmark analysis [29].

4.3.4 Perioperative Myocardial Infarction and Myocardial Injury

4.3.4.1 Definition of Myocardial Infarction and Myocardial Injury After Noncardiac Surgery, Etiology, Incidence, and Prognosis

The Joint Task Force of the European Society of Cardiology, American College of Cardiology Foundation, the American Heart Association, and the World Heart Federation define acute MI as “the presence of acute myocardial injury detected by abnormal cardiac biomarkers in the setting of evidence of acute myocardial ischemia.” There are several types of MI based on the mechanism.

- Type 1: MI caused by acute atherothrombotic coronary artery disease and usually precipitated by atherosclerotic plaque disruption (rupture or erosion).
- Type 2: MI caused by a mismatch between oxygen supply and demand.

Myocardial injury is defined in the Fourth Universal Definition as elevated cardiac troponin values (cTn) with at least one value above the 99th percentile of the upper reference limit. MINS is defined as myocardial cell injury during the first 30 days after noncardiac surgery due to an ischemic etiology (i.e., no evidence of a nonischemic etiology like sepsis, rapid atrial fibrillation, pulmonary embolism,). MINS includes MI (both symptomatic and nonsymptomatic) and patients with postoperative elevations in troponin but who do not have symptoms, electrocardiographic abnormalities, or other criteria that meet the universal definition of MI and thus have no evidence of a nonischemic etiology for their troponin elevation [30].

The most common pathologies are either underlying obstructive coronary artery disease, which can cause elevations of cardiac troponin due to a supply-demand mismatch, or an acute thrombus. The incidence of MINS ranges between 8% and 19%. Myocardial infarction accounts for about 20–40% of MINS based on the type of the troponin marker (high sensitivity cTn/non-high sensitivity cTn). Atherosclerotic plaque rupture was found in 50% of the cases of perioperative MI characterizing a type 1 MI [31]. Independent of the etiology, troponin elevation perioperatively up to 30 days after surgery is a sign of a worse prognosis.

Additionally, several prospective and observational studies have achieved the same conclusion [30, 32–36]. Those studies were performed in Canada and Europe. In one study where the patient’s median age was 74 [33], the authors concluded that perioperative myocardial infarction is a common complication after noncardiac surgery and, despite early detection during routine clinical screening, it is associated with substantial short- and long-term mortality. An observational study conducted in the United States found that any degree of perioperative myocardial injury detected by cardiac troponin T is independently associated with long-term mortality after noncardiac vascular surgery. Patients with type 2 MI received less intensive treatment with fewer patients being initiated on β-blocker, aspirin, and clopidogrel; very few offered stress test or left heart catheterization [37].

4.3.4.2 The Question is to Screen or not to Screen?

The Canadian Cardiovascular Society Guidelines recommend obtaining daily troponin measurements for 48–72 h after noncardiac surgery in patients with a baseline risk >5% for cardiovascular death or nonfatal myocardial infarction at 30 days after surgery (i.e., patients with an elevated NT-proBNP/BNP measurement before surgery or, if there is no NT-proBNP/BNP measurement before surgery, in those who have an RCR SCORE >1, age 45–64 years with significant cardiovascular disease, or age 65 years or older) [24]. The ACP based on ACC/AHA 2014 guidelines recommends screening in patients with signs or symptoms of myocardial ischemia. Is it time to change the guidelines or are more prospective studies needed? Should we do prospective studies including the elderly with multiple conditions considering their functional status as well?

There is a paucity of data on the elderly with emergent noncardiac surgery and MINS. A recent multicenter prospective cohort study (part of the VISION study) found a higher incidence of MINS in patients >75 years old, history of diabetes mellitus, hypertension, heart failure, CAD, and end-stage renal failure. The authors suggest that postoperative troponin monitoring in elderly with risk factors for atherosclerotic disease may help reduce postoperative cardiovascular events [38]. Another study similarly found that patients with elevated troponin were older, male, had a history of ischemic heart disease, underwent high-risk surgery, but were less likely to be diabetic [37]. A study analyzing hospital readmission after perioperative MI associated with noncardiac surgery using the 2014 US Nationwide Readmission database found that among patients with perioperative MI approximately 1 in 7 died and 1 in 5 were readmitted within the first 30 days after discharge. Hospital readmissions occurred due to infections, cardiovascular, or bleeding complications [39].

The majority of the patients who suffered MINS were asymptomatic in a study that analyzed MINS in vascular surgical patients [40]; the majority of patients in the POISE study were asymptomatic as well [26]. The results of the studies suggest that perhaps we should measure baseline troponin level and monitor troponin perioperatively in order to recognize MINS. Another study aiming to determine the impact of aging on cardiac troponin levels in elderly patients without acute cardiac events but in the presence of comorbidities found that increased cardiac troponin levels were associated with the presence of preexisting comorbidities independently of age; increased level should always be considered as pathological, for which a specific etiology should be searched [41].

4.3.4.3 Treatment of MINS

For treatment of ST-elevation Myocardial infarction, the expert opinion of multiple societies' guidelines recommend the use of high dose atorvastatin, aspirin, β-blocker, and left heart cardiac catheterization. If a drug-eluting stent is placed or the patient had no reperfusion therapy, then DAPT is recommended. Patients with non-ST-elevation MI should be started on aspirin and high dose of Atorvastatin as well: the initiation of beta-blocker is debatable. Patients might require risk stratification or go directly to cardiac catheterization depending on ischemic and hemodynamic stability. For patients who are troponin positive but do not meet the criteria for MI, aspirin and atorvastatin might be helpful as they are likely to have coronary artery disease with fixed obstruction. Evidence to support the initiation of medications after MINS comes from a study of 66 MINS patients and 132 matched non-MINS patients who underwent major vascular surgery [42]. Patients treated with therapy had fewer 12-month adverse cardiac outcomes. If the risk of bleeding is not too high, then dabigatran 110 mg twice a day might be started for the duration of 2 years, based on the results of MANAGE trial [43]. The authors of MANAGE trial concluded that dabigatran 110 mg twice daily lowered the risk of major vascular complications with no significant increase in major bleeding.

4.3.5 Cardiac Arrhythmias

The ACP recommends the continuation of antiarrhythmic medications for patients with cardiac arrhythmias who are undergoing surgery. Patients with a history of atrial fibrillation are at risk for atrial fibrillation with rapid ventricular response secondary to stress related to surgery, postoperative pain, and major fluid losses. In patients with implantable pacemakers and implantable cardioverter-defibrillator (ICD), physicians should be aware of the risk of electromagnetic interference during the surgery and use of electric knives. The use of electric knives may interfere with the pacemaker's proper functioning. In patients with ICDs, electromagnetic interference by electric knives may trigger the device, which may deliver a shock during surgery [44]. Cardiology should be consulted for adjustment of the pacing mode and/or turning off the ICD. If an ICD is deactivated, then the patient should be on continuous cardiac monitoring. In patients with implantable pacemakers and ICDs, antibiotic treatment should be initiated during surgery to minimize the occurrence of pacemaker infection [45].

4.3.6 Hypertension

Surgery should be delayed and hypertension should be controlled preoperatively only if there is evidence of end-organ dysfunction. In elective cases, surgery may be deferred in patients with a systolic blood pressure of 180 mmHg or higher, or diastolic blood pressure of 110 mmHg. In the case of emergent surgery, the use of intravenous antihypertensive medication tailored secondary to the patient's specifics is recommended. The ACP recommends continuation of α1-blockers, α2-blockers, and β-blockers in the perioperative period. Calcium channel blockers should be continued as well, but withheld for preoperative hypotension. It is reasonable to withhold ACE inhibitors if large fluid shifts are expected intraoperatively or if hypotension, hyperkalemia, or acute kidney injury are present. Withholding diuretics preoperatively is recommended. Nitrates and vasodilators should be continued unless hypotension is present. If antihypertensive therapy is withheld before surgery, medication should be restarted once the patient is hemodynamically stable. Postoperative hypertension is related to stress after surgery, pain, hypoxia, hypothermia, fluid overload, or discontinuation of antihypertensive therapy.

4.3.7 Pulmonary Hypertension

Patients with pulmonary hypertension should be continued on their pulmonary vascular-targeted therapy such as phosphodiesterase-5 inhibitors.

4.3.8 Heart Failure

Diagnosing heart failure before or after surgery is very important. Congestive heart failure strongly predicts serious morbidity, unplanned reoperation, readmission, and surgical mortality for noncardiac operations [45]. A recent study showed that even patients with end-stage heart failure supported with ventricular assist devices (VADs) have an acceptable risk profile for abdominal surgery [46].

There are two types of heart failure. The first is heart failure that results from systolic dysfunction and is characterized by reduced stroke volume and ejection fraction. It is designated heart failure with reduced ejection fraction (HFrEF). The second is heart failure resulting from diastolic dysfunction that is characterized by abnormal relaxation during diastole and preserved ejection fraction. It is designated heart failure with preserved ejection fraction (HFp EF). Whenever the physician suspects heart failure, it is advisable to obtain an EKG, chest x-ray, and BNP level. Echocardiogram will distinguish one type of heart failure from the other but in emergent surgeries time is limited, so the most important thing is patient stabilization.

Medical therapy for systolic heart failure includes ACE inhibitor and Angiotensin Receptor blockers (ARB), Angiotensin receptor Neprilysin Inhibitor (ARNI), β-blockers (carvedilol, metoprolol succinate, bisoprolol), loop diuretics, aldosterone antagonists (spironolactone, eplerenone), digoxin, combination of isosorbide dinitrate–hydralazine, and ivabradine. Patients on these medications should continue to receive them if they are hemodynamically stable or there are no specific contraindications for each class of medication to prevent fluid overload and acute decompensated heart failure. If the patient presents for emergent surgery with decompensated heart failure, expert opinion is necessary since time is limited. In cases of acute decompensated heart failure pre- or postoperatively, diuretic therapy is the principal treatment. Effective diuresis is essential and it can be achieved via intravenous administration of high dose diuretics in bolus or continuous infusion. If acute kidney injury is present at the same time, diuretic therapy remains important since the most likely cause of the injury is poor kidney function secondary to vascular congestion. If β-blockers were discontinued because of low cardiac output, they should be reinitiated when the patient becomes euvolemic.

4.4 Perioperative Management of Anticoagulant Therapy

4.4.1 Laboratory Testing

The routine tests are prothrombin time/international normalized ratio (PT/INR) and activated partial thromboplastin time (aPTT). These tests are useful for patients who are receiving vitamin K antagonists such as warfarin. Routine coagulation testing is not useful for determining the anticoagulation status of a patient receiving a non-vitamin K antagonist oral anticoagulant (NOACs) or otherwise known as the direct-acting oral anticoagulants (DOACs). This new class of anticoagulants includes dabigatran, rivaroxaban, apixaban, and edoxaban. Thrombin clotting time (TT), if available, can be used in patients receiving dabigatran. A normal TT is considered sufficient for eliminating the anticoagulant effects of dabigatran.

4.4.2 Anticoagulation Reversal

In patients who are on anticoagulation therapy, immediate reversal of anticoagulation most likely will be required. For patients who are on warfarin therapy, immediate reversal can be achieved by using prothrombin complex concentrates (PCCs) or plasma products such as Fresh Frozen Plasma (FFP) along with vitamin K, with a target INR of 1.5. Dabigatran, an oral direct thrombin inhibitor can be reversed by idarucizumab. Following FDA approval, idarucizumab has been reported to successfully reverse the effect of dabigatran in small groups of patients with cardiac tamponade associated with catheter ablation [47] bleeding or urgent surgery [48]. Physicians should evaluate patients for thrombotic events [49] and consider cost effectiveness as well [50]. Rivaroxaban, apixaban, and edoxaban are all oral direct factors of Xa inhibitors and can be reversed by andexanet alfa.

4.4.3 Bridging

Bridging is the administration of the therapeutic doses of short acting parenteral therapy (usually heparin) when oral anticoagulant therapy is being withheld during the perioperative period in patients with elevated risk. Patients on warfarin or patients who are unable to take oral anticoagulant medications for an extended time after surgery need bridging. Patients with elevated risk of NOACs therapy do not need bridging. They may be resumed once hemostasis is established and can reach therapeutic levels in 1–3 h.

4.4.3.1 When Is Bridging Started?

After surgery, restarting anticoagulation therapy is a decision made based on bleeding and thrombotic risks. Close collaboration with the surgeon is absolutely essential. If the patient is at low risk of bleeding bridging anticoagulation can be started after 24 h, if the patient is at high risk of bleeding bridging anticoagulation can be started after 48–72 h, or even later [51]. Early bridging, 24 h after surgery is safe for minor procedures as per the PROSPECT study [52]. More studies are needed for major/emergent surgeries regarding timing and safety of bridging. In the PROSPECT study, only six patients with elected major general surgery were included, one of them had abdominal wall hematoma [52].

4.4.4 Atrial Fibrillation

4.4.4.1 Who Are Candidates for Bridging?

The American College of Chest Physicians (ACCP) and American College of Cardiology (ACC) have their recommendations for perioperative bridging in patients with atrial fibrillation. As per ACCP, patients with high annual risk for thromboembolism with CHADS2 score of 5 or 6, recent stroke or TIA, rheumatic valvular heart disease, history of stroke with warfarin interruption are candidates for bridging. The ACC recommends bridging in patients with CHA2 DS2–VASc of 7–9, ischemic stroke, TIA, or systemic embolism within the last 3 months. The BRIDGE trial [53] has shifted the mentality and practice of physicians towards a more conservative approach to bridging anticoagulation in patients with nonvalvular atrial fibrillation. The results of this trial resulted in a rapid and significant decline in the use of periprocedural bridging anticoagulation [54]. The authors of the PAUSE study concluded that patients with AF who had DOAC therapy interruption for elective surgery or procedure, a perioperative management strategy without heparin bridging or coagulation function testing was associated with low rates of major bleeding and arterial thromboembolism. Among 1007 patients with a high-bleeding-risk procedure, the rates of major bleeding were 2.96% (95% CI, 0–4.68%) in the apixaban cohort and 2.95% (95% CI, 0–4.76%) in the rivaroxaban cohort. The DOAC regimen was started 2–3 days after the high-risk surgery [55].

4.4.5 Prosthetic Heart Valve

Patients with mitral valve prosthesis, caged ball or tilting disc aortic valve prosthesis, recent stroke, or TIA have a high thromboembolism risk and are recommended for bridging as per ACCP. Patients with bileaflet aortic valve prosthesis and one or more of the following risk factors—atrial fibrillation, previous stroke or TIA, hypertension, diabetes mellitus, heart failure, age >75 years—with a moderate annual risk of 5–10% have an indication for bridging unless the surgical procedure is associated with high-bleeding risk. Bridging is not recommended in patients with low-annual risk (<5%), such as those patients who have a bileaflet aortic valve without atrial fibrillation and no other risk factors for stroke.

4.5 Venous Thromboembolism Prophylaxis

An ACCP guideline for venous thromboembolism prophylaxis recommends using the Caprini score to estimate risk for postoperative thrombosis in patients undergoing general surgery or abdominal-pelvic surgery. In patients with Caprini scores of 3–4 or ≥5 and average bleeding risk, low molecular-weight heparin, low-dose unfractionated heparin, or intermittent pneumatic compression are recommended. For those patients with Caprini scores of 3–4 or ≥5 and high bleeding risk, intermittent pneumatic compression is recommended. Risk factors suggesting high–bleeding risks are patient on antithrombotic therapy, known or suspected bleeding disorder, active bleeding, liver or kidney disease, and sepsis.

4.6 Pulmonary Perioperative Management

Elderly patients undergoing emergent surgery are at risk of developing pneumonia, exacerbation of underlying lung disease, and respiratory failure. It is important that we screen patients for obstructive sleep apnea (OSA) and any underlying lung disease. A chest x-ray will be helpful in patients with suspected underlying lung disease. Screening for OSA can be done using STOP-BANG score (Snoring, Tiredness, or sleepiness during the day, observed apnea, high-blood pressure, BMI >35, Age >50, Neck circumference >40 cm, Gender = male). Each of these factors is equal to one point. If score is ≥3 patients are at increased risk for OSA, if score is ≥5 they are at increased risk for severe OSA. Those patients should be placed on continuous pulse oxymetry and monitored closely postoperatively. All patients with known OSA should use their CPAP machine in hospital. Aspiration precautions and limitations of the nasogastric tubes postoperatively are recommended for the prevention of postoperative complications [56]. A European study that investigated the diagnostic timing of surgical site infections and pulmonary complications after elective or emergent laparotomy noticed that pneumonia was present in 3.5% of the patients at a median time of 5 days after the surgery; respiratory failure was present in 2.3% of the patients and median time was 3 days after the surgery [57].

4.7 Endocrine Diseases

4.7.1 Perioperative Management of Diabetes Mellitus

Patients with diabetes are at an increased risk for perioperative complications. In an analysis of about 10.5 million noncardiac surgeries from a large U.S. Hospital admission database, perioperative major adverse events such as acute myocardial infarction or acute ischemic stroke and perioperative in-hospital all-cause mortality were more common among patients with DM versus those without DM [58]. The goal of perioperative management is to avoid hypoglycemia, hyperglycemia, and prevent ketoacidosis or hyperosmolar state. It is reasonable to check hemoglobin A1c preoperatively. Good preoperative glycemic control with hemoglobin A1c levels <7% is associated with a decrease in infectious complications across a variety of surgical procedures [59]. It is also important to know preoperatively if the patient has type 1 or type 2 diabetes mellitus. In critically ill patients with type 1 and type 2 diabetes mellitus, intravenous insulin therapy is recommended. Usually, those patients are located in the intensive care unit.

In patients with type 1 diabetes mellitus, basal insulin should be continued perioperatively and the dose should not be reduced. Preoperative dosage reduction 25–50% may be considered for patients with type 2 diabetes mellitus taking insulin therapy and who have a history of hypoglycemia with skipped or delayed meals. Postoperatively, if a patient is eating, ACP recommends a basal bolus regimen with prandial coverage and correction boluses for premeal hyperglycemia [60]. Oral or noninsulin injectable agents are not recommended when patients are admitted to a hospital. Instead, insulin therapy should be initiated for management. In general, insulin is preferred for inpatient management of hyperglycemia 180 and above, and adjusted to maintain a glucose level between 140 and 180 mg/dL. Physicians should avoid the use of sliding scale–only regimen. As patients are getting ready for discharge with stability in nutritional status, reinitiating oral agents or noninsulin injectable agents may be considered [61]. Transition from hospital to home or to a rehabilitation facility is risky for older patients with diabetes. Medication reconciliation, patient and caregiver educations, and medical team communication are important steps for a safe transition of care.

4.7.2 Thyroid Disease

Patients with hypothyroidism treated with levothyroxine therapy should continue. It is reasonable to obtain a thyroid-stimulating hormone level to evaluate the severity of hypothyroidism. Patients with severe hypothyroidism are at risk of myxedema coma, arrhythmias, and perioperative hypotension. Patients with hyperthyroidism should continue the therapy with β-blockers and thionamides. Patients with uncontrolled hypothyroidism are at risk of thyroid storm. Consultation with an endocrinologist is advised in patients with severe thyroid disease requiring emergent surgery [60].

4.7.3 Adrenal Insufficiency

Patients with adrenal insufficiency should be evaluated for the need of supplemental glucocorticoid dosing. The dose and duration are based on the patient profile risk and anticipated surgical risk. Patients with primary adrenal insufficiency, hypothalamic-pituitary adrenal axis disease, Cushingoid features, equivalent of >5 mg prednisone for >3 weeks during the previous 3 months, high dose inhaled glucocorticoid therapy are considered to be high risk and require stress dosing of glucocorticoids. Patients with high anticipated surgical stress require 100 mg of intravenous hydrocortisone followed by 50 mg every 6 h for 2–3 days. Those with moderate surgical stress require 50–75 mg of intravenous hydrocortisone for 1–2 days [62].

4.8 Perioperative Management of Neurological Disease

Patients with epilepsy are at risk of seizure breakthrough; the risk is mostly related to the severity of the underlying disease, and less from anesthesia or type of surgery. Antiepileptic medications should be continued. If patients are unable to tolerate oral intake, alternative formulations should be used. Patients with Parkinson's disease are predisposed to complications such as delirium, hallucinations, orthostatic hypotension, and complications related to dysphagia. Patients should continue their medications to avoid Parkinson's hyperpyrexia syndrome which is related to medication withdrawal or dose reduction. It is characterized by fever, rigidity altered mental status, and autonomic instability [63]. Antidopaminergic antiemetic medications should be avoided.

4.8.1 Perioperative Stroke

Perioperative stroke is defined as a stroke occurring within 30 days of surgery. It is a rare, but devastating, complication that increases perioperative morbidity and mortality. The incidence of covert stroke or clinically unrecognized stroke is as high as 7% in patients 65 years and older [64]. Advanced age, preexisting valvular heart disease, previous stroke, emergency surgery, and postoperative hypotension are significant risk factors for perioperative stroke [65]. Perioperative strokes are predominantly ischemic. Recognition of stroke-related neurologic deficits in the postoperative patient is often difficult. The anesthetic medications, analgesic and opioids, and postoperative delirium are confounding factors. Noncontrast head CT is the most used test for the diagnosis of stroke. It is rapid, low cost, and has high sensitivity for hemorrhagic stroke. The noncontrast head CT is often normal in ischemic strokes especially in patients seen within 3 h of symptoms and even after 24 h of onset in patients with small infarcts and those located in the brainstem. Patients with ischemic stroke should be evaluated for reperfusion therapy. Major surgery is an exclusion criterion for intravenous alteplase administration in patients with acute ischemic stroke but mechanical thrombectomy might be a treatment option for those patients. For patients who are not eligible for thrombolysis or endovascular intervention, antiplatelet therapy is recommended. Aspirin administered either orally or rectally within 48 h of stroke reduces the short-term risk of recurrence. In patients with hypertension and ischemic stroke treated without thrombolysis, blood pressure should not be treated within the first 48 h unless it is greater than 220/120 mmHg, or there is evidence of end-organ dysfunction [66]. Statins can be considered in patients with an atherosclerotic type of stroke.

Treatment of intracerebral hemorrhagic stroke aims at preventing hematoma expansion. In patients with acute hemorrhagic stroke, ACP recommends treating cautiously systolic blood pressure; if greater than 180 mmHg, treatment with a systolic blood pressure goal of no less then140 mmHg is recommended by the ACP. Anticoagulation should be reversed, but routine use of platelet transfusion in patients treated with antiplatelet therapy is not indicated. Elevated intracranial pressure can be managed with mannitol or hypertonic saline. Early surgical evacuation of cerebellar hemorrhages greater than 3 cm is necessary to prevent hydrocephalus, brainstem compression, and neurologic deterioration [67].

4.9 Conclusion

Emergency surgery in the elderly is challenging for surgeons, anesthesiologists, internists, and geriatricians. There are multiple contributing factors such as frailty, comorbidities, and polypharmacy. Elderly patients can have poor outcomes. The severe outcomes can manifest in increased perioperative death, complications, prolonged length of stay or readmission rates, or discharges at subacute rehabilitation facilities rather than home. Besides prompt diagnosis and timely surgical intervention, a comprehensive geriatric assessment, and management of comorbidities and polypharmacy, careful postoperative care can reduce complications. The hospitalist is often the geriatrician who is comanaging the geriatric patient. This chapter emphasizes the characteristics of the elderly patient, perioperative risk evaluation, perioperative care, perioperative medication management, and management of major comorbidities.

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Reversing the Effect of Anticoagulants Safety in Patients Undergoing Emergency Surgery

5

E. Brogi, F. Coccolini, and F. Forfori

5.1 Introduction

The perioperative management of patients receiving anticoagulant represents a real challenge in a daily clinical setting, especially in case of emergency invasive procedure. Interruption of anticoagulant increase thromboembolic risk; however, continuing anticoagulation increases the risk of bleeding associated with invasive procedures, both affecting mortality. The perioperative management is based on the balance between reducing the risk of thromboembolism and prevevnting excessive bleeding. The decision and the timing of the interruption are influenced by patient's characteristic, type of surgery, type of anesthesia (i.e., general anesthesia, neuraxial anesthesia), and type of anticoagulants. Even if not conclusive, preliminary data suggests that the bleeding rate differs between different types of anticoagulants [1, 2]. Unfortunately, especially in the emergency setting, there is a lack of well designed clinical trials, consequently, the decision of anticoagulant interruption and reversal is often based on scarce evidence or routine clinical experience.

Once the decision of anticoagulant interruption has been made, additional issues to cope with are represented by the timing of the interruption and the necessity of bridging with a shorter-acting drug. The timing is strictly related to specific anticoagulant used, due to its half-lives and metabolism. Premature withdrawal is strictly connected to an increased risk of thromboembolism events (e.g., venous thromboembolism-VTE); however, at the same time, the agent should be stopped in sufficient time to obtain marginal or no residual anticoagulant effect to minimize bleeding complications [3–5]. Moreover, not only the appropriate time of

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interrupting perioperatively but also the proper time to resume anticoagulants postoperatively is challenging. Bridging anticoagulation consists of the administration of short-acting anticoagulant drugs, generally, subcutaneous injection of low-molecular-weight heparin (LMWH) or intravenous administration of unfractionated heparin (UFH), started on the day of vitamin K antagonists (VKAs) interruption in order to reduce thromboembolic complications [6, 7]. Unfortunately, bridging anticoagulation may increase periprocedural bleeding, then, bridging has to be reserved for patients with high thromboembolic risk (e.g., mechanical valve, high $CHADS_2$ score, VTE in the previous 3 months) [8, 9].

Warfarin and other vitamin k antagonists are extensively used. The indications of VKAs are represented by prophylaxis and treatment of thromboembolic complications associated with atrial fibrillation (AF) and/or cardiac valve replacement; prophylaxis and treatment of venous thrombosis and pulmonary embolism (PE); Antiphospholipid syndrome; and high-risk post Myocardial infarction [10]. VKAs present several disadvantages. They require frequent monitoring (i.e., INR), have a narrow therapeutic range, and present several drug and food interactions. In the last years, in addition to heparin and VKAs, several new agents for the prevention and management of thromboembolic disease are released in the market. Direct oral anticoagulants (DOACs) include direct thrombin inhibitors (dabigatran, lepirudin, argatroban, desirudin, bivaluridin) and direct factor Xa inhibitors (rivaroxaban, apixaban, and edoxaban). DOACs are currently approved for the treatment of VTE, VTE prophylaxis in orthopedic surgery, prevention of stroke, and thromboembolism in non-valvular atrial fibrillation [11, 12]. These drugs are not indicated in patients with severe renal impairment, with prosthetic heart valve, pregnancy, and antiphospholipid syndrome. DOACs pose specific new challenge because they present individual characteristics, pharmacokinetics, pharmacodynamics, and bleeding risks [12]. The advantages of DOACs include rapid onset, wide therapeutic window, shorter half-lives, and no food interactions without the necessity of coagulation monitoring. However, these drugs present liver or renal metabolism, consequently, DOACs have to be used with caution in patients with liver or renal impairment [13]. Not to be underestimated, recent studies have found interindividual variability in plasma drug levels of DOACs. The patients have a higher bleeding risk when the serum concentration of these drugs is high, whereas the patients present a high risk of thromboembolism when the serum concentration is low. Consequently, pharmacogenomics of DOACs and drug interaction can contribute to increasing the bleeding risk or the thrombotic risk of patients [14]. Even more, besides for Dabigatran, no specific antidote is available for DOACs.

Finally, the reversal of the anticoagulant could be required for emergency procedures, not only to prevent but also to treat perioperative bleeding. Conventionally, fresh frozen plasma (FFP) has been widely used as VKAs reversal agent. Furthermore, Prothrombin complex concentrates (PCC) represents an alternative strategy in order to reverse the effects of anticoagulation treatment. PCC contains coagulation factors II, IX, X, and VII derived from pooled plasma. Comparison between FFP and PCC [15, 16] shows that the use of PCC allows the reduction of volume requirements, thus preventing fluid overload, and the decrease of adverse immune-related risks. Other anticoagulant reversal option includes protamine, phytonadione, hemodialysis, oral-activated charcoal, antifibrinolytic agents (tranexamic agents, desmopressin). Even more, a specific reversal agent, Idarucizumab, is available for the reversal of Dabigatran [17].

5.2 Thrombotic Risk Vs. Bleeding Risk

Interruption of anticoagulant temporarily increases thromboembolic risk, consequently, it is vital to estimate the thromboembolic risk of a patient in order to decide whether to interrupt it or not. Evaluating thromboembolic risk is the first step in order to optimize perioperative antithrombotic management. Thromboembolic risk is categorized into low, moderate, and high-risk categories (Table 5.1).

The major factors that increase thromboembolic risk are:

– *Patients with atrial fibrillation*: CHA_2DS_2VASCc (Congestive heart failure, Hypertension, Age > 75 years, Diabetes mellitus, Stroke or transient ischemic attack, or thromboembolism, vascular disease, sex category) calculates the stroke risk for patients with AF [18]. CHA_2DS_2VASc represented the updated version of $CHADS_2$ score, providing a better stratification of low-risk patients [19, 20]. CHA_2DS_2VASc score includes the following stroke risk factors: congestive heart failure/left ventricular dysfunction, hypertension, age ≥ 75, diabetes, stroke, vascular disease, age 65–74, and sex category (female). The maximum score is 9. A CHA_2DS_2VASc of 0 (or 1 in female) outlines a low-risk patient not requiring

Table 5.1 Thromboembolic risk stratification

		Thromboembolic risk	
	Low risk	Intermediate risk	High risk
AF	CHA_2DS_2VASc score 0–2	CHA_2DS_2VASc score 3–4	CHA_2DS_2VASc score 6 and above Recent stroke (within 3 months)
Prosthesis heart valve	Mechanical bileaflet aortic valve No history of stroke or AF	Mechanical bileaflet aortic valve and one of the following risk factors: AF, prior stroke, hypertension, diabetes, congestive heart failure, Age > 75 years	Any mitral valve Any caged-ball or tilting disc aortic valve prosthesis Multiple mechanical valve Prior thromboembolic event
VTE	VTE > 12 months No other risk factors	VTE within 3–12 months No severe thrombophilia Recurrent VTE	VTE within 3 months Active cancer Severe thrombophilia

AF atrial fibrillation, *CHA_2DS_2VASc* Congestive heart failure, Hypertension, Age > 75 years, Diabetes mellitus, Stroke or transient ischemic attack, or thromboembolism, vascular disease, sex category, *VTE* venous thromboembolism anticoagulant agents. In males with CHA_2DS_2VASc of 3–4 the risk is moderate and oral anticoagulation should be considered. Finally, in case of a patient with a CHA_2DS_2-VASc score of 6 and above, oral anticoagulation therapy with a Vitamin K Antagonist (in case of valvular AF) or one of the non-VKA oral anticoagulant drugs (in case of non-valvular AF) is recommended [18]. The decision for thromboprophylaxis needs to be balanced with the risk of major bleeding, especially ICH. Above all HAS-BLED (**H**ypertension, **A**bnormal renal and liver function, **S**troke, **B**leeding, **L**abile INR, **E**lderly, **D**rugs or alcohol) is recommended for bleeding risk assessment (see below). It is important to highlight that CHA_2DS_2-VASc score has not been prospectively validated in the perioperative setting; however, it can be used to assess thromboembolic risk and the necessity of heparin bridging.

– *Prosthetic heart valves*: prosthesis-related complications include embolic events, thrombosis, regurgitation, hemolytic anemia, patient-prosthesis mismatch. The anticoagulant agents indicated to prevent thrombosis and thromboembolic events are VKAs and heparin [21]. The risk of thrombosis is highest in the first months after surgical valve repair, consequently, all elective invasive procedures have to be postponed at least 3 months after valve surgery. In case of VKAs interruption, bridging with heparin has to be considered. In particular, International Normalized Ratio (INR) value should guide the decision on drug interruption, the necessity of bridging, or reversal agents. Even more, there are several elements to take into account in order to assess thromboembolic risk: the number, the type, and the location of the valvular prosthetic in addition to the presence of further cardiac risk factor (e.g., AF, congestive heart failure, previous stroke, hypertension, diabetes, age > 75 years) [22].
– *Recent venous thromboembolism*: the risk of recurrent thrombosis is highest in the first 3 months after VTE events and declines over time, consequently, all elective invasive procedures have to be postponed at least for 3 months [23, 24]. The risk of VTE reoccurrence is also related to whether the VTE was due to a detectable factor (i.e., surgery, hospital admission), and whether this factor is transient (major surgery, immobility, pregnancy, estrogen therapy), or permanent risk factors (inherited thrombophilia, chronic heart failure, inflammatory bowel disease, malignancy). Thromboembolic risk is categorized into low, moderate, and high-risk categories [25]. Bridging anticoagulants has to be considered in case of interruption.
– *Recent arterial thromboembolism*: due to AF, paradoxical embolism, thrombotic endocarditis, dilated contractile left ventricle, left ventricle aneurysm [26]. The risk of thrombosis is highest in the first month after the acute event and declines over time, consequently, all elective invasive procedures have to be delayed when possible.

The continuation of anticoagulants increases the risk of bleeding related with invasive procedures. In 2010, the International Society on Thrombosis and Haemostasis for surgical studies [27] has defined major bleeding as:

– A fatal bleeding;
– A symptomatic bleeding in a critical organ (i.e., intracranial, intraspinal, intra-ocular, retroperitoneal, pericardial, non-operated joint, intramuscular with compartment syndrome);
– Bleeding in an extra surgical site causing a decrease in hemoglobin of ≥2 g/dL or requiring transfusion of ≥2 units of blood within 24–48 h to the bleeding;
– Surgical site bleeding requiring a second intervention or a hemarthrosis responsible for delaying mobilization, wound healing;
– Unexpected and prolonged surgical site bleeding responsible for hemodynamic instability, associated with a decrease in hemoglobin of ≥2 g/dL or requiring transfusion of ≥2 units of blood within 24 h to the bleeding.

This definition was followed by the definition of perioperative bleeding in adult cardiac surgery in 2014 [28].

The estimation of the bleeding risk is based on the type of surgery, urgency, and the type of anesthetic technique. Some types of procedures are associated with higher bleeding tendencies, like cardiovascular, urological, neuraxial, and intracranial surgery. Invasive procedures are categorized into low, moderate and high bleeding risks (Table 5.2) [29]. In particular, neuraxial anesthesia/surgery, as well as intracranial and cardiac surgery are specifically concerning regarding bleeding risk because of the serious complication linked to the bleeding.

Table 5.2 Bleeding risk stratification related with invasive procedures

	Bleeding risk:	
Low	Intermediate	High
• Dental procedures • Hernia repair • Cholecystectomy • Appendicectomy • Breast surgery • Ear Nose Throat procedures without planned flap or neck dissection • Gastrointestinal endoscopy • Cystoscopy • Bronchoscopy	• Spine surgery: arthrodesis, laminectomy • Laparoscopic hysterectomy • Prostate or bladder biopsy • Intra-abdominal surgery without bowel resection • Intra-thoracic surgery without lung resection • Anal surgery • Minithoracotomy • Splenectomy • Gastrectomy • Pacemaker implantation	• Thransurethral resection of the prostate/ transurethral resection of the bladder • Colorectal surgery with bowel resection • Neuraxial anesthesia • Thoracic surgery • Kidney transplant • Intracranial surgery • Major abdominal and gynecological cancer surgery • Major joint replacement (shoulder, knee, and hip) • Open radical prostatectomy, cystectomy • Hepatic surgery • Major oncologic head and neck surgery • Esophagectomy • Aortic surgery • Infective endocarditis surgery • Major transplant surgery (heart, lung, liver)

Patients characteristics and medical history (e.g., age, renal function) also influence the bleeding risk; any comorbidities that may influence the coagulation cascade are all important elements to take into account [30]. HAS-BLED score is a scoring system developed for the evaluation of bleeding tendency in anticoagulated patients [31, 32]. HAS-BLED score assigns one point for each seven parameters included; hypertension, abnormal renal or liver function, stroke, bleeding tendency, labile INR, elderly age, antiplatelet drugs, or alcohol. The total score ranges between 0 and 9. HAS-BLED is recommended by the European Society of Cardiology (ESC) guidelines for the bleeding risk assessment in AF patients [18]. An HAS-BLED score of ≥3 indicates a high risk of bleeding [33].

By combining risk scores for patient comorbidity and type of surgery, we can stratify overall perioperative risk. In the case of high bleeding risk, the anticoagulant must be discontinued. If the patient presents also a high risk of thromboembolism, the anticoagulant has to be stopped for the shortest feasible time, bridging has to be considered and the anticoagulant has to be resumed as soon as possible. Furthermore, elective invasive procedures have to be postponed at least 3 months after valve surgery and recent episodes of arterial or venous thromboembolism, due to the highest risk of thrombosis during this period. However, if surgery cannot be postponed, a temporary vena cava filter has to be considered in patients with recent episodes of acute venous thromboembolism. On the other hand, in case of low bleeding risk procedure, anticoagulant agents can often be continued (e.g., dental procedure, skin biopsy, implantation of cardiac electronic device, catheter ablation for AF) [34–36]. When the decision to not interrupt VKAs agents has been taken, INR has not to be within the therapeutic range.

In elective surgery, preoperative evaluation process can include optimization of risk factors for bleeding (e.g., blood pressure control, anticoagulant management, treatment of anemia) in order to reach the best possible health status before surgery. In an emergency setting, the reversal may be required for urgent surgery/procedure or to treat perioperative bleeding (as discussed below). In this case, physicians have to choose specific agents with prothrombotic effects (i.e., vitamin K, PCC, FFP, Idarucizumab).

5.3 Timing of Anticoagulant Interruption and Resuming

Besides the intrinsic bleeding risk of the procedure, the main factor influencing the timing of stopping anticoagulant agents is represented by the elimination half-life of the drugs. Determining the time of anticoagulation interruption depends on the pharmacokinetic properties of the specific agent; particular attention has to be given to the renal function. Even more, laboratory tests (i.e., standard coagulation assays, quantitative assay of plasma drug concentration) can guide clinicians in decision-making [37]. An overview of pharmacokinetic properties, laboratory tests, and reversal strategy for anticoagulant agents is shown in Table 5.3.

Table 5.3 Pharmacokinetic properties, laboratory test, and reversal strategy for anticoagulant agents

Drug	Half-lives (h)	Metabolism	Excretion	Dose[a]	Monitoring Coagulation test	Possible intervention	Reversal	Last dose before operation
				Vitamin K antagonists				
Warfarin	20–60	Hepatic	Renal	2–10 mg, Individualized, adjusted with INR	PT/INR	Not dialyzable	Vitamin K; 4-FPCC; FFP	5 days
Acenocoumarol	8–11	Hepatic	Renal	2–8 mg, Individualized, adjusted with INR	PT/INR	Unknown dialysability	Vitamin K; 4-FPCC; FFP	3 days
				UFH-LMWHs				
UFH	0.5–2.5	Endothelial cell sequestration	Renal	80 units/Kg bolus followed by 18 units/Kg/h continuous infusion	aPTT	Not dialyzable	Protamine	2–6 h
LMWHs	3–4.5	Liver	Renal	1 mg/Kg twice a day; CrCl < 30 mL/min once a day/prefer UFH	Anti-factor Xa	Not dialyzable	Protamine (partial effect)	24 h[b]
Fondaparinux	17–21	Excreted unchanged	70% Renal	5/7.5/10 mg (weight dose adjustment); 1.5 mg in renal impairment; CrCl < 30 mL/min contraindicated	Anti-factor Xa	Dialyzable	Activated PCC	24–48 h[b]

(continued)

Table 5.3 (continued)

Drug	Half-lives (h)	Metabolism	Excretion	Dose[a]	Monitoring Coagulation test	Possible intervention	Reversal	Last dose before operation
				Direct thrombin (factor IIa) inhibitors				
Dabigatran	12–17 h	Conjugation into four acyl glucuronides	80% Renal clearance; 20% Bile	150 mg Twice a day; 110 mg Twice a day CrCl 30–50 mL/min; CrCl < 30 mL/min contraindicated	TT/ECT/PT	Active charcoal within 2 h of ingestion; Haemodialysis; Antifibrinolytic agent	Idarucizumab; 4-FPCC	24–48 h[b]
				Direct factor Xa inhibitors				
Apixaban	9–14 h	CYP3A4	73% Faecal; 27% Renal	5 mg Twice a day; 2.5 mg Twice a day Serum Creatinine ≥1.5 mg/dL	Apixaban-specific anti Xa activity	Active charcoal within 2 h of ingestion; Haemodialysis; Antifibrinolytic agent	4-FPCC; Under investigation: Aripazine Andexanet	24–48 h[b]
Edoxaban	10–12 h	CYP3A4	50% Renal; 50% Biliary/intestinal excretion	60 mg; 30 mg CrCl 15–50 mL/min	Edoxaban-specific anti Xa activity	Active charcoal within 2 h of ingestion; Antifibrinolytic agent	4-FPCC; Under investigation: Aripazine Andexanet	24–48 h[b]
Rivaroxaban	5–13 h	CYP3A4/CYP2J2	66% Liver; 33% Renal-unchanged	20 mg; 15 mg CrCl 30–50 mL/min	PT/aPTT; Rivaroxaban-specific anti Xa activity	Active charcoal within 2 h of ingestion; Antifibrinolytic agent	4-FPCC; Under investigation: Aripazine Andexanet	24–48 h[b]

PT prothrombin time, *h* hours, *INR* international normalized ratio, *aPTT* partial thromboplastin time, *PCC* prothrombin complex concentrate, *4F PCC* four-factor prothrombin complex concentrate, *FFP* fresh frozen plasma, *UFH* unfractionated heparin, *LMWH* low-molecular-weight heparin, *CrCl* creatinine clearance, *TT* diluted thrombin time, *ECT* ecarin clotting time

[a]Dose refers to therapeutic dosage

[b]Applicable in patients with normal renal function

- ***VKAs:*** Warfarin competitively inhibits the enzyme vitamin K epoxide reductase, a protein essential for activating vitamin K [10]. Vitamin K is required for the synthesis of active clotting factors, such as coagulation factors II, VII, IX, and X, as well as protein C and protein S. Consequently, the depletion of Vitamin K due to warfarin action leads to a reduction of coagulation factors. INR is routinely used for VKAs in order to assess the coagulation status and the residual pharmacodynamic effects of VKAs. In order to obtain a good hemostatic status and reduce bleeding risk at the time of the surgery, Warfarin has to be discontinued 5 days before elective surgery [38]. Restart warfarin 12–24 h after surgery, generally the evening of the day after surgery, if an adequate hemostatic status has been obtained intraoperatively. Normalization of the INR may differ among patients, especially in the elderly, consequently, it is important to check Prothrombin time (PT) and INR prior to surgery and invasive procedure (e.g., neuraxial anesthesia) in order to confirm normalization of INR. Bridging has to be reserved in patients at very high risk of thromboembolism and in case of prolonged period of anticoagulant interruption.
- ***DOACs*:** Thrombin has a fundamental role in hemostasis. Once activated, thrombin can activate factors XI, which in turn can lead to further generation of factor IXa, Xa, VIIIa, and Va; this mechanism serves as an amplification pathway for thrombin generation. Thrombin is central in sustaining the coagulation cascade by feedback activation of coagulation factor. Even more, Thrombin (IIa) converts soluble fibrinogen to insoluble fibrin and it also activates factor XIII; a protein with clot stabilization function. Finally, Thrombin activates platelet. Thrombin can be inhibited by the binding of different drugs to one or two of its three domains (i.e., the active site and exosites 1 and 2). Direct thrombin inhibitors (Dabigatran, Lepirudin, Argatroban, Desirudin, Bivaluridin) bind directly the thrombin to the active site or to the active site and Exosite I [39]. Exosite I is the site of the interaction between Thrombin and fibrinogen, factor V, protein C thrombomodulin, and thrombin receptors on platelets. On the other hand, direct factor Xa inhibitors (Rivaroxaban, Apixaban, and Edoxaban) bind the active site of factor Xa with a direct inhibitor mechanism [40]; inhibition of Xa prevents the amplification of thrombin generation. In fact, factors Xa acts at the convergence between the intrinsic and extrinsic coagulation cascade and it cleaves prothrombin to thrombin.

  Elimination half-life of DOACs can be prolonged in renal and liver dysfunction, in the elderly and due to drug interactions. Consequently, renal and liver function has to be checked before surgery. DOACs generally do not require routine laboratory test monitoring; however, in an emergency setting, it is important to determine plasma drug concentration and their effect on coagulation. Laboratory tests can provide information on the residual anticoagulant effect of the anticoagulant agents. A normal PT/INR cannot be used for this purpose. Direct measurement of anti-factor Xa levels, calibrated to the specific anticoagulant, used to monitor anticoagulant effect can be misleading due to interindividual variability [41]. Especially in emergency clinical scenarios, viscoelastic tests have to be considered in order to obtain a global view of coagulation status and bleeding risk.

Dabigatran: an orally administered direct thrombin inhibitor with a half-life of 12–17 h. Absorption is not influenced by food intake. Eighty percent of the drug is eliminated unchanged by renal excretion, consequently, patient with renal impairment requires drug dose adjustment (patient with Creatinine clearance between 15–30 mL/min). Even more, interaction with G-glycoprotein inhibitors (e.g., rifampin, ketoconazole, verapamil) has to keep in mind due to the possible consequent increase of the anticoagulant effect of Dabigatran [42]. Dabigatran has to be discontinued 2–3 days before elective surgery, a longer interruption (2–4 days) is required in patients with severe renal impairment. Restart Dabigatran after surgery if an adequate hemostatic status has been obtained intraoperatively. However, due to the rapid onset of this drug (peak effects 2–3 h after administration), particular attention has to be given in resuming Dabigatran after procedures with a high risk of bleeding. Generally, bridging is not required due to intrinsic pharmacokinetic properties of Dabigatran; however, bridging has to be considered in patients at very high risk for postoperative thromboembolism and in case of prolonged anticoagulant interruption.

Rivaroxaban: an orally administered direct factor Xa inhibitor, with a half-life of 7–11 h. Patients with renal or hepatic impairment require drug dose adjustment. Rivaroxaban should not be used in severe renal impairment (creatinine clearance <15 mL/min) and in patients with severe hepatic dysfunction (Child-Pugh class B and C). Rivaroxaban shows interaction with dual G-glycoprotein and CYP-3A4 inhibitors effects (e.g., voriconazole, ketoconazole) [43]. Rivaroxaban has to be discontinued 2–3 days before elective surgery/invasive procedure; a longer or shorter interruption may be required in patients with severe renal impairment or for low bleeding risk procedures, respectively. Restart Rivaroxaban after surgery if an adequate hemostatic status has been achieved. Due to the rapid onset of action, postpone for 2–3 days the resuming of Rivaroxaban after procedures with high risk of bleeding. Bridging has to be reserved in patients with very high risk for postoperative thromboembolism and in case of prolonged anticoagulant interruption.

Apixaban: an oral direct factor Xa inhibitor with a half-life of 8–12 h. Patients assuming dual inhibitors of G-glycoprotein and CYP-3A4 and with severe renal impairment (Creatinine Clearance 15–30 mL/min) require drug dose adjustment [44]. Interrupt Apixaban 2–3 days before invasive procedures in patients with normal renal function; longer/shorter interval in case of high or low bleeding risk, respectively. Resume Apixaban when good hemostasis has been obtained. Similarly to Dabigatran and Rivaroxaban, Apixaban presents a rapid onset of action, consequently, postpone the recommencing of Rivaroxaban after procedures with high risk of bleeding. Bridging is generally not required; it has to be considered in patients at high risk of thromboembolism and in case of extended anticoagulant interruption. *Endoxaban:* an oral direct factor Xa inhibitor with a half-life of 10–14 h. Dose reduction is required in patients with renal impairment (Creatinine Clearance 15–50 mL/min). Discontinue Endoxaban 2–3 days before a procedure in patients with normal renal function; longer/shorter interval in case of high or low bleeding risk, respectively. Restart Endoxaban when hemostasis has been reached. Likewise, the aforementioned DOACs, postpone the resuming of Endoxaban after procedures with high risk of bleeding and bridging has to be considered in patients at high risk of thromboembolism and in case of extended anticoagulant interruption.

5.4 Bridging

Bridging consists of replacing long-acting with short-acting anticoagulants (LMWH/UFH) in order to minimize the risk of thromboembolism in high-risk patients or patients requiring a prolonged anticoagulant interruption. The goal of heparin bridging is to reduce the period the patient is not anticoagulated; thus, decreasing the risk for perioperative thromboembolism. Due to peculiar pharmacokinetics of DOACs (rapid onset and short half-life), bridging is generally reserved in patients assuming VKAs. Not to be underestimated, when prescribing heparin bridging therapy, it is important to monitor for heparin-induced thrombocytopenia [45].

Unfractionated heparin and low-molecular-weight heparin inhibit thrombin indirectly by binding antithrombin(AT). The binding of AT induces a conformational change in AT. The complex heparin–antithrombin can bind the exosite 2 on thrombin. UFH presents a much more efficient inactivator mechanism of Thrombin due to its intrinsic molecular conformation. LMWH lacks the longer chains of UFH and, consequently, has less binding efficacy to thrombin thus decreasing its ability to neutralize thrombin [46]. Even more, UFH, LMWH, and Fondaparinoux can inactivate factor Xa.

LMWHs have progressively substituted UFH; however, in patients with renal insufficiency, UFH has to be chosen because UFH dosing is not affected by renal clearance. Therapeutic dose of LMWH (1 mg/Kg subcutaneous) used for bridging should be stopped 12–24 h before surgery, whereas 4–6 h in case of therapeutic UFH administration (80 units/Kg bolus, 18 units/Kg/h intravenous continuous infusion). If an adequate hemostatic status has been obtained intraoperatively, restart bridging 24 h after surgery. In case of risk of bleeding, bridging should be delayed 48–72 h [38].

Patients at particular risk of thromboembolism and in which bridging is particularly appropriate are [47, 48]:

- Mechanical mitral valve;
- Non-bileaflet aortic valve;
- ≥2 Mechanical valves;
- Aortic valve replacement and previous stroke;
- Cardioembolic events;
- VTE within the past 3 months;
- VTE while in therapeutic anticoagulation;
- AF with a very high risk of stroke.

5.5 Reversal and Management of Severe Bleeding

In case of emergency surgery or invasive procedures, there is not enough time to stop anticoagulant agents and, consequently, the risk of bleeding complications is increased. In this scenario, specific reversal factors are available; however, the decision to reverse is based on the balance between stopping and treat the bleeding versus the risk of clotting [48]. Unfortunately, there is a lack of strong evidence, consequently, the decision of reversal strategies is often based on expert panel or routine clinical experience.

The main indications of reversal are represented by [49];

– Emergency invasive procedure;
– Overdose (due to excessive intake, reduced drug elimination, or drug interactions);
– Bleeding.

Obviously, in an emergency setting, the first approach to a patient on anticoagulant agents is based on the appropriate resuscitation support. Airway management, intravenous access placement, evaluation and treatment of the hemodynamic status, the management of hemorrhagic shock, the correction of body temperature, and pH/electrolyte disorders represent the initial management of unstable patients. It is vital to identify and treat quickly the site of bleeding (e.g., endoscopy, surgery, interventional radiology) [50]. Even more, bleeding assessment (site, rate of hemorrhage, amount of blood loss, bleeding into closed space-intracranial/retroperitoneal/compartment syndrome) is fundamental to decide whether to reverse anticoagulant effects or not. Packed red blood cell transfusion has to be considered depending on the rate of blood loss. Parallelly, a methodological management of patients on anticoagulant agents requires an accurate evaluation of medical and pharmacological history including: the type of anticoagulant, timing of last ingestion, the dose, other medications (possible interactions), and the evaluation of renal/liver function [51, 52]. This global evaluation aids clinicians to establish when choosing reversal. Routine anticoagulation (e.g., PT/INR) can be used to evaluate residual anticoagulation effects and orientate the reversal strategy in patients on VKAs or UFH [53]. However, these tests cannot be used to determine the degree of anticoagulation in patients on other anticoagulants. Measurement of plasma anti-factor Xa activity, calibrated to the specific anticoagulant, is generally used to monitor the anticoagulant effect; however, it can be deceiving due to interindividual variability [54]. For Dabigatran, ecarin clotting time (ECT) and diluted thrombin time (TT) can be used as surrogate to plasma drug concentration. However, those tests are not widely and promptly available [54, 55]. In an emergency setting, point of care viscoelastic test can provide useful aids of the anticoagulation status of patients; however, data are lacking on the correlation between drug concentration and anticoagulant effects [56].

Then, agent-specific strategies include:

- ***UFH/LMWH:*** due to its short half-life, UFH reversal is rapidly achievable by stopping continuous infusion. However, UFH can be reversed using Protamine (1 mg Protamine/100 units UFH) [49]. No specific antidotes are available for LMWH; Protamine presents a partial effect on LMWH. In clinical trials, Ciraparantag has shown efficient reversal effects for LMWHs [57].
- ***VKAs:*** several agents are available for VKAs reversal; vitamin K, PCC, and FFP. The strategy of reversal warfarin effects consists of omits warfarin and monitor INR. Then in case of supratherapeutic INR and minor bleeding, consider oral administration of Vitamin K (2.5–5 mg/day) and monitor INR after 24 h as long as bleeding control strategies. Repeat Vitamin K if needed. In major bleeding or emergency surgery, immediate reversal is required, then, administer PCC (25–50 units/kg) plus intravenous Vitamin K (5–10 mg) [48]. Vitamin K provides substrates to coagulation factors synthesize (e.g., factors II, VII, IX, X, protein C, and S). VKAs rapid reversal should be accomplished using PCC rather than FFP [48]. Four factors PCC contain factors II, VII, IX, and X. PCC is rapidly available, it provides rapid INR reversal, it allows the reduction of volume requirements thus preventing fluid overload, and the decrease of adverse immune-related risks in comparison to FFP [58]. Limitations of the use of PCC are represented by cost and availability.
- ***DOACs*: ** Given the short half-lives, interruption of these drugs can represent the only therapeutic strategy in case of minor bleeding. However, in major bleeding or emergent invasive procedure, an aggressive treatment is needed in order to achieve a good coagulation status. In patients with normal renal and hepatic function, drug elimination can require up to 24–48 h, whereas, this interval can be prolonged in patients with severe renal and/or hepatic dysfunction. Determine the residual anticoagulation effect of DOACs can be challenging and specific laboratory tests are not widely available. For Dabigatran and Rivaroxavaban a plasma concentration of 30 ng/mL or below is considered compatible with surgery [59]. Above this threshold, surgery must be postponed, and plasma drug concentration must be monitored. Otherwise, in emergency surgery and actively bleeding patients, a reversal has to be considered. A plasma level above 400 ng/mL represents a major hemorrhagic risk. Several reversal strategies can be chosen for DOACs. If the last drug dose was taken in the previous 2 h, gastric lavage with oral-activated charcoal can be used to reduce the plasma concentration of DOACs. Furthermore, hemodialysis can be considered for the elimination of supratherapeutic levels of Dabigatran; however, it is not always feasible, especially in hemodynamically unstable patients. A specific antidote is available only for Dabigatran; Idarucizumab, an FDA-approved human antibody fragment. Idarucizumab provides an immediate reversal of the anticoagulant effect of Dabigatran [60]. Due to its cost, the use of Idarucizumab has to be reserved in case of significant plasma drug levels and undergoing emergency procedures. For Rivaroxaban/Apixaban/Edoxaban, Andexanet alfa is currently under investigation as reversal agent. Furthermore, the administration of PCC (25–50 U/Kg) has to be reserved for active bleeding and life treating conditions due to the

possible thromboembolic risk and when specific antidotes are not available. However, the evidence on the real risk of thromboembolism using PCC in emergency situations is scarce [61]. Due to its cost, short half-life, and a higher risk of INR rebound, recombinant factor VIIa is not recommended for emergency reversal [59]. Finally, the use of antifibrinolytic agents (i.e., tranexamic acid) and pro-hemostatic therapy (e.g., Desmopressin) to enhance hemostasis have to be considered in major bleeding [62]. The evidence regarding the role of these agents in DOACs-related bleeding is poor. However, their low risk of thrombosis and wide accessibility make these agents reasonable in the case of life-threatening bleeding or emergency settings.

5.6 Conclusions

The complex management of anticoagulants in patients undergoing surgery or invasive procedures required a deep knowledge of pharmacokinetics and pharmacodynamics of the different agents. It is vital to carry out a detailed anamnesis of the patients in order to identify possible interactions or comorbidities responsible for prolonged anticoagulant effects of these drugs. Furthermore, it is important to take into account the interindividual variability in plasma drug levels. A precise estimation of the bleeding versus thromboembolic risk has to be made in order to reach a clinical decision on whether to interrupt these drugs preoperatively or not. Laboratory tests can aid in clinical decision-making; however, these tests present specific limitations to bear in mind, especially for DOACs. In an emergency setting, a precise reversal strategy has to be chosen in order to prevent or treat bleeding complications.

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6 Anesthetic Concerns in Advanced Age Undergoing Emergency Surgery

Bianca M. Wahlen and Andrea De Gasperi

6.1 Introduction

Caring for elderly patients (≥65 years) is more and more frequent in everyday clinical practice. The process of aging is often associated with an increasing number of comorbidities, able to impact on the perioperative risk more than the aging process per se. Increased perioperative morbidity and mortality is a reality in the emergency surgical setting: age-related physiological changes and their impact on anesthetic techniques are to be well known and, if possible, proactively managed. Safety of modern anesthesia is based on great attention paid to physiological changes: a solid knowledge of the changes of the aging process is key for choosing the safest and wisest options for the patient. Intraoperative hypotension, also due to the increased incidence of CV diseases, is a feared and increasingly observed complication in the elderly surgical patients: in such a setting, hot debate exists on the pros/cons of general versus regional anesthesia, and on the impact an anesthetic regime might have on arterial hypotension and patient's cognitive dysfunction. Changes in PK/PD characteristics should guide the pharmacological strategy and drug choice, neuromuscular drugs, and opioids being perhaps the best examples. In this chapter, we will discuss and update the most relevant anesthesia-related topics when dealing with the elderly patient admitted to emergency surgery.

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6.2 Emergency Airway Management in the Elderly

Emergency intubation of older adults is becoming more frequent and is expected to double between 2001 and 2020 [1]. Older adults, however, will survive with a very poor outcome and quality of life [2]. More than 70% of older adults with serious illness prioritize quality of life and quality of dying over longevity and consider some health states worse than death [3]. The fact that more than 50% of older adults do not have any advanced medical directives when they present in the emergency (ED) might raise a new challenging ethical dilemma [4].

6.2.1 Emergency Intubation in the Elderly: What to Expect

Generally speaking, elderly patients might display some peculiar anatomical features, which could lead to difficult mask ventilation (DMV) or difficult intubation. Preparation, backup devices, and algorithms do not differ from other patients. For the most updated algorithms, see those endorsed by ASA [5] and those proposed by DAS (Difficult Airway Society) [6–8].

With increasing age several anatomical and physiological changes occur, able to impact on the airway management in elderly patients. In general, a rapid sequence induction (RSI) is needed in patients who have to undergo emergency surgery under general anesthesia. Mask ventilation, one of the basic and fundamental skills for the anesthesiologist, might become mandatory in the emergency setting. Patients with beard, high body mass index (BMI above 26 kg/m^2), history of snoring, or age above 55 are at risk for difficult mask ventilation (DMV) [9]. In addition, Kheterpal et al. defined extend of mandibular protrusion, abnormal neck anatomy, sleep apnoea, and also snoring to be independent predictors of both grade 3 or 4 DMV and difficult intubation [10]. Induction of anesthesia and supine position lead to a decreased oropharyngeal space, posterior displacement of the tongue: epiglottis in the lower part of the airway and soft palate in the oropharyngeal area are able to worsen the space for and appropriate vocal cord exposition and visualization, leading to a situation which might result in closed airway access [11]. Some anatomical and age-specific features of the elderly patient might lead to problematic mask ventilation: frequent modifications are (para) physiological muscle atrophy in the elderly and loss of teeth [12]. In geriatric patients, reduced upper airway tonus increases the possibility of airway obstruction, leading to difficulties in appropriate mask ventilation, and requires occasionally special techniques for mask ventilation [13]. In addition, the lack of teeth may lead to ineffective, or even impossible, mask ventilation: having been identified as an independent risk factor for DMV, it has to be strongly considered at anesthesia induction in the aged due to the prevalence (up to 60%) of edentulous patients above 65 years of age [14]. Problematic intubation in patients sharing these problems is to be anticipated: due to teeth loss, the standard facemasks usually do not seal properly around the cheeks. This phenomenon can be a result of the aging process of skin, muscle, fat tissue, tendons, and facial skeleton. While there is an ongoing controversy whether ligaments are involved in the aging process or not [15, 16], firm points are available for the other components. It is known that facial bones undergo lifelong changes [17–19]. The facial shape is influenced by fat tissue. Hypertrophic changes of the superficial facial fat compartment cranial to the nasolabial sulcus during the aging process have been reported. This hypertrophic fat tissue has the tendency to shift inferiorly. The loss of skeletal muscle mass and strength as a result of aging and/or immobilization is specifically defined as *sarcopenia* and it has to be considered for the whole skeletal muscles [20]. Then age-related muscle, bone, skin, and ligament changes contribute to the *sunken cheek syndrome*, which, in the end, may result in difficult mask ventilation [21]. Aside from difficult mask ventilation, not always indicated in the emergency patient, difficulties concerning the loss of teeth as well as the range of motion of joints might complicate the airways manipulations [22, 23]. As the cervical spine has the largest range of motion, it is predisposed to degenerative changes [24]. Those misaligned spine segments consecutively lead to pressure in certain areas and finally to degeneration in these segments [25, 26]. An observational study showed that neck tilt, thoracic inlet angle, and cervical angle (CC2–7) increased with age, especially in the population above 40 years [27]. Concerning the sagittal curvature parameters, the authors found results [27] consistent with other publications [25, 26]. Ossifications of the intervertebral discs can cause severe limitations in the range of motion of the spine [28, 29]. On the other hand, there are also age-related osteoporotic changes that may cause asymmetric compressions of the vertebrae resulting predominantly in a thoracic hyperkyphosis [30]. This age-related changes might aggravate the predescribed risk of spinal cord injury following intubation in patients with known cervical spine injuries [31], with unknown cervical spine injuries [32], and in patients without any preexisting pathology in this region [31].

Together with the risk of difficult intubation in the elderly population, the risk for dental damage due to intubation is real. Givol et al. [33] reported that patients between 50 and 70 years are prone to dental injuries during intubation due to the increased incidence of periodontal diseases in this age group. An additional risk factor, especially when nasotracheal intubation or the presence of nasogastric tubes is required, is the increased prevalence of nasal polyps. Patients above 60 years of age have a 5% chance of developing nasal polyps compared to 1% in people less than 40 years [34]. Another factor in the elderly patient is the loss of elastic as well as collagen fibers. This has an impact on the whole body and in case of endotracheal intubation, the risk of lacerations and therefore bleeding is increased in this area [12, 22]. A subgroup of geriatric patients suffers from increased saliva production, which may cause, beside others, fixation problems of the tube or supraglottic airway management devices [22]. Occasionally the anesthetist might face in an emergency situation a patient suffering from oropharyngeal cancer, the incidence of which is increased, especially in the male population above 50 [35]. Of major importance is the preparedness, and therefore the predictability of difficulties which might arise in this subgroup of patients. Studies showed that aged patients had low head and neck movement, a short thyromental distance, and poor dentition relative to the middle and young age groups. Limited head and neck movement, a small inter-incisor gap, a high Mallampati score, and rigid cervical joints were seen more frequently in the old and middle age groups relative to the young age group. This indicates that factors related to difficult endotracheal intubation increase with age; as a result, C-L grades of 3 or 4 were more common in the middle and old age groups than in the young age group [36].

Following the ABC algorithm, to secure the airway is, independently of age, the priority. This is especially true in acute critically ill patients who are at risk for respiratory distress or aspiration and the assessment of the elderly emergency patient is not different from any other patient. In general, and in specific emergency patients (e.g., patient with head and midface trauma or neck injuries) a fast but accurate evaluation of the airway might be life-saving. Every patient should be assessed for mask ventilation, tracheal intubation and/or surgical airway access. As most of these patients are at increased risk for aspiration, the supraglottic airway devices play a minor role in the airway management. The LEMON score, which has been also included in the eighth edition of the Advanced Trauma Life Support Manual (ATLS) in 2009, is a useful tool for assessing the airway of every emergency patient [37, 38].

Difficult airway prediction tools may not be not practical for emergency intubation, as physiological data are not included. The HEAVEN criteria (Hypoxemia, Extremes of size, Anatomic challenges, Vomit/blood/fluid, Exsanguination, Neck mobility) were recently proposed for emergency intubation [39, 40] and very recently retrospectively tested during emergency rapid sequence intubation (RSI) in a large (>5000) cohort of patients [41]. Each HEAVEN criterion has been associated, when compared to no criterion present, to lower intubation success rate: the total number of HEAVEN criteria has been documented as inversely proportional to first attempt intubation success, overall intubation success, and first attempt intubation success without oxygen desaturation; success using direct laryngoscopy (DL) and video laryngoscopy (VL) intubation was also considered. With an intubation success of 97%, CL 3/4 view was reported in 25% of DL attempts and 15% of VL attempts. Interestingly enough, each HEAVEN criterion and a total number of HEAVEN criteria were associated with both CL 3/4 laryngoscopic view and with failure to intubate on the first attempt (with and without oxygen desaturation) for both DL and VL, documenting for the HEAVEN criteria the usefulness in predicting laryngoscopic view and intubation performance for both DL and VL during emergency RSI.

In general, video laryngoscopes are well-recognized alternatives, often offering, compared to conventional direct laryngoscopy, a better view. However, the real role of these devices in emergency airway management remains unclear. Two recent meta-analyses [42, 43] were not able to show any advantage of VL over DL, particularly when experienced physicians performed intubation under DL. In the most recent "real life" trial comparing, in case of prehospital emergency intubation, direct laryngoscopy (DL) and McGrath MAC Video Laryngoscope (MGRVL) [44] the success rate using the two devices was very similar (MGRVL 98.5% vs. DL 98.1%), with no differences in tracheal intubation times, number of attempts, or difficulty. Glottis exposition and vocal cords view were better with MGRVL, but DL gave less technical problems particularly in bright ambient light (difficult vision on the monitor due to technical problems). As already reported, DL was associated with a shorter (5 s) intubation process: this is usually associated, using VL, with problems in intubating, or better in tube manipulation to advance the tube towards the laryngeal aditus, in spite of a better vision ("*I see the vocal cords, but I can't intubate*"). On the one hand, this pragmatic trial showed the equivalence of the two devices for emergency intubation in the prehospital setting. On the other hand, it showed that after a first failed attempt, immediate switching to the alternative device led to a significantly higher success rate of intubation, regardless of the first device.

However, other devices for a backup plan might include flexible fiberscope or optical stylets such as Bonfils or Bullard: all are mentioned in international guidelines [5–8].

However, all those alternatives imply an experienced user and a laryngeal view not compromised by blood or other secretions. More important, indirect optical devices may be useless in ongoing bleeding, as to be expected for example in midface or neck injuries. According to ASA recommendations, [5] in case of problematic intubations, alternatives include (but are not limited to) combinations of solutions or techniques: among them, Laryngeal Mask Airway as an intubation conduit (with or without flexible scope guidance); flexible scope intubation; intubating stylet or tube changer, and light wand. In patients with maxillofacial, laryngeal, or tracheal trauma, oral or nasal blind intubation is discouraged, and surgical airway facilities should be immediately available.

6.3 Regional Versus General Anesthesia in the Elderly

The population above 65 years of age is predicted to reach more than 1.5 billion by 2050 [45]. Due to the change in life expectancy, the potential number of elderly patients, and therefore the burden on the healthcare system will increase [46]. Over the course of time surgical and anesthesia techniques are under continuous improvements and relevant refinements. Whether regional anesthesia or general anesthesia or the so-called combined techniques is the method of choice for the aging patient is still under debate. So far, there is no evidence in the literature that any method has an impact on the long-term outcome after surgery, particularly in the elderly emergency patient. Nevertheless, regional anesthesia techniques are excellent alternatives and/or additional tools for the perioperative pain control: the final decision concerning the anesthetic technique is mainly driven by the patient's comorbidities, as well as the type of surgical procedure.

In patients undergoing abdominal surgery, some publications indicate the benefit of epidural analgesia to reduce postoperative pulmonary complications and to improve bowel motility [47, 48]. One of the main surgical concerns after abdominal surgery is the return of coordinated, synchronized gastrointestinal motility and the fear of postoperative ileus. A recently updated review concerning the use of epidural analgesia with or without opioids revealed that both are beneficial with respect to ileus prevention and hospital stay [49].

Aside from the neuraxial procedures, ultrasound-guided abdominal blocks, such as *transversus abdominis plane (TAP) block* and rectus sheath block, single shot as well as catheter-based continuous infusion, are in use.

In 2013, Godden et al. showed the efficacy of an ultrasound-guided rectus sheath block in open colorectal surgery when compared to epidural anesthesia, together with less frequent hypotensive episodes [[50]. Nevertheless, and particularly in the specific setting of emergency surgery in the elderly, in addition to patient's comorbidities and medication (anticoagulants among others) type and timing of the emergency procedure have to be considered. Due to lack of time, a patient with an acute bowel obstruction or aortic dissection will probably not be eligible for an epidural anesthesia or analgesia, but will most likely benefit from ultrasound-guided transversus abdominal plane and/or rectus sheath block performed at the end of surgery run under general anesthesia and endotracheal intubation. The transversus abdominis plane (TAP) block was first described by Kuppuvelumani [51]. Some years later, in 2001, Rafi et al. further described in detail the blunt landmark-guided technique [52]. A complete review of techniques and approaches was published by Tsai and colleagues in 2017 [53]. Nowadays, it is basically used as an ultrasound-guided injection of local anesthetic into the space between the transversus abdominis muscle and the internal oblique muscle, thereby blocking the afferent parts of the thoracolumbar nerves T6–L1, which supply sensory nerves to the anterolateral abdominal wall [54]. It is used for a number of abdominal procedures, and it has been proved to be efficient for cesarean section, hysterectomy, cholecystectomy, colectomy, prostatectomy, and for example hernia repair [55–61]. The TAP block plays a pivotal role as a single-shot block in the setting of multimodal analgesia as well as continuous infusion [62–68]. In spite of the absence of clear evidence in the literature, a systematic review with meta-analysis published in 2018 (stated) that TAP block and epidural analgesia might be equally effective. Moreover, the TAP block seems to be associated with less hypotensive episodes [69]. An earlier meta-analysis (2016) showed the benefits of TAP block(s) with respect to pain management after abdominal surgery, particularly when neuraxial techniques or opioids are contraindicated [70]. In the upper abdomen, Cholecystectomy, either open or laparoscopic, is a frequently reported emergency procedure in the elderly: a systematic review and meta-analysis published in 2016 showed statistically significant benefits of a supplementary TAP block in addition to the general anesthesia with regard to postoperative pain intensity, nausea, and vomiting [71]. Regarding the lower abdomen, the TAP block is already a frequently used tool in open appendectomy in children [72]. Appendectomy (often with peritonitis) and inguinal hernia repair [73], if incarcerated, are other frequent emergency procedures of the lower abdomen performed in the elderly. In case of emergent hernia repair, there is a strong tendency favoring the laparoscopic approach versus the open repair. Even though some guidelines [74] suggest to abandon neuraxial blocks (NABs), they are still used in up to 20% of the cases [73]. Furthermore, a recently published systematic review and meta-analysis showed that NABs are still indicated, especially in certain subpopulations of ASA 3–4 patients with cardiovascular and pulmonary comorbidities. While general anesthesia is less frequently associated with urinary retention, the NABs are more beneficial in postoperative pain control [75]. Another meta-analysis investigating paravertebral blocks showed that they are associated with fewer side effects like nausea and vomiting compared to general anesthesia as well as NABs [76].

The *rectus sheath block* also belongs to the abdominal field blocks and was first published in 1899 [77]. The ventral branches of the spinal nerve roots T7–T11 supply the central portion of the anterior abdominal wall. They enter the rectus muscle close to the midline and continue between the rectus abdominis muscle and the posterior rectus sheath [78]. Usually, the local anesthetic is spreading cephalocaudally within this compartment [79]. A bilateral rectus sheath block has been described to be beneficial in patients undergoing an umbilical hernia repair (T9–T11) [80]. Concerning the provider of the block, a 2017 published study showed no statistically significant difference between the block performed under ultrasound guide or during the surgical procedure [81].

In summary, the reduced use of epidural anesthesia as the first choice anesthetic technique is mainly due to the fact that emergency procedures are usually time-critical. In patients undergoing a lower abdomen open emergency procedure and in whom general anesthesia or postoperative opioids should be avoided, the spinal anesthesia still plays a pivotal role. In a time where multimodal postoperative analgesia is standard (particularly in the elderly patient with a number of comorbidities) supplementary, ultrasound-guided abdominal blocks are of the greatest value. The TAP block is suitable for open cholecystectomy (T6–T9), open appendectomy (T10–T11), and open inguinal hernia repair (T9–T11). The bilateral rectus sheath block can be useful for open umbilical hernia repair (T9–T11) and in combination with the TAP block (but known not to cover the complete upper part of the incision) for midline laparotomy (T6–T12).

6.4 Postoperative Dysregulations

The phenomena of postoperative delirium (POD) and postoperative cognitive dysfunction (POCD) are summarized under a state of cerebral cognitive alterations in the postoperative period. The literature suggests that age is the number one factor in postoperative cognitive decline. Patients over the age of 65 years who underwent noncardiac surgery had a 26% prevalence of POCD within few weeks which decreased to 10% 3 months postoperatively [82]. In spite of having been described by Bedford in 1955 [83], plenty of studies were unable to give evidence of long-term postoperative cognitive dysfunction after general surgery [84–87]. In fact, a large part of the studies dealing with POCD is weak with respect to factors involved, test sensitivity, sample size, or control group.

Patient-specific factors should strongly contribute to POCD. Physically active and fit patients with a strong social environment are less likely to develop POCD compared to immobile, depressive, frail, and socially isolated surgical patients [88]. The International Society of Postoperative Cognitive Dysfunction states that POCD develops when postoperative deficits are observed in a patient in one or more discrete areas of mental state such as attention, concentration, executive function, memory, visuospatial ability, and psychomotor speed [89]. Unfortunately, the knowledge about the underlying pathophysiological causes is still limited. Causes like hypotensive episodes, cerebral microemboli, inflammation, hypo-, or hyperventilation have been investigated. Hypotension was among the first potential causes recognized and therefore investigated with regards to POCDs [90]. The underlying idea was that POCD might be caused by decreased cerebral blood flow as a result of cerebral hypoperfusion secondary to systemic hypotension. Unfortunately, most of the upcoming studies have not been able to support this hypothesis [91–94]. Another possible cause, investigated and described, is the cerebral microembolism. Microemboli have been described in MRI, especially in patients undergoing cardiac surgery in up to 50% of the cases [95] as well as in postmortem studies [96]. However, no correlation was found between the size of emboli and the postoperative cognitive dysregulation [97, 98]. Various other risk factors have been considered as possibly associated with POCD: among them postoperative infections (e.g., respiratory complications) [94], sepsis [99], dysglycaemia [100], or hypoxemia [101]. A promising approach seems to be the study of the role of inflammation as a possible contributing factor to POCD. A large body of studies showed a correlation between extracorporeal circulation, used, for example, in cardiac surgery, and postoperative cognitive dysregulation [102]. Over the course of time, the initial assumption that the cause of POCD is secondary to an activation of the immune system after blood contact with the extracorporeal circulation [103, 104] has been abandoned, as researchers realized that also off-pump surgeries lead to the same POCD symptoms [105, 106]. This has not only been shown in cardiac surgery but also in a large series of surgical operations [107–109] and it is well known that systemic inflammation may even lead to multiorgan failure including the brain. Symptoms may range from mild cognitive deficit and delirium to septic encephalopathy and coma [110]. However, the underlying mechanism is not yet fully understood. An older study from Moller et al. [94] described the occurrence of POCD in patients after different types of surgery, such as cardiothoracic, abdominal, or orthopedic surgery without any incidence of hypoxemia, hypotension, or any other known risk factor. Serving as a differential diagnosis and often mixed up in daily clinical practice is the postoperative delirium (POD). The POD is defined as consciousness disorders, change in cognition, attention disorders, and fluctuations in the psycho-emotional state over time [111]. Studies showed that up to 50% of geriatric patients display signs of delirium after an operation [112], affecting the individual himself with a proven significantly increased mortality and morbidity [113], but also heavily impacting the healthcare system costs [114]. Recently Kotekar et al. extensively pointed out background, possible causes and preventive strategies for POCD [114]. According to Kotekar, during anesthesia especially in the elderly population, sedatives and anxiolytics are not recommended [114]. Interestingly, studies showed that the molecular size of the used anesthetic agent or the combination of anesthetic agents may result in oligomerization and therefore might contribute to POCD [115, 116]. As there is still a controversy dealing with emboli as a possible cause of POCD, early postoperative mobilization is recommended. Glucose level should be tightly controlled, as hypo- as well as hyperglycemia cause additional cerebral symptoms. Special attention should be paid to maintain intraoperative normothermia, as hypothermia is known to influence drug metabolism, possibly affecting immunity as well as coagulation. Desirable for every patient, but especially for children and elderly patients, is a quiet environment for the hours immediately after surgery. It has been shown, that the presence of family members is beneficial in terms of prevention of POCD.

In Summary, optimization of cardiovascular and pulmonary comorbidities if allowed in the time frame of an emergency procedure, avoidance of preoperative sedative drugs, the use of small molecular size drugs for anesthesia, and preference for regional anesthesia in combination with a quiet, family-centered environment should have utmost priority. Further studies specifically addressing possible risk factors and their management should be able to shed light on this relevant postoperative complication, able to heavily impact the clinical outcome and the social condition.

6.5 Pharmacology in the Elderly: the Impact on Anesthetic Drugs

Elderly adult patients—by definition individuals above 65 years of age—represent today close to one-third of the entire surgical population [117]: extended operative/invasive indications in older patients and major advances in perioperative care are at the base of this observation. Age-related physiologic modifications include, among others, loss of anatomic units (neurons, alveoli, nephrons, hepatocytes) [118], affect neurologic, cardiovascular, respiratory, hepatic, and renal systems, are associated with increased incidence of comorbidities, more frequent use of drugs, major, and minor complications (morbidity 40%, mortality 10%) [119]. While fit elderly patients maintain a good physiological profile, stress induced by surgery and anesthetic manipulations can challenge this equilibrium in less fit, "frail" individuals [118], particularly in emergency. Changes in body composition, end-organ function and reserve, altered homeostasis are among the most relevant features introduced by the process of aging and impact on the pharmacokinetic (PK) and pharmacodynamic (PD) profiles of anesthetics and analgesics in the elderly surgical patient. Changes include reduced total body water content and lean body mass, increased fat presence and its distribution, and reduced protein synthesis [118–121]. However, key for the PK and PD changes are also the increased prevalence of comorbidities [120]. In such a setting, and particularly in emergency, pivotal will be the differentiation between functional versus chronological changes associated with the aging process. In elderly patients, a condition of fit versus frail makes the difference in terms of physiological and pharmacological consequences [118]. Large part of the drugs used as anesthesia and analgesia agents are highly protein-bound, highly extracted by the liver, and eliminated by the kidneys, and thus potentially affected by the aging process. Tailoring anesthesia pharmacology for the elderly population constitutes a relevant part of the global care of the surgical patient, aiming at a safer and personalized care and better results [117, 120] (Table 6.1).

Table 6.1 Age-induced physiologic changes and potential perioperative consequences

Organ System	Physiologic Changes	Perioperative Consequences
Neurologic System	• Increased neuronal degradation from increased enzymatic activity • Decreased brain mass • Decreased neurotransmitter synthesis • Ill-defined changes in receptor function • Decreased functional connectivity between neurons	• Increased sensitivity to anesthetic drugs[184] • Decreased hypoxic drive, hypercarbic ventilatory drive • Increased likelihood for postoperative delirium and cognitive dysfunction. especially in the presence of infections, blood loss, fever, opioids, anticholinergics, opioids, anticholinergics, preexisting cognitive impairment, or renal failure
Cardiovascular System	• Alterations in blood pressure, pulse pressure, and sinoatrial node conduction • Reduced left ventricular compliance, increased wall thickness and size • Increased myocardial oxygen demand • Reduced aortic and great vessel compliance[185] • Decreased baroreceptor sensitivity, decreased responsiveness to β-adrenoreceptors and renin-angiotensin-aldosterone system[34]	• Increased risk of hypotension on induction and greater lability during anesthesia[83,186] • More sensitive to the cardiovascular depression from propofol[187] • Hemodynamic lability is associated with more adverse outcomes during surgery[188,189] • Decreased chronotropic response to noxious stimuli. Decreased ability to increase in cardiac output • Reduced response to β_1-agonism[185]
Pulmonary System	• Physiologic shunt, ventilation-perfusion mismatch, closing capacity, and work of breathing are increased • Chest wall compliance, minute ventilation, respiratory muscle strength, and vital capacity are decreased	• Decreased forced expiratory volume in 1 second • Increased likelihood of atelectasis and hypoxia • Decreased reserves in presence of adverse respiratory events from decreased gas exchange and pulmonary mechanics
Hepatic System	• 10% decrease in hepatic blood flow per decade of life • 20%-40% decrease in liver mass in elderly patients[185]	• Anesthetic drugs metabolized by hepatic microsomal enzymes have reduced metabolism (up to 40% by age 80 yr) • Clearance of drugs where metabolism is limited by flow to the liver may be reduced by 30%-40%. Drugs that are highly extracted by the liver or highly protein bound (e.g., midazolam, fentanyl, lidocaine, and propofol) are likely to be more affected[190] • Decreased: onset/effectiveness of prodrugs (e.g., angiotensin-converting enzyme inhibitors)
Renal System	• Decreased renal mass and number of nephrons • Reduced renal blood flow (30%-50% by age 70 yr) and glomerular filtration rate[191,192] • Reduced concentrating ability	• High urine volume is required to excrete waste • May be prone to volume overload and pulmonary edema • Less able to respond to changes in sodium load • Less able to conserve water under conditions of water deprivation. More prone to hyponatremia
Body Composition	• 10%-15% decrease in total body water[193] • 20%-40% increase in body fat increases with decrease in muscle mass[190] • Decreased blood albumin concentration	• A decrease in initial distribution volume can lead to higher anesthetic drug plasma concentrations after intravenous bolus administration[185] • Lipid-soluble anesthetic drugs may have a larger distribution that can prolong effect • Increase in the unbound fraction of selected drugs (e.g., warfarin, phenytoin). Of note, other drugs are primarily bound to α_1-acid glycoproteins (e.g., lidocaine)[194]

From [118]

In clinical PK [118–121], practical consequences of decreased total body water (10–15%), increased fat content (up to 40%), and reduced lean body mass, also able to impact pharmacodynamics, are

1. Higher *Volume of distribution* of fat-soluble drugs, main consequence being increased dosage of highly lipophilic drugs; however, due to a decreased metabolism and increased half-life, accumulation is possible and should be considered;
2. Lower V_d of hydrophilic agents in presence of reduced central circulating blood volume, main consequences being higher peak plasma concentration with amplified systemic pharmacodynamic effects, in particular for some anesthetics, making reduced loading doses mandatory [118–121];
3. Structural protein changes and decreased protein synthesis, in particular, a reduced plasma albumin concentration: free drug concentration is increased and PD effects for the anesthetics are amplified.

As above alluded to, reduced end-organs function and reserve could affect both *drug metabolism*, primarily performed by the liver, and *parent drug and metabolites excretion,* mainly performed by the kidneys (other routes of elimination are skin, lungs, feces, and chemical degradation) [121]. Half-life of many compounds could be prolonged: among them are some anesthetics (an example is fentanyl). However, the real impact of aging on hepatic metabolic processes is still not completely understood, and under extensive investigations. Half-life of compounds excreted by the kidneys is prolonged, leading to an increased drug concentration at a steady state. Compounds excreted by the kidneys and eliminated unchanged deserve an appropriate reduction in their dosage. Less clear and less studied in the elderly population is the role of lungs in anesthetic drug metabolism [120].

In elderly patients, a prudent reduction of IV administered anesthetic agents (fentanyl, midazolam, propofol are relevant examples) is warranted, due to an increased sensitivity: main reasons are PK/PD modifications, different drug disposition, reduced circulating blood volume, in particular, reduced central volume and decreased end organs perfusion [118–121]. Peculiar are the changes reported for the brain, with microvessel deformities, decreased perfusion, increased blood-brain barrier permeability [118, 119]. Older patients are more sensitive to inhaled anesthetics (IAs): widely accepted since long is the use of a reduced minimum alveolar concentration (MAC) [118, 120]. Reduced cardiac output (CO) is not uncommon in the elderly patients: CO can be further reduced by the effect of IV anesthetics. Low cardiac output could reduce V_d, may decrease end-organs perfusion (slowing drug total clearance, as for propofol and etomidate), and might generate higher than expected peak drug concentrations. The reduction of pulmonary blood flow may increase end tidal IAs concentration, amplifying the systemic effects of volatile anesthetics [118–121].

6.6 Neuromuscular Blocking Agents (NMBAs) and the Elderly Surgical Patient

NMBAs are classified, according to the action on the acetylcholine nicotinic receptors (AChRs) at the neuromuscular junction (NMJ), in *depolarizing* and *non-depolarizing* compounds [119, 120, 122, 123].

In general, in older patients the onset time of NMBAs is prolonged. To speed up the process, an increased intubating dose ($ED_{95} \times 2–3$) could reduce the delay of onset, but the recovery time will be prolonged [119, 120, 124, 125].

As evident, NMBAs mandate quantitative neuromuscular monitoring (NMM) for their optimal intraoperative use and to avoid residual neuromuscular blockade [126, 127]: the PK modifications introduced by the aging process give further relevance to NMM, whose use is now endorsed by many anesthesiological scientific societies [119, 128–130]. Train-of-four stimulation (TOF) is the most common test used in clinical practice: TOFr (T4/T1) above 0.9 is the value associated with a safe extubation [128–130]. Being beyond the aims of this chapter, we invite the interested reader for a complete and comprehensive review of neuromuscular physiology and pharmacology to refer to *Martyn JAJ. Neuromuscular physiology and pharmacology. Chapt 18 (pp. 423–43) in Miller's Anesthesia. VIII Ed. RD Miller, LI Eriksson, L Fleisher, JP Wiener Kornish, M Cohen and WL Young Editors. Elsevier 2015* and to *Ortega R, Brull JS, Prielipp R, Gutierrez A, De La Cruz R, Conley MC. Monitoring neuromuscular function. N Engl J Med, 2018;378:e6, quoted in the references.*

6.6.1 Succinylcholine (SCh, suxamethonium)

SCh is composed of two ACh molecules linked through the acetate methyl groups. The presence of two quaternary ammonium cations mimics the quaternary nitrogen of ACh and the affinity for nicotinic receptors on NMJ. SCh acts as a partial antagonist by binding to the two α1 subunits of the AChR, resulting in a much longer and persistent postsynaptic membrane depolarization, compared to the rapidly degraded ACh. SCh in a dose of 1–1.5 mg/kg ensures in 60 s the onset of flaccid paralysis, usually preceded by *fasciculations.* In patients with normal pseudocholinesterases (CHE), recovery of muscle tone (90%) occurs in 7–13 min. Half-life of SCh is less than 1 min and volume of distribution (V_d) is high (>30 mL/kg): in the elderly, onset time may be prolonged, while in older frail patients duration of action could be increased, particularly in case of low CHE level, usually due to reduced synthesis [118–120].

SCh is contraindicated in Multiple Sclerosis, Lateral Amyotrophic Sclerosis (LAS), muscular dystrophies, in critically ill patients suffering from Critically Ill polyneuropathy (CIP), Guillain-Barrè syndrome, stroke sequelae, burns, physical trauma, and brain injury in polytrauma patients. Side effects associated with SCh (mainly dysrhythmias, extreme bradycardia included, hyperkalemia, malignant hyperthermia, increased intraocular, and intracranial pressure) could be enhanced in the elderly [119, 122, 123, 131–133]. The use of SCh is now declining: the rapidly acting non-depolarizing NMBA, rocuronium, and its specific antagonist (sugammadex), together with the relevant side effects make the use of SCh less common even in emergency intubation. High dose rocuronium is nowadays an appealing and safer option for this challenging situation [133, 134].

6.7 Non-depolarizing Neuromuscular Blocking Agents (NDNMBAs)

N*on-depolarizing* agents are classified according to their ***chemical structure*** (*steroidal vs. benzylisoquinoline derivatives*) as well as their ***duration of action*** (*short, intermediate, long-acting compounds*). Non-depolarizing NMBAs (NDNMBAs) include ***aminosteroids*** (mainly *vecuronium*, *rocuronium, and pancuronium* pulled from the market in the majority of the developed countries), and ***benzylisoquinoline derivatives***: the short-acting *mivacurium,* very seldom used, and intermediate-acting agents *atracurium* and *cisatracurium* [119, 122, 123, 131–133].

Generally speaking, for all NDNMBAs the process of aging may consistently impact PK parameters, considerably less being the changes related to dynamic variables (PD) [119, 120]. In fact, according to Matteo et al. [135], the process of aging has minimal influence on receptor sensitivity (PD), but, due to the relevant PK modifications, should be responsible for the different clinical effects recorded in the elderly population [120].

6.8 Aminosteroids (ASs)

Due to aging process, V_d and total clearance are reduced and for the reduced redistribution, more drug is present in the central compartments. Protein binding, low for ASs, is not affected. These specific PK changes are able to prolong ASs action in the elderly. *Vecuronium (VEC)* is characterized by unchanged V_d and reduced metabolization (mainly hepatic). It is excreted unchanged 40% in the bile and 30% in the urine. Due to the decreased renal and hepatic perfusion of the elderly, total clearance is reduced by 30%, prolonging the duration of action and recovery time. Dose-to-effect titration, instead of fixed doses at fixed times, should optimize the recovery time [12, 120, 131–133]. *Rocuronium (ROC)*, whose use is now increasing in clinical practice, has minimal hepatic metabolism and no active metabolite: it is mainly eliminated in the bile (75%), with a minor urine elimination (close to 10%). In elderly patients due to a reduced total clearance (30%), half-life of ROC is longer, prolonging the duration of action [119, 120]: this effect, evident after the first intubating dose, mandates NMM to optimize its intraoperative use [126, 127, 134–137]. Reversal of both VEC and ROC is today eased by the use of sugammadex, an efficient and safer alternative (if and when appropriate) to acetylcholinesterase inhibitors (ACEIs) [136].

6.9 Benzylisoquinolin (BIQ) Derivatives

The aging processes alter PK parameters of BIQ derivatives, with reduced clearance and increased elimination half-life [119, 120]: recovery time could be increased. *Atracurium* (a mixture of ten stereoisomers, ATR) and *Cisatracurium* (the cis–cis isomer of atracurium, CIS), are the two BIQ compounds more frequently used. ATR, due to histamine release and more frequent allergic reactions, is now less used in favor of CIS. Both ATR and CIS have medium to high protein binding, concurring in the elderly to increase V_d [119, 120]. Their peculiar chemical structure enables spontaneous degradation by nonspecific esterase hydrolysis, and nonenzymatic pH and temperature-dependent degradation (the Hofmann reaction). While spontaneous degradation accounts for 80% for CIS (renal elimination is close to 15%), ATR has up to 50% renal elimination. NMM is mandatory for the optimal intraoperative use, to avoid residual neuromuscular blockade and related complications [138, 139] and for proper use of reversal agents: for BIQs, ACEIs (mainly neostigmine) constitute the only available option [126, 127, 139].

6.10 Reversal of Neuromuscular Blockers

The most feared consequence of the use of neuromuscular blockers is postoperative residual blockade: according to Murphy et al. [140] its incidence and the related complications (among others, airway obstruction, hypoxia, acute respiratory failure) [140, 141] could be doubled in older patients. Perioperative NMM is again warranted for an optimal drug management [119, 120, 126, 127, 139]. When needed, anticholinesterase drugs, increasing Ach availability at NMJ, ease and speed up recovery from all NDNMBAs: neostigmine, the drug of choice, has low lipid solubility leading to an increased V_d, and a longer duration of action. Atropine or glycopyrrolate are given to reduce/prevent adverse cholinergic effects [133].

Sugammadex (SUG), the first selective ASs binding agent, is the new way to reverse VEC and ROC action [133, 136, 140, 141]. This modified gamma cyclodextrin has been specifically designed to "encapsulate" free circulating ASs forming an Ass–SUG complex, excreted primarily by the kidneys [122, 123, 131]. In the elderly, due to the reduced renal function, clearance may be reduced, with a possible prolongation of half-life, duration of action, and time for reversal. The clinical relevance of these changes is still under discussion [119, 120]. According to Kadoi et al. [142] TOFr >0.9 took longer time to be recorded in the elderly when compared to young individuals. Bradycardia and anaphylaxis reactions, even if rare, have been reported; however, the global profile seems to be safe also in older patients [136].

6.11 Opioids

Depending on country, hospital, or department, a large variety of opioids is used, most of which are known to have different pharmacokinetic (PK) and pharmacodynamic (PD) properties. Due to the changes in PK/PD properties introduced by aging, opioids, particularly those cleared by the kidneys and metabolized to active substances, should be used with caution: meperidine [143] and morphine are examples. Apart from sufentanil [144] large part of the other opioids, including Remifentanil [145], show in their pK profile a prolonged clearance [145]. Fentanyl is very commonly used in the intraoperative period. This opioid is mainly metabolized by the liver. Relevant changes in pK characteristics in the elderly are well known since mid-1980s, when a study clearly demonstrated the need for a 50% dose reduction in young patients when compared to elderly individuals. The same study demonstrated that changes in PK parameters introduced by the increasing age were responsible for the dose readjustment [146]. Morphine is one of the most often used drugs in the perioperative period. Among the changes in PK properties introduced by aging are the changes in V_d, reduced by 50%. Furthermore, metabolism of morphine results in active metabolites morphine-3-glucuronide and morphine-6-glucuronide: in the elderly patient the renal clearance is decreased, with longer duration of action, and possible side effects. Clearance of remifentanil is independent of liver and kidney metabolism. The fast degradation by blood and tissue esterases is the reason for its short duration of action. Reduced enzyme activity and the lower V_d introduced by aging should explain the initially higher peak concentrations [147]. The hypnotic effect is more pronounced. According to the relevant changes introduced by the process on PK/PD profiles, the elderly patient might experience more pronounced side effects to the drugs, such as sedative, respiratory or circulatory depressant, or analgesic effects [148, 149]. Furthermore, the frequently seen comorbidities, including reduced function of the clearance organs will prolong the drug effects and side effects. Especially respiratory depression is one of the major concerns in older patients [150]. Therefore, multimodal therapy including the use and combination with regional anesthesia in order to reduce amount of opioids becomes a relevant option. According to pK properties, the most appropriate intraoperative opioid for elderly patients is perhaps remifentanil, due to its short duration of action and its renal and liver independent clearance. Infusion rates should be reduced by one third [145], being aware of the fact that it has a slower onset of action. In young adults, usually an onset of around 90 s is observed, whereas up to 2–3 min in the elderly can be expected.

A general and wise advice for the use of opioids in the elderly patient in emergency is to use them “low and slow”. Opioids should be carefully chosen according to the patient’s comorbidities, and PK/PD properties, and appropriately and wisely titrated. Longer intervals between the doses must be considered and the total amount of drugs should be reduced by 25–50%. Since long the multimodal approach has gained more and more attention, due to the documented improvements in the outcome after various surgical interventions [151–153]. By choosing different analgesics targeting different receptors the overall dosage of each drug can be reduced and the total amount of opioids decreased, resulting in less side effects [154]. In adding nonsteroidal anti-inflammatory drugs (NSAIDs), widely used in the United States [155], the total requirement of central opioids, and accordingly their side effects, are reduced [156]. However, caution should be used with NSAIDs in the elderly, due to the possible relevant side effects. A wise behavior built on a basic but solid PK/PD knowledge of the pharmacological armamentarium is mandatory for the anesthesiologist (or the emergency physician) facing the elderly in the emergency setting. In fact, it was clearly demonstrated that reducing the side effects of the drugs improved both patient satisfaction and quality of recovery improved [157, 158].

6.12 Propofol

The PK/PD features as well as metabolism and forensic aspects of propofol are described extensively elsewhere [159]. Propofol has been the most commonly used intravenous hypnotic for more than 30 years [160–164] since it was made commercially available in the mid-1980s [165]. Its major advantages are a short context-sensitive and rapid terminal half-life time as well as its potentially antiemetic properties [165–168]. Propofol is used for a wide range of anesthesiological procedures. It is suitable for procedural sedation [169], sedation on the intensive care unit [170] and general anesthesia [159]. As a short-acting substance, it is favorable in outpatient anesthesia [171]. In healthy adults younger than 55 years of age, an induction dose of 2–2.5 mg/kg is recommended. 6–12 mg/kg/h is recommended when propofol is used in TIVA (total intravenous anesthesia) mode. Elderly and critically ill patients are more sensitive to propofol. The underlying reason are changes in PK/PD properties of propofol, induced by the aging process [172] resulting in reduced drug clearance, increased plasma levels, and a consequent increased sensitivity [172–175]. According to the most recent literature, mechanism of action of propofol at the cellular level enhances the $GABA_A$ receptor activity through hyperpolarization of the cell membranes, leading to a loss of consciousness through a reduction in the higher order networks activity (and auditory networks): in other words, to an increased brain sensitivity [164]. In fact, the same drug concentration leads, among other changes, to deeper EEG stages. Simultaneously, the time to reach deeper anesthetic stages, as well as the time for recovery, may be prolonged [176]. Changes in pharmacodynamics are displayed in an enhanced effect of the same drug concentration in the elderly. Pharmacodynamic alterations are associated with a reduction in clearance and volume of the central compartment. As a matter of fact a reduction in drug dosage is needed in the elderly population [177]: a general rule of thumb is to reduce by 25–50% the dosage, as in clinical practice the tendency seems to be an overdosage in the elderly population [178–180]. In addition to a reduction of the propofol dosage, a decrease in the speed of induction as well as a decreased infusion rate during TCI (TIVA) is warranted [181]. Concerning the infusion rate, a 75-year-old patient would only require about 50% for the TCI infusion rate of a patient in the mid-20s. Furthermore, when continuous propofol infusions are used, it should be considered that the context-sensitive half-time of any given drug is also changing with age (20–30 min in young patients compared to 1–2 h in the elderly patient) [182]. However, most of the studies included predominantly healthy older and not fragile patients. Studies including the very elderly patients, above 80 years of age, are scarce and the indexed patients are very few at best [183]. Even though large part of the anesthetists are aware of the reduced requirement of anesthetics in the elderly population, studies and surveys are able to show that safety dosage limits are frequently ignored, making mandatory a strong recall on this item [178, 179, 184].

6.13 Etomidate

Etomidate has been first described in the literature in the mid-1960s [185] and has been used from the beginning of 1972 [186, 187] until replaced more and more by propofol.

Its great benefit is a minimal negative influence on the cardiovascular system. The changes in heart rate and blood pressure are unremarkable. Therefore, it has neither influence on the sympathetic tone nor on the myocardial function [188, 189], even in patients with valvular or ischemic heart diseases [190–194]. Because of its extraordinary hemodynamic properties, it has been used by emergency medicine physicians as the drug of choice for rapid sequence intubation [195–197]. In addition to that, it causes no histamine release and rarely allergic reactions. Compared to other drugs pharmacodynamics in etomidate is not age-dependent. On the contrary, clearance is prolonged, elimination half-life is increased, and initial volume of distribution, as well as protein binding, is decreased [198–200].

In summary, the plasma drug levels are significantly higher in the elderly patient. Accordingly, a reduction of 50% and more is required in an 80-year-old patient compared to a 20-year-old patient [199]. Therefore, a reduction of the induction dose from 0.3–0.4 mg/kg down to 0.2 mg/kg in the elderly surgical population is recommended. Changes in cerebral blood flow, $CMRO_2$ as well as intracranial pressure are similar in etomidate and propofol. However, mean arterial pressure is reduced to a lesser extent [201]. Even though etomidate is usually not compromising the hemodynamic parameters during induction of anesthesia, it is known to significantly suppress the hormone release of the adrenal gland up to 3 days [202]. However, the side effect does not seem to be associated with increased mortality [203].

6.14 Volatile Anesthetics

Dealing with the maintenance of general anesthesia, there is no proven benefit of volatile anesthetics over TCI, according to a recent Cochrane review. As recently stated by Miller et al., comparing the effect of inhalational and intravenous maintenance of anesthesia on the cognitive outcome in elderly people undergoing noncardiac surgery, no clear effect was evident on hospital stay, postoperative delirium, postoperative cognitive dysfunction, or mortality [204]. However, during maintenance of anesthesia in the elderly, the anesthetic gases seem to offer some advantages. Volatile anesthetics in general are eliminated through the lungs, and to a various extent in the blood: blood solubility has been shown to be greater in aged patients [205]. This peculiarity, in combination with low-blood solubility, as is for desflurane, is of the utmost importance in the elderly patients. As above alluded to, the aging process is characterized by slower and less predictable metabolism in combination with a reduced central volume of distribution, a PK feature associated, after bolus injection, with higher plasma concentration of an intravenous anesthetic. Elderly patients tend to have a slow wash-in time of high soluble volatile anesthetics due to the increased fat tissue as well as a decrease in minute ventilation. While this cannot be demonstrated for low soluble agents like desflurane, isoflurane shows a normal wash-in time and no major difference in the wash-in time of younger and elderly patients [206]. Low soluble gases like desflurane are associated with a great hemodynamic stability in young adults [207]: on the contrary, a study comparing desflurane with isoflurane in geriatric patients could not confirm this peculiarity [208]. Whereas there is no consensus in the literature concerning whether the recovery time from anesthesia is dependent on the type of volatile anesthetic [209, 210], the length of stay in the postanesthesia care unit seems to be shortened in young adults [208] as well as the elderly population.

However, according to a general rule of thumb, the anesthetic requirement of volatile anesthetics in young adults is about 20% higher than needed in the very elderly [211]. According to some authorities, caution should be considered with desflurane in elderly cardiac patients due to a relevant, even if transient, orthosympathetic cardiovascular stimulation: in case of rapid increase of DES concentrations, signs of sympathetic activation (tachycardia and hypertension) were associated with ST segment changes [212–214].

6.15 Perioperative Fluid Management: the Hemodynamic Challenge of the Acute Elderly Surgical Patient

6.15.1 Fluid and Hemodynamic Management

Aim of a rational fluid management (FM) is the maintenance of the euvolemic status, to ensure normal cellular perfusion while avoiding or preventing salt and water overload and interstitial edema: FM affects the outcome of surgical patients [215–218]. Main targets of intraoperative fluid therapy are the correction of dehydratation, if and when present, and the treatment of hypovolemia to avoid organ hypoperfusion and related complications. "Zero fluid balance" is the goal of the so-called restrictive fluid therapy, even if very recent advices call for more cautious use of a too restrictive intraoperative policy and for a rational goal-directed fluid therapy. Instead, restrictive strategies are to be considered in the postoperative period [217]. During general anesthesia, with an appropriate modality of mechanical ventilation, intraoperative fluid management should be guided by minimally invasive hemodynamic monitoring and fluid challenge using volume responsiveness and dynamic parameters (changes of Pulse Pressure Variation, PPV, and Stroke Volume Variation, derived from heart-lung interaction, or of Stroke Volume, SV): in other words, the goal-directed therapy (GDT) [218, 219]. However, GDT, able to impact morbidity, LOS, and costs, does not reduce mortality in noncardiac surgery. To be underlined, the most recent reviews [216–219] claim for a limited pooled sensitivity and specificity of PPV and SVV. Intraoperative hypotension is a relevant problem, in general, but particularly in elderly patients: a correlation exists between intraoperative hypotension and postoperative complications (major cardiac, neurological, renal events, mortality) [220–223]. Whether absolute (Mean Arterial Pressure below 65 mmHg for more than 5 min) or relative hypotension (<10–20% of baseline pressure) is responsible for the adverse events is still under discussion: specific blood pressure targets are under research and eagerly awaited [221–223]. Invasive arterial monitoring might be of choice in high-risk patients [218]. Cardiac output may be an issue in the elderly: a trial (FLOELA, The FLuid Optimisation in Emergency Laparotomy) is currently underway to establish the effect of cardiac output monitoring in emergency laparotomy patients [224].

6.16 Type of Fluids

According to the most recent literature, crystalloids are the fluid to be used in the operative setting: balanced solutions are to be preferred over normal saline [215–217]. Colloids (in particular hydroxyethyl starches), used in large part of the surgical studies, were banned from the ICU due to increased risk of acute renal failure and possibly death. However, recent meta-analysis does not confirm these results in surgical patients. The discussion is (and will be) a hotly debated topic [216, 217]. Normal saline (0.9%), with 154 mmol of both sodium and chloride, has zero strong ion difference (SID): its infusion in blood in large volumes and/or as exclusive fluid further reduces SID, due to hyperchloremia. Adverse effects and extreme consequences of normal saline overload are, apart from the obvious hemodynamic consequences of fluid overload, hyperchloremia, metabolic acidosis, and acute kidney injury (supposed due to reduced renal perfusion). Particularly prone to these complications are, among others, elderly patients, already at risk for heart and kidney function impairment. On the contrary, balanced solutions with high SID (Plasmalyte Baxter, Hartmann solution, Ringer lactate or Ringer acetate), due to the net proton consumption, are the crystalloids of choice for both fluid resuscitation and maintenance, because able to avoid acidosis. However, to be underlined once again is the recent conclusion of a systematic review in surgical patients: robust conclusions on major morbidity and mortality associated with buffered versus non-buffered perioperative fluid choices are still lacking [225]. So-called biochemical benefits are a significant reduction in postoperative hyperchloraemia and metabolic acidosis.

6.17 Anemia and the Elderly Surgical Patient

Anemia (hemoglobin below 13 g/dL, according to the WHO definition) is reported in more than half of the acute elderly patients. Perioperative anemia leads to impaired oxygen supply with a risk of vital organ ischemia [226–228]. Elderly frail patients, if compared to fit adult individuals, have less compensatory mechanisms because of multiple comorbidities and age-related decline of functional reserves: symptoms and tolerance of this state are closely correlated with the aging process and comorbidities [220]. Functional dynamic transfusion triggers (central venous saturation, $SCvO_2$, as an example) and not the sole hemoglobin level should base the decision to transfuse [226, 227]. Even if adverse events of red blood cell transfusion are more frequent in older patients, several studies have demonstrated lower mortality and better overall outcome with liberal than restrictive transfusion strategies, particularly in the emergency setting: this contradicts current restrictive transfusion approaches [228]. The LIBERAL trial [227] should (hopefully) strongly contribute to an evidence-based transfusion practice for the geriatric population.

6.18 Conclusion

Emergency surgery and in particular laparotomies are performed with increased frequency in elderly patients. Complexity due to frailty, comorbidities, and polypharmacological treatments is associated with high perioperative morbidity and high mortality [229–232]. Together with standardized pathways with evidence-based interventions and dedicated bundles, updated pharmacological and pathophysiological knowledges are pivotal for anesthesiologists and surgeons involved in the urgent/emergent treatment of the older surgical patient.

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Biology of Perioperative Nutrition: An Update

7

Rifat Latifi

7.1 Introduction

The publication of this book coincides with the passing of my hero, Dr. Stanley Dudrick who pioneered parenteral nutrition in the 1960s (Fig. 7.1). While this chapter in a broad sense describes nutrition overall, and does focus on total parenteral nutrition (TPN), it is clear that TPN quickly improves the nitrogen balance; this

Fig. 7.1 Prof. Stanley J. Dudrick, MD, FACS, April 9, 1934–January 18, 2020

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results in a reduction in the noninfectious complication in severely malnourished patients, and is used primarily in patients who cannot tolerate enteral nutrition.

Malnutrition in hospitalized surgical patients is present in as much as 66.88% of all hospitalized populations [1]. During the perioperative period, the goal is to evaluate the nutritional status of the patient, treat malnutrition to optimize nutritional status, or prevent further deterioration of nutritional and metabolic status. The impact of malnutrition during the perioperative period is significant, and it results in decreased immune function, an increased risk of hospital-acquired infections, impaired respiratory function, increased pressure ulcer disease, and an increased overall risk of mortality [2]. Understanding the surgical stress response is critical to evaluate the importance of nutrition during the early postoperative period in surgical recovery. The surgery itself results in a metabolic cascade known as the surgical stress response. It is characterized by metabolic, hormonal, hematological, and immunological changes [3]. The extent of these changes depends on the magnitude of surgical procedure and duration of surgical injury [4].

Surgical stress response results in clinical consequences involving nutrition, and including hyperglycemia and whole-body protein catabolism. Catabolism results in the wasting of lean tissue that releases amino acids into circulation, which allow the synthesis of acute phase reactants, as well as the production of glucose via gluconeogenesis in the liver, while insulin resistance can result in hyperglycemia. To maintain the physiological integrity and strength, preoperative energy reserves, such as lean body mass, are required to support the stress-induced mobilization of reserves [5].

7.2 Specific Metabolic Changes in Critically Ill Patients

7.2.1 Protein and Nitrogen Metabolism

Severely injured and critically ill patients characteristically demonstrate significant muscle losses and consequently are in the negative nitrogen balance [6]. During critical illness, dietary amino acid requirements are increased two or three times as a result of hypercatabolism and inefficient reutilization of endogenous nitrogen. Furthermore, amino acids are redistributed from peripheral tissues to splanchnic organs to maintain protein synthesis in the gut mucosa and immune system. Although different tissues have different rates of protein synthesis and respond differently to stress and trauma, both muscle protein and albumin synthesis rates correlate with the metabolic status and severity of the disease. The stressed, but well-nourished, patient tolerates a brief period of accentuated proteolysis, ureagenesis, and negative nitrogen balance. If, on the other hand, the patient is malnourished prior to injury or surgery, or develops a complication that precludes adequate oral intake, or if a patient sustains a prolonged catabolic phase, then special nutritional support is indicated.

Metabolic response to injury is the striking increase in protein catabolism along with a marked increase in urinary losses of nitrogen, phosphorus, sulfur, potassium, magnesium, and creatinine. Skeletal muscle and nitrogen losses following injury may occur secondary to the actual destruction of tissue by injury, blood loss, and exudates from wounds and muscle wasting secondary to atrophy. The process of increased nitrogen losses correlates with an increased metabolic rate, which peaks several days after injury and gradually returns towards normal over several weeks [7–11]. This phenomenon occurs consistently following major fractures or major blunt injury, burns, sepsis, and various injuries [12–16]. Critically ill patients with sepsis have a variable, but normal muscle protein synthesis (PS) rate, whereas protein degradation rates are dramatically increased (up to 160%), and it is thought to be due to increased activities of both the proteasome and lysosomal proteolytic systems [17]. Muscle wasting is the result of muscle protein breakdowns exceeding protein synthesis, and it is the result of a myriad of ICU-related factors including inflammation, altered energy and substrate metabolism, immobilization, and drug administration (i.e., corticosteroids, sedatives, and muscle relaxants) [18]. Other authors have also demonstrated that critically ill patients with multiple organ failure have an increased protein turnover [19].

The mechanism for net protein degradation is not entirely clear, although hormonal effects of insulin resistance, cortisol effects, and proinflammatory cytokines activity have synergistic effects. Diminished activity of antioxidants, such as glutathione, may affect protein stability within the cell itself. Metabolic response to severe surgical illness is associated with mobilization and utilization of nutrient substrates such as fatty acids, amino acids, and glucose. Although there is an orchestrated redistribution of body protein from the carcass to visceral organs, the rates of tissue protein synthesis vary with different trauma; however, it correlates with clinical status, and overall metabolic indices, clearly exacerbated during critical illness and is directly influenced by the illness itself, the PO_2, pH, and hemoglobin [20]. As protein is broken down, 3-methylhistidine is released and excreted unchanged by the kidneys, especially following critical injury, burns, postoperative trauma, infections, and other critical illness [16].

Understanding the complex metabolic interactions involved in muscle wasting will be key to design targeted, individualized interventions with a higher chance of success [21]. Nevertheless, it has become clear that muscle mass and function during and following critical illness undergoes three phases (Fig. 7.2): a catabolic phase

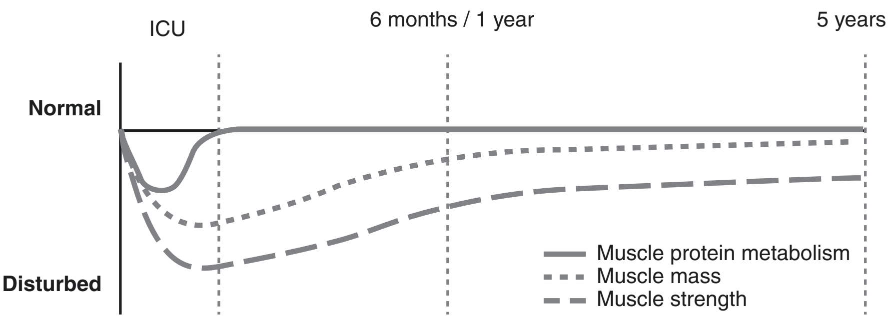

Fig. 7.2 Protein metabolism in critical illness and impact on muscle mass and function. Changes over time in muscle protein metabolism, mass, and function, distinguishes a short catabolic phase during ICU stay with subsequent persistent impact on muscle mass and function. Put together, this timeline further emphasizes the long-lasting impact of the relative short period of disturbed protein metabolism

where muscle protein catabolism subsequently drives loss of muscle mass and function; a recovery phase where protein balance is restored followed by some recovery in mass and to a lesser extent function; and an enduring state where recovery of muscle mass and function stagnate, and muscle function, is persistently lower prior to ICU admission [21].

In summary, muscle wasting during critical illness is the consequence of muscle protein breakdown exceeding protein synthesis, and this has substantial effects during the ICU stay and post ICU discharge. Once we better understand the muscle wasting, we may be able to create more effective nutritional formulas to prevent, and perhaps speed up, the process of muscle synthesis and recovery and prevent serious complications arriving from this process.

7.3 Amino Acid Metabolism

Specific nutrients such as glutamine, arginine, branched-chain amino acids, and others have been at the center of research and discussion for decades and have continued to be recommended with enthusiasm over the years. Despite the diligent efforts by many societies and medical groups to publish updated recommendations related to the usefulness of these individual nutrients, and declaring level I evidence, new research sometimes brings more questions and less answers to guide our practice. The role of amino acids (AA) in human physiology is crucial, but the specific roles and clinical implications of each amino acid in the perioperative period are always evolving [22]. Although plasma amino acid levels have been measured in critically ill and injured patients in an effort to identify specific changes related to the catabolic response, the results have been inconsistent [23].

The mobilization of amino acids from muscle protein leads to an irretrievable loss of nitrogen from the body in the form of urea, ammonia, uric acid, creatinine, and other excreted compounds. If left uncorrected, the adverse consequences for the critically ill patients are at a rapid loss of muscle mass and subsequent marked debility. In a recent study, Liebau et al. addressed the question: can short-term infusion of infusion improve protein balance in critically ill patients?[24] These authors studied the effects of parenteral amino acid supplementation (equivalent to 1 g/kg/day) over the course of 3 h on whole-body protein turnover in 13 critically ill patients (once) in the ICU. They found that infusion of parenteral amino acids over a 3 h period improved whole-body protein balance and did not increase amino acid oxidation rates in critically ill patients during the early phase (first week) of critical illness [24].

All amino acids are required for optimal protein synthesis; however, alanine and glutamine are the major carriers of nitrogen from muscle and constitute as much as 70% of the amino acids released from skeletal muscle following injury [25]. Alanine is a major substrate for production of glucose by the liver, and during that process, the nitrogen released is incorporated into urea. This represents the final breakdown step of the protein and results in an irreversible loss of nitrogen from the body's metabolic pool. Glutamine, a nonessential amino acid, serves as an important respiratory substrate for the enterocytes and other rapidly diving cells, including the bone marrow, endothelial cells, and proliferating cells in wounds and areas of inflammation [26, 27].

Following surgical interventions, glutamine consumption by the gastrointestinal tract is greatly increased [28, 29]. Glutamine has been identified as primary fuel for enterocytes, and for other rapidly dividing masses of cells where it is converted to alanine. The utilization of glutamine by the intestine as an oxidative fuel has a sparing effect on glucose. During the sepsis, glutamine depletion is even more severe and lasts longer than that associated with hypercatabolism following injury. In sepsis, the lung and kidney, in addition to the skeletal muscle, becomes an organ of net glutamine release [30, 31]. Furthermore, during the sepsis the liver has increased glutamine uptakes, and it becomes the primary organ for glutamine utilization [31]. In the presence of endotoxemia, glutamine may be used in the liver for gluconeogenesis, ureagenesis, and synthesis of proteins, nucleotides, and glutathione [32, 33].

Following surgery, severe injury, or sepsis, the rapid fall in the concentration of glutamine in the plasma and in the intracellular pool is greater than that of any other amino acid and is inversely correlated with the severity of the underlying insult. It is reversed only late in the course of recovery [33]. This marked decline in glutamine concentrations in blood and tissues during critical illness indicates that glutamine is being consumed at a greater rate than in endogenous synthesis. Thus, it has been hypothesized that glutamine is a conditionally essential nutrient, especially following injury. Glutamine supplementation has been shown to exert trophic effects on intestinal mucosa. TPN solutions enriched with glutamine [34] increase jejuna mucosal weight, nitrogen and DNA content, and significantly decrease atrophy; in addition, it has been proven beneficial for patients with intestinal mucosal injury secondary to chemotherapy and radiation [35, 36]. Reduction of hepatic steatosis [37], pancreatic atrophy [38], and in bacterial translocation from the gut [39], associated with standard TPN solutions have been reported with the use of glutamine supplemented TPN solutions. Glutamine also improves the nitrogen balance and reduces the skeletal muscle glutamine loss in patients following elective cholecystectomy [32] and other major surgeries. Administration of glutamine in TPN as glutamine-containing dipeptides has decreased the incidence of infections in bone marrow transplant patients [40].

Supplementation of glutamine has become controversial [41]. Nonetheless, given the important role that glutamine plays, and the numerous observations that its levels are depleted in some patient groups during critical illness, it has been the recommendation of the European Society for Parenteral and Enteral Nutrition to include glutamine in enteral nutritional regimens for patients suffering from trauma and burns [42]; whereas, the Society of Critical Care Medicine and the American Society for Parenteral and Enteral Nutrition have additionally included other ICU patients on mechanical ventilation as well [43].

However, subsequently, the Canadian Clinical Practice Guidelines Committee recommended that enteral glutamine no longer be used in critically ill patients [44]. This follows their downgraded recommendation in 2013 regarding the use of glutamine supplementation of parenteral nutrition in critically ill patients with shock and multiple organ failure [20]. This review aims to discuss some of the articles that influenced these changes and describes their potential impact on future clinical practice. Moreover, the Reducing Deaths due to Oxidative Stress (REDOXS) [45] trial was a blinded, factorial 2×2 randomized trial consisting of 1223 mechanically ventilated adult patients with multiple organ failure conducted in 40 ICUs in the United States, Canada, and Europe (i.e., Switzerland, Germany, and Belgium). The patients were randomly assigned to one of four treatment groups: glutamine, antioxidant therapy, combination of glutamine and antioxidants, or placebo. In contrast from most trials that combine glutamine with other supplements related to immunonutrition, this study design allowed for the specific effects of glutamine to be observed, with or without additional antioxidants. All the solutions were provided at a continuous rate over a 20–24 h period for up to 28 days and were administered as soon as possible after randomization. The primary outcome of the study was 28-day mortality, whereas secondary outcomes included length of stays in the ICU and hospital, infectious complication development, duration of mechanical ventilation, sequential organ failure assessment scores, and 6-month survival. The researchers found increased 28-day mortality in those who received glutamine (32.4%) as compared with those who received a placebo (27.2%). There was also a statistically significant difference in 6-month mortality between these two groups (43.7% in glutamine group vs. 37.2% in placebo). Overall, there seemed to be no benefit to the patients that received glutamine; instead, there were trends towards harm and increased stays in both the hospital and the ICU.

Another international, multicenter, double-blinded parallel group trial was performed in 14 ICUs across Europe (i.e., Germany, France, Belgium, and the Netherlands) [46] in 301 mechanically ventilated adult patients who had a BMI less than 40 kg/m^2, and no contraindications to enteral feeding. They were randomized to receive either high-protein enteral nutrition or high-protein enteral nutrition supplemented with the immune-modulating nutrients including glutamine, v-3 fatty acids, and antioxidants. The target energy requirement was 25 kcal/kg of body weight, with a maximum of 2500 kcal/day. The primary outcome of the study was the incidence of new nosocomial infections, whereas some secondary outcomes included duration of mechanical ventilation, sequential organ failure assessment scores, length of stay in the hospital and ICU, and mortality at 28 days and 6 months. There were no statistically significant differences in the incidence or duration of nosocomial infections reported between the two groups, except for the 6-month mortality rate within the subgroup of medical patients.

A recent systematic review and meta-analysis specifically looked at the effects of enteral glutamine on critically ill patients [47]. A total of 11 studies were synthesized, involving 1079 critically ill patients with diagnoses that included trauma, sepsis, and burns. Glutamine supplementation was associated with neither a reduction in hospital mortality, nor a reduction in infectious complications, and reduction of ICU LOS. To this end, the shift in recommendations related to glutamine supplementation needs to be considered in the context of the available literature presented [41].

7.4 Arginine

Arginine is considered a nonessential amino acid in the diet of healthy adults because the endogenous synthetic pathways provide adequate amounts of this amino acid. Arginine stimulates a release of growth hormone and prolactin, and also induces a marked release of insulin [48]. Supplementing the diet with arginine has been shown to improve weight gain, increase nitrogen retention, and accelerate wound healing in animals and in human beings [49]. The trophic effects of arginine on the immune system in humans have also been demonstrated [50]. In animals and humans, plasma arginine levels decrease significantly following a burn injury [51]. Experimentally, arginine and glutamine, as well as dehydroepiandrosterone, reversed the susceptibility to infections caused by prednisone and may be useful agents for preventing infections in patients treated with steroids [52].

On the other hand, there has been some controversy raised by those who thought that Arginine use might worsen hemodynamic status in critically ill patients. In contrast, Martin et al. [53] concluded in their review of literature available up to 2025 that it is clear that arginine is safe in septic patients when administered by either the enteral or parenteral route and may be beneficial to septic patients. Moreover, these authors argue that it seems to be the group of patients with persistent immunosuppressed inflammatory catabolic state (PICS) of the ICU population that may benefit from L-arginine supplementation.

The same group of authors published an elaborate series of tracer studies in a clinical trial that dealt with citrulline and L-arginine metabolism in septic patients [54]. The complex metabolic alterations noted in sepsis that contribute to reduced citrulline and L-arginine availability would suggest that L-arginine supplementation may be beneficial in the septic population. In another investigation of metabolic studies that used tracer technology, Kao et al. evaluated L-arginine in sepsis; they concluded that L-arginine might be deficient in sepsis, via inadequate de novo synthesis, but with supplementation improved end-organ perfusion [55]. Arginine supplementation in septic patients, while it may have transient hemodynamic side effects when supplied as a bolus, is safe to continuously be given the role of arginine in infection and sepsis [56] and it does not alter hemodynamic parameters [57]. In an animal model, supradietary doses of parenteral L-arginine increased shock severity, organ injury, and mortality [58].

7.5 Branched-Chain Amino Acids (BCAA)

BCAA have been a center of attention for a long period of time in a number of clinical disciplines, particularly in trauma, sepsis, liver failure, and hepatic encephalopathy. Mattick et al. [59] have reviewed all clinical studies when BCAA were used (Table 7.1). Another recent analysis [60] of six randomized clinical trials included 827 participants with hepatic encephalopathy classed as overt (12 trials) or minimal (four trials). Eight trials assessed oral BCAA supplements and seven trials assessed

Table 7.1 Clinical studies investigating the effects of amino acid-enriched nutritional supplementation on survival and recovery

Year	Author	# Pts	Condition	Duration	Administered supplements	Outcomes	Notes
1984	Manelli et al.	22	Severe burn	5 days	BCAA-enriched (41%) vs. conventional (22% BCAA) parenteral nutrition	BCAA supplementation demonstrated improvement in protein catabolism	No beneficial effect upon nitrogen loss or nitrogen balance was shown
1988	Yu et al.	12	Severe burn	48–96 h	Enteral feeding with BCAA-enriched (44%) vs. conventional egg protein formulation	BCAA-enriched feeding failed to demonstrate significant benefits in terms of protein synthesis or degradation	Cross-over design study; no parallel controls
1990	King et al.	14	Severe burn	15 days	Standard regimen (16% BCAA) vs. BCAA-enriched (31%) or a similar regimen where 65% of the leucine is replaced by KIC	Leucine enrichment reduced muscle protein breakdown compared to a standard feed, whereas KIC enrichment did not	Nitrogen balance or serum albumin levels were not significantly affected
1997	Garcia-de-Lorenzo et al.	69	Sepsis	11 days	Total parenteral nutrition, either 1.5 g amino acids/kg/day with 23% or 45% BCAA or 1.1 g/kg/day with 45% BCAA content	Lower mortality rate observed in patient groups with high BCAA loads. Higher plasma conc. of BCAAs and rapid protein turnover is shown	
1997	Griffiths et al.	84	Critically ill	6 months	Glutamine containing parenteral nutrition vs. isonitrogenous isoenergetic control	Survival at 6 months was significantly improved in patient group receiving glutamine. Total ICU and Hospital cost per survivor was reduced by half.	
2003	Marchesini et al.	174	Advanced cirrhosis	1 year	BCAA vs. lactoalbumin or maltodextrin	BCAA significantly reduced combined event rates compared with lactoalbumin and non-significantly compared with maltodextrin	Liver function tests of the patients were stable improved with BCAA treatment

2005	Muto et al.	646	Decompensated cirrhosis	2 years	Orally administered BCAA vs. diet therapy with defined daily food intake	The incidence of events decreased in the BCAA group. Serum albumin concentration increased significantly	
2007	Fukushima et al.	7	Cirrhosis	8 weeks	All subjects received oral granular preparations consisting of BCAAs alone	Basal levels observed initially were low total albumin and high oxidized/reduce albumin ratio. BCAA supplementation improved oxidized/reduced albumin ratio	No controls BCAA supplementation increased the turnover leading to reduction in its circulation half-life and therefore reduced level of oxidation
2008	Ohno et al.	27	HCV positive cirrhosis	6 months	Oral granular preparations of BCAAs vs. no supplementation	BCAA supplementation reduced production of oxidative stress and microinflammation which lead to a decreased occurrence of HCC	
2011	Ken et al.	236	Living donor liver transplantation	1 month pre-op	Oral supplementation with BCAAs 1 month before surgery or no supplementation	Incidence of bacteremia after transplantation was lower in BCAA group	

Reprinted from Wiley interdisciplinary reviews. Systems biology and medicine., Vol 5, John S.A. Mattick, Kubra Kamisoglu, Marianthi G. Lerapetritou, Ioannis P. Androulakis, and Francois Berthiaume, Branched Chain Amino Acid Supplementation: Impact on Signaling and Relevance to Critical Illness, 449–460, (2013), with permission from Francois Berthiaume intravenous BCAA. The control groups received placebo/no intervention (two trials), diets (10 trials), lactulose (two trials), or neomycin (two trials). In 15 trials, all participants had cirrhosis. The authors concluded that that BCAA had a beneficial effect on hepatic encephalopathy, but outcomes on effects on mortality, quality of life, or nutritional parameters called for additional clinical trials.

Following injury and sepsis, an energy deficit that may develop in skeletal muscle is met by oxidation of the BCAA; BCAA oxidation is increased after trauma and sepsis, and evidence indicates that skeletal muscle is the major site of BCAA degradation [61–65]. Another study has demonstrated that when critically ill patients, unable to be fed enterally, were given total parenteral nutrition fortified with BCAA of 23% and 45%, respectively as compared with standard TPN which provided 1.5 g/kg/day of protein, they had significantly love morbidity and mortality [66]. The decrease in mortality correlated with higher doses of BCAA to >0.5 g/kg/day. Furthermore, BCAA rich parenteral nutrition formulas have been shown to correct the plasma amino acids imbalance that consistently exits in critically ill patients, and improves plasma concentrations of prealbumin and retinol-binding protein in septic patients.

In a series of trauma patients, nitrogen retention, transferring level, and lymphocyte counts were all improved with BCAA supplementation. Since the concentration of BCAA is low in septic patients, probably as a result of overutilization, supplementation of feeding regimen with BCAA may be beneficial.

7.6 Nucleotides and Nucleic Acids in Nutritional Support

Nucleotides, as the building blocks of DNA and RNA, are essential to the genetic mechanism, protein synthesis, regulation, and structure. These low molecular weight, highly biological compounds are involved in virtually all biochemical processes [67–85]. They consist of a nitrogenous base, a 5-carbon sugar, and at least one phosphate group; RNA and DNA are high molecular weight, highly biological compounds that are made up of long chains of nucleotides. They form the genetic code and are essential for protein synthesis; they function as an energy source in cellular metabolism and as intermediates in biosynthetic and oxidative pathways. The synthesis of nucleotides is a major activity of the cell. Next to protein synthesis, nucleotides contain either purine or pyrimidine bases. Adenine, inosine, and quinine are purine bases while thymidine, cytosine, and uracil are pyrimidine bases. Purine nucleotides are synthesized de novo from glutamine, glycine, aspartate, CO_2, and phosophoribosyl pyrophosphate (PRPP), while pyrimidines are synthesized from aspartate or glutamine, NH_3, and CO_2. Purine nucleotides, with their high-energy phosphate side chains, are fundamental to cellular energy metabolism and are intermediaries in biosynthetic and oxidative pathways. Purine nucleotide biosynthesis produces inosine monophosphate (IMP). IMP is synthesized by the de novo pathway of prune biosynthesis from glycine and is then converted to AMP and GMP.

The three main sources of nucleotides are: dietary nucleotides, salvage of nucleotides released by intracellular metabolism, de novo synthesis from amino acids and sugars. The addition of a pentose sugar to a nitrogen base, a nucleoside, can be ribonucleoside or a deoxyribonucleoside. Nucleosides are produced by intracellular metabolism and are used for purine biosynthesis via the salvage pathway. The most common pathway is the resynthesis of IMP from inosine, which is a product of adenosine nucleotide metabolism.

The adenosine monophosphate (AMP), adenosine diphosphate (ADP), and adenosine triphosphate (ATP) are energy sources and participants in carbohydrate, protein, and lipid synthesis. Nucleotides are required in all cells undergoing proliferation, but they are especially important in tissues with rapid cell proliferation such as intestine, liver, and lymphoid tissue. T lymphocytes require nucleotides to maintain a normal cellular immune response. Various tissues in the body, such as the liver, are capable of synthesizing nucleotides de novo. When tissues are unable to synthesize purine nucleotides, purines are transported from another tissue. For example, adenosine is released from the liver and taken up by the lung in large amounts.

The small intestinal mucosa requires a constant supply of nucleotides to produce DNA and RNA. In these rapidly proliferating cells, the content of DNA and RNA must double for cell division to occur. However, in these cells, the enterocyte has a limited capacity for de nova biosynthesis. The small intestine must rely on the salvage pathway to synthesize nucleotides from nucleosides. The nucleosides inosine, adenosine, and so on, come either from the blood or from luminal nucleosides. The latter may come from the diet, and the sloughing of enterocytes, or from bacterial breakdown. In addition, nucleotides themselves can be absorbed from the intestinal lumen.

It is clear that the small intestinal mucosa relies partially on intestinal nucleotides and nucleosides to meet synthetic demands. There are at least two significant implications. The first is that diets that contain no nucleotides or nucleosides may not offer sufficient support to the intestinal mucosa in some circumstances. This includes many enteral diets, especially elemental clinically in certain enteral products. Nucleotides exert multiple protective actions on the intestinal mucosa and facilitate repair of the injured mucosa. Experimental rats receiving TPN supplemented with nucleotides displayed higher protein and DNA content in the intestinal mucosa, increased maltase activity, higher villous height, and more proliferative activity in crypt cells compared with rats receiving nucleotide-free TPN. In mice, intraperitoneal and oral administration of a mixture of nucleotides and nucleosides reduced bacterial translocation and improved repair of mucosal injuries.

Clinically, the frequency of diarrhea in children was reduced from 68% to 52% when mil formulas were supplemented with nucleotides. While the basis for this protective action is unclear, it is known that dietary nucleotides enhance intestinal epithelial proliferation and the metabolic fate of any exogenously administered nucleotide depends on its entry position in the overall pathway of purine metabolism. Nucleic acids undergo partial hydrolysis in the stomach, after which they are subjected to pancreatic nuclease to yield nucleotides. Phosphodiesterases and alkaline phosphatases cleave phosphate groups to form nucleosides. The presence of charge phosphates in nucleotides impedes their transport across cell membranes. Phosphodiesterases and alkaline phosphatases cleave phosphate groups to form nucleosides. The presence of charge phosphates in nucleotides impedes their transport across cell membranes. Phosphates remove the charged phosphates, and together with nucleotidase, facilitate transport across the cell membrane. Dietary nucleotides converge in the cell cytoplasm in the form of nucleosides, which are then used in the salvage pathway to reform nucleotides. Nucleotides may be supplied either enterally or parenterally. Parenterally administered purine and pyrimidine derivatives are effectively used throughout the salvage pathway. TPN formulas supplemented with a mixture of nucleotides and nucleoside can promote ulcer healing in rats by restoring villous architecture and accelerating cell proliferation. TPN supplemented with a mixture of nucleotides and nucleosides in animals undergoing massive intestinal resection resulted in significantly higher residual jejuna total mucosa weight, protein, DNA, RNA, and the ratio of proliferating cells per crypt as compared with a standard TPN formula. The clinical use of nucleotides in liver disease has been suggested in order to improve healing of the liver. Experimental studies have suggested beneficial effects. A mixture of nucleotides and nucleosides given subcutaneously has prevented ethionine-induced liver injury by suppressing the accumulation of triglycerides in the liver, reducing the increase of liver enzymes, and preventing the decrease of hepatic ATP concentration. In rats undergoing a 70% hepatectomy, supplementation of TPN regimens with nucleotides and nucleosides improved both nitrogen balance and whole-body protein turnover. Nucleotide supplementation was beneficial in galactosamine-induced liver injury by reducing the extent of injury histologically and by improving clinical biochemical liver indices. Currently, nucleotides are not included in standard TPN solutions; however, there are now enteral formulas fortified with nucleotide (in addition to arginine, omega-3 fatty acids, and glutamine) that are intended to enhance the immune system in patients receiving them.

The immunologic roles of nucleotides have been studied mainly in experiments with nucleotide-free diets. In the early 1890s, it was observed that renal transplant patients receiving standard nucleotide-free TPON had better graft function with few rejection episodes, and required increased doses of immunosuppressants to maintain graft function and prevent rejection. Clearly, the patients were immunosuppressed on TPN.

It was postulated that the lack of preformed nucleotides in TPN was a cause of this immunosuppressant. Animal studies have demonstrated the effects of nucleotide-free diets. These diets diminish T-cell mediated immune responses, displayed a delayed-type cutaneous hypersensitivity to various antigens, decreased mitogens, and decreased survival from systemic infections caused by Staphylococcus aureus and Candida albicans in an animal fed nucleotide-free diet. The increased susceptibility to systemic infections has been shown to reverse with RNA supplementation. Furthermore, nucleotide deficiency reduces splenic stem cell proliferation. This can be reversed with RNA supplementation. Dietary nucleotides modulate T-helper cells, mediate antibody production, and have a preferential effect on antigen-driven T-helper cell-mediated immune responses. Nucleotides and nucleosides are major essential components of all cells. The metabolic rate of nucleotides is accelerated in hypermetabolic conditions such as sepsis, trauma, or surgical stress. Substantial evidence suggests that these nutrients are conditionally essential for normal stress responses. The conditions that increase nucleotide requirements are rapid cellular proliferation, which include hepatic injury or resection, intestinal development and adaptation following massive intestinal resection, and other non-specific challenges to the host immune system.

Nucleotides are component of several “immune-enhancing” formulas that also contain glutamine, arginine, and omega 3-fatty acids. These formulas have been shown to be beneficial in multiple clinical trials. Glutamine, arginine, nucleic acid, and omega 3-fatty acid supplemental enteral feeding in severe trauma patients reduced major infection rates, decreased the use of antibiotics, and shorten hospital stays. In a prospective, randomized, placebo-controlled, double-blinded, multi-center trial of patients in the surgical intensive care unit, early enteral feeding supplemented with arginine, nucleotides, and omega 3-fatty acids was shown to reduce postoperative and wound complications. Septic patients fed early enterally with the same supplemented diet (in another double-blinded multicenter study) had a substantial reduction in the hospital stay. No clinical study has examined the beneficial effect of isolated nucleotide supplementation in enteral feeding formulas in critically ill or trauma patients. However, as a component of an immune-enhancing formula, nucleotides have a role in nutritional support of the critically ill. Nucleotides should not be administered as a calorie source, only as a promoter of protein synthesis and cellular immunity. It seems likely that nucleotides will become an essential component of nutria-pharmacologic intervention in critically ill and trauma patients. Published studies have used different terms to describe various nucleotide supplementation regimens, including nucleotides, polynucleotides, nucleotide-nucleotide mixtures, RNA, purines, and pyrimidines.

Purine nucleotides with their high-energy phosphate chains are fundamental to cellular energy metabolism and are intermediaries in biosynthetic and oxidative pathways. Nucleotides exert multiple protective actions on intestinal mucosa and facilitate repair of the injured mucosa. They prevent ethionine-induced liver injury by suppressing accumulation of triglycerides in the liver, reducing the increase of liver enzymes, and preventing the decrease of hepatic ATP concentration. In rats undergoing a 70% hepatectomy, supplementation of TPN with nucleotides and nucleosides improved both nitrogen balance and whole-body protein turnover. Furthermore, nucleotide supplementation was beneficial in galactosamine-induced liver injury by reducing the extent of injury histologically, and by improving clinical biochemical indices. The turnover rate of nucleotides is accelerated in hypermetabolic conditions such as sepsis, trauma, or surgical stress. Substantial evidence suggests that these nutrients are conditionally essential for normal stress response.

7.7 Omega 3-Fatty Acids

The ability of omega 3-fatty acids to incorporate into a cell membrane, the way they are used during the inflammatory process, as well as their ability to modify the inflammatory response, is the rationale for using them in a dietary formula in critically ill patients [86]. Omega 3-fatty acids affect cytokine production, decrease both tumor necrosis factor (TNFα) and IL-1 synthesis, and significantly modulate the inflammatory response in adult respiratory distress syndrome (ARDS) [87].

Chen et al. [88] analyzed 25 RCTs, of which nine used enteral nutrition (EN) and 16 used parenteral nutrition (PN). The total mortality rate in the omega-3 fatty acid group was lower than that in the control group. However, the odds ratio (OR) value was not significantly different in the EN or PN subgroup. Eighteen RCTs, including 1790 patients with similar severity of sepsis and ARDS, were also analyzed. The OR value was not significantly different in the EN or PN subgroup. The authors of this review found that omega-3 fatty acid supplementation could reduce the mortality rate of sepsis and sepsis-induced ARDS. Other authors [89] also found that the use of enteral pharmaconutrition in patients with ARDS was associated with decreased mortality, when used in higher doses than currently recommended, after analyzing 7 studies with 802 patients, of which 405 were randomized to pharmaconutrition. In addition, the ICU LOS was shorter in patients randomized to pharmaconutrition (RR = 0.5 [0.85–0.16]).

7.8 Growth Hormone

Growth hormone has been shown to attenuate the protein catabolic response after major surgery; induce nitrogen retention in patients undergoing gastrointestinal surgery with epidural anesthesia and TPN; and attenuate forearm glutamine, alanine, 3-methylhistidine, and total amino acid efflux. Moreover, growth hormone has been shown to preserve both muscle protein synthesis and the decrease in muscle-free glutamine, and improve the whole-body nitrogen economy after surgery [90]. In addition, growth hormone has been shown to reduce skeletal muscle release of glutamine. Most recently, growth hormone and insulin-like growth factor 1 was shown to promote intestinal uptake and hepatic release of glutamine in sepsis [91]. On the other hand, the use of growth hormone in critically ill patients has become controversial [92–100]. The administration of GH was shown to accelerate protein gain in stable adult patients receiving aggressive nutritional support, and attenuate the catabolic response to injury, surgery, and sepsis, more recently.

GH treatment in critically ill patients has been associated with increased mortality and morbidity. In a prospective, multicenter, double-blind, randomized placebo-controlled trial, patients treated with high dose GH (0.1 mg/kg body weight) had a higher mortality rate than patients who did not receive GH ($P < 0.001$) [92]. Consequently, due to the conflicting results of the study, the administration of high dose GH is not recommended in critically ill and trauma patients [101, 102].

7.9 Timing of Nutritional Initiation in Gastrointestinal Surgery

During the last several decades, patients undergoing gastrointestinal surgery, including resection and anastomosis, were kept "*nil per oral*" to avoid complications related to the anastomosis, such as vomiting, and aspiration until the return of bowel function [103]. Several recent studies have questioned this routine practice [104, 105].

In a study reported by Hur et al., patients who underwent gastrectomy with Billroth II reconstruction [106] were divided into two groups. Early feeding was defined as the initiation of clears on a postoperative day (POD) 2 and soft diet on POD 3, while late feeding was defined at the initiation of clears on POD 3 and soft diet on POD 6. They concluded that early oral feeding following gastrectomy for gastric cancer is feasible and can result in a faster recovery of bowel function, and a shorter hospitalization [106]. These findings were then duplicated in a randomized controlled clinical trial of 58 patients undergoing gastric resection [104]. Mahmoodzadeh et al. performed a randomized clinical trial of patients with esophageal or gastric tumors undergoing resection and evaluated the impact of early nutrition. In their analysis, clears were started on POD 1 in the early group, while the diet was started in the late group after the return of bowel function. After analyzing 109 consecutive patients, they concluded that early oral feeding after the surgical resection of esophageal and gastric tumors is safe. Furthermore, it is associated with improved in-hospital outcomes with a quick recovery of GI function and earlier hospital discharge [105]. These findings were analogous to results published by Han et al. [107] which analyzed patients undergoing minimally invasive esophagectomy, and published results by Han et al. [107] which analyzed patients undergoing open esophagectomy. Contrary to these findings, Shimizu et al., in a multicenter randomized controlled trial, failed to demonstrate the superiority of early feeding in patients who underwent distal gastrectomy (DG) or total gastrectomy (TG) for gastric cancer in term of hospital length of stay [108].

Another group of patients requiring nutritional support in the early postoperative period are bariatric surgery patients. The goal is to maximize weight loss, yet prevent micronutrient deficiency and lean body mass. Guidelines recommend early initiation of oral feeds usually on POD 1 after a gastrografin swallow test to evaluate for the leak [109]. In a single-center study of patients undergoing primary or revisional laparoscopic sleeve gastrectomy and Roux-en-Y gastric bypass, Bevilacqua et al. demonstrated the safety and superiority of early feeds on POD 0 when compared to the traditional feeds on POD 1 [110]. In their analysis, starting oral feeds on POD 0 was associated with a reduced hospital stay in primary cases and not in revisional surgery. Furthermore, there were no differences in 30-day outcomes when either group was compared. Similar reports were published by Tariq et al. [111].

The crucial step regarding nutritional support is to screen for nutritional deficiency given the alteration in anatomic and physiological changes in the GI tract after bariatric surgery. This presents us with the question, when we can feed the patient undergoing lower GI surgery? While some form of postoperative ileus may occur in the colon for 48 to 72 h [112], nonselective utilization of the nasogastric tube after surgery is unnecessary [113] and patient can be fed. The first randomized study to demonstrate enteral feeding via jejunal tube that was tolerated within 24 h of surgery was published in 1979, and it showed a reduced length of hospital stay in patients fed early [114]. Subsequently, multiple studies have evaluated the safety and beneficial aspects of early feeds. In a prospective study, Mehla et al. evaluated 146 patients who underwent elective ileostomy reversal. When they compared patients who received feeds within 24 h regardless of the return to bowel function versus those who received feeds after the return of bowel function, they concluded that early feeds can be safely introduced with early resolution of ileus and shorter hospital stay [115]. In a recent Cochrane review, which analyzed 17 RCTs with 1437 participants undergoing lower gastrointestinal surgery, early initiation of enteral nutrition within 24 h of surgery via oral intake and tube feed (gastric or jejunal) was compared with traditional management (delayed nutritional support) [116]. They did not find any differences in the incidence of postoperative complications: wound infection, intraabdominal abscesses, anastomotic leakage/dehiscence, pneumonia, and mortality. Furthermore, patients who received early feeds were likely to be discharged 2 days earlier compared to the delayed group. Early postoperative feeding has now been incorporated in enhanced recovery after surgery protocol.

7.10 Immune-enhancing Enteral Nutrition: Clinical Evidence

Enteral formulas fortified with immune-enhancing substrates are associated with significant reductions in the risk of infectious complications as well as a reduction of overall hospital stays. Providing adequate standard enteral or parenteral nutrition support does not necessarily protect critically ill patients from developing nosocomial infections. Since most critically ill patients are immune-compromised, modulating or enhancing their immune status with nutrient substrates has great potential [117–122]. It has been demonstrated that certain nutrients can modulate inflammatory, metabolic, and immune processes. Amino acids such as arginine and glutamine improve body defenses, tumor cell metabolism, increase wound healing, and reduce nitrogen losses. RNA and omega 3-fatty acids also modulate the immune function. To this end, supplementation of enteral diets in critically ill patients with specific immune-nutrients such as arginine, glutamine, nucleotides, nucleosides, and omega 3-fatty acids in critically ill patients have been shown to be clinically beneficial. These immune-enhancing formulas improve immune response experimentally as well as clinically. Studies performed in burn, trauma, or surgical patients have shown outcome advantages with a reduction in infections, total complications, or length of stay. The majority of the prospective, randomized, clinical trials published to date used formula fortified with arginine, RNA, omega-3, and omega-6 fatty acids. Although various formulas are used, they all are associated with an improved outcome. The mortality rate, however, has not been reduced by the use of these immune-enhancing formulas.

The effect of the first immune-enhancing formula on the length of hospital stay and complication rate of critically ill and septic patients was studied in a multicenter study of 296 traumas, post-surgery, and septic patients [117]. The patients in this study had entry requirements of an APACHE II score greater than 10, therapeutic intervention score (TIS) greater than 20, they were stratified by age (less than 60 or greater than 60 years) and whether they had sepsis or systemic inflammatory response syndrome (SIRS), and they were highlighted by fever and leukocytosis. One hundred sixty-eight patients were randomized to receive the fortified formula, while 158 were fed with isonitrogenous enteral diet. Both groups tolerated early feeding well, had a low tube-feeding related complication rate, and achieved a similar nitrogen balance. Patients receiving a diet supplemented with arginine, nucleotide, and fish oil had a higher level of plasma arginine and ornithine concentration of linoleic acid in patients with a common formula (control group), while patients receiving an immune-enhancing formula had higher concentrations of eicosapentaenoic acid. There were no differences in mortality between the groups; however, both groups had an overall lower than expected mortality. Moreover, patients who received at least 821 mL/day of an enteral diet had an average length of hospital stay reduced by 8.1 days. The most beneficial effects were demonstrated in severely ill and septic patients with a reduction of length of hospital stay by 10 predicated days, along with a major reduction in the frequency of acquired infections ($p < 0.01$). In a subgroup of septic patients in whom early enteral feeding goals were achieved, the median length of stay was reduced by 11.5 days. In a group that was stratified as SIRS, there were no statistical differences in benefits between the groups. These investigators concluded that early enteral feeding in severely ill patients is safe and is associated with significant benefits, especially if patients where septic [117].

Another immune-enhancing enteral diet contained glutamine reduced septic complications in patients with severe trauma [118]. This study, unlike the previous study, had an isonitrogenous (INIC) control not receiving the immune-enhancing diet (IEF). In a prospective, blinded study, 35 severely injured patients with abdominal trauma were supplemented with glutamine, arginine, nucleotides, and omega-3 fatty acids, or INIC diet ($N = 18$). Nineteen other patients without enteral access served as a control. Significantly fewer major infections and complications (6%) developed in patients that received IEF than in patients receiving the INIC diet (41%, $p = 0.02$), or in the patients in the control group (58%, $p = 0.002$). The hospital stay, antibiotic use, and the development of intraabdominal infections were significantly lower in IEF group. Patients that were not fed had the highest rate of complications.

In another prospective, randomized, placebo, double-blind, multicenter study of surgical intensive care patients that underwent upper gastrointestinal surgery, the clinical outcome and cost were compared [119]. Early enteral feeding with arginine, dietary nucleotides, and omega-3 fatty acids was associated with a significant reduction in the frequency rate of late postoperative infection and wound complications. Furthermore, the treatment cost was substantially reduced in the immune-nutrition group as compared with the control group. Immunonutrition (Impact, Novartis Nutrition, Minneapolis, MN) was given to [119] patients, while an isocaloric and isonitrogenous diet was given to [119] patients. Enteral feeding was initiated within 12–24 h after surgery and advanced to a target volume of 80 mL/h by postoperative day 5. There were no differences in early postoperative complications between the groups; however, there were significantly fewer late complications in the immune-nutrition group.

Achieving nutritional goals early in critically ill patients with immune-enhancing enteral diet has been shown to greatly reduce morbidity and shorten time on mechanical ventilation [120]. These investigators studied 390 critically ill surgical and medical patients. Out of the 101 patients achieving early enteral nutrition (within 72 h), 50 patients fed with impact had a significant reduction in requirements for mechanical ventilation compared with controls. There was also an associated reduction in the length of hospital stay. The administration of immune-enhancing enteral nutrition had no clear benefits over standard high-protein enteral diets in burn patients and was even found to increase the incidence of adult respiratory distress syndrome [65].

A recent prospective double-blind, randomized trial of patients with major burns (>50% body surface) demonstrated that supplemental intravenous glutamine infused continuously over 24 h was significantly better than just isonitrogenous amino acid solutions. In this study, 26 severely burned patients (20–90% were randomized to either intravenous glutamine (0.57 g/kg/body weight) or randomized to either isonitrogenous control amino acid solution (0.57 g/kg/body weight, without glutamine) administered continuously in addition to enteral nutrition support, or enteral and parenteral nutrition, for those patients unable to achieve nutritional goals with enteral nutrition alone. The study group receiving glutamine and a lower incidence of Gram-negative bacteremia (8% vs. 43%; $p \leq 0.04$), displayed significant improvements in serum transferring and prealbumin at 14 days after the injury ($p < 0.01$ and 0.04, respectively). Furthermore, there was a trend towards lower mortality, decreased bacteremia incidence, and antibiotic usage in the glutamine group [121]. Other studies have shown similar results in multiple trauma patients, where the use of glutamine was associated with a significant reduction in the incidence of bacteremia, septic episodes, and pneumonia [122]. Patients treated with glutamine had not had episodes of Gram-negative bacteremia; whereas Gram-negative bacteria caused 54% of all bacteremia and 63% of sepsis. Although the mechanism is not entirely clear, it appears from both of these studies that glutamine protects from Gram-negative bacteria in most critically ill patients.

Meta-analysis of 11 randomized controlled clinical trials of enteral nutrition, with immune-enhancing formula that included 1009 patients [123], concluded that nutritional support supplemented with key nutrients (arginine, glutamine, branched-chain amino acids, nucleotides, and omega-3 fatty acids) results in a significant reduction in the risk of developing infectious complications and reduces the overall hospital stay in critically ill patients and in patients with gastrointestinal cancer.

Although multiple studies have shown beneficial effects of IED, their use is not widespread yet. A consensus panel from a recent conference on immune-enhancing enteral therapy [124] recommends the use of IED in the following patients: a) severely malnourished patients (albumin <3.5 g/dL) undergoing upper GI surgery or patients with albumin <2.8 g/dL undergoing lower GI surgery; b) patients with blunt or penetrating torso trauma with an ISS of >18 or abdominal trauma index >20. Although there are insufficient data to recommend the use of IED, patients undergoing elective aortic surgery with preexisting chronic pulmonary disease, or those undergoing major head and neck surgery with preexisting malnutrition, severe head injury patients (GCS <8 with an abnormal CT scan), burn patients (>30%, third-degree), and ventilatory dependent patients at risk of subsequent infections may benefit from early IED use.

The most recent metanalysis published [125] demonstrated from the analysis of 19 RCTs with a total of 2016 patients (1017 IEN and 999 SEN) undergoing esophagectomy, gastrectomy, and pancreatectomy that when immunonutrition was administered postoperatively it was associated with a significantly lower risk of wound infection (risk ratio and shorter length of hospital stay $p < 0.00001$). In another small prospective, randomized trial with two parallel treatment groups receiving an immune-enhancing dietary supplement for 7 days before colorectal resection and 5 days postoperatively or dietary advice [126], the use of laparoscopy and supplementation with immunonutrients reduced surgical wound infection in patients undergoing colorectal surgery. Moreover, Moya et al. [127] performed a prospective, multicenter, randomized trial with two parallel treatment groups receiving either the study product (an immune-enhancing feed) or the control supplement (a hypercaloric hypernitrogenous supplement) for 7 days before colorectal resection and 5 days postoperatively. The authors reported that while the median length of the postoperative hospital stay was not different between the groups, a decrease in the total number of complications in the immunonutrition group compared with the control group, primarily due to a significant decrease in infectious complications, was significantly lower (23.8% vs. 10.7%, $P = 0.0007$), particularly in wound infection (16.4% vs. 5.7%, $P = 0.0008$). This study supports the addition of ERAS protocols with immunonutrient-enriched supplements to reduce the complications of patients undergoing colorectal resection.

Finally, in another major study [128] of 56 trials with 6370 patients, perioperative nutrition was associated with a lower risk of postoperative complications such as postoperative infections and postoperative noninfectious complications, as well as shorter LOS in the intervention group. In a position paper by A Position Paper of the International Study Group on Pancreatic Surgery (ISGPS) [129], it is stated that concentrating on nutritional support and therapy is of utmost value in pancreatic surgery for both short- and long-term outcomes.

7.11 Nutritional Assessment

Nutrition assessment is critical in the process of identifying patients who are either at risk for developing malnutrition or are already malnourished. A comprehensive nutritional assessment should include history, physical examination, and laboratory testing to provide the overall nutritional health of the patient. Patients with chronic illness and alcoholism have associated vitamin deficiency and protein-calorie malnutrition; those with a history of gastrectomy, or small bowel resection, can have a deficiency of iron, vitamin B12, or folate. Similar deficiencies occur in patients with an end-stage renal disease requiring dialysis; cirrhotic and cancer are deficient in some vitamins. The Academy of Nutrition and Dietetics (Academy) and the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) in 2012 published recommendations for identifying the malnutrition that includes a standardized set of diagnostic characteristics that are etiologically based and incorporate a current understanding of the role of the inflammatory response on malnutrition's

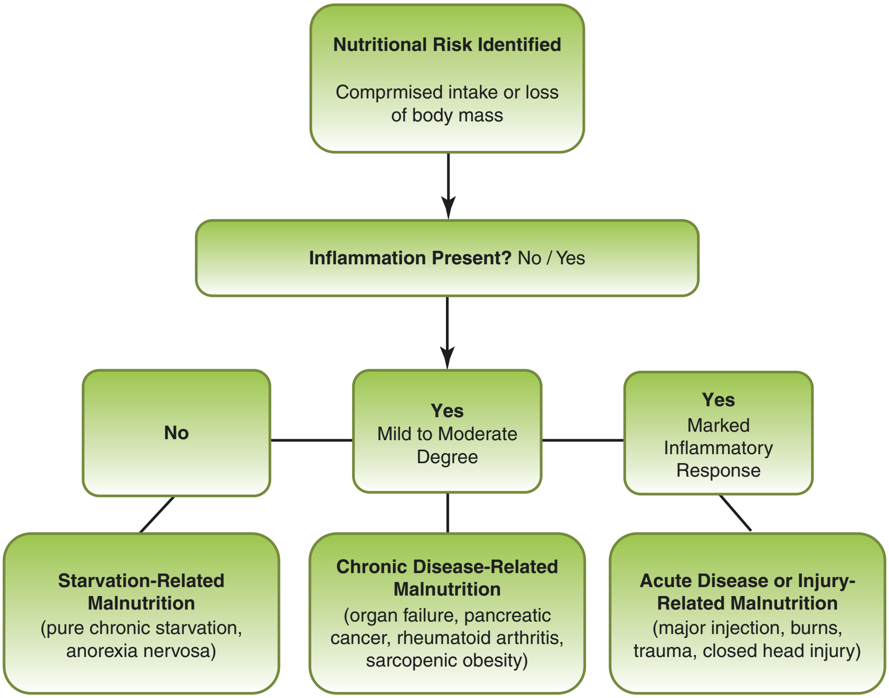

Fig. 7.3 Etiology-based malnutrition definitions

incidence, progression, and resolution is proposed [130] (Fig. 7.3, Table 7.2). However, while each of us can recognize rather readily when we see a cachectic and severely malnourished patient, the definition of malnutrition has not been defined. The hope is that a universal use of a single set of diagnostic characteristics will facilitate malnutrition's recognition, contribute to more valid estimates of its prevalence and incidence, guide interventions, and influence expected outcomes, to assist in more accurately predicting the human and financial burdens and costs associated with malnutrition's prevention and treatment, and to further ensure the provision of high quality, cost-effective nutritional care [130]. Most recently, The Global Leadership Initiative on Malnutrition (GLIM) was convened by several of the major global clinical nutrition societies and published an empirical consensus on a two-step approach for the malnutrition diagnosis [143].

The severity of malnutrition among hospitalized patients, that was called the skeleton in the closet, has been recently documented by a study by Hudson et al. that compared malnutrition identified by the Academy of Nutrition and Dietetics/ American Society for Parenteral and Enteral Nutrition (AND/ASPEN) consensus criteria with clinical outcomes. The authors studied the 30-day readmissions (primary outcome), hospital mortality, length of stay (LOS) in survivors, and time to discharge alive (TDA) in all patients assessed as malnourished or not malnourished using these criteria during a 1-year period. Of the 3907 patients referred for

Table 7.2 Academy of Nutrition and Dietetics (Academy)/American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) clinical characteristics that the clinician can obtain and document to support a diagnosis of malnutrition[a,b]

	Malnutrition in the context of acute illness or injury				Malnutrition in the context of chronic illness				Malnutrition in the context of social or environmental circumstances			
Clinical Characteristic	None-severe (moderate) malnutrition		Severe malnutrition		None-severe (moderate) malnutrition		Severe malnutrition		None-severe (moderate) malnutrition		Severe malnutrition	
(1) Energy intake [131]	<75% of estimated energy requirement for >7 days		≤50% of estimated energy requirement for ≥5 days		<75% of estimated energy requirement for ≥1 month		<75% of estimated energy requirement for ≥1 month		<75% of estimated energy requirements for ≥3 months		≤50% of estimated energy requirement for ≥1 month	
Malnutrition is the result of inadequate food and nutrient intake or assimilation; thus, recent intake compared to estimated requirements is a primary criterion defining malnutrition. The clinician may obtain or review the food and nutrition history, estimate optimum energy needs, compare them with estimates of energy consumed, and report inadequate intake as a percentage of estimated energy requirements over time												
(2) Interpretation of weight loss [132–135]	%	Time	%	Time	%	Time	%	Time	%	Time	%	Time
	1–2	1 wk	>2	1 wk	5	1 mo	>5	1 mo	5	1 mo	>5	1 mo
	5	1 mo	>5	1 mo	7.5	3 mo	>7.5	3 mo	7.5	3 mo	>7.5	3 mo
	7.5	3 mos	>7.5	3 mos	10	6 mo	>10	6 mo	10	6 mo	>10	6 mo

(continued)

Table 7.2 (continued)

	Malnutrition in the context of acute illness or injury		Malnutrition in the context of chronic illness		Malnutrition in the context of social or environmental circumstances	
Physical findings [135, 136]			20 1 y	>20 1 y	20 1 y	>20 1 y
Malnutrition typically results in changes to the physical exam. The clinical may perform a physical exam and document any one of the physical exam findings below as an indicator of malnutrition						
(3) Body fat	Mild	Moderate	Mild	Severe	Mild	Severe
Loss of subcutaneous fat (e.g., orbital, triceps, fat overlying the ribs).						
(4) Muscle mass	Mild	Moderate	Mild	Severe	Mild	Severe
Muscle loss (e.g., wasting of the temples [temporalis muscle]; clavicles [pectoralis and deltoids] shoulders [deltoids]; interosseous muscles; scapula [latissimus dorsi, trapezious, deltoids]; thigh [quadriceps] and calf [gastrocnemius])						
(5) Fluid accumulation	Mild	Moderate to severe	Mild	Severe	Mild	Severe
The clinician may evaluate generalized or localized fluid accumulation evident on exam (extremities; vulvar/scrotal edema or ascites). Weight loss is often masked by generalized fluid retention (edema) and weight gain may be observed						
(6) Reduced grip strength [137]	N/A[c]	Measurably reduced	N/A	Measurably reduced	N/A	Measurably Reduced
Consult normative standards supplied by the manufacturer of the measurement device						

[a]A minimum of two of the six characteristics above is recommended for diagnosis of either severe or non-severe malnutrition. Height and weight should be measured rather than estimated to determine body mass index. Usual weight should be obtained in order to determine the percentage and to interpret the significance of weight loss. Basic indicators of nutritional status such as body weight, weight change, and appetite may substantively improve with refeeding in the absence of inflammation. Refeeding and/or nutrition support may stabilize but not significantly improve nutrition parameters in the presence of inflammation. The National Center for Health Statistics defines "chronic" as a disease/condition lasting 3 months or longer [12]. Serum proteins such as albumin and prealbumin are not included as defining characteristics of malnutrition because recent evidence analysis shows that serum levels of these proteins do not change in response to changes in nutrient intake [22, 23, 52, 53]

[b]This table was developed by Annalynn Skipper Ph.D., RD, FADA. The content was developed by an Academy workgroup composed of Jane White Ph.D., RD, FADA, LDN, Chair; Maree Ferguson MBA, Ph.D., RD; Sherri Jones MS, MBA, RD, LDN; Ainsley Malone, MS, RD, LD, CNSD; Louise Merriman, MS, RD, CDN; Terese Scollard MBA, RD; Annalynn Skipper Ph.D., RD, FADA; and Academy staff member Pam Michael, MBA, RD. Content was approved by an A.S.P.E.N. committee consisting of Gordon L. Jensen, MD, Ph.D., Co-Chair; Ainsley Malone, MS, RD, CNSD, Co-Chair; Rose Ann Dimaria, Ph.D., RN, CNSN; Christine M. Framson, RD, Ph.D., CSND; Nilesh Mehta, MD, DCH; Steve Plogsted PharmD, RPh, BCNSP; Annalynn Skipper, Ph.D., RD, FADA; Jennifer Wooley, MS, RD, CNSD; Jay Mirtallo, RPh, BCNSP Board Liaison; and A.S.P.E.N. staff member Peggi Guenter, Ph.D., CNSN. Subsequently, it was approved by the A.S.P.E.N. Board of Directors. The information in the table is current as of February 1, 2012. Changes are anticipated as new research becomes available. Adapted from: Skipper A. Malnutrition coding. In Skipper A (ed). Nutrition Care Manual. Chicago, IL: Academy of Nutrition and Dietetics; 2012 Edition

[c]N/A not applicable. Reprinted from Journal of the Academy of Nutrition and Dietetics, Vol 112, Jane V. White, Peggi Guenter, Gordon Jensen, Ainsley Malone, Marsha Schofield, Consensus Statement of the Academy of Nutrition and Dietetics/American Society for Parenteral and Enteral Nutrition: Characteristics Recommended for the Identification and Documentation of Adult Malnutrition (Undernutrition), 730–738, (2012), with permission from Elsevier

Refs. [138–142]

nutrition assessment, a staggering 66.88% of patients met criteria for moderate or severe malnutrition. Malnourished patients were older (61 vs. 58 years, $P < 0.0001$), and survivors had longer LOS (15 vs. 12 days, $P = 0.0067$) and were more likely to be readmitted within 30 days (40% vs. 23%, $P < 0.0001$). In adjusted models, 30-day readmissions and hospital mortality were increased, and the likelihood of earlier TDA was reduced in those who had >2-day stay [1].

This includes first screening to identify at-risk status by the use of any validated screening tool, and second, to assess for diagnosis and grading the severity of malnutrition. GLIM participants selected three phenotypic criteria (non-volitional weight loss, low body mass index, and reduced muscle mass) and two etiologic criteria (reduced food intake or assimilation, and inflammation or disease burden). In order to diagnose malnutrition, at least one phenotypic criterion and one etiologic criterion should be present. Phenotypic metrics for grading severity are proposed. The etiologic criteria should be used to guide intervention and anticipated outcomes. Endorsements from leading nutrition professional societies will be required to identify overlaps with syndromes like cachexia and sarcopenia, and to promote dissemination, validation studies, and feedback [143].

7.12 Summary

The biology of nutrition support has become much better understood, although we are far from knowing all we need to know in this complex field. One thing is for sure; nutritional support affects long-term outcomes positively [144, 145]. Amino acids are a key component of the nutritional and metabolic management of critically ill patients. As our current knowledge of the altered regulation of amino acid metabolism in critically ill patients increases, the formulation and administration of more effective parenteral and enteral therapeutic feeding regimens will inevitably evolve. The use of specific amino acids in pharmacological, and in special combinations and ratios, is likely to be beneficial to critically ill patients. As our current knowledge of the altered regulation of amino acid metabolism in critically ill patients increases, the formulation and administration of more effective parenteral and enteral therapeutic feeding regimens will inevitably evolve. The use of specific amino acids in pharmacological doses and in special combinations and ratios is likely to be beneficial to critically ill patients. A working knowledge of the multiple and complex functions of amino acids is essential to the competent and efficacious practice of medicine. Due to the fact that derangements in amino acid metabolism are common in pathologic states and are detrimental to optimal metabolic function, reversal of these pathophysiologic alterations by optimal nutritional support will be obligatory if the outcome of critically ill patients is to be significantly improved. Metabolic changes of amino acid pool and milieu simply cannot be ignored any more, and will need to be taken into account when creating a new formulation of nutrient formulas: enteral as well as parenteral. Standardization of methodology of studying endpoints of nutrition support, clinical criteria for specialized nutrient substrate such as those fortified with BCAA, patient's selection, and other variables will resolve the contradictory findings of future clinical studies. The main difficulty in obtaining evidence-based data in surgical nutrition support when different nutrient substrates are used, lie in the patient selection criteria and study end point, as well as multiple other variables. The use of specific immune-enhancing formulas with amino acids in higher pharmacological doses and in special combinations and ratios is beneficial to critically ill patients.

One should compare nutrition support and advance the need to be made with other fields, such as management of anemia in critically ill patients. Today, one can manage anemia virtually without transfusing blood using genetically created recombinant erythropoietin (Procrit®-Ortho Biotech) [146]. We can support anemic patients with substrates that will mimic, or better off, substitute the perfect nutrient substrates for most critically ill patients and correct the cellular imbalances caused by injury, severe sepsis, or other disorders. Derangement in amino acid metabolism, nucleotides, vitamins, and trace elements are common in critically ill patients. Reversal of these pathophysiologic alterations by optimal nutritional support with immune-enhancing formulas is obligatory if the outcomes of critically ill patients are to be significantly improved. Ideally, the formula used for nutrition and metabolic support in critically ill patients should contain high doses of arginine, glutamine, taurine, BCAA, nucleotide and nucleoside, omega 3-fatty acids, zinc, selenium, and vitamins A, E, and C. It is also important for this formula to be inexpensive and should be available in the enteral as well as parenteral form. Finally, a recent consensus paper by Wernerman et al. [147] has brilliantly addressed the nine questions that address just about everything in nutritional support. Although we have addressed the majority of these questions, the reader is advised to read this review article for more practical advice on how to support metabolically the critically ill patients.

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Gut Access for Nutritional Provision

8

Ryan Malcom and Rifat Latifi

8.1 Introduction

Early nutrition in ill patients is shown to improve outcomes. The optimal route of administration is via the GI tract. In a patient who is unable to eat for at least 3–5 days, an alternative route for nutrition should be sought. If the patient has a functional GI tract, it should be used [1, 2].

Enteral nutrition (EN) is safe and cost-effective. It is practical. There are metabolic advantages as it reduces the risk of hypoglycemia. It promotes enteric hormone secretion. It can aid in electrolyte maintenance. There are immune benefits as well. EN decreases bacterial translocation across the bowel wall and maintains the mucosal structure.

Even if full feedings are not appropriate, trophic feedings may still have benefits. Trophic feedings are low rate (10–30 cm^3/h) and can contribute to maintaining the mucosal structure. Unless the use of the GI tract is impractical, inadequate, ill-advised, or impossible, it should be accessed and used.

There are several techniques to access the GI tract, and the choice must be tailored to the individual patient. Temporary measures include nasoenteric or oroenteric tube placement, usually placed at bedside. This may be an orogastric, nasogastric, nasoduodenal, or nasojejunal tube. Long-term access is performed surgically or endoscopically. Examples are gastrostomy, gastrojejunostomy,

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jejunostomy, and percutaneous endoscopic gastrostomy (PEG). We will review these techniques and their indications in this chapter.

Nutritional support can be provided in orally, enterally, and/or parenterally. Enteral nutrition should be used as main modality of nutritional support whenever possible. Often, however, supplementation by parenteral nutritional therapy is required, in order to meet the calorie and protein requirements. Nutritional supplementation should be tailored to be disease-based. Early nutritional support during the postoperative course is an essential step to prevent subsequent malnutrition-related complications. The next section of this chapter will address gut access in surgical patients.

8.2 Percutaneous Endoscopic Gastrostomy (PEG)

Most commonly, access to the stomach to provide nutrition is via percutaneous endoscopic gastrostomy (PEG) described in 1980 [3]. This clearly has revolutionized the nutrition provision and minimally invasive gut access. The exit site for the tube is through the anterior wall of the stomach and anterior abdominal wall. This avoids stenting the lower esophageal sphincter and avoids complications and discomfort related to an exit through the nasal passage. Placement can be performed bedside in an ICU, in a GI suite, or in the operating room (OR). An alternative is a hybrid method, per-oral image-guided gastrostomy (PIG) [4, 5]. The outcomes are similar for both techniques [6]. Although one early study demonstrated rates of successful tube placement to be higher for radiologic gastrostomy than for PEG; as well as one meta-analysis (99.2% vs. 95.7%, $P < 0.001$) [7]. In addition, major complications occurred less frequently after radiologic gastrostomy in this study [6] and in the meta-analysis (5.9% vs. 9.4% for PEG and 19.9% for surgery, $P < 0.001$) [7]. Thirty-day procedure-related mortality rates were highest for surgery (2.5% vs. 0.3% for radiologic gastrostomy and 0.53% for PEG, $P < 0.001$). Nonetheless, PEG has become a procedure of choice in most hospitals [8].

There are absolute and relative contraindications to PEG. Absolute contraindications include inability to pass the endoscope through the oropharynx or esophagus. This may be due to trauma, recent surgery, obstruction from tumor, or other pathology. Other absolute contraindications include the inability of the GI tract to receive nutrition and limited life expectancy. When there is no possibility of performing a PEG, other surgical techniques should be used; most commonly, laparoscopic-assisted gastrostomy placement or open technique.

Relative contraindications to the endoscopic approach include esophageal or gastric varices, hepatomegaly, or peritoneal dialysis. Also included are anatomical changes to the stomach, such as a large hiatal hernia or previous surgery. It is necessary to have a window to approach the stomach through the anterior abdominal wall. To evaluate this, plain films should be taken and prior films reviewed. This should be mandatory in patients who have had previous abdominal surgery.

Technique for placement should begin with a full upper endoscopy. The endoscope should be introduced through the oropharynx and into the esophagus under direct vision. An alternative nasogastric method has been described [9]. The esophagus, and then stomach, should be insufflated and then the scope is passed into the duodenum. The duodenum, stomach, and esophagus should be examined. Particular attention should be paid in evaluating any pyloric obstruction. In the case of pyloric obstruction, if it can be traversed, a percutaneous endoscopic gastrojejunostomy may be an option.

The endoscope should then be advanced or withdrawn into the body of the stomach and the stomach is insufflated. The abdominal wall should then be transilluminated to find an area most accessible for tube placement. The room may be darkened to aid transillumination. In addition to transillumination, external palpation of the abdominal wall with simultaneous visualization of the gastric indentation via the endoscope can allow for the identification of the best puncture site. It should be a point in the mid to left epigastrium. If the abdominal wall is unable to be transilluminated, then another method of feeding access may be better; in other words, what do you do when you do not see the light? Laparoscopically assisted PEG tube placement is a great option if the patient has not had laparotomies, in which case, open procedures are options which will be discussed below. Interventional radiology or endoscopic ultrasound can also be used depending on local expertise. Difficulty in transillumination may be due to obesity, or previous abdominal surgery.

Local anesthesia should be administered at the best puncture site and a 1 cm transverse incision should be made. An angiocatheter needle and syringe should then be passed with negative pressure applied on the syringe. If the needle is slowly advanced by the indentation, then the needle should be visualized by the endoscope. If air is encountered before reaching the stomach, the needle may have entered the colon. If blood is encountered, the needle may have entered the liver. In either case, the needle should be removed and an alternative puncture site should be chosen.

Once the needle is safely in place, it can be pulled from the angiocatheter leaving the angiocatheter in place. A wire is then fed through the angiocatheter into the stomach. From there, there are two methods used to place the gastrostomy tube across the abdominal wall into the stomach; there is the push method and the pull method. Using the pull method, the guidewire is grasped with a snare from the endoscope. Then the endoscope is withdrawn pulling the guidewire out of the mouth. Outside the mouth, the gastrostomy tube (tapered to transverse the abdominal wall) is attached to the guidewire. The guidewire now reaches from the gastrostomy tube outside the mouth, through the esophagus into the stomach, and across the anterior abdominal wall exiting the puncture site. The guidewire is then gently pulled, advancing the gastrostomy tube along the above path, from the mouth into the stomach. Subsequently, more forceful tension is applied to the guidewire pulling the gastrostomy tube into position across the abdominal wall. The bumper on the gastrostomy tube should end up against the gastric mucosa on the anterior stomach wall, snug but without undue tension. This should be confirmed visually with the endoscope.

If the push method is used, once the guidewire is passed through the angiocatheter into the stomach, the angiocatheter is removed and the gastrostomy tube is pushed across the abdominal wall over the guidewire into the stomach. This is facilitated by pulling the guidewire in tension using the endoscope in the stomach and an assistant pulling on the guidewire external to the abdominal wall. Using the push method, the bumper must be a balloon in order to cross the abdominal wall. Once in the stomach, it can be inflated under endoscopic vision and placed snug, but without undue tension, against the anterior stomach mucosa.

Using either method, at this point, the guidewire and endoscope can be removed. An external bumper should be applied to secure the PEG in place. A distance of around 1–2 mm should be between the external bumper and the skin to decrease skin breakdown. The measurement on the gastronomy tube should be noted and recorded, and/or marking added. This is for subsequent evaluation and identification of dislodgement.

8.3 Complications Post PEG Placement

While PEG has been demonstrated as safe and effective in providing nutritional support, there are a number of complications that could occur during, or following the placement. These complications can include wound-related complications, bleeding, dislodgment of the tube, peritonitis due to feeding in the abdomen, trans colonic PEG tube, or other organ perforation, and finally, need for reoperation [8]. In this study of 559 consecutive patients who underwent G (86) or GJ (473) tube insertion, primary technical success was 100%. The overall complications were 1.6% for major and 10.7% for minor complications, with an overall complication rate of 12.3%. The 30-day complication rate was significantly higher for GJ compared to G tube insertion (13.5% vs. 5.8%, $p = 0.049$). There was a trend towards a higher 30-day minor complication rate for the GJ group (11.8% vs. 4.7%, $p = 0.057$), but no significant difference between groups with respect to major complications (1.7% vs. 1.2%, $p = 1.0$). Four procedure-related deaths occurred resulting in overall procedure-related mortality of 0.7%. No significant difference in the procedure-related mortality was found between GJ and G groups (0.6% vs. 1.2%, $p = 0.49$). Overall, complications are errors in technique or errors in management. Additional complications, such as bleeding, occur in patients that are under antiplatelet therapy [10].

Other complications occur due to mechanical factors, such as excessive tension on the tube, leading to tissue necrosis or progressive enlargement of the stoma. Minimizing tube tension and mobility aids in prevention. Excessive tension can lead to buried bumper syndrome. This occurs when the bumper migrates from the gastric lumen into the subcutaneous tissue. Resultant feeding into the subcutaneous tissue, or into the peritoneum, can be disastrous. The rate of wound problems is significantly increased in patients with malignancy, cirrhosis, and radiation exposure. Prophylactic IV antibiotics during PEG insertion can reduce peristomal wound infection. Perforation is a complication of upper endoscopy, most common at the pharynx and upper esophagus.

8.4 When can You Initiate Feedings Post PEG Placement?

Resumption of feeding after placement tube feeding has been controversial. However, there is plenty of evidence to start tube feeds as early as less than 3 h following the procedure [11]. In a retrospective study of patients who underwent PEG and at least 24 h of EN, patients were stratified according to time to tube-feed initiation: immediate (<1 h), early (1–4 h), and late (4–24 h). The three groups were similar with respect to demographics, comorbidities, and 30-day mortality. Sixty-one percent of patients in the immediate group were advanced to the previously met goal EN rates compared to 24% and 18% in the early and delayed groups, respectively ($P < 0.0001$).

Care for the PEG is a multidisciplinary approach including doctors, nurses, and a nutritional support team. The tube position at the skin level should be checked routinely to recognize problems early. As opposed to the open approach, the stomach is not sutured to the abdominal wall. It will take 5–7 days for a tract to form. During this time, particular diligence against dislodgment must be maintained. And thorough radiographic or endoscopic confirmation of position should be obtained if there is any question of tube position.

8.5 Gastrojejunostomy

Gastrojejunostomy feeding tube can be placed either by open technique or laparoscopically assisted. Gastrojejunostomy feeding tube may have a single or dual lumen tube placed in similar fashion as a PEG, but with a distal lumen advanced with the endoscopy into a post pyloric position, that allows for post pyloric feeding. In addition, the proximal lumen in the stomach can be used for gastric decompression. Another method involves passing a small 8 or 8.5 French jejunostomy tube through an existing PEG and advancing it post pylorus using the methods similar to those described above for the placement of a nasoduodenal tube. In our practice, when we reoperate and we believe that the patient may need gastric decompression and enteral feeding for an extended period of time, we place a triple lumen GJ tube, which both decompresses the stomach and feeds the proximal small bowel with the distal lumen [12–15].

PEJ tube placement is successful in 90% of the cases; therefore, it takes a more advanced skill level than other procedures. In a long-cohort study by Lim et al. [16], technical failures were related to the inability to ~~have~~ obtained adequate transillumination, but interestingly were not influenced by BMI, age, gender, or indication. Perioperative (30-day) adverse events occurred in 11 (13%) patients, including wound infection (3), leakage around the stoma (4), minor bleeding requiring no intervention (2), and aspiration (1). The rest of the complications were rare: one case (1.2%) of gastric perforation after PEJ insertion, and one case of intestinal perforation (1.2%) occurred after jejunostomy tube replacement at 6 months of insertion, which was successfully managed with surgery.

Overall, GJ tube insertion is associated with a higher overall complication rate [17] and should be done only by those technically trained and proficient.

8.6 Surgical Gastrostomy

If the surgeon is already in the abdomen, a PEG tube is contraindicated; or, if it is the surgeon's preference, an open gastrostomy is an option. The most commonly used technique is the Stamm gastrostomy described by Martin Stamm in 1874. An upper midline incision, over the middle third between the xyphoid and umbilicus can be made and closed swiftly. It provides adequate access and can be enlarged as needed. Once the peritoneum is entered, a stab incision is made in the abdominal wall overlying the body of the stomach and a large hemostat is passed from inside the abdomen through the abdominal wall to grasp the gastrostomy tube. The gastrostomy tube should have a flanged or balloon tip, and a foley catheter is a reasonable option. It is then pulled through the abdominal wall into the peritoneal cavity. Two concentric purse-string sutures are made in the anterior wall of the stomach. In the center of the purse strings, electrocautery is used to enter the stomach taking care to pass through all layers of the stomach into the lumen, including the mucosa. The gastrostomy tube is then passed into the stomach and the balloon inflated. Fourpoint sutures should be used to anchor the stomach to the parietal peritoneum of the abdominal wall. The purse-string sutures can be used for two of these. The gastrostomy tube is pulled snug to the abdominal wall as the anchor sutures are tied. A stitch is then used to anchor the gastrostomy tube to the skin. The abdomen is then closed. Feeding can begin post-op.

An alternative approach is a laparoscopic gastrostomy [18, 19]. This technique has been described in a number of published papers. In short, two ports are used; one at the umbilicus, and another at the right upper quadrant (RUQ). A 30° camera is placed through the umbilical port. The stomach is grasped with the RUQ port and brought to the abdominal wall, and an appropriate location for gastrostomy tube placement is then selected. T-fasteners through the anterior abdominal wall and gastric wall can secure the tissue for placement. A stab incision is made in the skin and a needle passed into the stomach. A guidewire is passed into the gastric lumen. Over the guidewire, the tract is serially dilated until the gastrostomy tube is introduced. The gastrostomy tube is secured to the skin and the port sites closed. As with the PEG, the stomach is not sutured to the abdominal wall, so it will take 5–7 days for a tract to form.

Post complications are similar to PEG. Also, if the tube is not secured at the skin, or is replaced, the balloon at the tip can migrate distally and obstruct the pylorus or duodenum. If there is any question about tube location, a radiographic study should be performed. This technique is useful in the elderly as well [20].

8.7 Laproscopically Assisted (LA-PEG)

In patients where transillumination is difficult during a PEG procedure, it should be converted to a laparoscopically assisted PEG. In fact, lots of surgeons (including our group) prefer LA-PEG. In other words, when you cannot see the light safely, convert to LA-PEG [19]. This technique is particularly useful in obesity or when a patient has had previous abdominal surgery. An umbilical port is placed for a 30° camera. One or two 5 mm ports are then inserted. If indicated, laparoscopic scissors can be introduced for adhesiolysis. Before introducing the angiocatheter, the intraperitoneal pressure should be lowered to 8–10 cm H_2O to allow the approximation of the stomach to the posterior abdominal wall. The endoscope is used to inflate the stomach; afterward, the angiocatheter can be introduced across the abdominal wall and into the stomach as with PEG, but with the additional direct vision from the laparoscope (in addition to the endoscope). Subsequently, proceed as with the PEG insertion described above. In a recent meta-analysis, [21] the complication rates between LA-PEG and PEG in children were compared. In this study, PEG placement was associated with a significantly higher risk of major complications compared to LA-PEG placement. Therefore, LAG should be the preferred method for gastrostomy, not just on children, but also in adults as well.

8.8 Surgical Jejunostomy

A jejunostomy provides feeding access distal to the stomach, minimizing the risks of aspiration associated with gastric feeding, and allows feeding distal to the ampulla of Vater if desired. It is often placed during another open procedure but can be placed on its own. There is an open and laparoscopic approach. It is usually done under general anesthesia, but can also be done under local. Usually, a midline incision is used, though a left paramedian incision can be used as well. A loop of jejunum approximately 20–25 cm distal to the ligament of Treitz is elevated. A stab incision is made on the left side of the abdomen overlying the loop of jejunum. A hemostat is used to bring the tube through the abdominal wall. The jejunostomy tube should not have a balloon, and a standard 12–16 F red rubber catheter is a reasonable choice. Using electrocautery, an opening is made in the antimesenteric side of the jejunum. Care is taken to enter all layers of the bowel, including mucosa, and into the lumen. Be sure to avoid making a false passage in the bowel wall. The catheter is inserted approximately 15 cm into the jejunum. A Witzel technique is an option that can be utilized using interrupted seromuscular stitches to suture fold the intestine over the tube for approximately 4 cm. An excessive length should be avoided to prevent bowel narrowing. An introduction into the jejunum using a needle and guidewire, or a purse-string Stamm technique, is also an option. The jejunum is then suture fixated for several centimeters to the abdominal wall. A suture is placed to anchor the catheter to the skin. Care is taken, so the catheter is directed distally in the bowel and that the bowel is not twisted. The abdomen is closed.

Alternatively, laparoscopic approach can be performed. After establishing pneumoperitoneum and placing a 30° camera through an umbilical port, two other trocars are placed. In a small diamond shape incorporating the seromuscular layer of the jejunal wall, 3 or 4 transabdominal sutures are placed. The catheter is inserted through the center of the diamond into the bowel and anchored to the skin.

Complications include wound infection and catheter dislodgment. As with the other types of tubes, radiographic confirmation using contrast should be performed to confirm the correct position if there is suspicion of dislodgment, as feeding the subcutaneous layer or intraperitoneal cavity can have severe consequences.

8.9 PEG Placement in Elderly with Dementia and Other Cognitive Disorders

Nutritional access in elderly with severe dementia and other cognitive or neurological disorders is controversial and the ethics of placing a feeding tube in a patient with no possibility of getting better has been, and continued to be, debated [22].

Both healthcare providers and the patient's family have serious difficulties, such as not allowing the patient to die from starvation or remain hungry. In the US, the issue of gut access takes an even more practical view. Patients without permanent or long-term gut access often cannot be discharged to a rehab or nursing home. In a recent study, out of 303 patients undergoing PEG placement (mean age of 77.4 years); 42 (13.9%) patients had dementia [23].

While short-term complications were similar to those without dementia, patients with dementia survived significantly shorter after PEG placement than did patients without dementia. Adjusted for age and sex, patients with dementia had a 49% increased risk of mortality. The authors concluded that the insertion of a PEG tube in patients with dementia is not appropriate.

Moreover, another study [24] demonstrated that the presence of dementia was also associated with shorter mean time to death ($P < 0.05$). More importantly, PEG placement in dementia patients did not improve neither short-term and long-term mortality, nor did it improve rehospitalization rate as compared with patients who underwent PEG placement for alternate indications, such as other neurological diseases or head and neck malignancy, and even was associated with shorter time to death.

Therefore, careful selection of patients with dementia is warranted before PEG placement weighing the risks and benefits on a personalized basis. Interestingly, the rate of improvement of the nutritional biomarker albumin was lower in the dementia group compared to other groups of patients undergoing PEG placement ($P < 0.02$). Multivariate regression analysis showed that the presence of dementia was an independent predictor for mortality rate within the first year, and 1 month mortality rate in patients undergoing PEG insertion. In another study by Gingold-Belfer et al. [25] out of 189 patients aged ≥64 years with severe dementia who underwent PEG tube insertion, increased albumin levels at baseline, and continuous increases were the only predictors of survival after adjustment for age and comorbid diseases ($p = 0.004$).

C-reactive protein was identified as an early predictive factor of mortality in patients undergoing PEG [26]. This study included 135 patients (mean age of 73 ± 17 years): 90.4% with neurological dysphagia and 9.6% with tumors compromising oral intake. Higher CRP levels were the only independent predictive factors for 30-day mortality and were also a risk factor for 90-day and 180-day mortality. CRP levels ≥35.9 mg/dL could predict death at 30 days with a sensitivity of 0.810 and a specificity of 0.614.

A large Japanese study [27], which included 1199 hospital patients and 2, 160 long-term care patients 65 years or older with PEG tube placement, has demonstrated there is a significant discrepancy with what healthcare workers (physicians and nurses) perceive and expect will occur after PEG, and what in reality happens following PEG placement. In the hospital patient group of this study, 62.9% of patients had advanced dementia, while in the long-term care patient group, 61.7% of patients had advanced dementia. PEG tube feeding was expected to prolong survival for 51.1% of hospital patients with advanced dementia. Improved QOL was expected for 39.1% of them. The rate of patients enjoying their own lives was lower in long-term care patients who had advanced dementia (4.2%) than in the other patients (16.4%). To make things more complicated, approximately 60% of relatives reported satisfaction with the QOL of the patients, both in the long-term care patients with advanced dementia and the other patients. We will continue to place feeding tubes despite the fact there is no evidence to suggest long-term survival rates improved in patients with advanced dementia who undergo PEG placement for dysphagia [28].

8.10 Final Thoughts

Nutritional status in the elderly has been shown to affect mortality, functional decline, hospital length of stay, and risk of fall. The elderly are at increased risk for malnutrition and often present to the hospital in a malnourished state. Improved nutrition has been shown to decrease the incidence of disability and improve functional outcomes. The best access to nutrition is enteric, and aggressive use of enteric nutrition is recommended in the elderly population when the goal is to improve outcome.

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9 Antibiotic Management in the Elderly Patients

Massimo Sartelli

9.1 Introduction

The antibiotic dosing regimen should be always established depending on the host factors and properties of antibiotic agents. Antibiotic pharmacodynamics integrates the complex relationship between organism susceptibility and patient pharmacokinetics. Pharmacokinetics describes the fundamental processes of absorption, distribution, metabolism, and elimination, and the resulting concentration versus time profile of an agent administered in vivo. The achievement of appropriate target site concentrations of antimicrobials is essential to eradicate the relevant pathogen. Suboptimal target site concentrations may have important clinical implications and may explain therapeutic failures, in particular, for bacteria for which in vitro MICs are high [1].

To be able to provide effective antibiotic therapy to this population, it should be important to understand the altered pharmacokinetics and pharmacodynamics of drugs in elderly patients due to comorbid conditions and the normal physiological changes associated with aging and the increased risk of acquiring drug-resistant bacterial infections.

Rational and effective dosage and administration strategies based on pharmacodynamic breakpoints and detailed understanding of the pharmacokinetics of antibiotics in elderly patients can increase the chances of achieving complete eradication of an infection in a timely manner. Importantly, this strategy helps prevent the selection of drug-resistant bacteria and minimizes the toxic effects of antibacterial therapy in elderly patient [2].

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9.2 Alterations in Pharmacokinetics

Antibiotics are among the most prescribed drugs in the world. In the last years there has been an increase of antibiotics prescription in elderly patients. As persons age, the gastrointestinal tract undergoes a variety of morphological and functional changes leading to delayed gastric emptying, reduced splanchnic blood flow, and alterations in pH.

Key pharmacokinetic parameters such as the bioavailability of orally administered antibiotics are affected by these changes in the intraluminal environment. Therefore, when treating elderly patients with oral antibiotics, it is important to consider the impact, even if small, that these gastrointestinal changes may have on drug absorption [2].

Elderly patients tend to have an increased proportion of adipose tissue to lean mass compared to younger patients. With this increased fat content, lipophilic antibiotics are more readily soluble in tissue compartments, leading to increased half-lives of lipid-soluble drugs, including rifampin, fluoroquinolones, macrolides, oxazolidinones, and tetracyclines [3]. A concomitant decrease in total body water and lean mass contributes to decreased solubility of water-soluble drugs in tissue compartments, leading to increased plasma concentrations of hydrophilic antibiotics, including aminoglycosides, beta-lactams, and glycopeptides [3]. Due to this decreased total body water, elderly patients with severe infections should be administered full loading doses of aminoglycosides and glycopeptides when indicated.

As patients age, there is an increased risk for decreased clearance of drug from the body due to declining function of the lung, kidney, bladder, gastrointestinal, and circulatory system, which leads to drug accumulation [3].

Renal function declines as part of the normal aging process, even without concomitant renal disease. Therefore, it is paramount to assess renal function when considering the pharmacokinetics of antibiotics in elderly patients. The kidneys are essential for drug elimination of many antimicrobial agents, including but not limited to beta-lactams, glycopeptides, aminoglycosides, daptomycin, ciprofloxacin, levofloxacin, and trimethoprim/sulfamethoxazole. With decreased renal function leading to impaired drug clearance, renally eliminated drugs can accumulate in the body resulting in prolonged half-lives, high serum concentrations, and increased risk of toxicity. When renal replacement therapy is utilized in advanced kidney failure, drugs may be eliminated to a greater extent than with normal renal elimination, requiring patient- and agent-specific dosage adjustments.

9.3 Elderly Patients and Antimicrobial Resistance

Antimicrobial resistance (AMR) is one of the greatest threats to public health, sustainable development, and security worldwide. Its prevalence has increased alarmingly over the past decades. In 2008, the acronym "ESKAPE" pathogens which refer to Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter species was proposed to highlight those pathogens where ABR is of particular concern and to emphasize which bacteria increasingly "escape" the effects of antibiotics [4]. These organisms are increasingly multi-drug- (MDR), extensive-drug- (XDR), and pan-drug-resistant (PDR) and this process is accelerating globally.

Elderly patients are at increased risk of acquiring drug-resistant bacterial infections due to multiple factors including more frequent and prolonged contact with the health care system, chronic disease states that impair immune function, immunosenescence that comes with normal aging, and use of medical devices prone to bacterial colonization including indwelling catheters. Patients and residents in long-term care facilities are more likely to be colonized with at least one MDRO, including extended-spectrum beta-lactamase producers, methicillin-resistant Staphylococcus aureus (MRSA), and vancomycin-resistant Enterococcus (VRE) [5].

Compared to infections with antimicrobial-susceptible organisms, infection with an MDRO is associated with significantly increased mortality [6].

9.4 Conclusion

Infections are leading causes of morbidity and mortality in the advanced aged.

With an increasing elderly population in the world, and increasing antimicrobial resistance, it is important that clinicians understand how to utilize antibiotics effectively and safely in this patient population.

Rational and effective dosage and administration strategies based on pharmacodynamic breakpoints and detailed understanding of the pharmacokinetics of antibiotics in elderly patients can increase the chances of achieving complete eradication of an infection in a timely manner. Importantly, this strategy helps prevent the selection of drug-resistant bacteria and minimizes the toxic effects of antibacterial therapy in the elderly patient.

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10 Enhanced Recovery in Emergency Abdominal Surgery

Joël L. Lavanchy and Beat Schnüriger

10.1 Introduction

The concept of ERAS includes pre-, intra-, and postoperative treatment bundles in order to improve patients' outcomes on different levels. One of the first study collaborations to scientifically elaborate best practices on perioperative care was founded in 2001 by Ken Fearon and Olle Ljungqvist. This collaboration resulted in an evidence-based guideline on elective colonic resection and was published in 2005 [1]. The legacy of the ERAS-study group lies in the definition of treatment bundles in the pre-, intra-, and postoperative course involving all aspects and professions of surgical care including surgeons, nurses, anesthesiologists, ICU physicians, etc. It has been successfully applied in clinical practice and scientifically investigated for patients undergoing elective bariatric [2], cardiac [3], colorectal [4, 5], gynecologic [6], head and neck [7], hepatic [8], pancreatic [9], reconstructive [10], thoracic [11] and urologic surgery [12].

However, it is in the nature of emergency surgery that patients are unprepared for surgical intervention at the time of admission and that they present in altered psychosocial and pathophysiological conditions. This group of acutely ill patients is not amenable e.g., for a prehabilitation program. Moreover, as timely decision-making and treatment is critical in the emergency setting, the possibilities of preoperative optimization are limited.

Nevertheless, there is great optimization potential during the intra- and postoperative course of acute surgical interventions. ERAS protocols have been successfully implemented in emergency patients—selected articles will be presented in this chapter.

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10.2 Definition of Enhanced Recovery After Surgery

The optimization and standardization of interventions aim to enhance the recovery of patients in order to reduce morbidity, intensive care unit length of stay, and H-LOS. Which in turn, translates into reduced hospitalization costs and socioeconomic benefits for the entire society. Table 10.1 shows the items of the latest ERAS protocol [4]. Of note, enhanced recovery programs not only define treatment bundles but also monitor whether patients are treated according to the defined protocols.

10.3 Enhanced Recovery After Surgery Protocols in Emergency Abdominal Surgery

The introduction of ERAS protocols in various fields of elective abdominal surgery led to decreased morbidity resulting in faster recovery and shorter H-LOS [16–18]. Succeeding in elective surgery, ERAS protocols have been adapted for emergency surgery by focusing on intra- and postoperative treatment bundles, as preoperative optimization is not feasible.

10.3.1 Contents of ERAS Protocols in Emergency Surgery

Currently, there are four trials investigating ERAS versus conventional care (CC) in patients undergoing emergency abdominal surgery [13–15, 19]. These studies included patients undergoing emergency colonic resections or required operation for perforated peptic ulcer. In three studies [13–15], the pre-, intra-, and postoperative ERAS items were described in detail and are marked with asterisks (*) in Table 10.1. One study does not give details on the assessed ERAS items [19].

Table 10.1 Items of ERAS protocols

Preoperative	Intraoperative	Postoperative
Counseling* Optimization (Risk assessment, smoking cessation, etc.) Prehabilitation Improving nutritional care Management of anemia Prevention of nausea and vomiting* Preanesthetic medication* Antimicrobial prophylaxis and skin preparation* No bowel preparation* Fluid and electrolyte management Avoidance of fasting and carbohydrate loading*	Standard anesthetic protocol* Fluid and electrolyte management* Prevention of hypothermia* Minimal surgical access* Avoidance of drainage of the peritoneal cavity* Avoidance of nasogastric intubation*	Analgesia* Thromboprophylaxis* Fluid and electrolyte management* Early removal or avoidance of urinary drainage* Prevention of ileus* Glycemic control Nutritional care* Early mobilization*

*Investigated in emergency abdominal surgery [13–15]

10.3.2 Impact on Outcomes of Enhanced Recovery After Surgery Protocols in Emergency Surgery

The first study that compared ERAS with conventional care (CC) in patients undergoing emergency abdominal surgery was published in 2014 [13]. Since then, three additional studies followed [14, 15, 19]. The mean age of included patients in these four studies ranged from 36.6 to 68 years.

In 2014, a randomized controlled trial assessing the applicability of ERAS protocols in emergency abdominal surgery was published [13]. These investigators demonstrated that an ERAS protocol in peptic ulcer surgery in young patients with a mean age of 36.6 years is able to reduce the H-LOS with similar morbidity and mortality rates. Likewise, in 2014, a retrospective matched cohort study showed that an ERAS protocol reduced H-LOS in patients undergoing emergency colorectal resection compared to conventional care [14]. However, in 2016 a retrospective cohort study did not demonstrate reduced H-LOS in emergency abdominal surgery patients following an ERAS protocol, but reduced major complications compared to conventional care [19]. A retrospective matched cohort study of patients undergoing emergency colorectal resection—published in 2018—showed a shorter time to normal bowel function, reduced H-LOS and morbidity when comparing ERAS to CC [15].

In summary, the findings of these four studies comparing ERAS with CC in patients undergoing emergency abdominal surgery suggest, that (1) ERAS is feasible also in emergency cases, (2) had a positive impact on H-LOS and morbidity, and (3) was without impact on mortality.

10.4 ERAS Protocols in Elderly Patients Undergoing Emergency Surgery

Currently, there are no studies available that specifically assess ERAS protocols in elderly patients undergoing acute surgical interventions. However, ERAS protocols have been investigated in elderly patients undergoing *elective* surgery [20–23].

In 2012 and 2014, there were two prospective, randomized controlled trials published comparing ERAS with CC in a total of 78 and 233 elderly patients undergoing elective colorectal resection for cancer [20, 23]. The median age of the investigated populations were 71.5 and 75.2 years, respectively. Both studies revealed a shorter H-LOS in the ERAS compared to the CC group. On the other hand, in 2016 a matched retrospective cohort study of 88 patients with a median age of 77.2 years undergoing elective open pancreaticoduodenectomy showed similar morbidity when comparing ERAS with CC [21].

Despite the lack of direct scientific evidence, ERAS protocols are expected to be beneficial also in the elderly acute population [24]. Frail patients, in particular, would profit from an adapted enhanced recovery program. The geriatric population with increased cardio-pulmonary, renal, hepatic, and neurologic comorbidities and reduced reserves including e.g., malnutrition are more susceptible to worse outcomes [25, 26]. Therefore, close monitoring, early mobilization, optimization of perioperative analgesia, adapted volume resuscitation, tight glucose control, etc., are even more important than in younger, otherwise healthier patients. However, the feasibility of ERAS protocols in elderly emergency patients needs to be assessed thoughtfully. It is of paramount importance to adapt the ERAS bundles according to the capabilities of geriatric patients, e.g., early mobilization might not be possible due to coexisting musculoskeletal or neurologic disorders. Therefore, the feasibility and impact on outcomes of the implementation of defined ERAS protocols in the elderly emergency population need to be investigated in prospective, randomized studies.

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The Role of the Internist in the Care of Elderly Patients Undergoing Emergency Surgery

11

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11.1 Introduction

Internists are physicians who specialize in internal medicine. Internists differ from physicians who specialize in family practice because internists only care for adults while family practice physicians may practice pediatrics, obstetrics and gynecology, and surgery. Internists are adept at obtaining medical histories and performing physical exams. Since internists do not specialize in any one disease, they are able to care for patients who present with concerns across the spectrum from wellness and prevention to the most complex medical conditions.

Internists can practice in many different clinical settings. For example, internists can practice in the outpatient setting, hospital, or other institution such as a rehabilitation facility or long-term care facility. Internists who care for patients in offices or clinics outside the hospital are often referred to as primary care physicians. Internists who care for patients who are hospitalized are called "hospitalists." The term "hospitalist" was defined in the landmark article, "The Emerging Role of Hospitalists in the American Health Care System" published in the New England Journal of Medicine in 1996 [1]. The authors defined a hospitalist as "a physician whose primary professional focus is the general medical care of hospitalized patients. Their activities include patient care, teaching, research, and leadership related to Hospital Medicine." Internists, therefore, practice in an outpatient setting as primary care

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physicians, as hospitalists, or a combination of both. Since the 1990s, the number of hospitalists has grown considerably. The American Hospital Association notes that while there were 1000 hospitalists in the USA in 1996, the number grew to 38,000 in 2012 and greater than 44,000 in 2014 [2]. Hospital medicine is considered the fastest growing medical specialty [3]. Hospitalists are often most closely involved both in the training of internal medicine residents and clinical research.

The question often arises as to what happens when a patient cared for by a primary care physician requires urgent surgery? In particular, what happens when an elderly patient requires emergency surgery? This is a very pertinent question as the population ages. Physicians are faced with the question of whether a patient is ever too old or too ill to have surgery, especially emergency surgery. In this chapter, we propose that the elderly patient requiring emergency surgery is the patient that requires all of the expertise of the internist, from the primary care physician to the hospitalist. The internist must have constant and meticulous communication with the surgeon and the surgical team. In caring for the elderly patient contemplating surgery, the wishes of the patient or the health care proxy must be considered and carried out. The internist contributes to all aspects of the care of the patient both before and after surgery. It is often the internist, particularly the primary care physician, who coordinates all of the follow-up care after hospitalization for surgery.

Faced with a medical or surgical emergency, to whom does the patient turn? Often, it is the primary care physician. The internist working in the outpatient setting may have had the opportunity to form a long-term relationship with the patient and the patient's family. The PCP will know the patient's medical and surgical history, the patient's medications and medication allergies or adverse reactions to medications. The physician's knowledge of the patient's social history cannot be underestimated. The primary care physician will know the patient's living situation and his or her network of social support, if there is one. Even when the relationship between the physician and the patient is new or even brand new, the internist is specifically trained to obtain accurate data expeditiously.

The primary care physician is often the first contact between the patient and the medical community. The internist will assess the patient's condition and arrange the appropriate diagnostic testing. If surgery is contemplated or indicated, the PCP will often rely on the close relationship with the patient to make a decision. Particularly in the elderly, a discussion of care in the event of an emergency may have occurred prior to the acute event. Even if this discussion has taken place previously, these issues are discussed again. If the conversation has never occurred, the patient's wishes must be elucidated and understood.

At the time of an emergency, it is often the internist, specifically the primary care physician, who will have an understanding of the patient's wishes. In the best situation, the primary care physician will know the patient, the family member, or other previously appointed health care proxy, and will have had these crucial discussions about end of life care *before* the emergency occurs. When the emergency requires surgical evaluation, the patient may be referred directly to the emergency room or hospital. Internists form communication pathways and referral networks with surgeons who are contacted. Care must be coordinated. It is the internist's responsibility to convey information accurately and succinctly. In the traditional model, when a patient is admitted to the hospital, the primary care physician continues to care for the patient. It is at this point, however, if the primary care physician admits the patient to a hospital staffed with hospitalists, that care is transferred to the hospitalist. There are pros and cons of this transition. One concern is that once the patient's care is transferred from the primary care physician to the hospitalist, the bond between the patient and the PCP may be broken. The primary care physician may become more peripherally involved at a point in time when the patient is most ill. This transfer may be perceived as a loss of control or "power" by the primary care physician and may make the PCP less satisfied with his or her role [4]. The patient may also be disappointed when his or her long-term physician is less involved.

Once care has been transferred to the hospital, the term "comanagement" has been used to describe the collaboration between hospitalists and surgeons in the care of patients. Comanagement is described as a "negotiated relationship that lets the medical specialist share the responsibility, authority, and accountability for the care of the surgical patient." [5] Later in this chapter, we will discuss the evidence to support whether this collaboration actually improves clinical outcomes.

Once the primary care physician has evaluated the patient, conducted the appropriate diagnostic evaluation, and recognized the need for emergency surgery, the physician will have a frank discussion with the patient and/or the health care proxy. Advance directives may have already been discussed, but now the attention turns to the surgical procedure. Important questions to consider include the following: What are the patient's intentions or expectations? What is the likelihood that the patient will recover from the surgery and return to baseline status? If the baseline condition is relatively "good" and surgery is expected to return the patient to baseline, the physician, the patient, and the proxy may all consider the option of surgery and the adherent risks to be acceptable. If, however, the baseline condition of the elderly patient is poor, the decision to proceed with surgery must be carefully considered. For example, if the patient has dementia or multiple chronic medical problems, surgery may not even return the patient to the prior poor baseline status and the choice may be not to proceed with surgery. In this context, all parties concerned, the patient, the health care proxy, the primary care physician, the hospitalist, and the surgeon must consider the quality of life versus merely prolonging life. Concepts of "frailty" and "futility" will be discussed as we proceed with this discussion.

11.2 Medical Evaluation of the Elderly Patient Requiring Emergency Surgery

11.2.1 Goals of the Medical Evaluation

The internist is frequently called upon to conduct a medical evaluation for patients planning to undergo surgery, whether in an outpatient or acute care setting. Patients undergo medical evaluation in order to minimize known risks and identify any unknown risks, including underlying comorbidities, that may compromise patient safety. In the past, the term "medical clearance" has been used to describe this process. However, this term has fallen out of favor among many providers and has been replaced with "medical evaluation," a term thought to be more representative of the provider's role [6]. To some, the term "medical clearance" is a misnomer implying that a patient has been "cleared" of risks that the surgery may present. The patients and their families may mistakenly be led to believe that the surgery is without risk and that safety is essentially guaranteed. Additionally, the term "clearance" undermines the true goal of the assessment and it fails to deliver useful information to the surgeon. Designating a patient as "cleared" for surgery does not give any information about estimating risk or predicting postoperative outcomes. Goals of the medical evaluation include:

- Quantifying the risk involved.
- Identifying additional risk factors that may affect the patient's operative risk.
- Determining what interventions can be taken to mitigate the risk.

A thorough medical evaluation ensures that the surgeon, patient, and patient's family understand the potential risks and likelihood of complications perioperatively or postoperatively. Thorough and effective communication between teams is essential when a patient is being evaluated for surgery. Numerous factors contribute to operative risk in elderly patients, including age, cardiac health, exercise tolerance, obesity, smoking status, comorbidities, and medications. Surgical scoring systems take these factors into consideration to predict the risk to the patient [7].

11.2.2 Surgical Scoring Systems

Numerous risk calculators and scoring systems exist to aid the internist and surgeon in evaluating and classifying the patient's risk. Commonly used tools include: the National Surgical Quality Improvement Program (NSQIP) Myocardial Infarction or Cardiac Arrest (MICA) risk-prediction rule, the NSQIP surgical risk calculator, and the Revised Cardiac Risk Index (RCRI). These scoring systems were developed based on clinical databases.

The RCRI is a multivariable predictive index used to stratify the risk of major perioperative cardiac complications; it is largely included in the American College of Cardiology and American Heart Association guidelines to assess risk based on clinical factors [8]. Published in 1999 and adapted from the original Goldman Cardiac Risk Index, it is simpler and easier to use, gaining widespread use among clinicians conducting medical evaluations. The RCRI is composed of six equally weighted factors (Table 11.1).

Data was based on a single-center prospective cohort of 2893 patients undergoing major elective noncardiac surgery over the age of 50. The patients were then monitored for major cardiac complications including cardiac arrest/ventricular fibrillation, acute myocardial infarction, third-degree heart block, pulmonary edema, and cardiac death [9, 11] (Table 11.2).

Table 11.1 Revised cardiac risk index factor (RCRI) [9]

1. History of coronary artery disease
2. History of congestive heart failure
3. History of cerebrovascular disease (stroke or transient ischemic attack)
4. Diabetes requiring treatment with insulin
5. Chronic kidney disease (creatinine >2 mg/dL)
6. High-risk surgery including suprainguinal vascular, intraperitoneal, intrathoracic

Table 11.2 Risk of complications with associated confidence intervals (CI) [9, 10]

	Risk for cardiac death, nonfatal myocardial infarction, and nonfatal cardiac arrest	Risk for myocardial infarction, pulmonary edema, ventricular fibrillation, primary cardiac arrest, and complete heart block
With no risk factors	0.4% (95% CI: 0.1–0.8)	0.5% (95% CI: 0.2–1.1)
With one risk factor	1.0% (95% CI: 0.5–1.4)	1.3% (95% CI: 0.7–2.1)
With two risk factors	2.4% (95% CI: 1.3–3.5)	3.6% (95% CI: 2.1–5.6)
With three or more risk factors	5.4% (95% CI: 2.8–7.9)	9.1% (95% CI: 5.5–13.8)

The RCRI was evaluated for its ability to predict cardiac complications and mortality in a 2010 systematic review [12]. The review analyzed 24 studies totaling 792,740 patients from 1966 to 2008. The authors concluded that the RCRI stratified low- versus high-risk patients undergoing noncardiac surgery moderately well with the exception of vascular noncardiac surgery. Additionally, it was not an accurate predictor of all-cause mortality, an expected result given that cardiac events only make up a proportion of perioperative and postoperative mortality.

The two other aforementioned scoring systems were developed from the American College of Surgeons (ACS) NSQIP. The NSQIP is a risk-adjusted database of surgical outcomes. It originated in 1994 among the Veterans Affairs medical centers, in response to high rates of morbidity and mortality [13, 14]. Studies subsequently showed a considerable decrease in surgical morbidity and mortality, leading to the creation of ACS-NSQIP in 2004 [15]. At participating hospitals, an NSQIP-trained Surgical Clinical Reviewer analyzes medical records to collect 135 variables preoperatively and up to 30 days postoperatively. Complications fall into nine main categories:

- Overall mortality
- Overall complications
- Cardiac complications
- Postoperative pneumonia
- Intubations required within 48 h post-surgery
- Unplanned intubations

- Pulmonary embolism and venous thrombosis
- Renal dysfunction
- Surgical-site infections including superficial, fascia, and deep infections

NSQIP data is risk-adjusted and validated using a logistic regression model. As such, even if two participating hospitals are of different sizes and serve different patient populations, their results can be compared. Using data from over 525 participating hospitals and more than one million operations, the ACS created the NSQIP MICA risk-prediction rule and the NSQIP surgical risk calculator.

The NSQIP MICA risk-prediction rule assesses the risk of perioperative myocardial infarction or cardiac arrest (CA). The tool, which was developed in 2011, is based on a single large multicenter study analyzing intraoperative and postoperative MI or CA up to 30 days after surgery. Cardiac arrest was defined as "chaotic cardiac rhythm requiring initiation of basic or advanced life support", while an MI was defined as meeting one or more of the following criteria: "documented electrocardiographic findings of MI, ST elevation of ≥1 mm in >1 contiguous leads, new left bundle-branch block, new Q-wave in ≥2 contiguous leads, or troponin >3 times normal in the setting of suspected ischemia" [8].

Additionally, the study also looked at intraoperative and postoperative MICA among patients undergoing aortic or noncardiac vascular surgery as a secondary endpoint. Overall, the authors concluded that the MICA risk calculator has a high discriminative ability for intraoperative and postoperative MICA that surpasses RCRI. This was especially seen in patients undergoing vascular surgery [16].

The NSQIP Surgical Risk Calculator assesses risk based on the type of surgical procedure being performed. This calculator takes 21 patient-specific factors into account, such as age, sex, BMI, functional status, and whether the case is emergent or non-emergent. Using this tool, clinicians can calculate the estimated percentage risk of a major adverse cardiac event (MACE), death, and eight other outcomes. Because it is based on "procedure targeted" models, the NSQIP surgical risk calculator may be the most accurate in predicting the risk of surgery-specific MACE and mortality.

Each of these three scoring systems has utility in assessing the risk of surgical complications; all three are recommended in the 2014 American College of Cardiology/American Heart Association Perioperative Guidelines [8]. However, limitations exist for each system, as such, it is important to identify the most appropriate score for every individual clinical scenario. As previously stated, the RCRI is not an accurate predictor of all-cause mortality and has a lower discriminative ability compared to NSQIP MICA. The NSQIP surgical risk calculator takes emergent versus non-emergent cases into account, but it is not specifically designed for patients undergoing emergency surgery. According to the ACS-NSQIP, the definition of an emergency is one which "is usually performed within a short interval of time between patient diagnosis or the onset of related preoperative symptomatology". It is implied that the patient's well-being and outcome is potentially threatened by unnecessary delay and the patient's status could deteriorate unpredictably or rapidly. The NSQIP Principal Operative Procedure must be performed during the hospital admission for the diagnosis." [17].

Additionally, the two tools based on NSQIP data have not been validated with a population outside the NSQIP database, limiting the MICA and surgical risk calculator. Furthermore, the NSQIP definition of an MI may underpredict the number of cases, as the criteria do not necessarily include every case of myocardial infarction. Another limitation is that these systems use the American Society of Anesthesiology Physical Status Classification, a risk scoring system with poor inter-rater reliability [18]. Additionally, NSQIP MICA and RCRI mainly look at elective procedures, and may not be as applicable to patients undergoing emergency procedures. Therefore, these scoring systems, while useful in stratifying risk, may underestimate the risk of morbidity and mortality in patients undergoing emergency surgery. Compared to patients undergoing non-emergent surgery, emergency surgery patients have substantially higher rates of major perioperative complications [19].

In fact, a study published in 2019 found that the ACS-NSQIP risk calculator "significantly and consistently underestimated the risk of mortality and morbidity in all nonagenarians (individuals between 90–99 years old) undergoing emergency general surgery (EGS)"; this was especially pronounced in certain populations, particularly those with any combination of weight loss, steroid use, or septic shock [20]. For patients with any two out of these three risk factors, mortality greatly increased.

The study population consisted of 4724 nonagenarians undergoing EGS, identified from 2007 to 2015 in the NSQIP database. For patients who experienced concomitant weight loss and had been prescribed steroids, the study reported a mortality rate of 100%; the rate predicted by the ACS-NSQIP risk calculator, however, was approximately 50%. Similarly, there was a mortality rate of 93% among nonagenarians undergoing EGS who presented with weight loss and septic shock, compared to approximately 70% predicted by the ACS-NSQIP risk calculator. For patients with septic shock and steroid use, the ACS-NSQIP risk calculator predicted a mortality rate of roughly 65% compared to the 80% reported in the study population. In light of these findings, the authors recommended that the ACS-NSQIP risk calculator be used with caution in nonagenarians undergoing EGS, as morbidity and mortality may be significantly underpredicted.

The Emergency Scoring System (ESS) is a recently developed risk stratification tool specifically designed for patients undergoing emergency surgery; it is validated to predict mortality in emergency surgery patients. Additionally, a follow-up study showed that it reliably predicts the rate of 30-day postoperative complications in emergency surgery patients [21]. The ESS was developed using ACS-NSQIP data, identifying 22 variables that impact mortality to assess risk. Compared to other risk stratification calculators, ESS is unique in that it was developed using data from emergency surgeries and intended for patients undergoing emergency surgery. Additionally, the variables in the ESS calculators are objective and clearly defined.

11.2.3 Frailty as a Predictor of Postoperative Outcomes

The risk assessment calculators are convenient tools to help determine the risk of perioperative and postoperative complications. These scoring systems, however, do not provide meaningful information on the patient's quality of life postoperatively. Elderly patients undergoing emergency surgery may survive the initial treatment, but then suffer significant physical and mental disability secondary to comorbidities and underlying health [22].

Age alone is not a valid predictor of postoperative morbidity, as patients of the same age may vary widely in their exercise tolerance, ability to live independently, and ability to tolerate medical procedures. Even when taking into consideration the patient's comorbidities, the ability to predict long-term postoperative outcomes remains a challenge. Picture two patients: the first, a 76-year old with coronary artery disease and a history of a prior myocardial infarction; the second, a 90-year old with the same medical history. At first glance, the 76-year-old patient might seem like a better surgical candidate. If, however, we knew that the 76-year old was wheelchair-bound, while the 90-year old regularly participated in half marathons, the older patient may then be viewed as a better surgical candidate.

This missing information is best quantified as a patient's frailty. Frailty is a syndrome that is characterized as the physiologic decline in many systems associated with older age. This decline depletes the body's ability to return to homeostasis after stressors, increasing vulnerability to illness and surgery [23, 24]. Simply put, the frail adult is unable to recover as easily as the non-frail adult and will experience a decline in health disproportionate to the degree of the stressful event. These patients are at an increased risk of postoperative morbidity, and thus may have better long-term outcomes with less aggressive measures. It is, therefore, imperative for the internist to identify these adults to help guide the surgeon and family in decision-making. Ideally, this can be done during the patient's visits to their primary care physician, but may also be completed by the hospitalist or surgeon at the onset of an acute event. While some patients may be readily identified as frail, the term is imprecise and can be difficult to objectively delineate.

Many different scoring systems have been developed to identify the frail individual. Some are more comprehensive, such as the Canadian Study of Health and Aging Frailty Index, which has 70 items and would be unlikely to be used in the emergency setting. A 2016 comprehensive review found 67 different frailty assessment tools capturing different aspects of the syndrome [25]. The study identified the Physical Frailty Phenotype as the most commonly used, followed by the Deficit Accumulation Index and the Vulnerable Elders Survey. The Physical Frailty Phenotype (PFP), also known as the Fried or Hopkins Frailty Phenotype, consists of five criteria:

- Low physical activity (Kcals/week)
- Unintentional weight loss (greater than 5% of body weight in the last year)
- Weakness (grip strength)
- Slow walking speed (greater than 6 s to walk 15 feet)
- Exhaustion (self-reported)

Each of the criteria has 1 point value: 0 indicating "not frail", 1–2 indicating "intermediate-risk" of frailty, and 3+ indicating the "frail" phenotype [26].

Table 11.3 FRAIL Scale [27]

Each letter is valued at 1 point for a positive response
Fatigue ("Have you felt fatigued? Most or all of the time over the past month?")
Resistance ("Do you have difficulty climbing a flight of stairs?")
Ambulation ("Do you have difficulty walking one block?")
Illnesses ("Do you have any of the following illnesses: hypertension, diabetes, cancer (excluding minor skin cancer), chronic lung disease, heart attack, congestive heart failure, angina, asthma, arthritis, stroke, and kidney disease?") Five (or greater) = 1, fewer than 5 = 0
Loss of weight ("Have you lost more than 5% of your weight in the past year?")
Scores range from 0 to 5. 0 = non-frail, 1–2 = prefrail status, 3–5 = frail status

While convenient in the outpatient setting, this frailty assessment tool requires patient participation and would not be suitable for evaluation in the emergency setting. A quicker frailty screening assessment tool that has been developed is the FRAIL scale (Table 11.3), which uses the mnemonic FRAIL to help clinicians remember the five items of the questionnaire [27].

Other frailty indexes have been specifically developed for the emergency setting. One such tool is the Emergency General Surgery Specific Frailty Index (EGSFI), which is a 15-variable measurement tool that includes comorbidities, daily activities, health attitude, and nutrition [28]. This assessment tool was validated as a reliable predictor of postoperative complications and mortality in geriatric emergency general surgery patients.

It is worth noting that many of the frailty assessment tools focus on physical ability and health without taking into account a cognitive assessment of the patient [29]. Frailty has been shown to be associated with an increased rate of cognitive decline and an increased risk of cognitive impairment [30, 31]. Additionally, patients with cognitive impairment have an increased risk of adverse outcomes following physical insult. Therefore, the effects may be compounded in the cognitively impaired frail patient.

Regardless of the frailty assessment tool used, identifying the frail patient is an important part of the medical evaluation by the internist. The presence of the frailty syndrome can significantly impact postoperative outcomes of the geriatric patient undergoing emergency surgery and may heavily influence the type of treatment deemed appropriate in the clinical situation.

11.2.4 Final Decision-Making Considerations

Once a medical evaluation has been performed, the decision to treat surgically versus non-surgically can be fully undertaken. It is worthwhile to note that semantics are very important when discussing with the patient and their family whether or not to proceed with surgery. The decision to perform surgery should not be referred to as whether to "treat or not." This can convey a sense of abandonment in situations when the patient might not be an ideal surgical candidate thus leading the family to opt for more aggressive measures. Instead, the language should focus on whether to treat *surgically* or *medically*, thereby conveying proper treatment of the patient with either choice.

The final decision will consider the surgical risk calculation for the operation along with the patient's frailty index. These calculations can give useful information about the risk of complications and the likelihood the patient will make a meaningful recovery. This information has its limitations and cannot be used as a sole deciding factor, rather it should be used as a guide for the patient, the patient's family, and physicians to make a decision on the most appropriate course of action. Even with the risk assessment and frailty index tools, it is often difficult in emergency situations for a surgeon to make an informed decision without knowledge of a patient's baseline level of function and medical history as age alone has not been proven to be a good indicator. For this reason, obtaining input from the primary care physician, the medical record as well as any advance directives is imperative to making a final decision [32].

It is worth noting that there should be a balance between time spent obtaining these records and expediency of treatment. In the event that immediate surgery may provide life-saving treatment, it is important not to delay surgery, which may be associated with reduced overall outcome. In the case of elderly patients severely injured by trauma, it is recommended that aggressive measures be taken initially as outcomes have been found to be the most favorable with this approach [33]. Overall, the decision to proceed with surgery or not will largely be dictated by the individual clinical picture, the expectations and wishes of the patient, his or her health care proxy, availability of alternate treatments, and the risks of not performing the surgery.

11.3 Decision: Surgery

In the following section, we will discuss the role of internists in the care of elderly patients who are deemed to be appropriate surgical candidates.

11.3.1 Postoperative Management of Surgical Patients

The burden of emergency surgery on the elderly patient is immense, as postoperative mortality rates steadily increase with age with a notable jump after age 75 [34]. The mortality rate after an appendectomy, for example, is 6–7 times higher in those over 70 compared to those 20–49 years old [35]. Given the elevated risks of surgery in this population, proper management during the postoperative period is crucial. Many complicating factors contribute to this elevated mortality including the presence of comorbid conditions as well as altered physical and mental status masking clinical improvement or decline. Postoperative delirium is another important consideration as up to 18% of these cases are complicated by delirium [36].

The American Geriatrics Society's Geriatrics for Specialists Initiative has released guidelines for the optimal care of geriatric patients in the postoperative period [37]. They recommend the use of interdisciplinary teams, early mobility and walking, avoiding restraints, sleep hygiene, adequate nutrition, fluids and oxygen, and appropriate pain control. Postoperative management of elderly patients also necessitates the assessment of goals of care with patients and their families as well as rehabilitation to work towards a satisfactory discharge status [36]. The complicated nature of caring for the geriatric patient in the postoperative period warrants tailored care by a multidisciplinary team to ensure optimal outcomes.

11.3.2 Comanagement between Internists and Surgeons

A care model that has been gaining traction is comanagement between the primary surgical and hospitalist teams. In this care model, the internist performs daily rounds on comanaged patients, orders diagnostic and therapeutic interventions as well as consults as needed, manages all chronic medical comorbidities, and responds to nurse and nurse practitioner questions [38–40]. These care models have traditionally been implemented for patients with elevated risk for perioperative complications determined by advanced age and presence of comorbid conditions [38].

Many studies have investigated the impact of these integrated care teams and have come to conflicting conclusions. Importantly, studies have demonstrated comanagement techniques leading to reduced mortality [40, 41], decreased length of stay (LOS) [41–44], decreased surgical delays [41, 42], decreased complications [38], and improved postoperative functional status [44]. Two studies looked at health care professional and resident perceptions of comanagement and both demonstrated a strongly positive view of the programs [39, 40]. Of note, the study that found the greatest improvement in mortality with comanagement was done in the department of vascular surgery. The authors of this paper posit that the complex nature of their patients and the presence of multiple comorbidities made internist management an invaluable adjunct to patient care [40]. Other studies, however, failed to find a notable impact of comanagement on mortality or complication rates [39, 41–44]. Potential pitfalls of this care model may include the fragmentation of care and disengagement of the surgeon [5]. Table 11.4 shows the outcomes of seven

Table 11.4 The impact of comanagement on patient outcomes

Author	Department	Length of stay (LOS)	Mortality	Surgical delays	Complications	Post-op functional status
Huddleston [38]	Orthopedic surgery	No change	N/A	N/A	Decreased for minor only	N/A
Batsis [45]	Orthopedic surgery	Decreased	No change	Decreased	No change	N/A
Pinzur [43]	Orthopedic surgery	Decreased	No change	N/A	No change	N/A
Auerbach [39]	Neurosurgery	No change	No change	N/A	N/A	N/A
Lizaur-Utrilla [41]	Orthopedic surgery	Decreased	Decreased at 6 and 12 mo	Decreased	No change	No change
Tadros [40]	Vascular Surgery	Increased	Decreased	N/A	N/A	N/A
Adogwa [44]	Neurosurgery	Decreased	N/A	N/A	No change	Improved

recent studies investigating the impact of comanagement. The discrepancies between studies indicate the need for larger future studies with standardized comanagement approaches for a more definitive answer.

11.3.3 Multidisciplinary Geriatric Units

Another more intensive care model for the geriatric population is the multidisciplinary geriatric care unit. This care model has been described as a diagnostic and therapeutic strategy designed for the identification, prioritization, and appropriate management of the complex needs of the postoperative geriatric patient [46]. Riemen et al. proposed the seven key features of a multidisciplinary hip fracture program including orthogeriatric assessment, rapid optimization of fitness for surgery, early identification of individual goals for multidisciplinary rehabilitation, continued, coordinated orthogeriatric and multidisciplinary review, liaison with other services (mental health, falls prevention, bone health, primary care, social services), governance structure for all states, and palliative care [47]. Prestmo et al. outlined their own approach to the "comprehensive geriatric care unit" orchestrated by the Departments of Geriatrics and Internal Medicine [48]. This unit incorporated comprehensive geriatric assessment focusing on somatic health (comorbidity management, review of drug regimens, pain, nutrition, elimination, hydration, osteoporosis, and prevention of falls), mental health, function (mobility and activities of daily life [ADLs]), social situation, early discharge planning and early mobilization, and initiation of rehabilitation [48].

Comprehensive geriatric units show promising outcomes including improved mobility in 4 months [48], increased rate of discharge home [48], decreased length of stay [49], and decreased surgical delay [49]. Table 11.5 demonstrates outcomes from two studies investigating the impact of comprehensive geriatric care units. The role of the primary care physician in this multidisciplinary model is to communicate with the in-hospital team to obtain clear information on the complete evaluation, specialist consults, and management recommendations. Although additional research is required to validate favorable results in the literature, comprehensive geriatric units may, indeed, improve care for the increasing needs of the elderly population.

Table 11.5 The Impact of Comprehensive Geriatric Care Units on Patient Outcomes

Author	Department	Length of stay (LOS)	Mortality	Surgical delays	Complications	Post-op functional status
Biber [49]	Orthopedic Surgery	Decreased	No change	Decreased	No change	N/A
Prestmo [48]	Orthopedic Surgery	Longer	N/A	No change	N/A	Improved

11.3.4 Postoperative Care by the Primary Care Physician

The internist plays a key role in patient management in the postoperative period. In the paper by Brooke et al., the authors described how early follow-up with a primary care physician following thoracic aortic aneurysm repair with postoperative complications was associated with a reduction in readmission rate from 35.0 to 20.4% [50]. The authors hypothesized that these appointments allowed PCPs to identify errors in discharge, recognize postoperative complications, and intervene early [50]. Timely PCP follow-up after hospital admission has repeatedly been associated with superior outcomes and reduced readmission rates [50–53]. Further research is required to delineate specific subpopulations of elderly individuals who would most benefit from early PCP follow-up.

A significant cause of preventable readmissions is poor coordination during transfers of care. During these transitions, the elderly are particularly vulnerable to experiencing poor care quality and care fragmentation. After hospital discharge, elderly patients with continuous complex care needs frequently require ongoing medical care in multiple settings including subacute or long-term rehabilitation facilities. Given that fewer than 50% of patients see their PCPs within 2 weeks of hospital discharge, this lack of provider continuity increases the likelihood of errors and inappropriate care [50]. Primary care physician follow-up after hospital discharge has been highlighted as a key intervention point in medical care to prevent hospital readmissions. Comprehensive programs to enhance care during transitions between settings can reduce not only 30-day hospital readmissions but also readmissions for the entire year after the initial hospitalization [54–56]. Although elderly patients may have a primary care physician, post-hospitalization follow-up is frequently impacted by a variety of factors, including lack of health insurance, copayment requirements, transportation issues, as well as scheduling difficulties.

11.3.5 Wound Care

Wound care for the postoperative elderly patient in the outpatient setting should be managed with a multidisciplinary perspective. Palliation with symptom control and avoiding infectious complications should be the main goal of care. The physician and nursing staff are critical for dressing changes, choice of dressing, and documenting changes in wound status to the health care team [57]. Rehabilitation specialists such as occupational, physical, and speech therapists assist with maximizing mobility and feeding abilities. The nutritionist can assist with optimal protein and caloric intake to ensure optimal wound healing. Home attendants spend the most time with patients and often are the best resources for information on intake and functional status. The social worker assists in identifying social support systems and ensuring that the patient and/or family and home health aides are able to appropriately care for the wound and bring the patient to all appointments.

11.3.6 Medication Reconciliation

Medication errors harm an estimated 1.5 million people each year in the United States, and the majority of these errors occur during transitions of care [58]. Pharmacists are well-suited to detect these errors and to help patients manage drug-related issues during transitions of care. Studies have demonstrated that accurate medication reconciliation and medication education can decrease readmission rates, which could potentially improve patient outcomes. Reduction in readmission rates can also have significant financial implications to the health system. Studies have demonstrated the feasibility of incorporating pharmacy technicians in the medication reconciliation process. Expanding a pharmacy technician's role to include the initial phase of medication reconciliation can play a vital role.

11.3.7 Depression Screening

Depression in the elderly is common with an estimated prevalence of approximately 12% [59]. Depression is even more common in physically ill elderly patients in general hospitals with estimates of 5–58% and a mean prevalence of 29% [59]. Diagnosis and treatment of depression in hospitalized elderly patients will not only help to alleviate distress but could also help to reduce the risk of suicide. The identification of depression in elderly patients in the perioperative period is of particular importance due to its association with a myriad of complications. Increased rates of postoperative infection, cognitive impairment, and severe acute and chronic pain have all been linked with perioperative depression [59]. Unfortunately, diagnosing depression in perioperative elderly patients can pose particular problems. This is primarily because symptoms of depression, such as loss of appetite, weight loss, decreased energy and fatigue, and disturbed sleep are similar to symptoms of physical illness. This is further complicated by the fact that the elderly frequently deny low mood and physicians in the hospital often feel too busy to take time to inquire about depression. These difficulties highlight the pivotal role primary care physicians must play in postoperative depression screening in the elderly population.

11.3.8 Special Considerations: Pain Management in the Elderly

Pain management is a complex challenge for geriatric patients in the postoperative period. Special considerations in this population include decline in organ function, polypharmacy, change in pharmacokinetics and drug sensitivity, and frailty [60]. Although these factors make elderly individuals more prone to adverse effects of pain medications, rates of uncontrolled pain are consistently higher among older individuals, especially those with cognitive impairment [61, 62]. The mainstay of treatment for severe postoperative pain in the elderly population is opioids. Despite their side effect profile, opioids are safe in the elderly when awareness of patients' altered sensitivity is recognized [60]. Conservative initial dosing and continuous reassessment of patient response to pain medications are of vital importance [63].

The Beers criteria was developed to identify particularly high-risk pain medications for the geriatric patient. High-risk drugs include meperidine, antihistamines, muscle relaxants, tricyclic antidepressants, and benzodiazepines [64]. Adjunctive treatment with acetaminophen, nonsteroidal anti-inflammatory drugs, or other non-opioid drugs is the best way to reduce opioid consumption and duration of use [65]. Utilization of multimodal pain control remains the best way to manage postoperative pain for geriatric patients who are more sensitive to analgesia, sedation, respiratory depression, cognitive impairment, delirium, and constipation [60].

In conclusion, if a post-discharge follow-up visit is to succeed in reducing the risk of rehospitalization, it will need to include extensive exploration of the patient's changed medical condition, as well as provide education and support. Several guidelines have been produced, including a checklist for physicians by the California Healthcare Foundation [66] and the American Medical Association's there and Home Again Safely publication which details the responsibilities of primary care practices during transitions in care [67]. Recommended responsibilities include coordination with caregivers, case managers, and home health workers, sharing of recommendations and medication instructions with all members of the team, medication reconciliation, involvement of visiting home nurses, wound care, and extensive instruction to patients and caregivers to ensure safe post-hospitalization discharge in the elderly. With the rapid growth in hospitalists and development of the specialty of hospital medicine, it has become increasingly important for hospital-based physicians, surgeons, and primary care physicians to communicate relevant patient information at hospital discharge. Delays and omissions in discharge communications are common and may lower the quality of post-hospitalization care. A number of interventions appear effective in improving the timeliness and quality of discharge [66].

11.4 Decision: Nonsurgical Management

In the following section, we will discuss the care of elderly patients who, for a variety of reasons, are not deemed to be surgical candidates. It is imperative in these situations for the PCP to discuss advance directives with the patient and his or her health care proxy. A Health Care Proxy is a person or persons, either a family member or close friend, appointed by the patient to make health care decisions when the patient is no longer able to do so.

11.4.1 Advance Directives

Advance directives are legal documents that give a patient the opportunity to outline the type of care he or she desires in the event of an emergency or at the end of life. Different approaches have been developed to solve this problem including the deployment of MOLST forms [68]. MOLST, or Medical Orders for Life-Sustaining Treatment, formerly known as Physician Orders for Life-Sustaining Treatment (POLST), are a portable order set created and signed by the provider and patient to direct care across settings in the last stages of life [69]. The MOLST form is "based on communication between the patient, his or her health care agent or other designated surrogate decision-maker, and health care professionals that ensures shared, informed decision-making" and improved quality of care at the end of life [70]. Primary care physicians are encouraged to have discussions about end of life care with elderly patients so that their wishes will be known should a MOLST or other legal document not be available.

11.4.2 Early Palliative Care

Palliative care focuses on achieving the best possible quality of life for elderly patients and their caregivers, based on patient and family needs and goals independent of prognosis. Interdisciplinary palliative care teams assess and treat symptoms, support decision-making, and help match treatments to informed patient and family goals to ensure a safe and secure living environment.

Palliative care is provided both within and outside hospice programs. Palliative care outside hospice is offered independent of the patient's prognosis and simultaneously with life-prolonging and curative therapies for persons living with serious and life-threatening illnesses. Ideally, palliative care should be initiated concurrently with a diagnosis of a serious illness and at the same time as curative or disease-modifying treatment [71]. Unlike hospice, palliative care may be primary, secondary, or tertiary [70]. Primary palliative care should be part of what all treating primary care physicians provide their patients, such as pain and symptom management, and discussions about advance care planning. Secondary palliative care is offered when the primary care physician refers to palliative care experts for unusually complex or difficult problems. Tertiary palliative care includes research and teaching in addition to palliative care expertise [71].

11.4.3 Hospice

At some point along the palliative care continuum, patients may enter a phase when the transition to hospice care is warranted. While advanced disease states often require intensive and painful interventions, they are not always associated with improved outcomes, nor preferred by patients or their families. Both palliative care and hospice services for elderly patients focus on increasing quality of life and promoting comfort in patients. For elderly patients with multiple chronic conditions, palliative care serves to promote comfort whereas decline in physical or cognitive function during rehabilitation after surgery may warrant a referral for hospice. Early recognition by nurses to integrate palliative care or initiate an evaluation for hospice referral benefits elderly patients by encouraging care that promotes comfort and a desirable quality of life [72]. Nurses can play a pivotal role in transforming patient care by advocating for palliative approaches [72].

United States hospice services are delivered in a model established by statute in Medicare and followed by most other insurers. The Medicare Hospice Benefit is largely restricted to patients with a prognosis of living for 6 months or less if the disease follows its natural course, who agree to forgo treatment [57]. Hospice is designed to provide comprehensive, interdisciplinary, team-based palliative care, mostly in a place the patient calls home [57]. Hospice care is appropriate when patients and their families decide to forgo curative therapies in order to focus on maximizing comfort and quality of life, when curative treatments are no longer beneficial, when the burdens of these treatments outweigh their benefits, or when patients are entering the last weeks or months of life [57].

In the latter half of the twentieth century, most critically ill elderly patients died in hospitals. A recent study in the New England Journal of Medicine titled "Changes in the Place of Death in the United States" analyzed data from the Centers for Disease Control and Prevention and the National Health Statistics database for patients dying of natural death in the United States from 2003–2017 [73]. For the first time, the most common place of death is at home. The authors note that death at home is preferable for most people, but for many this may not be feasible. However, more information about the patient and family experience of dying at home is needed. Patients' family members can be given significant responsibility and may be unprepared.

There are existing barriers that impede the integration of palliative care services and timely referral for hospice among frail elderly patients. These barriers include lack of knowledge regarding the purpose, benefits and existence of palliative services and hospice care, and the lack of optimal utilization of integrative palliative care and timely hospital referral. MOLST forms are an important step for allowing the elderly near the end of life to translate their wishes into orders and to avoid unwanted resuscitation, artificial ventilation, or hospitalization. Furthermore, understanding and respecting patients' desires for place of death and supporting patients in achieving their wishes should be a priority among the healthcare team.

11.5 Conclusion

The care of the elderly patient undergoing emergency surgery requires a team approach. The internist plays a role in every stage of care. The primary care physician often has established a rapport with the patient prior to the acute event and has an understanding of the patient's underlying medical condition and goals. When a patient is admitted to the hospital, the hospitalist frequently assumes care of the patient and will be called upon to conduct a medical evaluation prior to the decision to pursue a surgical approach. The hospitalist and surgeon can form comanagement teams to improve outcomes. The primary care physician is called upon again to care for the patient after discharge from the hospital. The PCP also plays a role in establishing early palliative or hospice care, whether in a facility or at home. The contribution of the internist in the management of the elderly patient facing emergency surgery should not be underestimated.

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Acute Kidney Injury in the Elderly Surgical Patient

12

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In keeping with the focus of the book, this chapter will focus on "hot topics" in the diagnosis and management of acute kidney injury (AKI) in the geriatric (classically defined as over 65 years of age) surgical patient. The spectrum of AKI in the elderly is heterogeneous, and both patient and renal outcomes may be affected by the etiology of the injury, by comorbidities, and by unanticipated consequences of required treatments.

The extent of the problem is clear. It is estimated by the year 2030, almost 20% of the population in the US will be over the age of 65 [1]. Overall, compared with younger patients, elderly patients are more likely to be hospitalized, to require admissions to an intensive care unit (ICU), and to undergo invasive surgical and diagnostic procedures. The incidence of acute kidney injury in the elderly has steadily increased over the last several decades. A recent evaluation of patients admitted to intensive care units found the mean age of patients with acute kidney injury was 63 and a quarter of the patients were over the age of 75 [2]. Despite new advances, the overall mortality of patients with acute kidney injury remains about 50% and can be as high as 80% in some populations, especially in patients with underlying multisystem disease and sepsis. Acute perioperative kidney injury has been referred to as an "under-recognized problem [3]," and it has become increasingly clear that even a "minor episode" of AKI especially in the elderly can be complicated by increased morbidity, CKD and its attendant risks, and by an increase in mortality [2, 3]. After exploring background data, we will review some examples of targeted perioperative therapeutic approaches that may help mitigate renal injury.

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Selected areas and treatment options related to specific issues of AKI management will be reviewed and ethical considerations related to the initiation of dialysis care in elderly patients with AKI will be briefly explored.

12.1 Defining Acute Kidney Injury

First defined in early literature as “War Nephritis,” [4], the hallmark of acute kidney dysfunction is an abrupt change in the serum creatinine or a fall urine output, which usually occurs over a matter of hours or days. This sudden loss of renal function is associated with the accumulation of nitrogenous waste products (urea), and other measured and unmeasured substances typically cleared by urinary excretion. AKI leads to imbalances in all of the physiological systems normally maintained by the kidney, including regulation of body fluid volume, mineral, electrolyte and acid-base metabolism, and the regulation of RBC mass. Acute kidney injury itself is not a single disease with a uniform pathogenesis, but rather it is a manifestation of end-organ injury or dysfunction.

To facilitate more precise communication among clinicians and investigators, the terms and definitions of acute kidney injury (AKI) were initially standardized in 2004, with the publication of the RIFLE (Risk, Injury, Failure, Loss of Kidney Function, and End-Stage Disease) AKI criteria [5]. The classification is based on changes in the serum creatinine, or glomerular filtration rate (GFR), from a baseline value, and timed, body-weight adjusted urine flow rates. It consists of three severity grades: Risk, Injury, and Failure, and two outcome classes: loss and ESRD. The presence of renal dysfunction for greater than 4 weeks was defined as a persistent loss of renal function and patients were classified as having end-stage renal disease if the loss of renal function persisted for greater than 3 months.

The RIFLE criteria helped to standardize the approach to AKI, and clinical observations utilizing the criteria began to demonstrate the actual frequency and significance of AKI, especially among ICU patients [6, 7]. Although the RIFLE criteria were not initially designed as a tool to predict mortality or adverse outcomes, application of the RIFLE criteria across clinical populations suggested that mortality increased as RIFLE AKI severity increased, and further the RIFLE severity classes were associated with increased length of hospital stay, the development of CKD, and even death [3, 6–10]. These findings highlighted the importance of previous studies which demonstrated that even small (0.3 mg/dL) changes in the serum creatinine are associated with an increased risk of adverse events [11].

These observations demonstrated the potential immediate and long-term impacts of a “little episode of AKI” and further informed the need to more precisely define this common clinical occurrence. In 2007, the RIFLE criteria were modified. The requirement for a baseline serum creatinine was eliminated and instead The Acute Kidney Injury Network (AKIN) criteria required the measurement of two serum creatinine levels over a 48-h period [12]. More recently (Table 12.1), the criteria have been further revised by The Kidney Disease: Improving Global Outcomes (KDIGO) Workgroup [13]. This widely accepted definition utilizes a change in serum creatinine (not GFR) over a period of time (greater than 0.3 mg/dL within

Table 12.1 Criteria for acute kidney injury

Criteria for acute kidney injury

	RIFLE[1]	AKIN[2]	KDIGO[3]
Diagnostic criteria*			
		Increase in serum creatinine of ≥0.3 mg/dL or ≥50% within 48 hours OR Urine output of <0.5 mL/kg/hour for >6 hours	Increase in serum creatinine of ≥0.3 mg/dL within 48 hours or ≥50% within 7 days OR Urine output of <0.5 mL/kg/hour for >6 hours
Staging criteria			
Risk (RIFLE) or stage 1 (AKIN/KDIGO)	Increase in serum creatinine to 1.5 times baseline OR Urine output of <0.5 mL/kg/hour for 6 to 12 hours	Increase in serum creatinine of ≥0.3 mg/dL or to 150 to 200% baseline OR Urine output of <0.5 mL/kg/hour for 6 to 12 hours	Increase in serum creatinine of ≥0.3 mg/dL or 1.5 to 1.9 times baseline OR Urine output of <0.5 mL/kg/hour for 6 to 12 hours
Injury (RIFLE) or stage 2 (AKIN/KDIGO)	Increase in serum creatinine of to 2 times baseline OR Urine output of <0.5 mL/kg/hour for 12 to 24 hours	Increase in serum creatinine to 200 to 300% baseline OR Urine output of <0.5 mL/kg/hour for 12 to 24 hours	Increase in serum creatinine to 2.0 to 2.9 times baseline OR Urine output of <0.5 mL/kg/hour for 12 to 24 hours
Failure (RIFLE) or stage 3 (AKIN/KDIGO)	Increase in serum creatinine to 3 times baseline OR Increase in serum creatinine by >0.5 mg/dL to >4.0 mg/dL OR Urine output of <0.3 mL/kg/hour for >24 hours or anuria for >12 hours OR Initiation of renal replacement therapy	Increase in serum creatinine to >300% baseline OR Increase in serum creatinine by >0.5 mg/dL to ≥4.0 mg/dL OR Urine output of <0.3 mL/kg/hour for >24 hours or anuria for >12 hours OR Initiation of renal replacement therapy	Increase in serum creatinine to ≥3.0 times baseline OR Increase in serum creatinine of ≥0.3 mg/dL to ≥4.0 mg/dL¶ OR Urine output of <0.3 mL/kg/hour for ≥24 hours or anuria for ≥12 hours OR Initiation of renal replacement therapy
Loss (RIFLE)	Need for renal replacement therapy for >4 weeks		
End stage (RIFLE)	Need for renal replacement therapy for >3 months		

RIFLE: risk, injury, failure, loss, ESRD; AKIN: Acute Kidney Injury Network; KDIGO: Kidney Disease: Improving Global Outcomes; ESRD: end-stage renal disease.
* AKIN and KDIGO provided both diagnostic and staging criteria. RIFLE provided a graded definition of AKI that is implicit in the staging criteria.
¶ In patients <18 years, stage 3 AKI is also defined by KDIGO as a decrease in estimated glomerular filtration rate (eGFR) to <35 mL/min/1.73 m^2.

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48 h or greater than 50% within 7 days) or by a change in urine output. In addition, it also encompasses staging criteria for degree of severity, up to and including, the initiation of renal replacement therapy. Current criteria draw clear distinctions between acute and chronic kidney disease, and between transient and persistent acute kidney injury. Thus, kidney injury, which recovers within 48 h, is defined as *transient AKI*, whereas AKI that lasts more than 3 days but is reversible within 7 days is considered *persistent AKI*. If renal recovery occurs within a 90-day span, it is viewed as *acute kidney disease* and if it persists beyond 90 days, it is viewed as *chronic kidney injury* [13, 14]. These distinctions are important because they allow us to more precisely communicate regarding long-term risks and outcomes.

12.2 Approach to Acute Kidney Injury

AKI can be caused by factors external to the kidney (referred to as "pre-renal or post-renal" etiologies) or by factors and events intrinsic to the kidneys. In all cases, as will be reviewed in greater detail within the sections that follow, age-related changes in renal reserve and the presence of comorbidities increase the risk of AKI in the elderly.

12.3 Post-renal AKI

Post-renal acute kidney injury (or obstructive AKI) can be caused by obstruction to the upper urinary tract (from renal pelvis to bladder) or by lower tract bladder or urethral obstruction. Overall the incidence of obstruction accounts for about 5% of all cases of AKI. However, in the elderly, the incidence of obstruction-related AKI increases with age and approaches 10% of cases by age 70 [2].

Lower tract obstruction will affect both kidneys and result in diminished renal function. In elderly men, underlying prostatic hypertrophy or urethral strictures coupled with the use of postoperative narcotic preparations are the most common causes of functional postoperative obstruction. In women, diseases of the bladder and pelvic malignancies are often associated with lower tract obstruction. Neurogenic bladder disorders as seen with diabetes can affect both men and women. Patients with lower tract obstruction may have suprapubic tenderness or other voiding complaints. Assuming that a contralateral kidney is present and functional, upper tract unilateral obstruction may present with renal colic or it may be asymptomatic and detected by hydronephrosis on renal ultrasound. Urinary output will be absent if complete lower tract obstruction is present. However, with incomplete obstruction of either the upper or lower tract, urine output can be variable and can include polyuria. Depending on the etiology of the obstruction, the urinalysis may be normal or demonstrate hematuria. The urinary sodium and creatinine indices and urinary osmolality (discussed in more detail later) are variable in obstructive acute kidney injury. Structural or functional urinary obstruction should be considered in every elderly postoperative patient and the evaluation should include bedside bladder scanning, or if unavailable a trial of bladder catheterization.

12.4 Pre-renal AKI

A functional decline in glomerular filtration rate due to renal under-perfusion is classically referred to as pre-renal azotemia or pre-renal AKI. Glomerular under-perfusion may occur from hypovolemia as occurs with hemorrhagic shock, or from other disorders such as cardiac disease and sepsis. Glomerular under-perfusion can occur with increased "third-spaced" fluids and a reduction in the perceived effective intra-arterial volume as can occur with congestive heart failure, or be related to vasodilatation and splanchnic pooling as can occur with hepatic disease.

Renal vascular autoregulation is a key defense of renal perfusion. In states of volume depletion the sympathetic system, vasopressin, the renin-angiotensin system, and the prostaglandin cascade are activated. The angiotensin system causes both afferent (preglomerular) arteriole and efferent (postglomerular) arteriolar constriction. Relative to its effect on the efferent arteriole, angiotensin II-mediated afferent vasoconstriction is less pronounced, and this effect is further balanced by the effects of prostacyclin and vasodilatory prostaglandins on the afferent arteriole. The net compensatory effect in states of volume depletion is such that the balance of afferent and efferent pressures results in a predominance of efferent arteriolar constriction with preservation of the filtration pressure across the glomerular tuft. Thus, despite a fall in renal blood flow, these pressure changes help maintain GFR and lead to an increase in the filtration fraction, or ratio of the GFR and the renal blood flow. In the setting of pre-renal azotemia, following filtration into the renal tubule, under the influence of appropriately activated hormonal systems, the reabsorption of filtered salt, water, and urea is increased and a low volume (typically less than 0.5 mL/kg/6–12 h) of concentrated urine with a high osmolality and a low sodium concentration will be excreted. Alterations in baseline underlying intravascular volume and/or in renal vascular autoregulation as can occur with commonly used medications, such as diuretics, nonsteroidal agents (NSAIDS), and angiotensin enzyme inhibitors and receptor blockers (ACEi/ARBs), impair the renal response to intravascular volume depletion and increase the risk for pre-renal AKI.

Although there is no dogma on the absolute incidence of isolated pre-renal, it is estimated to account for 40–60% of the episodes of AKI in ICU patients, and the elderly are at increased risk [2, 15–18]. Baseline intravascular volume depletion is common among elderly hospitalized patients [19], and this coupled with the over-zealous use of diuretics, the ubiquitous use of NSAIDs (in some elderly populations their use approached 96%) [20], the widespread use of ACEi/ARBs and the presence of underlying cardiac disease, and most significantly the presence of underlying, underappreciated CKD all increase the risk of pre-renal AKI in the elderly. In addition, as discussed in more detail in later sections, both renal sodium reabsorption and maximum renal concentrating ability are reduced in the aged kidney and these physiological changes further reduce compensatory responses to renal hypoperfusion and increase the risk of pre-renal AKI [20–23].

Although in certain settings, even apparently trivial episodes of pre-renal AKI have been associated with increased mortality [24], typically, if detected early and mitigated, most cases of pre-renal azotemia are reversible. Rapid identification and correction of factors that led to the insult are critical. In elderly patients with reduced compensatory mechanisms, the failure to recognize pre-renal AKI increases the likelihood that contributory medications (ACEi/Diuretics, antibiotics) and/or conditions such as renal hypoperfusion will continue unabated and lead to acute intrinsic ischemic renal tubular injury (ATN) [25].

12.5 Intrinsic Renal Disease

Intrinsic AKI is caused by direct damage to the kidney. This damage can persist or progress, even after the original insult is removed. Acute intrinsic renal damage is typically classified by the pathologic location of the injury, and thus is classified as acute tubular injury (related to medications, toxins, or ischemic tubular injury), as interstitial injury (e.g., from antibiotics, proton pump inhibitors, NSAIDS, inflammatory injury, etc.), or from glomerular or vascular causes. Acute glomerulonephritis and acute vasculitis are less common in the acute surgical patient and will not be a focus here.

Acute kidney injury from intrinsic damage to the kidney typically follows a three-part sequence of initiation (ischemia-reperfusion), maintenance, and recovery. The tubular damage and death that result in what is commonly called acute tubular necrosis can arise because of a toxic insult, or ischemic insult to the kidney. Ischemic injury to the kidney is often thought of as a continuum of pre-renal azotemia. In fact, the causes of the conditions are similar. Ischemic acute tubular injury results when renal hypoperfusion is severe or sustained and exceeds the autoregulatory defenses of the kidney. In this situation the ischemia may result in cell injury, or if prolonged, in cell death with necrosis, apoptosis, cell sloughing, and intra-tubular obstruction.

In addition, as tubular injury progresses, cellular ATP is depleted, cellular polarity is lost, and tubular reabsorption is disrupted. Thus, prolonged or severe ischemic insults reduce GFR, impair tubular function, and disrupt the balance of minerals, electrolytes, and fluids.

Alternatively, some causes of ischemic tubular injury can occur in the absence of an episode of severe hypotension. This so-called normotensive ischemic injury is often seen in advanced age groups with underlying atherosclerosis, hypertension, or chronic kidney disease wherein changes in vasoactive hormone levels and/or changes in vascular elasticity and responsiveness impair renal autoregulation. Of note, even with normal renal function, otherwise mild illnesses in the elderly can increase the risk of ATN if medications such as the "triple-whammy" of NSAIDs, ACEi/ARBS, and diuretics are in use [26].

Endotoxin-related tubular injury, such as that seen with sepsis can be associated with an increase in renal glomerular blood flow, perhaps related to afferent arteriolar vasodilatation. Thus, the etiology of sepsis-related AKI is likely multifactorial. Activated inflammatory mediators can alter the endothelial function and increase the risk of hypoperfusion-related injury. Other intra-renal changes such as endotoxin triggered renal vasoconstriction, cortical-medullary vascular shunting, and changes in nitric oxide, endothelin, and mitochondrial metabolism occur which lead to tubular cell injury and death [27].

Toxic tubular injury, as distinct from ischemic injury, can be mediated through both endogenous and exogenous toxins. As the key excretory organ for the clearance of all water-soluble substances the kidney is particularly vulnerable to nephrotoxic injury. Medications such as aminoglycosides, and numerous other antibiotics, and antiviral agents, as well as radiocontrast material, and endogenous toxins such as myoglobin, free light chains, hemoglobin, and end products of calcium, phosphate, and uric acid metabolism all pose a threat to the kidney tubules. Data suggests that the cellular changes associated with aging alter tubular resiliency and increase the risk of tubular injury [18, 23–27].

Acute tubular necrosis (ATN) from ischemic and toxic injury accounts for up to 50% of the episodes of ATN in critically ill patients and it is estimated that sepsis accounts for approximately 30% of ATN episodes in the elderly. Recent surgery, age greater than 60, sepsis, the use of nephrotoxic drugs, diabetes CKD, and underlying cardiac disease are all predisposed to AKI in the ICU setting [2, 3, 18, 23, 28].

AKI related to acute interstitial disease is often overlooked and may be more common among the elderly. The classic triad of fever rash and eosinophilia is only present in approximately 10% of patients. The majority of cases of acute interstitial nephritis (60–70%) are related to medication use and the time course between the use of the medications and the onset of symptoms is highly variable and a high index of suspicion is required.

12.6 The Aging Kidney: Added Risks for AKI

Structural, functional, and cellular changes occur within the aging kidney that may increase the risk of AKI. Renal mass is about 25% lower in octogenarians, and it is estimated that by age 70 the number of cortical glomeruli has fallen by between

20% and 40% due to ischemic changes. Glomerular sclerosis occurs along with both tubular atrophy and increased interstitial fibrosis. As the number of glomeruli falls, the remaining undergo hyperfiltration injury and compensatory hypertrophy, which in turn can promote inflammatory mediators and alter the cellular response to stress. Both renal blood flow and GFR fall with aging, these changes may be universal or may be influenced by genetics or other comorbid factors such as hypertension and diabetes, but typically it is estimated that the GRF falls by about 10 mL/decade beginning at age 50. The presence of hypertension and atherosclerotic injury which are both very prevalent with aging further limit renal and glomerular blood flow, and the associated vascular wall thickening reduces vascular responsiveness and heightens the risk of progressive ischemic injury in the setting of pre-renal AKI. In addition to reduced reabsorption of glucose and increased protein spillage, the ability of the kidney to both reabsorb filtered sodium and to concentrate (and dilute) the urine fall with aging and together this impairs the ability of the elderly to quickly respond to changes in intravascular volume [2, 17, 18, 23]. Moreover, the production and response to vasodilatory mediators are reduced and the response to vasoconstrictor mediators is increased. Together these changes also reduce the response to, and increase the risk from, ischemic and hypoxic injury.

Numerous cellular changes occur with normal aging [18]. For example, the kidney requires enormous mitochondrial energy production to drive active transport and the age-related reduction in NAD, which is a requisite coenzyme for mitochondrial oxidative metabolism, increases the risk of AKI [29]. Recent data suggests that sirtuins which regulate proximal tubular epithelial mitochondrial and fatty acid oxidation are affected by aging and these changes may further increase the susceptibility of the mitochondrial rich proximal tubule to ischemic injury [30]. Other changes include a reduction in the rate of cell replication, increases in pro-fibrotic and inflammatory mediators, and the risk of glucose-mediated gene-induction and cellular injury may also be increased with aging [31]. Taken together the structural, functional, and cellular changes that accompany aging all limit kidney reserve, increase its susceptibility to injury, and impair its recovery from cellular stress.

12.7 The Diagnosis of AKI in the Elderly

The Old Guard: Creatinine, urinary indices, and the urinalysis—Utility and Limitations.

12.8 Serum Creatinine

The serum creatinine level does not measure the actual GFR and it is not a precise biomarker for renal function. Moreover, many common events among geriatric surgical patients can alter the serum creatinine concentration. For example, age-related reductions in baseline muscle mass, fluid resuscitation, decreased creatinine production (especially in the context of sepsis) [32], or malnutrition related to illness, can all lower the baseline creatinine. In the elderly a low, or slowly increasing, creatinine may simply reflect low muscle mass rather than "normal" renal function.

This is particularly important in the setting of subacute kidney injury, wherein the rate of rise of creatinine is already less marked [33] Approximately 10–40% of creatinine elimination is achieved by renal tubular secretion, and this too reduces the sensitivity creatinine as a marker of renal injury [34]. Tubular creatinine secretion can be decreased by some medications (e.g., Trimethoprim-sulfamethoxazole) and is increased by the occurrence of AKI. Changes in the serum creatinine may lag behind changes in GFR by several days [18] and relying solely on a change in creatinine to detect renal injury, or to adjust doses of medications lack the precision needed to rapidly detect and mitigate worsening AKI.

Similarly, almost every electronic laboratory report now includes a calculated GFR (eGFR) based on the serum creatinine. The use of these serum creatinine derived nomograms for the estimation of the glomerular filtration rate (eGFR) is inappropriate in the setting of a fluctuating creatinine, as is the case with AKI. For example, consider the following scenario: A 65-year-old female with a baseline creatinine of 1 mg/dL loses both kidneys in an accident. The next day her creatinine is measured at 2 mg/dL. A calculated, nomogram derived eGRF of 30 mL/min automatically appears in the electronic record. But, she has NO kidneys, therefore her actual GFR is zero, and employing the calculated eGFR for drug dosing, etc., will substantially increase the risk of drug-associated toxicity.

Similar to renal injury, the serum creatinine is also a delayed and imprecise marker of renal recovery [33, 34]. Defining the nadir creatinine marking “renal recovery” is especially challenging when the baseline, preadmission creatinine is unknown, as is often the case among surgical trauma patients. Thus, the impact of fluid therapy, antibiotics, diuretics, and other medications on the rate, and extent, of renal functional recovery is imperfectly assessed by the creatinine alone.

12.9 The Urinalysis and Urinary Indices and the Furosemide Stress Test

The etiologies and therapy of pre-renal AKI versus intrinsic causes of AKI differ, and a reliable way to quickly establish the correct diagnosis is clinically important. Urine microscopy is readily available and remains among the most reliable studies for the categorization of AKI [35]. However, reliance on automated laboratory-generated urinalyses may be misplaced. For example, the automated readings correctly identified pathologic granular casts only 24% of the time, as compared to a 76% accuracy rate for nephrologists. Similarly, utilizing an automated laboratory report, nephrologists reached a correct diagnosis only 19% of the time compared with an accuracy of greater than 90% when performing their own urinalyses [35, 36]. In pre-renal AKI the urine microscopy is typically quite bland, whereas in AKI associated with intrinsic tubular damage and acute tubular necrosis (ATN), the urine classically reveals renal tubular epithelial cells, and renal tubular casts, many of which are large, coarse, muddy brown granular casts. The presence of red blood cell casts suggests a glomerular lesion and dysmorphic red blood cells suggest a renal rather than bladder source of entry. White blood cells or white blood cell casts are typically seen in acute interstitial nephritis. Eosinophils may be seen in settings of infection, inflammation, or in the presence of allergic interstitial nephritis.

The predictive value of the urinalysis is improved by coupling the microscopic urinalysis with biochemical testing of the urine. In pre-renal azotemia, oliguria (defined by Stage 1 KDIGO as a urine volume of less 0.5 mg/kg for 6–12 h) can be a marker of "renal success," where oliguria is the expected and appropriate renal physiologic response to reduced effective arterial perfusion pressure. In this setting renal sodium (and water) retention is appropriately increased and, providing that no other confounders are present such as chronic kidney disease, diuretic therapy, or aminoglycoside use, among others, the urinary fractional sodium excretion (FeNa) is typically under 1%. However, if instead, oliguria is due to intrinsic damage to the tubules of the kidney, as is the case with acute tubular necrosis, the fractional excretion of sodium is typically greater than 1%. A similar situation holds for urinary osmolality and urea excretion. Thus, in the setting of oliguria, a bland urinary sediment, coupled with concentrated urine (urine osmolality over 500 mOsm/kg), together with a urea excretion of less than 35%, a FeNa of under 1%, and a supportive clinical history suggest a diagnosis of pre-renal AKI, and appropriate goal-directed therapeutic steps can be initiated [36, 37].

Despite their utility, in elderly patients underlying age-related changes in renal physiology can alter renal salt and water handling and reduce the diagnostic sensitivity and clinical accuracy of the urinary indices. These issues are especially important if diuretics, NSAID, or ACEi/ARB therapy have been ongoing. Thus, in elderly patients urinary osmolality readings of under 500 mOsm/Kg and a FeNa over 1% have been reported despite the presence of pre-renal azotemia [38, 39].

When the history and exam coupled with a well-performed urinalysis and urinary indices have not yielded a clear diagnosis, a Furosemide stress test can offer additional valuable information. The loop diuretic Furosemide administered as a stress test (FST) at 1.0 mg/kg for diuretic-naïve patients and 1.5 mg/Kg for diuretic-exposed patients is used to evaluate tubular integrity and nephron function. A timed 2-h urine output of less than 200 mL predicts progression from Stage 1 to Stage 3 KDIGO-AKI with a sensitivity and specificity of 87% and 84%, respectively [40].

12.10 The New Frontier-Biomarkers, Vascular Tone, and Artificial Intelligence

12.10.1 Biomarkers

The need quickly detect and if possible initiate steps to mitigate renal injury is especially important in elderly patients with diminished renal reserve. Because of the imprecision and lag time of the serum creatinine as a biomarker for renal injury and the categorization cross-over within urinary indices attention has focused on the identification of newer tools to detect the presence of renal injury [41]. Ideally, these biomarkers should distinguish renal injury from damage to other organs, have a high degree of sensitivity and specificity, and quantitatively evaluate the degree of cellular injury. If possible they should separately signal renal injury and renal recovery and be immune from the effects of medications or metabolic products.

Well-studied renal markers are Urine NGAL (neutrophil gelatinase-associated lipocalin), IL 18 (interleukin-18), LFABP (Liver Fatty acid-binding protein), KIM-1 (kidney injury molecule-1), and the product of urine tissue inhibitor metalloproteinase-2 and insulin-like growth factor binding protein 7 (urinary [TIMP-2]* [IGFBP-7]) [41–46]. Urinary NGAL and urinary [TIMP-2]* [IGFBP-7] are two of the most well studied AKI biomarkers in AKI.

The urinary [TIMP-2]* [IGFBP-7] are cell-cycle arrest biomarkers and are released from tubular cells and excreted in urine under conditions of tubular injury from ischemic or toxic stress. Unlike creatinine which is a functional biomarker, these proteins are structural biomarkers [41–44]. These biomarkers have been validated against 340 other candidate markers in prospective, multicenter studies and are approved by the FDA for the early prediction of AKI. Investigators have now validated these biomarkers in cardiac and noncardiac surgery and in ICU patients. A cut-off level of greater than 2 is associated with a ten-fold risk of moderate to severe AKI within a period of 12 h, with a positive predictive value of 90%. Additional studies found that this value also predicted a composite endpoint of the need for dialysis or death with a hazard ratio of 2.1 (95% CI 1.37–3.23 $p < 0.001$). A lower value (>0.3) was associated with a four-fold risk with a 97% negative predictive value. Though promising other factors (diabetes) can increase the urinary excretion of these compounds and though readily available and easy to perform, the assay is expensive and has not gained widespread clinical use.

Neutrophil gelatinase-associated lipocalin (NGAL) expressed by neutrophils and epithelial cell can be measured in plasma and urine and is the most extensively studied of the renal biomarkers. NGAL is found in low levels in urine and plasma, and is released many-fold by renal tubular cells in response to injury. Its levels correlate with the severity of the damage [22], and it can detect subtle injury. However, NGAL levels are increased by many other events (sepsis, respiratory failure, urinary infections) and this has limited its widespread use [45, 46].

Other recent studies have suggested that the plasma KIM-1 levels may be useful for predicting patients at risk for the development of radiocontrast-induced AKI, and a number of studies have suggested that biomarkers may be useful for predicting the progression and severity of AKI [47–51].

Recent studies have linked biomarkers together with other tools to try to better predict the severity of AKI and the risk of progression. For example, urinary biomarkers hemojuvelin (uHJV) and KIM-1 improved the ability to predict AKI progression and mortality after cardiac surgery [52]. Similarly, Koyner and colleagues demonstrated that the Furosemide stress test performed better than every biomarker (including plasma and urinary NGAL, urinary [TIMP-2]* [IGFBP-7], urine IL-18, and fractional excretion of sodium) in predicting progression to stage 3 AKIN-AKI, requirement for RRT, or inpatient mortality. When used in patients with elevated biomarkers (which improves pre-test probability), their combined ability to predict progression to Stage 3 AKIN-AKI and the need for dialysis improved to over 90% [53]. It has been suggested that the combined use of the studies like the Furosemide

Stress test and biomarkers may be akin to the presence of an increased Troponin in patients with heart disease (a "renal stress test") where an abnormal level prompts the need for closer investigation and follow up.

In addition to the FST and biomarkers, measurement of the renal perfusion via contrast-enhanced renal Doppler ultrasound imaging has recently been used to assess renal perfusion and predict AKI in the intensive care setting [54]. However, current studies suggest inter-user reliability is low and the ability to detect the expected changes in renal perfusion after the administration of epinephrine and other vasoactive medications is inconsistent [55]. Similarly, the results of studies on the use of renal vascular resistance to detect early AKI have yet to reliably predict AKI with the sensitivity and specificity required for clinical care [56]. Although additional research may demonstrate future clinical applicability at the present time these tools are not widely used.

12.11 Electronic Alerts and Machine Learning to Predict AKI

Recently, risk prediction scores and clinical decision support have been developed by linking the electronic medical record with artificial intelligence and machine learning. Several perioperative surgical risk scores have been developed, including the Simple Postoperative AKI Risk Classification score which was developed and validated for noncardiac surgery and the MySurgeryRisk algorithm which evaluates the postoperative risk of AKI, along with other major surgical complications and mortality. These machine learning algorithms use real-time, patient-specific data to predict the risk for the development of postoperative AKI [57, 58]. Clinically, these are extremely appealing tools, which, in theory, could help clinicians detect early-stage AKI and initiate timely, targeted interventions to mitigate the progression of renal injury. Prospective randomized trials will be needed to validate these prediction models and determine if their application improves renal outcomes in the general surgical population.

Role of Renal Biopsy: a renal biopsy is the "gold standard" for the diagnosis of AKI, but patient acuity and the potential risk of complications have limited the widespread clinical application AKI-linked biopsies. In 2017, NIH sponsored the Kidney Precision Medicine Project (KPMP), which will evaluate kidney biopsies from patients with clinical AKI [59]. In addition to providing a wealth of carefully cataloged clinical material, a kidney tissue and genome bank will be created to foster the study of genetic and cellular AKI-injury pathways, and promote the discovery of novel AKI therapies·

Over time, the information gained through renal biopsies, together with the development of more sophisticated biomarkers and the application of artificial intelligence, and will no doubt improve our ability to diagnose AKI at its earliest stages and to predict progression. However, at the current time, despite their limitations a complete history and examination together with validated serum and urine indices, a well-performed urinalysis, and careful determination of the urine output, remain trusted clinical tools for the diagnosis and monitoring of acute kidney injury.

12.12 Surgical AKI Mitigation, Outcomes, and Patient-Driven Options

As shown in Fig. 12.1, a patient-specific, standardized, sequential evaluation for relevant perioperative AKI risk factors should be performed for each patient. The presence of underlying chronic kidney, diabetes, and hypertension are important prognostic indicators in the elderly and deserve close attention. In addition, a few recent areas of clinical observation and investigation deserve special mention with regard to perioperative AKI risk mitigation [60].

12.12.1 Preoperative Outpatient Medications

In the elderly, especially in patients with underlying CKD, preoperative NSAIDs are best eliminated, if at all possible. The decision to discontinue ACEi and ARB therapy is less clear. In certain clinical setting, such as diabetes, large meta-analyses suggest that the continuation of these agents in the perioperative setting may reduce the likelihood of cardiovascular events, and decisions regarding their use must be individualized [61].

Apart from preoperative outpatient pharmacotherapy, surgical patients are likely to encounter a variety of potentially nephrotoxic agents as part of their inpatient care and few deserve special mention.

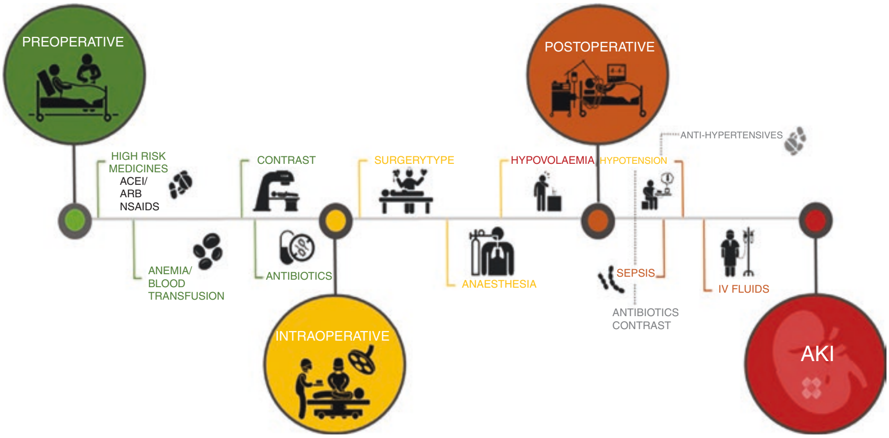

Fig. 12.1 Perioperative acute kidney injury: risk factors and potential perioperative nephrotoxic burden. Abbreviations: *ACEI* angiotensin-converting enzyme inhibitor, *AKI* acute kidney injury, *ARB* angiotension-receptor blocker, *IV* intra-venous, *NSAID* nonsteroidal anti-inflammatory drug. (Walker H. Bell S. Strategies to Reduce Perioperative Nephrotoxicity. Seminars in Nephrology Volume 39, Issue 5, Pages 419–516. Used with permission)

12.12.2 Antibiotics and Proton Pump Inhibitors

Both parent drug and drug metabolites can pose risks to the glomerulus, the tubular epithelia, and the interstitium. In addition, the high metabolic rate of tubular cells increases their susceptibility to nephrotoxins. Key risk factors for drug-associated nephrotoxicity include age (over 60), diabetes, underlying cardiovascular disease, preexisting CKD, and renal under-perfusion. Lists of potentially nephrotoxic agents are widely available; however, a few recent findings deserve special attention.

Vancomycin is one of the most commonly prescribed antibiotics in ICU. In the correct clinical context and at certain drug levels, Vancomycin may produce AKI. Recently more intensive Vancomycin dosing schedules recommend trough levels between 15 and 20 mg/L, and these have been associated with an increase in Vancomycin-induced nephrotoxicity. One recent meta-analysis reported a 2.7-fold increased risk of nephrotoxicity with troughs greater than 15 mg/L as compared to a trough of less than 15 mg/L [62]. Vancomycin therapy is frequently used in combination with piperacillin-tazobactam (PTZ), a beta-lactam antibiotic. This combination has been found to have twice the odds of AKI compared to either agent alone [63]. Similarly, the risk of AKI is increased by combination therapy with Vancomycin and Cefazolin (13% risk of AKI) [63].

Postsurgical patients commonly receive proton pump inhibitors [64, 65]. Evidence-based care suggests that overuse is common and only specific patients (rather than all patients) require therapy and those who receive them should be monitored for evidence of acute interstitial nephritis. A recent meta-analysis reported a pooled adjusted odds ratio of AKI of 1.61 (95% CI: 1.16-2.22; $I^2 = 98.1\%$) among over 2.4 million participants. The risk may be greatest in those with underlying CKD and though the majority of cases recover following drug withdrawal, many patients can be left with some degree of residual kidney dysfunction [64, 65].

12.12.3 Radiocontrast Agents and Gadolinium

Radiocontrast studies are frequently needed in the surgical population. While steps should be taken to identify and mitigate factors associated with contrast associated AKI (CI-AKI), their use should not be avoided if clinically indicated. Recent data suggest that the risk of CI-AKI in patients with normal renal function is negligible. However, in patients with diabetes, CHF, underlying chronic renal disease, and proteinuria (greater than 500 mg) the risk is increased. The CKD associated risk of CI-AKI is linked to the severity of the underlying CKD. In those with an eGFR between 30 and 59, the risk of AKI is approximately 4%. In studies in patients with more significant renal disease (creatinine of 3 mg/dL), the incidence of CI-AKI approached 30%. Most experts consider patients within an eGFR of under 60 with comorbid conditions (diabetes, CHF, liver failure), to be at risk for CI-AKI. Those with diabetes or proteinuria and a GFR of under 45 mL/min and all patients with an eGFR under 30 mLs/min are considered at high risk for CI-AKI [66–68].

The risk of CI-AKI is greatest with intra-arterial administration, and although in some settings low-dose (10–30 mLs in patients with advanced CKD) has been associated with the development of AKI, typically the incidence of AKI is low if less than 100 mLs of contrast is administered. Most data suggest iso-osmotic nonionic agents such as iodixanol are the preferred agents in patients at risk for CI-AKI and may be superior to low-osmolar agents such as lohexol [67]. We typically discontinue NSAIDs prior to the procedure (2–3 days if elective studies). Many experts recommend hydration with saline at 1 mL/kg/h for 6–12 h pre and post procedure [68]. The POSEIDON study demonstrated a reduced incidence of CI-AKI by adjusting fluid replacement therapy to LVEDP, when available, and this is an alternative strategy [69]. Dialysis after contrast exposure is based on clinical indications, rather than to remove the contrast agent.

12.12.4 Gadolinium-Based Contrast Agents (GBCA)

GBCAs are used in about one-third of all MRI exams. Though typically well-tolerated, GBCA has been associated with a small risk for nephrogenic systemic fibrosis (NSF) of the skin, and deposition has been detected in other tissues, including the brain. GBCAs are categorized as linear and macrocyclic, and are grouped as type I, II, and III agents. MRI-related NSF is linked to renal function and in general, both linear and macrocyclic agents are acceptable for patients with a GFR >60. Patients with AKI with or without underlying CKD are at risk for NSF, and if a contrast-enhanced MRI is required a type II, macrocyclic agent is strongly preferred, and linear type I agents should be avoided. More data are required regarding the use of type III agents in AKI. To ensure safety, the requesting clinician should review study plans and conditions with the radiology team [70].

12.12.5 Preoperative Medications, Anesthetics, and Intra-Operative Goals

The type of surgery has been linked to the risk of AKI [3]. For example, gastric bypass surgery is associated with an 8.5% incidence of AKI, whereas emergency cardiac surgery (especially that requiring cardiopulmonary bypass) has been associated with almost 55% incidence of AKI. Overall the incidence of AKI after emergency abdominal surgery is approximately 45% and routine abdominal surgery has a 7–12% incidence of AKI [3]. Regional and general anesthesia are associated with similar risks of AKI. A host of manipulations have been tried and abandoned in an effort to protect patients against preoperative AKI. Recent data suggest that the preoperative administration dexmedetomidine may reduce the risk of AKI [3]. This and other manipulations such as the use of nitric oxide in cardiac surgery to protect the kidney from the effects of red cell lysis [71], and NAD repletion to protect and restore mitochondrial oxidative metabolism have all emerged as potential novel therapies to reduce the risk of kidney injury [29].

One constant finding is the need to maintain renal perfusion, with close attention to mean arterial pressures and urine output. The primacy of volume status in the setting of both sepsis and surgery has been the subject of intense investigation [72–77]. New technologies including Bioelectrical Impedance Vector Analysis (BIVA) have been used to analyze volume status among ICU patients with AKI [78], and early findings suggest that mortality is increased among patients with a greater hydration volume at the time of AKI diagnosis [78].

The impact of fluid restriction on the development of organ dysfunction following major abdominal surgery [76] was recently evaluated in a randomized trial of approximately 3000 patients. The study included patients over the age of 70 and those with underlying CKD (SCr > 2.8 mg/dL) who were deemed at increased risk of postoperative complications. Patients received either fluid liberal (6146 mL) or fluid restrictive (3670 mL) replacement fluids during surgery and for 24 h postoperatively. The restrictive regimen was designed to provide net-even fluid balance. There was no difference in the primary outcome of disability-free survival at first year, but the incidence of AKI (1.71-fold increased risk), and need for dialysis (3.27 times more likely) were both greater among fluid restricted patients. Whether balanced salt-solutions or chloride-based fluids are the treatment of choice in surgical patients remains controversial [79–82]. Further studies are required, but the recent randomized case-controlled studies suggested a minimally decreased risk of major adverse kidney events in critically ill ICU patients and emergency room patients with chloride-restrictive buffered crystalloid as compared with chloride-rich fluids [81, 82].

Similar goal guided therapy has been tested by the application of a standardized KDIGO AKI management bundle in the care of patients deemed to be at high risk for acute kidney injury (Fig. 12.2). Recommendations are based on KDIGO staging of AKI [83]. Common mitigation strategies for all stages of the bundle include avoidance of nephrotoxins (including discontinuation of ACE-I and ARBs for the first 48 h), close monitoring of serum creatinine and urine output, avoidance of hyperglycemia, consideration of alternatives to radiocontrast procedures, functional hemodynamic monitoring, and optimization of hemodynamics by maintaining stroke volume variation <11, Cardiac index >3 L/min/m^2 and Mean arterial pressure >65 mmHg. Recent single-center studies (PrevAKI), applied the KDIGO-AKI bundle to cardiac surgery patients deemed at high risk for postoperative AKI, as identified by urinary [TIMP-2]* [IGFBP-7] biomarkers [84]. Patients who received the KDIGO care bundle showed a significant reduction in postoperative AKI, although the other endpoints, such as the need for dialysis, long-term renal dysfunction, and mortality, were not different between the groups. These data are promising as they suggested the early detection and standardized, outcome directed therapy may reduce the incidence of AKI. Larger multicenter trials may identify additional longer term benefits of this standardized approach to AKI management.

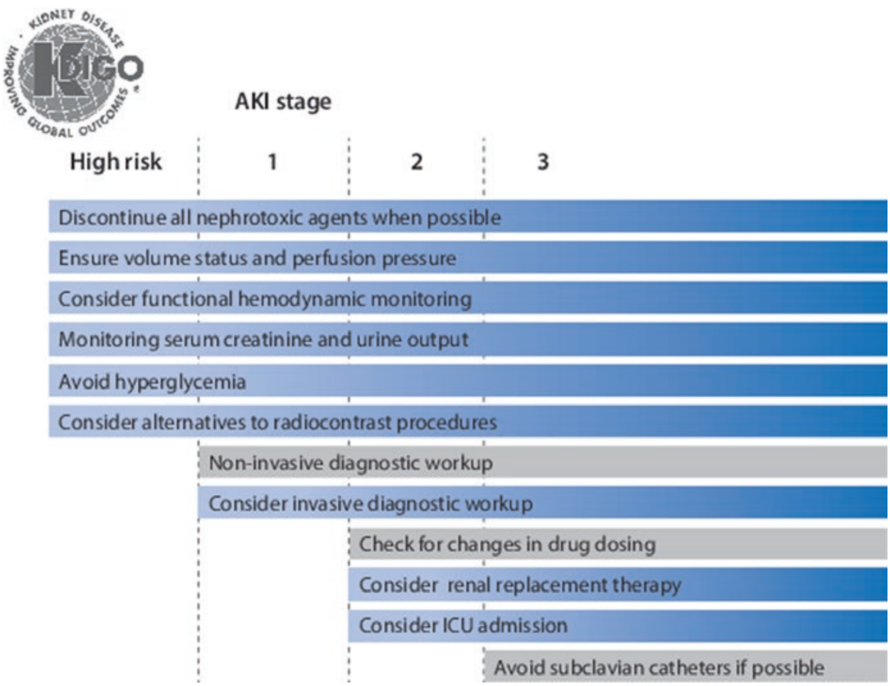

Fig. 12.2 Shading of rows indicates priority of action Solid shading indicates actions that are equally important at all stages, whereas graded shading indicates increasing priority as the intensity increases, *AKI* acute kidney injury, *ICU* intensive care unit. (Used with permission KDIGO Clinical Practice Guidelines for Acute Kidney Injury. Kidney International Supplements (2012) 2, 8–12 March 2012 http://www.kidney-international.org)

12.13 AKI Outcomes and Approach to Dialysis in the Elderly

Although mild episodes of acute kidney injury may be fully reversible, more severe AKI, especially in the setting of the impaired cellular repair and reduced renal reserve that accompany aging, may result in progressive CKD with its associated risk of increased morbidity, mortality, and more frequent hospitalizations. Approximately 30–40% of all cases of AKI occur in the postoperative setting [3] and a recent meta-analysis demonstrated that after an episode of AKI in patients over the age of 65 renal function failed to return to its prior baseline in almost a third of the patients [85]. Others reported a 2-year mortality rate among older patients with CKD superimposed on AKI of approximately 64% [86]. The mortality among elderly patients who develop dialysis requiring AKI can be as high as 80% especially in patients with serious comorbidities, and the rates of new onset long-term dialysis-dependent renal failure can range up to 40% in patients with AKI superimposed on underlying CKD [3, 87].

The decision to initiate renal replacement therapy for AKI in the elderly must be based on a reliable attestation regarding the patient's stated or known wishes. The decision should be predicated on an unbiased presentation of the patient's current situation and where possible, prognosis. Typically, the presence of dialysis-dependent AKI is one factor of many, such as cardiac disease, ventilator-dependent respiratory failure, malnutrition, sepsis, and increased frailty, that influence the patient's long-term prognosis [88, 89]. In fact, data from the USRDS on almost 420,000 patients over the age of 67 demonstrated that most started dialysis in the hospital and patients who received the highest intensity of care (hospital stay of 2 weeks or more with at least one intensive procedure) had a median survival of 0.7 years, compared to 2.1 years for those who initiated dialysis as an outpatient. Moreover, these patients spent a greater percentage of their remaining follow up time in the hospital [90]. These findings suggest that in some cases, dialysis may have been initiated under the technological imperative of "because we can," rather than as a means of achieving a patient-directed healthcare goal.

In the best-case scenario, the patient's goals and desires will have been reviewed and established prior to the patient's admission or surgical event. Such conversations are aimed at understanding the patient's life goals and establishing an understanding of illnesses and their treatment options. These "serious illness conversations" should seek to identify values and preferences and to explain both the current situation and as much as possible the future trajectory with or without ongoing intensive therapy [91]. There are multiple resources and tools to estimate the impact of underlying comorbidities such as cardiopulmonary disease, congestive heart failure, and diabetes, on the prognosis of patients requiring renal replacement therapy [92–96]. Patients have a right to be offered only evidence-based clinical interventions and they, in turn, have the right to determine if those interventions are in keeping with their life goals. If not, they have a right to refuse such interventions. In this scenario, the increased possibilities provided by technology create a moral necessity, rather than a technological necessity, for their proper application.

Often in the acute care setting decisions will be made by a healthcare proxy with or without the assistance of an advanced directive or living will. In this case, family members and healthcare workers align together in a shared decision-making process to determine what the patient would have chosen based on the current clinical facts and an understanding of the patient's wishes. Addressing the emotions that arise during these serious illness conversations with patients or families facilitates relationship building, and helps listeners process the information provided. The NURSE statements (Table 12.2) are a communication acronym that helps facilitate these conversations [96–98]. The choice of language is important. Referring to a therapy as "life-sustaining" or "life-saving," can make it difficult for family members to withdraw care and can be misleading. It is preferable to refer to treatments as "interventions used to achieve specific goals," and then address what can be done if those specific goals are not met. Often dialysis therapies can prolong life without having any other meaningful impact on the underlying illness or the associated comorbidities. Understanding the goals of treatment is particularly important when considering the initiation of dialysis in elderly patients with AKI. Clear goals regarding both the renal disease and the status of other comorbid conditions can allow for a time-limited trial of dialysis with a plan to discontinue therapy if

Table 12.2 NURSE statements for articulating empathy

	Example	Notes
Naming	"It sounds like you are frustrated"	In general, tum down the intensity a notch when you name the emotion
Understanding	"This helps me understand what you are thinking"	Think of this as another kind of acknowledgment but stop short of suggesting you understand everything (you don't)
Respecting	"I can see you have really been trying to follow our instructions"	Remember that praise also fits in here eg " I think you have done a great job with this"
Supporting	"I will do my best to make sure you have what you need"	Making this kind of commitment is a powerful statement
Exploring	"Could you say more about what you mean when you say that ... "	Asking a focused question prevents this from seeming too obvious

Back A, Arnold R, Edwards K, Tulsky J. Responding to Emotion: Articulating empathy using NURSE statements, an 2019. http://VITALtalk.org. Used with permission

anticipated goals of treatment are not achievable. There are conditions, such as irreversible profound neurologic impairment, terminal illness from non-renal causes, severe hypotension, or cardiac instability where dialysis intervention or long-term maintenance dialysis are more likely to harm than to help. Dialysis therapies are not suitable in such situations and the tenets of shared decision-making can help facilitate these discussions as well.

Goals of care are unique to the individual and may change over time. Thus, conversations must continue throughout the disease trajectory. Whether the decision is for conservative medical management or the initiation of dialysis therapy, the overarching goal should always be maximizing the quality of life and providing care that correlates with the patient's values and goals.

12.14 Conclusion

Acute kidney injury (AKI) is a common complication among elderly surgical patients and is never a trivial event. Even with recovery, the odds of long-term complications, including chronic kidney disease, more frequent hospitalizations and even death are increased. Normal aging is accompanied by changes in renal structure, function, and cellular metabolism, which reduce renal reserve, delay cellular recovery, and increase the kidney's susceptibility to all categories of AKI. This is exacerbated by comorbidities and risk factors including diabetes, atherosclerosis, and the widespread use of medications, such as nonsteroidal analgesics, and angiotensin blockers and inhibitors that alter renal compensatory mechanisms and impair the renal response to under-perfusion, which, if prolonged, can lead to ischemic injury and cell death. Approximately 30–40% of the episodes of AKI occur in surgical patients and it is especially prevalent among the elderly [3]. Widely accepted criteria which categorize the stages of renal injury have been established to define the earliest stages of renal injury when detection and mitigation are likely to be the most effective. Although widely used, changes in the serum creatinine lag behind renal injury, and creatinine levels are an imprecise marker of cellular injury. New tools and biomarkers may prove to be clinically useful for the early detection of cellular damage, and these, together with new therapeutic strategies, may help to improve the incidence and outcomes of AKI in this high-risk surgical population. If progressive AKI develops, patient-directed, rather than technologically directed, care is essential in this population. Patient established goals of care, often with the assistance of palliative care consultation, should be included as part of every plan of care in this population.

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Part II

Specialized Surgical Care in Elderly

Trauma in Elderly

13

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13.1 Introduction

The average life length has increased considerably throughout the world; over the next 20 years, the population over 65 years of age is projected to double insides, reaching 82.3 million by 2020 [1]. This implies an increase in healthcare costs for the treatment of this kind of patient. In fact, this age group represents 40% of hospitalized adults (in the US population) [2].

In western countries, old people keep driving cars as long as possible. As a consequence, 17% of all traffic fatalities involved older people, who are the 9% of all people injured in traffic crashes during the years [3]. However, physiological changes and decline make the body's compensatory mechanisms less effective following a trauma. Still, the higher comorbidity rates (66%) make complications more frequent during hospitalization. Blunt trauma is the principal kind of trauma (80%) in elderly patients (EPs). Falls are 70% of blunt trauma, caused by physiological change with age and comorbidities affecting the muscle-skeletal system and the brain causing tremor, rigidity, and dementia. The rest of the trauma causes are penetrating trauma and suicide attempts. Moreover, domestic abuses and assaults represent an underrated cause of trauma with an estimate 25.886 elderly people treated in emergency departments yearly in the US for lacerations, contusions, or fractures. By now there are no specific guidelines addressing the management and treatment of the trauma in geriatric patients. EPs even if seriously injured are underestimated in 25% of cases. This bias results in significant delay in treatment. In 43% of the EPs at the time of access to the emergency department had experienced a cardiogenic shock not associated with alteration of the hemodynamic state at the time of admission; consequently, they are erroneously considered hemodynamically stable.

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Fifty-four percent of these cases result in death [4]. Mortality among those patients may be substantially reduced by employing “age over 70”, as an activation code for the trauma team [5]. There is a strong relationship between age, Injury Severity Score (ISS), and mortality, so a clear trauma classification is essential for the management and treatment of the EPs at presentation. The invasive procedures are widely accepted in ISS > 18, whereas in ISS < 18 the indication needs to be continuously evaluated according to risks and benefits balance [6]. A recent study showed that the integration of new standard operative procedures (such as early whole-body CT scan, damage control surgery, and the use of goal-directed coagulation management) was associated with a lower mortality rate in severely injured geriatric trauma patients [7]. This same benefit was not demonstrated for a moderately injured patient (ISS 9–15). It has been evaluated that a poor pre-injury functional status is a strong predictor of undesirable outcome than the admitting diagnosis [8]. Respiratory complications are most frequent among all and increase the risk of in-hospital mortality [9]. The most important predictor of long-term mortality is age. Quickly accessible factors independently associated with mortality, besides age, are coagulopathy, acidosis, and a lower level of consciousness. These parameters can be defined as follows [10]:

– Coagulopathy: International Normalized Ratio—INR ≥ 1.4;
– Acidosis: arterial base excess—ABE ≤ –6;
– Level of consciousness: Glasgow Coma Scale—GCS score ≤ 8.

13.2 The Physiology of Aging

The body response to trauma may be related to the physiological change occurring with age (Table 13.1). In cases of trauma with bleeding, the first body reaction is the release of catecholamine hormones to raise blood pressure and provide more blood to muscle and brain. In EPs, the cardiovascular system responds to this stimulation with a consistent delay [11]. Furthermore, the heart becomes stiffer as fat and fibrous tissue replace cardiac muscle cells. This leads to a decreased responsiveness to endogenous stimulation and a limited capability to increase cardiac output. Also, medications such as beta-blockers or diuretic medications may mitigate the hormones’ effect and exacerbate a forced status of hypotension and hypoperfusion. EPs try to compensate by increasing systemic vascular resistance which results in an unreliable normal pressure. It will be necessarily a continuous parameters revaluation in EPs during the very first admission period; for example, Heffernan et al. found that mortality increased in EPs with a systolic blood pressure <110 mmHg and >130 beats/min, respectively whereas the same results were obtained when the blood pressure was <95 mmHg and >90 beats/min, respectively in youngers [12].

There are substantial differences between the physiology of adult patients’ population and EPs. Blood vessels may be extremely narrow and stiff; the cardiac reserve

Table 13.1 Physiological aging and management strategies

Organ system	Changes	Considerations and management
Head and Brain	• Cortical atrophy • Cerebrovascular vessel plaque • Cognitive decline • Cerebellar functions decreased → worse balance	• SDH are four times more common than in younger patients and may manifest later • EDH are rare • Combination of polypharmacy and injury may lead to delirium • High incidence of ICH in anticoagulated patients (even for minor head trauma)
Cardiovascular	• Loss of connective tissue elasticity → stiff veins and arteries • Death of cardiac muscle cell and replacement by fibrous tissue → stiff heart • Decreased responsiveness to stimulation (catecholamines)	• Medications such as beta-blockers or diuretics → forced status of hypotension and hypoperfusion • Unreliable vital signs → SBP < 100 mmHg; HR > 130 b/min • Limited physiologic reserves and rapid deterioration • Blood loss is not well tolerated, transfuse early
Pulmonary	• Increased chest wall stiffness, decreased pulmonary compliance • Reduced respiratory rate, impaired gas exchange (reduced PO_2) • Increased residual volume (air trapping)	• Higher risk of aspiration, atelectasis, pneumonia, and pulmonary embolism • Early intubation recommended • Do not underestimate severe trauma in EPs with "normal" respiratory function → frequent rapid decompensation
Renal	• Less effective filtration system • Loss of renal mass (glomerular tissue replaced by fibrous tissue)	• Decreased tolerance to hypotension and nephrotoxic drugs • Higher risk of acute kidney injury
Bones	• Osteoporosis and arthritis → decreased bone density	• Higher risk of more severe and multiple fractures
General	• Decrease immune system functions • Malnutrition • Loss of adequate thermoregulation	• Decreased wound healing • Higher risk of hypothermia

SDH subdural hematoma, *EDH* epidural hematoma, *ICH* intracranial hemorrhage, *SBP* systolic blood pressure, *HR* heart rate, *EPs* elderly patients

is limited; the respiratory rate and pulmonary compliance is decreased. Furthermore, lung tissue becomes fibrotic and this worsens pulmonary compliance. Hence, early intubation is recommended in patients with borderline respiratory function [13].

The kidneys filtration system is less functional, for those reasons, even temporary hypotension and hypoperfusion or nephrotoxic drugs represent a trigger for an acute kidney injury [14].

Osteoporosis and arthritis decrease bone density and make EPs susceptible to fracture, even in low-energy trauma [15]. Lastly, the loss of adequate thermoregulation may drive to hypothermia after a mild or moderate trauma, resulting in a coagulopathy worsening, and consequent raising of mortality risk [16].

13.3 Neurotrauma

The most common mechanism for traumatic brain injury (TBI) is the fall. To prevent such injuries several studies listed a number of strategies to decrease the probability of these traumatic events happening, like the careful choice of the more appropriate antihypertensive (thiazide-type diuretic therapy reduces hip and pelvic fracture risk compared with other antihypertensive medications), and the promotion of physical exercise to strengthen their musculoskeletal systems [17, 18]. In the general population TBI physiology is divided into two phases: the first phase consists of cellular death that leads to a neurological impairment and the second phase results in microenvironmental changes associated with inflammation and the consequent edema. In EPs, physiological age-related changes exacerbate the phases of TBI. Additionally, TBI conduces to further cellular loss and may boost the progression of preexisting diseases [19]. In Eps, the maintaining of an appropriate blood pressure and, consequently, a correct cerebral oxygenation is crucial, given the high rate of EPs with hypertension [20]. In EPs, the heart ejection should be precisely calculated to determine the fluid management. Currently, the mainstays in TBI treatment are as follows: (1) balance hypoxia and hypotension; (2) carefully avoid hypoperfusion from hyperventilation; (3) administer anticonvulsants over the first 7 days after the trauma; and (4) do not administer steroids [21]. For the typical physiological change in EPs (reduced brain volume; enlarged dead space between the brain and the head bone), a brain swelling with a consequent increased intracranial pressure needing surgical intervention is rare. Despite mannitol may worse cerebral edema, it remains the most efficient drug in the control of increased intracranial pressure in these patients. More recently, several studies have shown that statins reduce the risk of both in-hospital mortality and 12-month adverse outcome [22, 23]. From the surgical perspective, guidelines currently recommend evacuating an acute subdural hematoma when it is >10 mm and/or midline shift is >5 mm on CT scan, regardless of the patient's Glasgow Coma Scale (GCS) [21]. While this recommendation is well established for young patients, it is vague and controversial regarding EPs. Though, EPs who underwent craniotomy for hematoma evacuation showed acceptable outcomes (in-hospital mortality 5–16%) and a similar ability to return to the baseline when compared to younger counterparts. The difference is that EPs may result in a longer hospitalization and rehabilitation. Historically, most subdural hematoma cases were treated conservatively and resulted in a chronic event. Patients have occasionally reported headache and/or minor mental changes; less than 10% have reported substantial neurological symptoms [20]. As shown in some recent studies chronic subdural hematoma (CSDH) may lead to complications in the long-term. In the intermediate long-term CSDH in EPs may lead to a mortality rate of 26.3% and 32%, respectively at 6 and 12 months [24]; hip fractures have similar intermediate long-term results [25]. It might be postulated that CSDH may exacerbate preexisting comorbidities and affecting the brain functions may result in a mortality rate increase [25]. Further studies looking at specific TBI cohorts of EPs indicated "male gender" as a predictive factor for a worse outcome. In women better outcomes are likely due to estrogen and progesterone release, which act in the reparation process [26]. Another parameter that deeply affects the TBI outcome is the anticoagulation therapy commonly used in EPS. Even a ground-level fall in anticoagulated geriatric patients is a mechanism of injuries significantly associated with intracranial hemorrhages (ICH) [27]. Anticoagulants also make treatment much more demanding and challenging [28]. Howard et al. found a relationship between an increased risk of mortality in EPs and those on warfarin who fall [29]. However, not all the author agrees with this assertion. Indeed, over the last decade, new oral anticoagulants (NOACs) are available worldwide. NOACs are as efficient as warfarin but relatively safer, even though there is a significant risk of delayed ICH for elderly patients on NOACs, so repeated evaluation is recommended [27]. The action mechanism consists in the direct inhibition of the coagulation cascade. NOACs have a shorter half-life compared to warfarin (8–16 h vs. 1 week, respectively) and are, thus, easier to manage. The major limitation of NOACs is the lack of a specific antidote [30]. The RE-LY trial documented that low doses of NOACs decrease the risk of intracranial hemorrhage as compared with warfarin; conversely, high doses result in a similar risk [31].

13.4 Rib Fracture

Rib fractures after chest wall trauma are a common injury, especially in EPs. The age-related bone loss and osteoporosis make the bone easily fractured even with minor trauma. Furthermore, aging processes such as impaired mucociliary clearance of bacteria, reduced cough effectiveness, and reduction in lung and chest wall compliance make the respiratory performance globally reduced [32]. As a consequence, relatively simple rib fractures can lead to pneumonia and other pulmonary complications as respiratory failure. Rib fractures in patients older than 65 years are associated with an average mortality risk of 20% and a pneumonia acquisition risk of 19% [33]. They also carry a 10% increase in mortality risk for each additional rib [33]. Treatment options consist of oxygen support, pulmonary toilette, and analgesia. Pain control is critical in multiple rib fractures. In EPs is suggested to avoid polypharmacy or narcotic administration, epidural anesthesia and early intubation are strongly recommended. A decreased risk of delirium using regional analgesia in EPs with multiple rib fractures has been demonstrated [34]. Some authors have also suggested to consider rib plating as a valid treatment option, even in EPs, due to an improvement in outcome measures such as survival and quality of recovery [32, 35].

13.5 Pelvic Fracture

The pelvis is the strongest bone unit in the body and its fracture is secondary to high-energy injury (13–18%). However, comorbidities (osteoporosis, arthritis, and osteopenia), preexisting conditions (previous surgery, metastases), and age may weaken the bone pattern and make it prone to fracture even in cases of low-energy trauma [36]. In EPs, the most common cause of pelvic fracture is low-energy trauma (usually falls from standing) [37]. Therefore, prevention of falls is fundamental to decrease the risk factors. Pelvic fractures are more prevalent among males in younger patients and among females in EPs. The difference in prevalence between sexes is presumably attributable to the hormonal changes in females (estrogen and progesterone decline) which unleash subsequent osteoporosis [38]. In 64% of pelvis fractures, preexisting osteoporosis is present and this rises to 94% in <60-year-old patients [39]. Mortality in EPs (7.6%) is mostly related to hemorrhage; this is four times higher than in younger patients, where morbidity is due to incomplete healing and/or nerve damage [40]. Pelvic fracture management is standardized. According to ATLS, the first assessment is based on clinical findings and pain sites. Physical examination is essential to determine the anatomical site entailed in the trauma, which requires further investigations. Bimanual compression of the iliac wings can rule out either vertical or rotational instability [41]. Pelvic X-ray represents the first radiological investigation. Inlet, outlet, or judet views may offer additional data. CT scan may be useful in suspected active bleeding in order to define the site of a subsequent angiographic embolization if necessary [42]. When underlying osteoporosis is suspected, an extensive investigation, including levels of calcium, thyroid function, and sexual hormones in the serum, should be carried out [43]. As previously mentioned, management is primarily based on clinical presentation. In EPs comorbidities should be considered, especially for potential medication interactions. It is likely that home therapy might interact with drugs administered over the course of hospitalization, causing confusion and obnubilation. Is necessaries correct those therapies in order to avoid any aggravation of the EPs. A prompt correction of coagulopathy in patients on anticoagulants is essential, while desmopressin may help to treat patients with chronic kidney disease [44]. The clinical examination and the radiological investigations looking at potential bleeding define the diagnostic phase. Even if the patient is hemodynamically stable, there could be an identified bleeding, so a conservative treatment (bed rest, minimally invasive interventions, and pain control) is preferred. If there is a bleeding, can happen that the sites of hemorrhage are multiple. Besides, in one-third of pelvic fractures, sources of bleeding are outside of the pelvic borders [45] and that makes their identification more difficult. If the patient is hemodynamically stable and there is a small amount of bleeding, it can be controlled by putting in place a pelvic binder which stabilizes the fracture. Although arterial bleeding is unusual, its presence should be investigated with radiological investigations when suspected. Such bleeding is unlikely to be controlled with immobilization, and more invasive treatment (i.e., angioembolization and/or surgery) is required [46]. To prevent bone resorption and to decrease the risk of pulmonary infection and vascular or gastrointestinal complications a mobilization as soon as possible is recommended. The average hospital stays for EPs who sustain a pelvic fracture is around 21 days. A long rehabilitation is then necessary, but rarely there is a complete reestablishing for EPs [47].

13.6 Penetrating Trauma

While blunt trauma discussed so far (falls, motor vehicle injuries, or pedestrian collision) is the most common and with outcomes favorable [48], the same cannot be said for penetrating trauma, which is relatively rare but with an extremely poor prognosis. This poor prognosis is due to the scarce physiological reserve in association with several comorbidities, as such preexisting cardiovascular disease, which requires the administration of anticoagulants. Penetrating trauma is most commonly due to a suicide attempt. Social context (urban setting) and comorbidities (depression and chronic pain) may deeply affect EP quality of life. Self-inflicted injury rates increase with aging (46.2% between 65 and 74 years of age and 51.5% over 75 years of age). This type of injury represents a clear public issue [49]. In 80% of suicide attempts, firearms are predominantly employed, and the head is the site most commonly involved (54.2%), with an extremely high mortality (over 90%). Further anatomical sites of penetrating trauma are the thorax (13.5%) and abdomen (8.2%). In assaulted patients, the thorax and abdomen are the most commonly involved area (43%), followed by the extremities (16.9%). Higher mortality is recorded in suicide attempts (60%) as compared to assault-related patients (25%) or unintentional penetrating injuries (9%) [49]. Given the complex history and home therapy often present in EPs, these patients should be closely assessed and monitored. As mentioned above, it has been demonstrated that the classic hemodynamic criteria (systolic BP <90 mmHg or heart rate >120/min), which are typically applied in trauma team activation, are inadequate in EPs [12]. As soon as the patient is admitted, it is crucial to gather the detailed clinical history and the home therapy must be scrupulously evaluated. The anticoagulant therapy is frequent in EPs, so the anticoagulants need to be promptly interrupted and the coagulopathy corrected if the ISS is high [50]. Multiple blood tests may help in assessing EPs whose vital signs are modified by anticoagulants and beta-blockers. In these patients, vital signs "wrongly" considered stable may conceal potentially life-threatening bleeding. ATLS guidelines should be adopted. Radiological investigations need to be completed while monitoring vital signs continuously, and angioembolization or aggressive interventions should be considered in the first phase of the evaluation [51]. Fluid administration needs to be managed carefully because the physiological response between hypovolemia and edema in EPs is extremely thin. However, a regulated hydration and bicarbonate administration reduce nephropathy. In trauma patients, the thermoregulatory response may be dysregulated causing hypothermia, acidosis, and coagulopathy. Therefore, hypothermia prevention through the administration of warm fluids represents a mainstay in the management of trauma [52]. Surgical management is related to the injured area and whether vital signs are stable. If vital signs are stable, further investigations (such as CT scan, endoscopy, and bronchoscopy) should be considered and a conservative treatment evaluated. Patients with penetrating trauma to the neck need an emergency operation if the vascular or aerodigestive system is involved and vital signs are unstable. Historically, less than 15–20% of penetrating neck injuries need surgery [53, 54]. In cases of chest trauma with hemodynamic instability, an emergency thoracotomy or median sternotomy, depending on the site involved, is required. Most cases of penetrating trauma to the chest (nearly 80%) may be treated with a chest drain [55]. Penetrating trauma to the abdomen which results in peritonitis or in hemodynamic instability requires an emergency laparotomy [56]. An emergency laparoscopy should be taken into consideration in left thoracoabdominal trauma and penetrating trauma to the lower part of the left thorax, in order to rule out lacerations to the diaphragm [51] (Fig. 13.1).

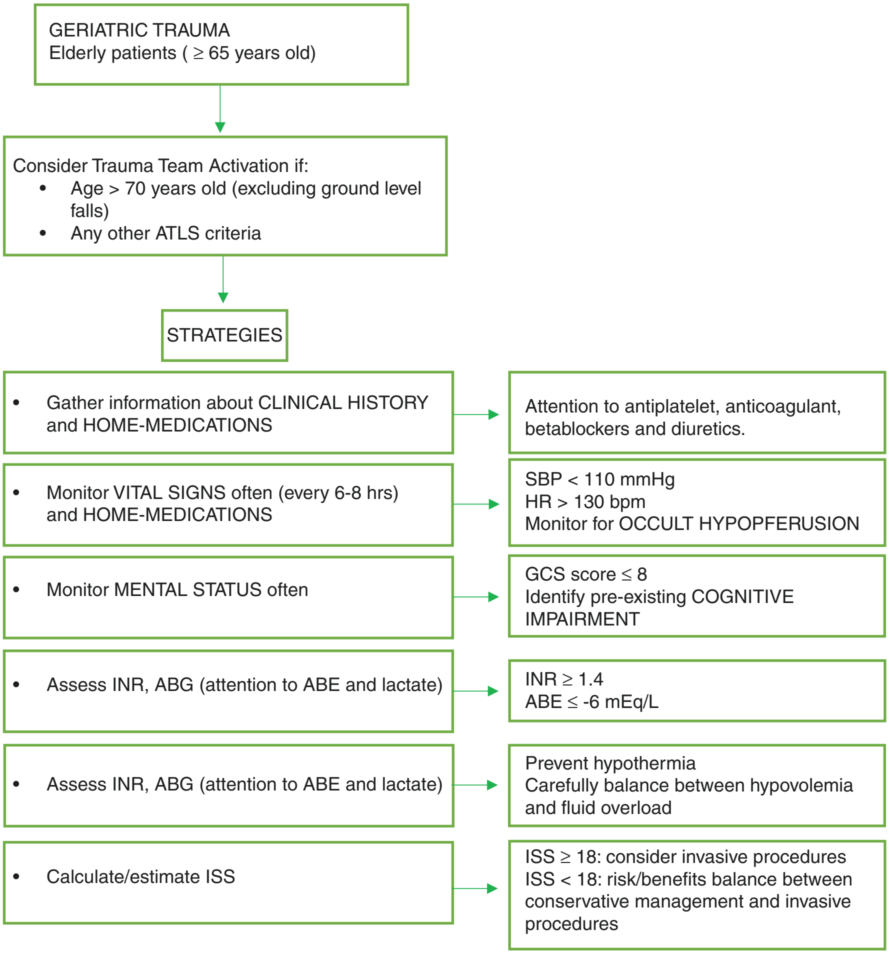

Fig. 13.1 Management strategies in elderly trauma patients

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Esophageal Perforation and Incarcerated Hiatal Hernia in the Elderly

14

Donna C. Koo, Clara Angeles, and Tracey L. Weigel

14.1 Introduction

With advancements in medicine and an aging population, physicians and surgeons are increasingly caring for a greater number of older patients [1]. In recent years, increasing awareness of geriatric syndromes and perioperative optimization techniques have improved surgical outcomes in geriatric patients [2]. When elderly patients present with surgical emergencies, however, surgeons must decide whether or not to offer them potentially lifesaving, but possibly highly morbid, surgeries. In the acute setting, frail elderly patients with myriad comorbidities are poor surgical candidates without the opportunity to optimize their perioperative risk [3]. However, leaving these vulnerable patients without surgical intervention in the face of acute, potentially life-threatening, conditions puts them at high risk for mortality.

Common thoracic surgical emergencies requiring acute surgical intervention include esophageal perforations (both spontaneous and iatrogenic) and incarcerated hiatal hernias that may be complicated by volvulus or obstruction. Appropriate management of geriatric patients presenting with such pathologies remain widely

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controversial, with mixed data in the literature supporting differing practices. This chapter will attempt to outline the diagnosis and management of these two common thoracic foregut surgical emergencies, with emphasis on special considerations for geriatric patients.

14.2 Esophageal Perforation

Esophageal perforation or spontaneous esophageal rupture are potentially life-threatening conditions in which a transmural injury to the esophageal wall causes leakage of caustic esophageal and gastric contents into the mediastinum and/or thoracic cavity that can result in necrotizing inflammation, mediastinitis and/or empyema, leading to septic shock, multi-organ failure, and death [4]. Although survival and recovery associated with esophageal perforation vary with timeliness of both diagnosis and treatment, some studies report morbidity and mortality rates as high as 44% [5]. Structurally, the esophageal wall is composed of four layers: mucosa, sub-mucosa, muscularis propria, and adventitia [6]. Unlike the rest of the gastrointestinal (GI) tract, the esophagus has no serosa layer [7]. This may contribute to its vulnerability to perforation and rapid widespread inflammatory response, as the serosa elsewhere provides structural support and stability [8].

14.2.1 Pathophysiology, Symptoms, and Diagnosis

Esophageal rupture can be caused by a variety of iatrogenic, traumatic, and spontaneous processes. The most common cause of esophageal rupture is iatrogenic perforation due to endoscopy for diagnosis and treatment of conditions such as esophageal dilatation, achalasia, and sclerotherapy of esophageal varices [4, 9]. It is estimated that iatrogenic causes may account for up to 70% of cases of esophageal rupture [9]. While endoscopic procedures are associated with the highest risk of perforation (1.7% for achalasia, 1–6% for endoscopic variceal sclerotherapy), other iatrogenic causes of esophageal perforation include nasogastric tube insertion, transesophageal ECHO (estimated 0.1–0.3% perforation rate), and thoracic surgery with esophageal manipulation [10]. Other common non-iatrogenic causes of esophageal rupture include malignancy, foreign body ingestion, including ingestion of animal bones and caustic chemicals [9]. Both blunt and penetrating trauma to the chest or upper abdomen [11] can lead to spontaneous rupture. Less commonly, esophageal perforation can be caused by prolonged straining and vomiting, commonly referred to as Boerhaave's syndrome [12, 13].

Early diagnosis and management of esophageal perforation can significantly improve outcomes. Some researchers estimate that when treated within 24 h of perforation, mortality rates can remain as low as 10–25% while untreated perforations beyond 48 h can have mortality rates as high as 40–60% [9]. Thus, prompt diagnosis and treatment can be lifesaving.

Signs and symptoms of esophageal perforation can vary depending on the location of injury, however, contributing to delays in treatment. Chest pain typically presents in 70% of patients with perforation of the intrathoracic esophagus and is characterized as a sudden sharp pain radiating to the back or left shoulder; approximately 25% then proceed to vomiting and shortness of breath. Together, chest pain, vomiting, and subcutaneous emphysema are known as the Mackler triad [14]. In patients with perforation of the cervical (upper third) esophagus, neck pain, dysphagia, dysphonia, and hoarseness can be hallmark symptoms [9]. In patients with perforation of the gastroesophageal junction (lower third), acute abdominal or epigastric pain and free air may be the presenting symptom and sign, respectively. Despite the varied presentations of pain in patients with esophageal perforations, other constitutional symptoms can steer diagnosis towards rupture. Most patients with esophageal perforation develop tachycardia, fever, and crepitus (a sign of subcutaneous emphysema).

The gold standard of diagnosis for esophageal perforation is contrast esophagography, in which a water-soluble contrast medium is swallowed as a patient undergoes radiography [15]. Esophageal perforation is identified by the extravasation of the contrast material into the mediastinum or pleural space. Thus, in addition to confirming diagnosis, contrast esophagography can also localize the source of a leak, informing repair and continued management. In intubated patients, contrast material can be administered via a nasogastric tube (NGT) with a gentle pullback of the NGT under fluoroscopy [16]. Although barium is initially avoided due to the possibility of the barium contrast inducing an inflammatory reaction in the mediastinum [9], if the initial esophagography with water-soluble contrast is negative, barium can be used for repeat imaging [15]. Alternatively, repeat imaging with water-soluble contrast can be performed 4–6 h after the initial negative study if clinical suspicion remains. Computed tomography (CT) imaging with oral contrast can also play a role in diagnosis and management in instances where patients are critically ill, intubated, or have additional traumatic injuries, as the site, direction of drainage, and degree of perforation may be more accurately identified using CT imaging [9].

14.2.2 Management and Prognosis

The initial management of patients with confirmed esophageal perforation includes aggressive fluid resuscitation, initiation of nil per os (NPO) status, and esophageal decompression with an NGT. Broad-spectrum antibiotics can be initiated intravenously to combat sepsis from bacterial translocation, which is a primary cause of mortality and morbidity in patients [16]. After initial stabilization and resuscitation, patients may be managed either operatively or with conservative, nonoperative treatment, depending on a variety of factors including location, size, and etiology of perforation, patient's baseline performance status, and long-term prognosis and institutional resources.

Prognosis for esophageal perforation also depends on location of injury, method of injury, and timeliness of treatment [9]. In terms of location as a prognosis, perforations in the thoracic esophagus (defined as the region of the esophagus extending from the suprasternal notch to the diaphragmatic hiatus [7]) are associated with the highest rates of mortality (27%) [9]. Perforations of the abdominal esophagus (extending from the diaphragmatic hiatus to the cardia of the stomach) are associated with slightly lower mortality rates of 21%, while perforations in the cervical esophagus (extending from the pharyngoesophageal junction to the suprasternal notch) have the best prognosis with a mortality rate of approximately 6%. Spontaneous esophageal perforation (Boerhaave's) is associated with the highest rates of mortality (36%), frequently due to delays in presentation and/or diagnosis. Iatrogenic perforation, on the other hand, is associated with mortality rates of 19%. Traumatic perforations are associated with mortality rates of 7%. Prompt diagnosis and treatment of esophageal perforation can reduce mortality rates by almost half, with mortality rates from delayed treatment (over 24 h) of approximately 27% while prompt treatment results in mortality rates closer to 14% [9].

14.3 Operative vs. Nonoperative Management

Operative repair of the esophagus has long been considered the gold standard of treatment for esophageal perforations [9]. Although the specifics of repair vary based on location, general principles of primary repair include debridement of the damaged tissue around the site of perforation with reapproximation of the surrounding healthy tissue. The esophagus is closed with sutures in a multilayer approach beginning with reapproximation of healthy mucosa to promote healing and restoration of function postoperatively. In cases with delayed treatment, significant tissue loss, or destruction with extravasation of caustic gastric contents, a flap can be used to buttress the repair. Options for flaps include usage of parietal pleura, the pericardial fat pad, and the intercostal or latissimus dorsi muscles. Of note, post-op leakage rates of up to 30% have been reported despite adequate repair, leading to further complications.

Surgical alternatives to primary esophageal repair include simple drainage of the mediastinum and thoracic cavity, esophageal diversion, and esophagectomy [17]. Diversion procedures aim to divert the flow of gastric contents externally to prevent ongoing spillage and damage to nearby structures [18]. Although many techniques exist, diversion procedures typically involve complex primary constructive and subsequent reconstructive operations, for initial diversion and subsequent restorative of intestinal continuity. Due to the high morbidity associated with diversions, they are typically reserved for patients who are critically unstable with defects that cannot be readily and rapidly repaired. In elderly patients with multiple comorbidities, the diversion may be permanent. For this reason and for the sake of speed, some surgeons may elect to use a T-tube for diversion while leaving a patient's esophagus in continuity. A T-shaped tube is placed in the esophagus such that the perpendicular arm protrudes through the defect in the esophageal wall to create a controlled outlet for esophageal contents, allowing for the maturation of an esophago-cutaneous fistula tract which can be repaired in 4–6 weeks or allowed to spontaneously close over gradual advances of the T-tube by drawing back 5 mm per week [17, 19]. Other techniques for diversion include the placement of a gastrostomy tube (for suction) and jejunostomy tube (for nutrition) at the gastroesophageal junction, as well as a thoracostomy tube in the chest for drainage [20]. Esophagectomy can be used as a last resort when patients have extensive esophageal damage, usually from toxic ingestion, with low chances of successful primary repair or diversion. Emergent esophagectomies are associated with high mortality rates of up to 40% [17].

Nonoperative management can be appropriate when certain criteria are met [18]:

1. Significant extraluminal extravasation of caustic gastric contents has not occurred.
2. The leak is contained with free drainage of contrast back into the esophageal lumen.
3. There is no underlying pathology impeding healing (malignancy, downstream obstruction, retained foreign body).
4. There are no signs or symptoms of sepsis.

Patients who meet all four criteria potentially can be observed and treated with broad-spectrum antibiotics, fluid resuscitation, and proton pump inhibitor therapy [17].

Other nonoperative strategies in management include percutaneous drainage and the use of endoscopic esophageal stents to temporarily seal the site of leakage and preserve esophageal continuity. The American College of Gastroenterology has recommended stenting as a possible form of appropriate management for esophageal perforations in patients with high surgical and anesthetic risk [21]. However, stenting frequently requires general anesthesia to protect the airway and for patient tolerance of procedure. Complications can arise from the use of stents, such as bleeding, stent-related strictures, fistula formation, and stent migration mandating additional procedures.

14.3.1 Special Considerations in the Geriatric Population

Principles of management of esophageal perforation in the elderly mirror those described above for the general population, with some additional considerations. Studies have shown that esophageal perforations are associated with higher rates of mortality in elderly patients [22]. One explanation for this phenomenon is due to decreased immunological reserves in the elderly; patients become more susceptible to infections as the immune system ages [23]. Esophageal perforation can induce rapidly progressing infections in elderly patients, resulting in fulminant inflammation and disseminated sepsis much faster than in younger individuals [24]. Additionally, delays in diagnosis of esophageal perforation in elderly patients result in delayed treatment and increased mortality. Diagnostic challenges in older patients include long complex medical histories, increased number of comorbidities, sarcopenia, frailty syndromes, and inaccurate or incomplete recount of acute symptoms due to cognitive slowing and/or dementia [25].

Similarly, increased incidence of chronic comorbid conditions such as cardiac and pulmonary disease, as well as polypharmacy and decreased physiologic reserves can make surgical treatment more challenging in the elderly. At baseline, many geriatric patients tend to be more frail compared to their younger counterparts, making them poor surgical candidates due to high perioperative risk [26–28]. Prior to elective thoracic operations such as VATS, lobectomies, and tumor resections, surgeons can work with elderly patients and families to optimize patients to improve surgical outcomes. Techniques such as prehabilitation [29] and home-based exercise regimens [30] can be used to decrease the length of hospital stay after thoracic cancer resection procedures [31]. In the case of emergent repair needed for esophageal perforations, thoracic surgeons do not have the luxury of pre-optimizing geriatric patients for surgery. The long operative time and complexity of esophagectomy and alternative diversion techniques can result in prolonged length of hospital stay and mortality in geriatric patients [24]. More conservative approaches such as direct repair, T-tube diversion, or use of endoscopic stents when feasible may reduce surgical morbidity and mortality in the elderly with esophageal perforations.

14.4 Complicated Hiatal Hernia

Hiatal hernias are characterized by protrusion of abdominal cavity contents through the esophageal hiatus of the diaphragm. Anatomically, hiatal hernias are divided into four types:

- **Type I**: sliding hernia—the gastroesophageal junction is displaced above the diaphragm without herniation of the fundus above the diaphragm.
- **Type II, III, IV**: paraesophageal hernias—displacement of the gastric fundus through a defect in the phrenoesophageal membrane within a hernia sac.
  - *Type II hernia*: the gastric fundus is herniated above the diaphragm while the gastroesophageal junction remains below the diaphragm
  - *Type III hernia*: both the gastroesophageal junction and the gastric fundus are herniated above the diaphragm
  - *Type IV hernia*: in addition to the stomach, other abdominal organs are also herniated above the diaphragm

Symptoms from sliding hernias are usually chronic, mainly include gastroesophageal reflux disease (GERD) and anemia. However, serious complications of paraesophageal hernias can present acutely, resulting in the need for emergent surgery. Such life-threatening complications of types II, III, and IV hernias include gastric volvulus, with gastric necrosis and/or outlet obstruction, bleeding, and respiratory distress from mechanical compression of the lung.

14.4.1 Pathophysiology and Symptoms

Paraesophageal hernias are caused by the laxity of ligaments that normally hold the stomach and gastroesophageal junction in place [32]. As most hiatal hernias are acquired, they are typically found in an older patient population, commonly in the seventh or eighth decades of life [33, 34]. Most hiatal hernias are asymptomatic or cause mild symptoms such as pain or postprandial fullness, bloating, and nausea. However, complicated hiatal hernias can present acutely with symptoms of gastric volvulus, strangulation, obstruction, and perforation. Respiratory symptoms can become evident as hernias enlarge due to lung compression and reduced forced vital capacity [35].

Gastric volvulus secondary to paraesophageal herniation typically presents with progressive chest pain, severe vomiting, with or without epigastric distension [34]. Chronic volvulus can cause vascular compromise, leading to gastric mucosal ischemia and ulceration. Patients may present with bleeding and iron-deficient anemia, present in 47% of patients with paraesophageal hernias [35]. Gastric volvulus is classified by the axis of rotation: organoaxial or mesenteroaxial. Organoaxial volvulus is more common, with rotation along the longitudinal axis due to normal fixation at the gastroesophageal junction. Mesenteroaxial rotation around the short axis is less common. Classically, Borchardt's triad, consisting of severe epigastric pain, unproductive retching, and inability to pass a nasogastric tube, indicates volvulus with resulting total gastric obstruction [36].

14.4.2 Diagnosis and Management

Hiatal hernias can be diagnosed using a wide variety of differing modalities [34]. On chest x-ray, a retrocardiac air-fluid level is pathognomonic for a paraesophageal hiatal hernia. Barium contrast studies may also be used to characterize the size and type of hernia. However, in patients presenting with acute symptoms of obstruction or volvulus, contrast studies are contraindicated due to risk of aspiration pneumonitis [37]. In an acute setting, computed tomography (CT) scans may be more readily available and can help diagnose complicated hiatal hernia with gastric volvulus. Strangulation and obstruction can similarly be visualized on CT with air-fluid levels visible in slices within the chest cavity. Alternatively, esophagogastroduodenoscopy (EGD) may be useful intraoperatively in the management of patients who require emergent surgery for strangulated hernia to determine viability of the affected gastric mucosa [34]. In addition, at the time of EGD, inability to visualize the duodenum in the context of a known hiatal hernia is diagnostic of gastric volvulus.

In geriatric population especially, the pros and cons of hiatal hernia repair must be weighed carefully. The risk of acute presentation of paraesophageal hernias requiring emergent surgery is 1.1% per year, while the mortality rate from elective paraesophageal hernia repair is up to 1.4% [38]. According to the Guideline for Management of Hiatal Hernias, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) recommends that all symptomatic paraesophageal hiatal hernias with acute obstructive symptoms or volvulus should be repaired [34]. In particular, acute gastric volvulus should be reduced with limited resection as needed for areas of gastric necrosis. However, routine elective repair of asymptomatic paraesophageal hernias is not recommended. Some studies suggest that repair is only indicated for patients who have the following criteria [34]:

1. Symptoms of gastric outlet obstruction.
2. Symptoms of severe gastroesophageal reflux or anemia.
3. Possible gastric strangulation.

Other studies report a significant increase in mortality of 500% associated with emergency surgery as compared to elective repair, and thus argue that surgical treatment should be considered in all symptomatic patients [32, 39, 40]. Some researchers recommend nonoperative management of asymptomatic paraesophageal hernias, stating that mortality rates from emergent paraesophageal hernia repair are often overestimated [38].

While open approaches have been traditionally favored, especially in the management of large paraesophageal hernias, recent studies show that laparoscopic approaches can be similarly effective with improved outcomes, especially for geriatric patients [41, 42]. Laparoscopic approaches to repair are associated with less perioperative morbidity and shorter hospital stays compared to an open approach [34]. Evidence also shows that hiatal hernias can be repaired effectively through a transabdominal or transthoracic approach. Benefits of the transthoracic approach include improved visualization and mobilization of the esophagus, despite increased morbidity and prolonged recovery periods postoperatively. Benefits of a transabdominal approach include the ability to perform fundoplication and intra-abdominal gastric fixation to reduce postoperative reflux, aspiration, and recurrence [43]. Of note, however, the need for routine fundoplication as an essential step in paraesophageal hernia repair is still disputed [34].

The need to reinforce the hiatus during a paraesophageal hernia repair has also been widely debated [33]. Although repair of the diaphragmatic crura with a simple suture has been broadly used, data has shown that a primary sutured crural repair is associated with high recurrence rates up to 42% [34]. The SAGES Guideline for Management of Hiatal Hernias further recommends the use of mesh for reinforcement of large hiatal hernia repairs to decrease short-term recurrence rates [34]. However, to date, there is insufficient data to indicate that mesh use can decrease recurrence rates long-term. The use of mesh can also be associated with complications such as mesh erosion into the esophageal or gastric lumen and esophageal stenosis [44].

Other recommendations for surgical considerations during a paraesophageal hiatal hernia repair by the SAGES Guideline for Management of Hiatal Hernias include returning the gastroesophageal junction to an infradiaphragmatic position and maintaining an intra-abdominal esophageal length of 2–3 cm through extensive mobilization. Establishing adequate intra-abdominal esophageal length through thorough esophageal mobilization is thought to reduce tension on the gastroesophageal junction, allowing it to remain below the diaphragm. When adequate intra-abdominal esophageal length cannot be maintained, i.e., the finding of a short esophagus, an esophagus-lengthening procedure may be indicated. A tip Collis gastroplasty is often performed, in which a gastric neo-esophagus is constructed to increase infradiaphragmatic esophageal length [45]. Critics argue that Collis gastroplasty results in high rates of dysphagia due to lack of peristaltic activity in the distal gastric neo-esophagus [34].

14.4.3 Special Considerations in the Geriatric Population

As mentioned, acutely complicated hiatal hernias are largely seen in the geriatric population. The management strategies and operative techniques discussed previously all apply in treatment of paraesophageal hernias in the elderly. The use of laparoscopic and robotic-assisted repair is evolving and especially relevant in this population, as minimally invasive surgery may result in decreased perioperative morbidity and mortality in geriatric patients, as well as reduce the length of hospital stay [42]. The appropriateness of prophylactic and elective paraesophageal hernia repair also continues to remain widely debated, as patients who present acutely tend to be older and have higher instances of morbidity [40]. The role of robotic-assisted laparoscopic repair in this population is wholly unknown at present. Elective laparoscopic paraesophageal hernia repair operations have only been shown to have increased benefit over watchful waiting in 17% of patients [38]; however, these data are historic and may not apply to the current era when laparoscopic and robotic-assisted surgical repair are widely practiced. Ultimately, the decision to repair a paraesophageal hernia electively to prevent the possibility of acute complications remains up to the individual surgeon and requires an informed, unbiased discussion with the patient.

14.5 Conclusion

As our population continues to age, the practice of medicine and surgery must strive to meet the demands for appropriate treatment of surgical emergencies in geriatric patients. Recent advances in perioperative risk assessment and preoperative optimization of elderly surgical candidates have led to significant improvements in surgical outcomes for elective procedures. With widespread adoption of laparoscopic, and now robotic, surgical techniques, the improved surgical outcomes in elective cases these advances have yielded should also be seen in emergent cases especially in the geriatric population. Randomized controlled studies utilizing laparoscopic and robotic approaches in these complex, acute emergent cases are lacking and desperately needed.

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15 Gastric and Duodenal Perforation in Elderly

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15.1 Acid-Related Diseases and Peptic Ulcer in Elderly

15.1.1 Etiology and Clinical Features

Conventionally, elderly has been defined as a chronological age of ≥65 years. While studies of geriatric patients should include evaluations of specific changes in functional and cognitive activities, comorbidities and co-medications, as well as the social role played by older people, only a few studies of peptic ulcer disease in the elderly have explored these topics [1, 2]. Epidemiological studies indicate that while the prevalence and incidence of peptic ulcer are declining in the general population, the incidence of gastric and duodenal ulcer hospitalization and mortality remains very high in older patients. Two major factors that might explain the observed increase in the incidence of peptic ulcer in elderly patients are the high prevalence of Helicobacter pylori infection and the high use of NSAIDs and aspirin. Also, the presence of concomitant diseases and multidrug therapy, especially bisphosphonates, antiplatelet drugs, warfarin, and SSRIs have been identified as significant risk factors for peptic ulcer disease and its complications in old age. Other risk factors may include excessive alcohol consumption and excessive acid production such as gastrinomas and Zollinger-Ellison syndrome. Duodenal perforation can also occur in people with conditions as duodenal diverticula, duodenal ischemia, infectious disease, and autoimmune conditions [3].

Probably other factors, including a reduction of the gastric and duodenal mucosal barrier that may occur with age, as a result of decreased mucosal blood flow, gastric mucus, bicarbonate secretion, or cell proliferation, are responsible for the increasing incidence of the *H. pylori*-negative, NSAIDs-negative peptic ulcers and peptic perforations observed in old age. Clinical features of complicated peptic

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ulcer in elderly patients are quite different from those of young or adult subjects, indeed, symptoms of peptic ulcer and perforation may be atypical in old age: often vague abdominal pain is the main symptom. Other symptoms associated with complicated peptic ulcer may be nonspecific, such as anorexia, weight loss, anemia, vomiting, and dysphagia. The presence of nonspecific symptoms has been reported as one of the most important reasons for late diagnosis in elderly patients with upper gastrointestinal disorders [4].

Disease of the upper gastrointestinal tract such as gastroesophageal reflux disease (GERD), peptic ulcer, and gastric cancer become more common and more severe with advancing age. Older individuals also tend to have a higher prevalence of comorbid factors, such as Helicobacter pylori infection, presence of other diseases, or use of medications (nonsteroidal anti-inflammatory drugs, bisphosphonates) that increase their risk for acid-related disorders. Unfortunately, in elderly patients with these disorders symptoms presentation may be slight or atypical, resulting in a delayed diagnosis [5].

GERD is a chronic condition, which develops when the reflux of stomach contents causes troublesome symptoms, impairs quality of life, or leads to mucosal damage or complications. It is thought to be caused by a combination of conditions that increase the presence of acid reflux in the esophagus [6]. A number of abnormalities that appear to play a pathogenic role in GERD are often more serious in elderly individuals and increase the rate of complications. Lifestyle factors can also increase the risk of reflux: smoking, obesity, caffeine, fatty foods, body position, and drugs. Furthermore, a large percentage of elderly patients with reflux esophagitis have a hiatus hernia [7].

The presentation of peptic ulcer disease in the elderly is subtle and atypical, and this may lead to a delay in diagnosis. Indeed, approximately one-third of elderly patients with peptic ulcer have no pain [8]. It is not rare that the first symptom might be owing to a severe complication, such as bleeding or perforation. In elderly people, perforation may be painless, and free air, that is a typical radiological sign of perforation, may be absent on plain radiographs in more than 60% of patients. In a study that looked at perforated ulcer in patients over age 60 years, 84% had only mild abdominal pain or aspecific symptoms [9].

Almost 70% of deaths from peptic ulcer disease are the results of perforation [10]. Generally, perforated peptic ulcer is a serious complication of peptic ulcer disease and patients with perforated ulcer often present with acute abdomen that carries a high risk for morbidity and mortality. The lifetime prevalence of perforation in patients with peptic ulcer disease is about 5%, and perforation carries mortality ranging from 1.3% to 20%. The classic triad of sudden onset of abdominal pain, tachycardia, and abdominal rigidity is the hallmark of perforated peptic ulcer [11]. Other classical symptoms of perforation include abdominal pain, upper abdominal discomfort, bloatedness, and feeling of fullness. When peptic ulcer disease worsen and eventually perforate, gastric juice and gas enter the peritoneal cavity leading to chemical peritonitis. Sudden onset of abdominal pain or acute deterioration of the ongoing abdominal pain is typical of perforated peptic ulcer. The absence of these classical symptoms in elderly patients may lead to a delayed diagnosis.

The most widely reported risk factor for mortality is increasing age; in most studies increase in mortality is associated with age over 60 [12–15]. A prospective secondary care-based study in the Netherlands found an increased risk of mortality in patients aged 58–71 years and patients aged 72–79 years when compared with patients aged 7–57 years [13]. Increased age has also been shown to be associated with increase in mortality after perforation [14]. The presence of comorbidity is also associated with an increase in mortality after hemorrhage and perforation. Tachycardia and abdominal tenderness with rigidity are common clinical signs. Severe pain, systemic inflammatory response from chemical peritonitis, and fluid deficit either due to poor intake or vomiting or pyrexia lead to compensatory tachycardia. In patients who delay seeking medical attention, hypotension ensues due to total body water deficit. If uninterrupted, this progress to mental obtundation and acute kidney injury. This leads to a state where patients become physiologically unfit for operative intervention which is absolutely necessary [11].

Other risk factors for increased mortality after perforation have been identified in the literature: shock at the admission, delay more than 12 h to onset of conservative management, and hemodynamic instability [16–18].

15.1.2 Diagnosis and Management

The clinical presentation of acute pain in the upper abdomen, with signs of peritonitis, is typical for perforated peptic ulcer, but it is seen in only about two/thirds of patients [19].

An urgent erect chest X-ray and serum amylase/lipase is a basic essential test in patients with acute upper abdominal pain. Seventy-five percent of perforated peptic ulcer have free air under the diaphragm on erect chest X-ray and in patients with upper abdominal symptoms, this finding establishes a diagnosis of perforated peptic ulcer [20].

CT scan is recommended as it has a diagnostic accuracy as high as 98% [21]. Besides, CT scan can exclude acute pancreatitis that would not need surgical intervention. In resource-poor healthcare facilities, oral gastrografin can be used to diagnose a perforation of the upper GI tract. Water-soluble contrast leaking into the peritoneal cavity can confirm the diagnosis of peptic ulcer perforation, but the absence of leak does not exclude the complication as the perforation may have sealed off spontaneously [22]. The utility of the CT scan is justified when clinical presentation is not specific to upper GI pathology or a malignancy is suspected and patients' hemodynamics is not deranged. When a localized perforation occurs in the gastric region, the possibility of cancer must be ruled out by multiple biopsies around the edges of the ulcer, since 10–16% of gastric perforations are due to gastric cancer [23]. This is not possible with nonoperative management. Upper endoscopy should be performed 6 weeks after successful nonoperative management to localize the site and confirm the healing of benign ulcers and to verify by multiple biopsies the absence of gastric malignancy [24].

Perforated peptic ulcer is a surgical emergency associated with high mortality if left untreated. In general, all these patients require prompt resuscitation, intravenous antibiotics, analgesia, proton pump inhibitory medications, nasogastric tube, urinary catheter, and surgical source control [3, 11].

Omeprazole and triple therapy for *H. pylori* eradication are useful adjuncts in the treatment of perforated peptic ulcer. Evidence has shown that PPI and triple therapy treatment reduces the recurrence rate significantly [25].

Studies have shown that about 40–80% of perforated peptic ulcer will seal spontaneously with conservative management and overall morbidity and mortality are comparable [26]. Conservative management consists of nasogastric suction, intravenous drip, antibiotics, and repeated clinical assessment. If they deteriorate, regardless of the presence and size of the leak, urgent operation is indicated. The principal problems with nonoperative treatment are the differential diagnosis and the risk of missing a perforated gastric cancer. Its role is not well defined; it may be useful in association with other minimally invasive procedures such as percutaneous drainage or as a bridge to surgery [27, 28]. In clinical practice, nonoperative management strategy requires a commitment of active regular clinical examination along with round the clock availability of a surgeon and if there is clinical deterioration, emergency surgery is warranted.

Since the gastric resections and truncal vagotomy for acid reduction became obsolete with the advent of PPIs, the main surgical treatment for perforated peptic ulcer has become a simple suture of the perforation site with or without the addition of an omental patch. The surgical trend has shifted towards minimally invasive laparoscopic surgery in selected patients [19, 29, 30]. In a meta-analysis published in 2005, [31] the mortality rate associated with laparoscopic surgery was 3–4.8% versus 5.3–11% for open surgery; this difference was not statistically significant but there were significant improvements in postoperative pain and use of analgesic medication with the laparoscopic technique. Management of perforated peptic ulcer is primarily surgical and different suture techniques for closure of the perforation are described. Primary closure by interrupted sutures, closure by interrupted sutures covered with a pedicled omentum on top of the repair (Cellan-Jones repair), and plugging the perforation with a free omental plug (Graham patch) are the common techniques [11]. Nowadays, emergency gastrectomy is reserved for a giant ulcer or a suspicion of malignancy when it is not safe to perform omental patch repair [32].

Shock on the admission, delayed presentation (over 24 h) after perforation, age over 70, ASA III–IV, and high Boey score should be considered adverse risk factors and should guide towards laparotomy rather than laparoscopy [33].

Moreover, primary stenting and drainage may be used as a new treatment option for perforated peptic ulcer. Bergström et al. has indicated stent treatment as a minimal invasive alternative with fewer complications compared to surgical treatment, but more data is required to prove the effectiveness of this method [3, 34].

There is consistent evidence of adverse effects of delay in diagnosis and delay before surgery, as well as higher mortality among the elderly [35]. Postoperative complications are frequent and include common diagnoses such as wound and other abdominal infections, thromboembolic events, and organ failure. Rare complications include omental patch leakage requiring reoperation in about 4% of patients and persistent duodenal fistula [36, 37].

15.2 Perforated Gastric Cancer

The spontaneous perforation of gastric cancer (PGC) is a rare complication with fatal outcome, which occurs in 0.56–3.9% of all cases of gastric cancer, with a high rate of hospital mortality (8–82%) According to the literature, gastric ulcers have been the main cause of gastric perforation and about 10–16% of all the cases are caused by gastric cancer [38].

It is difficult to preoperatively diagnose PGC because its preoperative symptoms are the same as those of a perforated peptic ulcer [39]. Only one-third of the PGC cases are diagnosed preoperatively, and the diagnosis is usually made only during the postoperative pathologic examination [40]. It is still under debate which surgical management of PGC should be accepted as a standard; meanwhile, the extent of malignancy and the degree of peritonitis are relied upon in deciding on the adequate surgical approach, that could be performed by employing the one-stage or the two-stage technique. The first procedure treats life-threatening peritonitis, followed by the second procedure which includes definitive gastrectomy with appropriate lymph node dissection. Unfortunately, PGC usually results in a poor outcome and long-term survival is rare. This condition is clinically characterized by general peritonitis and frequently occurs at the advanced stage of the disease [39–41].

PCG is experienced more often by elderly patients. In patients over 60 years old, malignancy should be considered, according to Ergul et al. [42]. Therefore, gastric perforation should raise suspicions of malignancy, particularly in elderly patients. It occurs often at the advanced stage of the disease: almost 60% of surgically treated patients had pathological tumor stages II–IV [41].

Surgical management of gastric perforation is also associated with a high mortality rate, regardless of the presence or absence of malignancy. Based on worldwide literature, it is recommended that in PGC the initial procedure should be the treatment of perforation and peritonitis [43].

15.3 Iatrogenic Duodenal Perforations

15.3.1 Etiology and Clinical Features

Endoscopic retrograde cholangiopancreatography (ERCP) is a routine procedure for the management of biliary and pancreatic disease. While it is generally safe, there remains a definite morbidity rate and rarely complications can develop, which carries a risk of death [44]. Around 10% of patients suffer a complication such as pancreatitis, bleeding, or perforation after ERC. The risk is related to technical factors including endoscopic sphincterotomy and patient factors such as sphincter of

Oddi dysfunction. The incidence of perforation varies between 0.09% and 1.6% with a mortality rate in modern series of around 8% [45].

Delay in diagnosis and intervention following duodenal perforation, leads to significantly higher mortality (8–23%) as a consequence of sepsis and multiorgan failure [46]. ERCP induced perforation may be retroperitoneal (typically in periampullary region due to sphincterotomy or guidewire usage) or intraperitoneal (typically in the lateral wall and endoscopy related) [47, 48]. While the patients with scope induced perforation would need surgical intervention, the first two groups could generally be managed conservatively as they tend to be smaller in size and are usually well contained [46].

The risk factors for perforation include patient-related factors and technique-related factors. In the first group, we can quote suspected sphincter of Oddi dysfunction, female sex, *older age*, normal bilirubin levels, previous history of post ERCP pancreatitis, abnormal or distorted anatomy such as situs inversus or post Billroth II gastrectomy. The related technique factors are difficult cannulation, pancreatic duct contrast injection, longer duration of the procedure, sphincterotomy and precut technique, balloon sphincter dilatation, and procedure performed by the lesser experienced endoscopist [45–49].

According to Machado, the definition of surgical timing (immediately or delayed) is the following: “the perforation was diagnosed immediately after it occurred, or delayed by at least 24 h after the procedure (recognized by abnormal vital or abdominal signs)” [46].

Duodenal perforations are difficult to diagnose during the ERCP procedure because they occur in the lateral wall of the duodenum by side view endoscope. Also, the routine use of sedation during the procedure makes the diagnosis even more difficult because it masks the symptoms [46]. Specific signs and symptoms suspicious of perforation are epigastric pain and back pain, tenderness with or without peritoneal signs, surgical emphysema, tachycardia, and fever, although the last two findings tend to be late. The presence of leukocytosis and fever are often seen 12 h or more after completion of ERCP. Signs of peritonitis usually develop after several hours when the duodenal contents extravasate into the peritoneal cavity [50, 51].

Early diagnosis and prompt treatment of duodenal perforation post ERCP is the essence for a better outcome. The index of suspicion should be high, in those patients with undue pain and fever, post-procedure. In those patients institution of systemic antibiotics and intravenous resuscitation is mandatory [46].

15.3.2 Diagnosis and Management

The diagnosis is made by urgent CT scan, which is very sensitive for extra-luminal gas and will show fluid collections. The complication can be recognized during the ERCP in certain circumstances, by either the endoscopic view of extra-luminal gas or contrast media. Diagnosis and early recognition of the complication improve the outcome.

Patients with significant retroperitoneal air and fluid are managed nonoperatively. Standard initial nonoperative management includes nil by mouth, nasogastric tube drainage, intravenous antibiotics, and PPIs, then the fluid collection is monitored by repeated imaging as persistent infected fluid collection can lead to nonhealing of the perforation site. Persistent large fluid collection may then require image-guided or surgical drainage [49, 52, 53].

Historically, ERCP-related perforation was managed surgically [54]. The indications for surgery include type I injury, generalized peritonitis not amenable to percutaneous drainage, major contrast leak, documentation of ERCP perforation with choledocholithiasis or retained hardware (Dormia basket), massive subcutaneous emphysema, and failure of nonsurgical treatment. The postoperative mortality after the failure of NOM is higher than those operated on primarily [45]. This is an important finding as clinicians need to be aware that those that fail NOM have a significant risk of death.

The site and mechanism of injury guides to the management approach.

The goals in the surgical management include to control sepsis (drainage of the retroperitoneal, intra-abdomen collection and drainage of the biliary system, removal of bile duct stones or retained basket) and to repair the perforation with or without diversion. In the last decade, management has shifted towards selective approach [3, 47–56].

Type I injury (duodenal perforation) will require surgical intervention: early surgical treatment gives the best results [44]. Type I lesions are often large perforations with intraperitoneal leakage and are quite different from Type III–IV perforations which are small, retroperitoneal, and rarely need immediate surgery. The closure of duodenum is performed transversely to ensure a patent duodenal lumen. For larger duodenal perforation, jejunal serosal patch is an option, which can be used to close the duodenal wall. The huge volume of fluid that traverses the duodenum daily will lead to high output fistula in the event of dehiscence of duodenal repair, a likely possibility when the wall is edematous and friable. As a result, duodenal diversion is usually reserved for high-risk patients with delay in diagnosis or larger defects in the duodenal wall. Duodenal diversion technique includes tube decompression, duodenal diverticulation, and pyloric exclusion [44].

The treatment of type II injuries (periampullary perforation of the medial wall of the duodenum associated with biliary or pancreatic sphincterotomy or precut papillotomy), the most common and important for the clinician, vary widely. In these cases, the management approach should be individualized based on the severity of the perforation, the underlying anatomy, and the patient's condition and reserve [45].

There are some who advocate immediate endoscopic treatment once the retroperitoneal perforation is identified. This constitutes of diversion of bile and pancreatic secretion away from the site of perforation using either an internal biliary stent or a nasobiliary stent [50, 51, 54]. The alternative is biliary decompression with percutaneous transhepatic biliary drainage.

The indications for surgery in Type II–IV injuries include failure of nonsurgical approach, large free or retroperitoneal collection, ongoing leakage, prominent peritoneal signs, or suspected suppuration. The surgical options are direct closure of the perforation and retroperitoneal drainage with or without duodenal diversion. Periampullary perforations have also been successfully repaired by performing sphincteroplasty using a minimal transverse duodenotomy [57].

15.3.3 Duodenal Perforation Caused by Migration of Biliary Stents

Duodenal perforation caused by the migration of plastic stents placed to treat biliary lesions is rare but can be life-threatening. Surgical management is preferred, but it may increase risks of mortality and morbidity, especially in patients with underlying comorbidities and those of advanced age. Plain X-ray can reveal stent position and migration. CT scan is the modality of choice for detecting perforations and locating the migrated stent. Surgical stent removal and closure of the perforation are the mainstays of treatment for intestinal perforation. However, endoscopic management of iatrogenic perforation in a clinically stable patient is justified due to improvements in endoscopic techniques. Indeed, several cases have been reported of duodenal perforation successfully treated with hemostatic clipping and fibrin glue under endoscopy [58–60]. If the perforation is small and is located in the retroperitoneal space, conservative management with antibiotics may be effective [61, 62].

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Gastrointestinal Bleeding in Elderly

16

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16.1 Epidemiology

Gastrointestinal bleed accounts for approximately 20% of emergency visits; 2% of hospital admission and its incidence has been increasing and rates of both upper and lower GI bleed increase with aging [1, 2]. The incidence of acute upper gastrointestinal bleeding (UGIB) has been reported to be around 500/100,000 per year in elder people (over 75 years), compared to 60/100,000 per year in the general population [3]. The median length of hospital admission for a patient presenting with a GI bleed in the UK is 4 or 5 days and a recent study showed a mean in-hospital cost of 2458 pounds per patient [4].

Mortality rate increases with aging and it is 3% in patient between 65–84 and 5.2% in patients over 85 years old. In elderly, GI bleeding mortality and morbidity increase is determined by the nature and the entity of bleeding, concomitant medical conditions such as chronic renal disease or prior occurrence or history of peptic ulcer disease, and assumptions of drugs such as the use of NSAIDs or oral anticoagulants [5, 6].

GI bleed is classified into four groups: upper or lower hemorrhages and acute (presenting as hematemesis, melena, or hematochezia) or chronic (occult GI blood loss or anemia) and can be either due to age-specific lesions [7].

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16.2 Specific Clinical Features of GI Bleeding in Elderly Vs. Younger Patients

No differences exist between the diagnosis and management of GI bleeding in the elderly or in younger people but there are some differences in clinical presentation and outcomes [5, 8, 9].

A few considerations must be kept in mind in managing GI bleeding in elderly:

- Mortality rate is higher;
- There are higher rates of rebleeding and hospitalization;
- They have atypical presentation of GI bleeding (the upper abdominal discomfort seems one of the main predictors of GI bleeding associated with nonsteroidal anti-inflammatory NSAIDs use);
- They usually assume much medications which may damage mucosal integrity;
- They usually have more comorbidities (i.e., cardiovascular or pulmonary disease).

GI bleeding is an unwanted side effect common to many NSAIDs drugs.

The increase of aspirin's use for the primary prevention of coronary events has caused an increase in major GI event. In particular, in patients who are prescribed with anticoagulant and antiplatelet medications, major hemorrhagic events have an incidence of 13.1 per 100 patients in the first year of therapy in the population older than 80 years (4.7% per year in individuals younger than 80) [10, 11].

GI mucosa injuries induced by NSAIDs vary from asymptomatic endoscopic erosions/ulcers to ulcer complications (bleeding, perforation, stenosis). In a meta-analysis of 24 randomized controlled trials, it has been calculated that about 1 out of 100 patients who used aspirin for a mean of 28 months had developed GI bleeding. Some studies suggested that even low dose of NSAIDs could increase the risk of peptic ulcer by three times [5].

16.3 Upper GI Bleeding: Clinical Presentation and Risk Factors

Acute UGIB is a common medical condition, which continues to yield a significant healthcare burden. Mortality due to all forms of AUGIB remains approximately 10% [12].

UGIB is defined as bleeding originating proximal to the ligament of Treitz (including stomach, duodenum, and esophagus) and is usually divided into two categories: variceal and non-variceal [13, 14]. UGIB is estimated to be five times more common than lower GI bleeding (LGIB) and in the presence of a GI bleeding must always be considered and eventually ruled out as UGIB [6, 15].

Hematemesis (vomiting of fresh, bright red blood), coffee ground emesis, and melena are the commonest presentations [6, 7, 13]. It is possible to have melena also with a refluxing more distal bleeding. Furthermore, rapid and high volume UGIB can result in hematochezia (bright red blood from rectum, with or without stool). UGIB may be chronic and in these cases anemia with hemoccult positive stools are the most common signs. Especially chronic loss of blood produces lightheadedness, orthostatic hypotension, and syncope. Nasogastric tube (NGT) insertion with returning bloody aspirate can confirm UGIB. As a counterpart, the absence of blood into the NGT does not exclude UGIB [6, 7].

Often in elderly, UGI presentation can be different, in particular, if associated with peptic ulcer that remains one of the most frequent causes of GI bleeding. In fact, up to 26% of elderly patients with peptic ulcers may not have pain [16]. In a comparative study by Kemppainem et al. [17] (age > 65 vs. age < 65 years, $n = 125$), typical epigastric pain in the older group was rare (35% vs. 91%, $p < 0.001$). Also, ulcer bleeding was present more commonly in the older age group (50% vs. 14%, $p < 0.001$). In order to decrease the delay of diagnosis, a specific questionnaire has been developed. The UEGISQUE is a 15-item questionnaire evaluating five symptom clusters: abdominal pain syndrome, reflux syndrome, indigestion syndrome, bleeding, and no-specific symptoms. The predictive value of this test was reported as good (area under ROC curve 0.78, CI 0.73–0.83) [18].

Mortality rates for gastric and duodenal ulcer hemorrhage have increased among the older population because of the large use of NSAIDs (including aspirin) and the high prevalence of *H. pylori* infections [19]. Several studies showed that in the elderly there is an imbalance equilibrium between hurting and protective factors on gastrointestinal mucosa (mucus, prostaglandins, and bicarbonate) [20–24]. Furthermore, seem that among the elderly gastrointestinal transit time and gastric emptying is slower, and so it is longer than the exposure time of ingested medications and acidity [25].

Often, elderly people assume many medications such as analgesic or antithrombotic. It is important to find the optimal strategy to minimize their gastrointestinal side effects [19]. There is anevidence that both histamine 2 receptor (H2RA) antagonists and PPIs instead of PPIs alone can reduce non-variceal UGIB in the aspirin and NSAIDs users; no definitive data of H2RA alone usage exist. [26–29]. If treatment with NSAIDs cannot be avoided, a combination of COX-2 inhibitor with PPIs should be considered in order to obtain the best mucosal protection [19].

There are some critics about the use of PPIs in elderly people, especially about the long-term PPIs use. A retrospective study by Maggio et al. [30] showed that PPIs use is associated with an increased risk of all-cause death in older patients discharged from intensive care hospitals. The main PPI use associated risks are:

- Higher risk of nutritional deficiencies such as hypomagnesemia, iron deficiency, vitamin B12 because of malabsorption;
- Higher risk of fracture (OR 1.44, 95% CI 1.21–1.70) even if the mechanism is still unclear [31];
- Significant higher risk of C.Difficile infection (OR 2.15, 95% CI 1 81–2.55) [32];
- Higher risk of community-acquired pneumonia (OR 1.36, 95% CI 1.12–1.65) [33] due to the modification of gastric pH that allows the colonization of certain bacteria species, leading to microaspiration and colonization of the lung. PPIs

may also alter the pH of seromucinous secretion of the respiratory tract, promoting bacterial growth [19].

16.4 Etiology

- Peptic ulcer (gastric or duodenal)
- Gastroduodenal erosions and gastropathy
- Esophagitis
- Esophageal and gastric varices
- Mallory-Weiss tear
- Oropharyngeal and gastric cancer
- Portal hypertensive gastropathy
- Arteriovenous malformations such as Dieulafoy lesion
- Boerhaave's syndrome
- Gastric antral vascular ectasia
- Hemobilia
- Hemosuccus pancreaticus
- Aortoenteric fistula

The most frequent cause of non-variceal bleeding is complicated peptic ulcer. A recent review on the epidemiology of complicated peptic ulcer disease found that hemorrhage was by far the most common complication of the peptic disease, with a reported annual incidence of hemorrhage in the general population ranging from 19.4 cases per 100,000 individuals to 57.0 cases per 100,000 individuals, with sample size-weighted average 30-day mortality of 8.6%. This high incidence of complicated peptic ulcer could be related to an increase in the use of ASA and NSAIDs and to the increasing number of elderly people [6, 7, 13, 34]. Peptic ulcer disease and gastropathy account together between 55% and 80% of patients presenting to the Emergency Department with UGIB [7].

The remaining percentage includes esophagitis and esophageal/gastric varices that are more common among elderly than younger people [7].

UGID related to portal hypertension are seen in patients younger than 60-years old and the mortality exceeds 30%. Data suggest that mortality after variceal hemorrhage correlates with the Child-Pugh score and not with advanced age [35].

Often "gastric antral vascular ectasia" is correlated with some medical comorbidities such as end-stage renal disease and cirrhosis: this condition usually is characterized by occult or subacute blood loss and anemia that require transfusion [7].

The risk of developing UGI malignancy is age-correlated and it is a common cause of UGI in elderly people, often the bleeding is the first sign [34].

Dielafoy lesion is a dilated submucosal artery, it can be found anywhere along the gastrointestinal tract, with the majority of which is found within the stomach, that can rupture and result in overt gastrointestinal hemorrhage. These lesions are not typical of elderly [12].

Aortoenteric fistula (AEF) develops in 0.5% of patients who have undergone aortoiliac bypass surgery or after endovascular aortic repair (and so especially in the elderly). The classical presentation is with a small bleed followed by exsanguinating hemorrhage (but often pass also 10 days before the diagnosis). Short term mortality exceeds 30% even after accurate diagnosis and repair [34, 36, 37].

16.5 Risk Assessment for Outcome

The recently published American College of Gastroenterology practice guidelines on the management of patients with ulcer bleeding recommend risk assessment in all patients in order to stratify them into high or low-risk categories, since it may assist in initial decisions regarding the timing of endoscopy, time of discharge, and level of care [34, 38].

There are various risk assessment scores; the much important are: Glasgow Blatchford Score (GBS), Rockall score that is divided into pre- and post-endoscopic (RS) and recently described AIMS65 (albumin level < 30 g/L (A), INR > 1.5 (I), altered mental status (M), systolic blood pressure ≤ 90 mmHg (S), and age > 65 years [39]) score [4, 34, 38].

The GBS is a pre-endoscopic score, it uses only clinical and laboratory data and in particular contains the following parameters: initial hemoglobin levels, urea, blood pressure, pulse, known syncope, melena, and liver or cardiac failure. This score can be used after hospital admission [34, 38, 40]. The GBS was designed to predict lower risk bleeds, and a GBS value of 1 or lower indicates a very low-risk category [38].

Furthermore, the GBS has the highest discriminative ability at predicting the need of intervention (for example, the need of endoscopic treatment, need of transfusions, etc.) and mortality compared with other scores like full Rockall score, admission Rockall score, and AIMS65 score (it can predict 30-day mortality better than GBS) [4].

The most commonly used RS consists of a pre-endoscopic evaluation part, which includes age, signs of shock, and comorbidities. Each value >2 indicates a high-risk patient [38, 41, 42]. So, this score can predict patient's outcome, death (after rebleeding), and estimated rebleeding risk. Patients with a score of 0 should be considered for non-admission or early discharge with outpatients follow-up; if the score is above 0 there is an important risk of mortality and endoscopy is recommended [4, 38, 42].

Full RS requires knowledge of the endoscopic findings to predict outcome and includes age, pulse rate, systolic blood pressure, comorbidity, endoscopic diagnosis, and the presence of stigmata of bleeding [42].

In a study including 335 elderly patients with UGIB, authors found the RS to be clinically more useful for predicting mortality (for complete RS: AUROC 0.788, 95% CI 0.726–0.849, $p = 0.001$ [42]) and rebleeding (for complete RS AUROC 0.787, 95% CI 0.716–0.859, $p = 0.001$ [42]) than the GBS even if the latter is superior in order to predict the duration of hospitalization and the need for blood transfusion.

16.6 Lower GI Bleeding

Lower GI bleedings (LGIB), that are less common than UGIB in the general population, are defined as a hemorrhage happening distal to the ligament of Treitz. The incidence of LGIB is higher in the elderly and in particular among men [6, 43].

In a retrospective study was seen that the incidence of LGIB is significantly higher from the third to the ninth decade of life and we can explain this because of the age-associated increase in the incidence of diverticular hemorrhage that is the most important cause of LGIB in elderly people; In almost 80% of patients not treated with surgery the GI bleeding will stop but the recurrence rate can be as high as 25% [15, 44].

16.7 Clinical Presentation and Risk Factors

LGIB can be classified as acute, occult, or obscure. Acute LGIB presents as melena or hematochezia. Melena is more common in UGIB but it may also be from the small intestine or right colon. The presence of blood in the occult blood stool exam is the most common presentation of LGIB in the elderly, occurs in 10% of the adult population and often this finding is associated with anemia.

"Obscure bleeding" are those impossible to be identified by either esophagogastroduodenoscopy or colonoscopy. In 2015, the American College of Gastroenterology recommended that the term "obscure" GI bleeding be replaced by small bowel bleeding as the majority of cases of "obscure" GI bleeds are due to bleeding in the small bowel [2].

Attention must be paid to symptoms in elderly people because abdominal pain may not be present or not specific [43].

Like UBIB even LGIB are more common in the elderly and some main points should be considered:

- Some common diseases in the elderly such as diverticulosis coli, vascular ectasia, ischemic colitis, and colonic neoplasm can cause LGIB.
- Associated comorbidities may increase the incidence and severity of LGIB (i.e., cardiovascular disease, cirrhosis, renal disease, diabetes mellitus, and malignancy).
- The presence of serious concurrent disease associated with the bleeding may favor mortality increase [45].
- The use of many medications (i.e., NSAID's, antiplatelets, steroids, and anticoagulants) increases risks. A meta-analysis is showed to increase 25% GI bleeding risk in patients treated with direct oral anticoagulants (DOACs). No definitive data exist for the different types of anticoagulants: DOACs and VKAs (vitamin K agonists) [8, 46].

16.8 Etiology

The main factors influencing the etiology of LGIB are the geographic localization of the population and the age. In Western Europe and the United States, the most common causes of LGIB are diverticular disease and vascular ectasia; less common causes are IBD (inflammatory bowel disease), neoplasia, post-polypectomy hemorrhage, and hemorrhoids. In Asia, the most common causes of LGIB are hemorrhoids, anal fissures, and malignant colorectal neoplasm [47–49].

16.9 Common Etiology

- Diverticular hemorrhage
- Vascular ectasia (telangiectasia)
- Inflammatory bowel disease
- Neoplasms
- Hemorrhoids
- Ischemic colitis
- Infectious colitis
- Drug-associated colitis

16.10 Less Common Etiology

- Post-polypectomy bleeding
- Stercoral ulcers
- Solitary rectal ulcer
- Radiation proctitis
- Dieulafoy's lesion
- Colorectal varices

The incidence of *diverticular disease* increases with the age from approximately 5% at the age of 40–65% at the age of 85 in Western Europe and the United States. LGIB is a common modality of presentation of diverticular disease (3–5% of patients). Usually, it presents as hematochezia (often with acute pain and usually ceases spontaneously) or frank colonic hemorrhage (less than 1% of patients require more than four units of blood). 50–90% of diverticular LGIB occurs from colonic diverticula. It is possible, however, to find diverticula even in the small bowel where they may be a source of "obscure bleeding." In some cases, bleeding can be hemodynamically significant in elderly people due to comorbid conditions or use of particular drugs [8, 44, 50, 51].

Vascular ectasia or angiodysplasia can occur in the colon, especially in the cecum or in the small bowel. It is a degenerative lesion to previously normal blood vessels, due to repeated episodes of colonic distension associated with transient increases in both luminal pressure and size. This results in multiple episodes of increased wall tension and obstruction of submucosal venous outflow. This process leads to dilatation of venules and capillaries with the development of vascular ectasia. They cause LGIB in 12–40% of patients. The LGIB associated with angiodysplasia is usually subacute but can be chronic and recurrent or massive in up to 15% of patients [52–54].

Inflammatory bowel disease (IBD) can develop among younger but we can have a second peak between the age of 60 and 70 years. About 15% of all patients with IBD develop symptoms after the age of 65 [55–57].

Ischemic colitis accounts for 3–9% of all cases of LGIB in the elderly. Colonic atherosclerosis is almost universal in the elderly and predisposes to ischemic colitis due to a reduced blood supply to the colon because of some factors like hypotension and vascular embolic events. There are other risk factors such as vasculitis, dehydration, and the use of diuretics and vasoactive agents. Often the symptoms of ischemic colitis include lower abdominal cramping pain followed by hematochezia (rarely severe). The treatment is generally nonoperative. It often is complicated by perforation or stenosis that requires surgery [43, 58].

The mortality by *infectious colitis* increases with age. LGIB is rarely massive in these patients. Hematochezia is noted in less than 10% of cases. The most common infectious agents in elderly people are Campylobacter, Salmonella, Shigella, *E. coli* O157:h7, and *Clostridium difficile* [59–61].

Malignant and benign neoplasm of the colon and rectum are a cause of LGIB in 10–20% of cases. LGIB can be the initial presenting symptom in up to 26% of patients with colorectal neoplasm. It is possible, however, to observe massive hemorrhage in the patients taking some drugs like NSAIDs or anticoagulants [39, 62].

Post-endoscopic polypectomy hemorrhage is the source of LGIB in approximately 3% of patients. The incidence of LGIB after endoscopic polypectomy in 0.7–2.5% [63–65].

Solitary rectal ulcer syndrome is generally due to rectal prolapse and mucosal damage because of constipation and straining. These diseases can be a source of massive LGIB in the elderly [66]. Stercoral ulcers are the result of mucosal damage by hard impacted stool in the rectum or by foreign body injury insertion to try to solve fecal impaction, such as rectal tube.

Radiation proctitis occurs in people who have undergone radiation therapy usually for rectal, prostate, genitourinary, or gynecologic malignancies. It can develop years after treatment has ended and can result in either overt rectal hemorrhage or chronic transfusion-dependent blood loss [7].

16.11 Diagnosis

16.11.1 Endoscopy

Clinical differentiation of GI bleed as UGIB versus LGIB is the first step in the diagnostic workup. Workup of overt UGIB starts with an upper endoscopy. Upper endoscopy has a 92–98% sensitivity and almost 100% specificity with the ability to treat patients effectively.

Workup of LGIB starts with colonoscopy. This exam is not effective without adequate colon preparation (in general polyethylene sulfate purge causes less associated water and electrolyte abnormalities and may be preferable to saline purge in elderly patients with comorbid renal or cardiovascular disease). If the patient is unable to take the purge per os, it can be given via nasogastric tube. The diagnostic and therapeutic yield of colonoscopy in managing patients with LGIB has a wide range of variability (8–100%).

Endoscopy is a stronghold both in the diagnosis and management of GI bleeding. There are some techniques we can use such as thermal therapy, topical therapy, injection therapy (with dilute epinephrine and normal saline), mechanical therapy (hemostatic clips).

Both the exams require conscious sedation, that is generally well tolerated in elderly patients. According to recent studies, midazolam is successfully tolerated but can cause desaturation in geriatrics. Furthermore, elderly patients may also be at increased risk of aspiration and of perforation during endoscopy. Zenker's diverticulum or cervical spine osteophytes can increase the risk of perforation. It is also necessary to monitor the vital sign and pay attention to unexpected respiratory arrest that may necessitate emergent endotracheal intubation [6, 12, 67].

16.11.2 Contrast-Enhanced Computed Tomography

This procedure has been reported to detect bleeding as low as 0.4 mL/min. It has the advantage of being noninvasive, widely available and avoids the risk associated with arterial puncture. Some disadvantages are radiation exposure and also the risk of acute kidney injuries (AKI) [68].

16.11.3 Contrast-Enhanced Angio-CT Scan

Contrast-enhanced angio CT-scan has become the first diagnostic option for stable patients presenting with GI bleeding. The accuracy of this test is 27–77% for bleeding localization. AG/AE like scintigraphy requires active bleeding in order to see active extravasation.

This procedure is safe and generally well tolerated among the elderly. Adverse events can be correlated to complications in the puncture site, such as bleeding, hematomas, and pseudoaneurysms, especially in patients who take anticoagulant or antiplatelet medications. AKI is a possible adverse event because of the use of iodinated intravenous contrast. Higher risk of AKI exists in people that suffer from chronic kidney injuries, diabetes mellitus, and in patients with dehydration prior to the procedure. The administration of acetylcysteine and bicarbonate fluid with adequate hydration can reduce adverse events. In recent studies, acetylcysteine was shown to provide minimal protection from AKI, while bolus infusion of sodium bicarbonate, in addition to an adequate hydration, may decrease AKI [6, 12].

As for CT-scan remains the priority stratification principle. The primary goal should be to stop bleeding. AKI prevention remains a priority but should be categorized according to the single patient situation.

16.11.4 Scintigraphy

Scintigraphy can identify the slowest active bleed: at a rate of approximately 0.05–0.10 mL/min and its accuracy is 24–78%. Finally, due to the stability of the radiolabel and physical half-life of Tc-99m, images can be acquired for up to 24 h, which can be helpful in cases of intermittent bleeding [12, 43].

Benefits of this exam include the noninvasiveness, the lack of need for bowel preparation, and the ability to identify both arterial and venous bleeds and it does not require iodinated contrast so it can be used without delay in patients with contrast allergies and those with limited renal function.

Unfortunately, scintigraphy is time-consuming and may not be available in an emergency setting for acute bleeds; moreover, even when positive, it does not provide any information regarding the bleeding cause. Lastly, tagged RBCs can localize at sites distinct from bleeds, such as sites of splenosis, pancreatic pseudocysts, and non-enteric bleeding (i.e., hematomas), leading to false-positive results. [12, 69, 70].

16.11.5 CT-Scan Enterography

Multiphase CT-scan enterography (CTE) is useful in evaluating hemodynamically stable patients with intermittent and occult GI bleeds. This exam utilizes a bolus (about 1.5–2 L) of a neutral oral contrast agent to be ingested by the patient. This luminal distension allows optimal visualization of enhancement of the small intestine wall and mucosa following intravenous contrast administration, thereby increasing the sensitivity of detection of bleeding and no-bleeding abnormalities [12]. The large volume of oral contrast, however, exposes elderly patients to the risk of aspiration.

16.11.6 Capsule Endoscopy

Capsule endoscopy has a diagnostic yield between 30% and 68%. This test is safe and well tolerated in the elderly but it presents some limits: inability to swallow the capsule, battery failure before capsule reaches the cecum, capsule retention, the long duration of the test, and lastly the impossibility to perform any kind of treatment [12, 71, 72].

16.12 Management

Although the basic principles of managing GI bleeding are the same in elderly and younger people, mortality remains higher in the elderly, despite strict adherence to modern algorithms [73].

The main goals in the treatment of GI bleeding are: (1) adequate resuscitation (2) localization of the cause of hemorrhage, and (3) control of the bleeding source.

16.12.1 Adequate Resuscitation

Initial evaluation as all bleeding patients should be according to the A-B-C scheme: airway, breathing, and circulation. The monitoring of vital signs is necessary (arterial blood pressure, heart rate), together with the presence of almost two large IV bores and urinary catheter placement. It is important to evaluate capillary refilling, peripheral vasoconstriction signs and obtain blood gas analyses in order to monitor pH, pO_2, pCO_2, lactates, and base excess assessment. Particular attention should be given to the patient's therapies and comorbidities in evaluating the severity of the bleeding effects. During the resuscitation phase in severe bleeding with hemodynamical impairment, is of paramount importance to guarantee an adequate airway protection, especially in elderly people. Supplementary oxygen delivery may be needed. Intubation should be considered only in severe and selected cases.

Adequate fluid resuscitation is of paramount importance and should be initiated as soon as possible while organizing for endoscopic procedure.

Hypotension at admission of the patient is associated with high mortality among elderly people and early aggressive fluid resuscitation can decrease mortality. International consensus guidelines for the management of non-variceal UGIB suggest a threshold of 90–100 g/L for transfusion in elderly patients with cardiac disease. Nasogastric tube (NGT) placement may be necessary in order to distend the stomach and to apply saline lavage; blood may be present in nasogastric tube in UGIB. Endoscopy should be performed as soon as possible in the event of blood through NGT.

Ematochezia is a sign suggesting a LGIB even if it may be also present in UGIB.

Digital rectal examination and eventual subsequent anoscopy are recommended as a standard component of the initial physical examination.

The patient's medical history should be accurately investigated with particular attention to prior GI bleeding, previous abdominal surgery, medications, comorbid disease (in particular, cardiovascular and pulmonary disease but also chronic liver disease or coagulation disorders).

The laboratory exams should include complete blood count, serum electrolytes, coagulation parameters, and liver biochemical tests. Thromboelastography (TEG) and thromboelastometry (TEM) can be useful, especially in patients taking anticoagulants. It is mandatory to correct eventual coagulation disorders as soon as possible. Endoscopic procedures should not be delayed unless INR is above therapeutic range.

Often with an adequate resuscitation, the GI bleed stops spontaneously.

A recent population-based study showed that most UGIB-related deaths are due to non-bleeding causes (79.9%) as opposed to bleeding causes (18.4%) [34, 43, 74, 75].

16.13 Localization and Control of the Bleeding Source

16.13.1 Endoscopy

Endoscopy is the primary diagnostic and therapeutic modality for both UGIB and LGIB in hemodynamically stable patients or in patients that have been adequately resuscitated.

Evidences suggested that esophago-gastro-duodenoscopy (EGDS) should be performed in an urgent, but nonemergent setting. In particular, for non-variceal UGIB the endoscopy should be performed within 24 h from admission. Patients with high-risk conditions as bloody emesis/nasogastric aspirate during hospitalization and contraindication to discontinuation of anticoagulants should be considered candidates for very early endoscopy (within the first 12 h of admission). In case of variceal bleeding, endoscopy should be performed within the first 12 h. In case of UGIB associated with hemodynamic instability refractory to volume resuscitation, EGDS should be performed as soon as possible in the operating room where in case of failure the patient can be immediately operated.

At EGDS some signs are suggestive of high risk of rebleeding or continued hemorrhage: the presence of spurting vessel, visible vessel and ulcer greater than 2 cm, adherent clot. Rebleeding is defined as the occurrence of a new episode of UGIB or the presence of recurrent hematemesis or melena or fresh blood in the nasogastric aspirate or circulatory instability during the patient's hospitalization once the initial bleeding had been stopped.

In case of rebleeding endoscopy should be the first procedure to be considered. Furthermore, the rate of rebleeding in the elderly has been demonstrated to decrease with endoscopic treatment even of those non-bleeding high-risk lesions [3, 7, 76–78].

Regarding LGIB, there is no consensus for the optimal timing for endoscopy because is necessary to prepare the patient for the exam. Colonoscopy performed within the first 24 h from admission may offer benefits by providing a definitive diagnosis in up to 96% of patients. If the bleeding lesion is not visible or cannot be controlled, the bleeding site should be marked with ink tattooing in order to allow the surgeon to identify the colonic lesion during surgery [79–81].

16.13.2 Angiographic Embolization

Historically, the first-line therapy for non-variceal UGIB was surgery. Angiography with percutaneous catheterization as a diagnostic tool for GI bleeding was first performed in 1965. After some years this technique has been used in order to treat an acute gastric hemorrhage. Furthermore, improvements in catheter technology, the development of new materials for embolization therapy, and wider availability of appropriately skilled interventional radiologists have led to the increased use of AG/AE in the management of UGIB. Therefore, arterial embolization should be considered as an alternative to surgery, especially in patients with high risk for poor surgical outcomes due to comorbid or advanced age and in hemodynamically stable patients.

The main adverse effects include acute kidney injuries, bowel ischemia, that has an incidence of 5–16% and can result in necrosis and perforation.

The decision between AG/AE and surgery should be made on an individual case-by-case basis and it remains a clinical dilemma. In a recent paper that includes 13 studies for a total of 1077 patients divided into two groups (one of these includes patients treated by AG/AE and the other treated by surgery): AG/AE is a safe and an effective procedure. When compared to surgery, AG/AE has a higher rebleeding rate, but this tendency does not affect the overall clinical outcome. In fact, the comparison of mortality rates for the two procedures highlights a slight drift towards lower mortality for patients undergoing AG/AE, despite the fact that AG/AE patient population usually includes those with greater comorbidities unfit for surgery. AG/AE could be a viable option as a first-line therapy for refractory non-variceal UGIB and, in the absence of strong evidences showing the superiority of one specific approach, local factors (organization of surgical and radiological services, availability of specific radiological skills, services availability during the night shift and weekends, etc.) will continue to determine the therapeutic pathway [13, 34, 82–85].

In a randomized prospective study, 100 patients with LGIB were randomly allocated to urgent colonoscopy or to technetium-labeled red blood cell scintigraphy followed by angiography. There were no differences between the groups for rebleeding rates, transfusion requirements, or the need for emergency surgery [70].

16.13.3 Surgery

Indications for emergency surgery are uncontrollable bleeding at initial endoscopy, rebleeding following endoscopic hemostasis not amenable of endoscopic re-treatment, proximal small bowel bleeding, unstable patients diagnosed with bleeding duodenal ulcer on computer tomography angiogram not amenable of endoscopic or AG/AE treatment, and the transfusion of 4–6 units of blood in 24 h for LGIB. Emergent surgery has a high rate of morbidity in the elderly.

In UGIB if gastric bleeding is suspected, an anterior gastrotomy may be performed with ligation of the bleeding source. If the gastric bleeding source cannot be individuated, gastric devascularization (ligation of the blood supply to the stomach with the exception of the short gastric vessel) can be performed. If the source of bleeding is the duodenum, a gastroduodenostomy with oversewing of the bleeding vessel is recommended.

In LGIB, after a previous endoscopy or an angiography in order to identify the source of bleeding, a segment resection of the colon is the treatment of choice. If results impossible to localize the source of bleeding (for example, in patients who suffers from colonic diffuse diverticulosis), and refractory to medical treatment a subtotal colectomy may be considered. Mortality rates for patients undergoing subtotal colectomy remain high, ranging from 20–35% and it is higher in elderly people (37% in patients >70 years old vs. 21% in patients <70). Every effort should be made to identify the bleeding source prior to referral for surgery. Blind segmental resection is associated with rebleeding and mortality rates of 47% and 57%, respectively [13, 43, 86–89].

16.13.4 Medical Therapy

The introduction of proton pump inhibitors, as well as the creation and improvement of effective endoscopic techniques, greatly changed the approach to non-variceal UGIB, shifting the therapeutic path from a surgery-first to a conservative-first approach.

For patients with high risk of bleeding (endoscopy proved), the recommended regimen for intravenous PPIs is either omeprazol (or pantoprazol) 80 mg bolus, followed by 8 mg/h for 72 h. Lower doses of PPIs reduce rebleeding but do not affect mortality. After 72 h, if there is no bleeding evidence, PPI intravenous therapy can be switched to oral.

It is usually recommended that aspirin and clopidogrel are discontinued after UGIB, but the risks connected to discontinuation of antithrombotic therapy should be considered. The risk of recurrence of underlying disease associated with discontinuation of a low dose of aspirin (LDA) has also been reported to be significantly higher than the risk of recurrence of hemorrhagic gastric ulcer associated with continuation of LDA therapy. So the risk-benefit balance of discontinuing or continuing antiplatelet or anticoagulant drugs should be evaluated according to the competent specialists. In such cases, a second-look procedure should be performed aggressively and antithrombotic medication should be resumed as soon as possible.

Lastly, the prevalence of H. pylori infection in patients with peptic ulcers aged over 65 years has been reported to be 58–78%. H. pylori has also been found to increase the risk of ulcer-related bleeding among NSAID users. However, no significant associations exist between H. pylori infection and any clinical outcome or type of stigmata of recent bleeding. In elder patients with a long-term use of NSAIDs H. pylori eradication significantly reduced the recurrence of peptic ulcers. The percentage of elderly patients with peptic ulcers treated for H. pyloriinfection has been reported to be low [3, 90, 91]. H. pylori eradication in all elderly patients with long-term NSAIDs treatment should be considered.

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Small Bowel Obstructions in the Elderly

17

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17.1 Epidemiology

According to the World Health Organization, old age is defined as 60 years of age or older, although in poorer countries with lower life expectancy than in developed countries, an age range between 50 and 55 is also taken into account.

Within the elderly population, further classification like the oldest old (normally those 80+) and centenarian (100+), and even super-centenarian (110+) are also made.

General conditions in elderly patients change from being fit and healthy to frailty. Frail older people are at greater risk of complication and death when they present with acute surgical emergencies [1].

Small bowel obstruction (SBO) is a frequent emergency diagnosis in elderly patients and its occurrence tends to increase with the increasing number of elderly patients thus requiring sometimes acute medical care and emergency surgery.

Cases of SBO have been documented throughout history, with descriptions dating back to the ancient Egyptians [2]. Generally, SBO accounts for 2–4% of emergency department visits for abdominal pain, representing as many as 16% of surgical admissions and more than 300,000 operations annually in the United States [3, 4]. In the UK, small bowel obstruction accounts for 51% of all emergency laparotomies (Team NP. The second patient report of the National Emergency Laparotomy Audit (NELA). London: The Royal College of Anaesthetists; 2016).

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Although some obstructions may occur in the large intestine, almost 80% of mechanical obstructions occur in the small intestine [5]. Unfortunately, patients may experience a high complication rate, and a considerable number of patients with SBO may undergo strangulation. Elderly patients are particularly at high risk for obstruction and its complications.

Anyway, the incidence of SBO is difficult to determine precisely though SBO in general is one of the most frequent causes of general emergency surgery. Emergency surgery in elderly patients is associated with high morbidity and mortality compared to elective operations or emergency surgery in younger counterparts.

About 10–12% of patients above 65 years of age presenting with abdominal pain at the emergency department (ED) are diagnosed with small bowel obstruction [6, 7].

In addition, although the overall SBO mortality rate is <3%, elderly patients with SBO have mortality rates of 7–14% [8].

17.2 Etiology and Classification

Older age is a risk factor for many SBO causes. Some of them, such as the congenital atresias, webs, malrotation, and Crohn's disease are much less likely to be seen in the elderly population.

The three most frequent causes of SBO are postoperative adhesions, hernias, and neoplasms (older patients with suspected SBO but without prior abdominal surgery and the absence of a hernia on examination should be evaluated for malignancy) and all of them have increasing prevalence in aged populations.

The application of various minimally invasive techniques like laparoscopy in the elderly is expanding because of reduced overall morbidity. As a consequence, new subclasses of iatrogenic causes of SBO have been reported with increasing frequency.

Endoscopically placed foreign objects, such as percutaneous endoscopic gastrostomy tubes [9] and endoscopic retrograde cholangiopancreatography (ERCP) biliary stents [10]; or video capsule used for total enteroscopy can become dislodged and lead to obturation obstruction.

As regards laparoscopy, although the formation of adhesions is rarer than after laparotomy, hernias can occur in trocar sites or through peritoneal defects created during the procedures.

There are several and different ways to classify SBOs. Among these, the following can be considered: complete or partial, high grade vs. low grade, simple loop or closed loop, high obstruction and low obstruction, mechanical vs. ileus, and chronic or acute [4]. Complete obstruction is diagnosed when no passage of fluid or gas in the site of obstruction is possible. If there is some passage of enteric contents, the patients are classified as having a partial obstruction. Compared with complete obstruction, partial SBO is associated with less severe distension. A high-grade SBO occurs with no passage of flatus, significant distension, and abdominal pain, while low-grade SBO is similar to a partial SBO with attenuated symptoms. The occlusion of the bowel at a single point is defined as simple SBO, while closed-loop

SBO occurs when both afferent and efferent parts of a bowel loop are occluded. This form is often associated with ischemia and strangulation with necrosis. A high SBO is defined as an obstruction proximal to the jejunum, associated with bilious vomit, while a low SBO is located in the distal ileum, associated with greater distension and sometimes with fecal vomit. Mechanical SBO occurs with a pathologic lesion (tumors) or material occluding bowel lumen (gallstone ileus, foreign bodies), while ileus is a functional obstruction with a disruption of the normal propulsive ability of the intestine due to the malfunction of peristalsis. Finally, chronic SBO is comprised of several low-grade obstructions that typically resolve without operative treatment. Acute SBO is the sudden onset of symptoms with no prior history of SBO, which more likely requires operative therapy [3, 5, 11].

Whatever classification is used, it can often be inaccurate and not clinically useful for decision-making. On the contrary, classifying SBO as nonoperative and operative can be much more useful for the surgeon. Within operative category, we can consider SBOs that are strangulated based on history, examination, or imaging; patients with peritonitis or hemodynamic instability, and those that fail to improve with nonoperative therapy. Nonoperative SBOs are those that are not strangulated and resolve without operative therapy.

17.3 Main Causes of Small Bowel Obstruction in Elderly

17.3.1 Adhesions

Adhesive small bowel obstruction (ASBO) is one of the leading causes of surgical emergencies and in particular of surgical emergencies that require an emergent operations [12].

"Adhesions" are pathological entities that refer to fibrous tissue connecting surfaces or organs within the peritoneal cavity that are normally separated. These adhesions are the results of a pathological healing response of the peritoneum upon injury [13] such as after abdominal surgery. Peritoneal adhesions may also be the result of other procedures, including radiotherapy, endometriosis, inflammation, and local response to tumors.

Postoperative adhesions are the first cause of small bowel obstructions, accounting for 60% of cases and about 20–30% of this require operative treatment [14]. The length of hospitalization and morbidity depend on the need for surgical intervention. However, in elderly patients a fundamental role is played by comorbidities and general clinical conditions. According to a recent analysis by Krielen et al. the average hospitalization after surgical treatment of ASBO is 16 days, compared to 5 days following nonoperative treatment [15].

The main principles for the prevention of adhesion and related complications are minimizing surgical trauma and using adjuvants to reduce adhesion formation. Therefore, one of the surgeon's concerns in the interventions in election should be to prevent the formation of adhesions. Laparoscopic technique is often believed to reduce adhesion formation and the risk for ASBO. Nevertheless, a number of important risk factors for aggravated adhesion formation are worth considering, such as the foreign body reaction, for example, as seen with meshes used for abdominal wall reconstruction [16]. In the era of technological innovation, no less important in the choice of energy device which can affect the formation of adhesions. Bipolar electrocautery and ultrasonic devices cause less damage to the peritoneum, and therefore a reduced probability of forming adhesions [17] compared to monopolar electrocautery.

Another important consideration for decision-making in the elderly is the assessment of the quality of life. Patients with a high frailty index have a prolonged recovery after a surgical procedure and may not be able to return to their previous functional state and quality of life [18]. Moreover, it should be considered that some therapeutic principles for small bowel occlusions could interfere with the patient's current therapies and his comorbidities especially in elderly patients as in "nil per os" for nonoperative treatment of small bowel obstruction.

A recent cohort showed that patients with diabetes might require earlier intervention although the level of evidence is rather low. Patients with diabetes were shown to suffer from a 7.5% incidence of acute kidney injury and 4.8% incidence of myocardial infarction if the operation was delayed more than 24 h [19]. The incidence of these complications was significantly higher when compared to diabetic patients that were operated within 24 h and non-diabetic patients with delayed operation.

17.3.2 Hernia

Hernias account for 15–20% of SBOs [20]. The comorbidities that most influence the incidence of hernia in elderly patients include benign prostatic hypertrophy, chronic obstructive pulmonary disease, constipation, and obesity. The most common localization is the anterior abdominal wall both as primitive hernias and as incisional hernias. Parastomal or peristomal hernias are also of great importance in patients who underwent intestinal or colorectal surgery. Internal hernias account for about 25% of hernia-associated SBOs and most of these are due to iatrogenic mesenteric defects created during prior surgery. They often occur through the mesentery at the site of a previous anastomosis and highlight the importance of repairing these defects. Among the patients with incarcerated hernia, 5–13% had emergency surgery and 10–15% required intestinal resection as a result of necrosis [21], and delay in surgical treatment is associated with higher mortality. The overall mortality rate of the SBOs due to a hernia is around 4% in general population, but in the elderly this rate may increase due to several factors. The mortality and morbidity rates for elective hernia repair are 0% and 5%, respectively while in emergency repair [20] they account for 8–14% and >50%, respectively. The low morbidity of elective repair and the high incidence of strangulation and considerably poorer outcome with emergent repair are strong reasons to advocate aggressive elective repair of hernias in elderly patients.

Particularly interesting in the elderly is the obturator hernia, referred to in a recent article as the "little old lady's hernia," [22] because the mortality from obturator hernia-associated SBO is as high as 15–25%. Although this cause accounts for only 1–2% of all SBOs, this type of hernia is almost universally reported in old thin women [23]. The diagnosis is complex because an obturator hernia is easily missed on physical examination. The obturator foramen is a rigid ring, and hernias in this location have a high incidence of strangulation (50%). Pressure and inflammation in the obturator foramen can lead to pain in the distribution of the femoral nerve; and the Howship-Romberg sign (thigh pain on external rotation of the thigh) can be elicited in about one-third of patients. For these reasons, in elderly patients without a history of surgery, a potential obstruction due to a herniation in the obturator must also be considered in the differential diagnosis.

17.3.3 Primitive and Metastastic Tumors

Neoplasms account for 16% of SBOs. Most of these are due to metastatic tumors or recurrent disease. The primary tumors of the small intestine are rare, although the diagnosis of new forms of central-abdominal localization is increasing, as for NET (Neuroendocrine Tumors) and GIST (Gastrointestinal Stromal Tumor). Most of them are due to direct extension or metastases from colonic, pancreatic, and gastric tumors.

In a recent study, Prost à la Denise et al. [24] observed a benign cause of SBO in half of the patients with prior history of cancer and in two-thirds of those without known recurrence.

Causes of SBO were benign (postoperative adhesions, post-irradiation strictures) in 68 patients (54.8%) and malignant in 56 (45.2%). Incomplete obstruction, acute clinical onset, nonpermanent abdominal pain, a shorter period between primary cancer surgery and the first episode of obstruction, and a known cancer recurrence were significant predictors of a malignant SBO. Benign causes of SBO were observed in 72.8% of patients who had no known cancer recurrence but were observed in only 11.1% of patients whose recurrences were known. In patients with cancer recurrence-related SBO, postoperative mortality was 28.6%, with a median overall survival of 120 days. One month after surgery, 38 (67.8%) of these patients tolerated oral intake.

Some surgeons have a nihilistic nonoperative approach in patients with an SBO with known intra-abdominal cancer. The combination of a partial SBO, short life expectancy due to known metastatic cancer, and poor operative risk should put operative management in question. However, given the significant incidence of benign causes in the face of recurrent cancer, an initial aggressive approach is warranted, including early surgical intervention. On the contrary, if a malignant obstruction is diagnosed, overtreatment resection should be avoided in deference to palliative measures, including bypass of the obstructed segment and placement of a gastrostomy tube.

17.4 Clinical Presentation and Diagnosis

The classic symptoms of small bowel obstruction, which are primarily determined by the anatomic level and degree of obstruction, include nausea and vomiting, abdominal distension, abdominal pain, and lack of passage of stool or flatus. In case of proximal (high) occlusion such as at jejunal level, the clinical presentation will be characterized by frequent vomiting of bilious material and dehydration early in the course of disease with relatively little abdominal distension. Conversely, in case of low (distal) occlusion swallowed air and gastrointestinal secretions can be found, which lead first to small bowel and abdominal distension. Only later do patients develop vomiting, usually after bacterial overgrowth has resulted in a fecaloid character to the enteric content.

A correct diagnosis may be difficult in the elderly population, due to a lack of detailed studies on symptoms. In fact, they seem to present later and to be less profound in the elderly compared to younger patients thus resulting in a higher rate of misdiagnosis [8, 25]. It must be considered that the classic symptoms such as fever, abdominal pain, and leukocytosis which make it possible to distinguish between a complicated by an uncomplicated occlusion, in the elderly are all attenuated [26]. The elderly have lower baseline temperatures and 20–30% of cases show no fever at all in cases of serious infection [27].

Since the patient's laboratory and clinical data are not always useful, it might be more difficult to recognize strangulation or ischemic bowel in the elderly.

After an abdomen x-ray, a CT scan should be performed (Fig. 17.1). Intravenous contrast-enhanced CT (Fig. 17.2, in fact, is a valuable diagnostic tool to identify patients with small bowel obstruction who require immediate surgery. Furthermore, CT may highlight other unacknowledged diseases such as unsuspected intra-abdominal neoplasm, intestinal pneumatosis, or portal venous gas. A study in

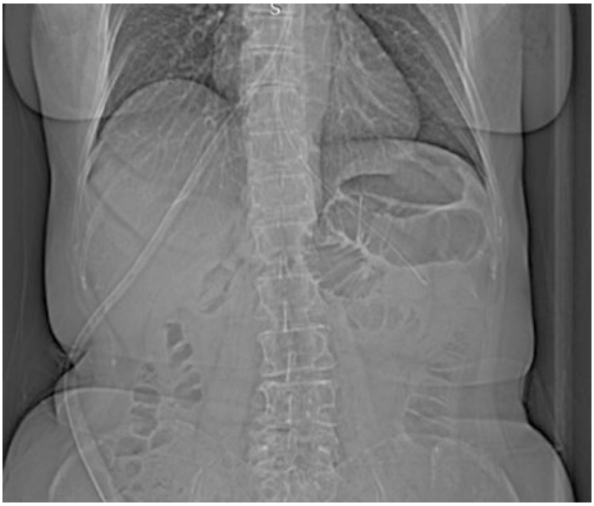

Fig. 17.1 RX abdomen

Fig. 17.2 CT scan

octogenarians and nonagenarians showed a significant change in small bowel obstruction diagnosis before and after CT [28]. A CT sensitivity and specificity between 90 and 98% for complete bowel obstruction was found in the elderly population [29]. Despite its great diagnostic value, contrast-enhanced CT could expose patients to contrast-induced nephropathy. Moreover, when patients have a history of malignancies, a CT may differentiate between malignant bowel obstruction and adhesive obstruction related to previous abdominal surgery.

Another useful imaging tool that is both diagnostic and therapeutic in particular in adhesive small bowel obstruction is water-soluble contrast follow through abdominal film or CT. This has proven to be a reliable diagnostic tool to distinguish complete from incomplete obstruction. A randomized study has been performed in elderly patients with small bowel obstruction to assess the therapeutic effects of a water-soluble contrast follow through investigation in combination with somatostatin (analog). In this study, the patients in the intervention group had less surgery, less pain, earlier start of oral intake, and earlier stool passage [30].

In addition to CT, other imaging techniques like Ultrasound might be useful in specific situations. Ultrasound, in particular, FAST (Focused assessment with sonography in trauma) is an operator-dependent technique but in experienced hands can provide more and fast information than plain X-rays, and is also available in most departments. A good ultrasound can highlight several signs that can change the therapeutic approach like distension of bowel loops, detection of free fluid (that might indicate the need for urgent surgery), and assessment of the degree of shock in dehydrated patients [31].

An assessment of the patient's frailty level is fundamental in the classification and diagnosis of SBO in elderly people. There is, in fact, existing evidence showing that frailty negatively affects outcomes in patients undergoing emergency surgery [32].

The evaluation of the state of frailty can affect the decision-making process. In fact, non-frail elderly patients can be considered as the rest of the general population, while frail patients are at high risk of postoperative complications. In a study focused on the evaluation of frailty in elderly patients with small bowel obstruction [33] 53% of patients were mildly to severely frail and 25% were pre-frail thus showing the high risk of progression to fragility after invasive treatments.

17.5 Management and Treatment

A popular surgical saying, in its various versions, recommends “do not let the sun rise or set on a small bowel obstruction.” In clinical practice, this is not always true especially in a particular category of patients like the elderly.

The initial approach to the SBO patient, even in the presence of a complete occlusion, includes the placement of a nasogastric tube for stomach decompression, electrolyte correction with fluid infusion, and nutritional support. In elderly patients, the possible onset of delirium or functional decline or other neurological manifestations due to electrolyte alterations must be considered.

Although the nasogastric tube is the first choice, in selected patients such as those with several previous laparotomies or patients for whom long-term nonoperative treatment is envisaged, it is possible to consider the endoscopic positioning of a triple lumen nasogastric tube or a naso-intestinal tube [34]. However, in elderly patients, in particular, sedation procedures such as endoscopy can be exposed to the risk of pulmonary complications due to ab-ingestis and accidental removal of the nasogastric tube may occur due to hyperactive delirium [35].

However, the main initial treatment of small bowel obstruction is “nil per os.” The exception to this fundamental principle is represented, in particular, in elderly patients, by the need to administer drugs for the treatment of comorbidities. Generally, long-term risk management drugs are suspended, other types of drugs can be administered through the nasogastric tube with a short clamping period, or administered via other routes such as the intravenous one.

Although the administration of drugs through the nasogastric tube for a short period of time is generally accepted, it is necessary to consider the possibility of an altered pharmacokinetics, and therefore absorption of unsuitable drug quantities.

The exact duration of the nonoperative management is still strongly debated but in general a period of 72 h is deemed suitable [12, 36] (Fig. 17.3).

In common practice, in the elderly population, there is a tendency to prolong the nonoperative period by claiming that the risk of surgery is too high. In reality, a protracted conservative approach in the elderly population should be questioned because of the more marked negative effects of delayed surgery [37]. The timing in these patients is therefore essential to ensure the best therapeutic choice. A recent article showed that in elderly patients the nonoperative solution is the ideal one but too long waiting times can lead to poor outcomes [33].

After an initial clinical and instrumental evaluation, and the exclusion of signs of strangulation or complete occlusion, the patient can start a nonoperative therapy with fluid infusion and clinical observation, it is possible to administer water-soluble contrast to the patient in the first 24 h and perform a check after 24–48 h. If the

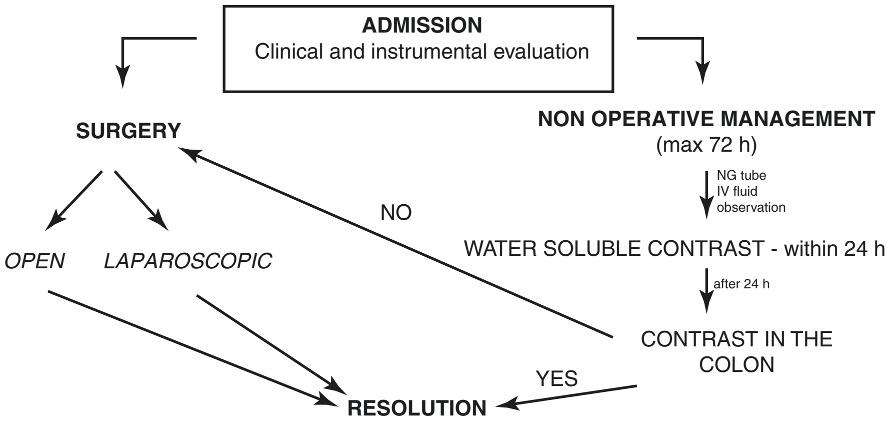

Fig. 17.3 Small bowel obstruction management flow chart

contrast is in the colon you can continue with a nonoperational management. If there is no resolution within 72 h, it is necessary to switch to operational conduct with surgery [36].

Another fundamental principle of the clinical management of patients presenting small bowel obstruction is the oral water-soluble contrast medium X-Ray (Gastrografin swallow) that could be given with both diagnostic and therapeutic purposes. Gastrografin may be administered either orally or via the nasogastric tube both immediately at admission and after an initial attempt of conservative treatment within the first 48 h. A recent meta-analysis conducted on 14 randomized trials on patients with a diagnosis of SBO, concluded that Gastrografin swallow is effective in predicting the need for surgery in patients with adhesive occlusions. In addition, it reduces the overall need for surgery and shortens the hospital stay by 30 days.

The oral water-soluble contrast medium X-Ray that could be given with both diagnostic and therapeutic purposes may be administered either orally or via the nasogastric tube. A recent meta-analysis conducted on 14 randomized trials on patients with a diagnosis of SBO, concluded that water-soluble contrast is effective in predicting the need for surgery in patients with adhesive occlusions. In addition, it reduces the overall need for surgery and shortens the hospital stay [30, 37].

In patients who did not reach resolution after 72 h of treatment or those with signs of ischemic suffering, it is necessary to proceed with emergency surgery, after adequate stabilization of vital parameters.

In case of surgical intervention, the administration of antibiotic prophylaxis should be foreseen in anticipation of a possible intestinal resection. Furthermore, particularly in elderly patients suffering from cardiovascular diseases, a hypotensive crisis is possible at the time of induction to anesthesia with potential perioperative ischemic events.

In the open approach, the laparotomy should be performed on the midline and started in an area of virgin skin under which it is assumed that there are no adhesions due to previous surgical operations.

Entry into the abdomen through the muscular fascia should be done with extreme caution without using energy devices such as the electric scalpel. The transmission of heat through the tissues, in fact, could damage the underlying intestine.

Especially in the elderly, the adhesions are stronger than the normal junctions between the layers of the small intestine wall, so dissection with scissors should be preferred to avoid damage to the abdominal organs.

Once the laparotomy is completed, an exploration of the abdominal cavity is necessary to identify the etiology of the occlusion. The exploration must be carried out by the Treitz up to the last intestinal loop and while the intestine is being examined, certain parameters must be assessed such as color, peristalsis, and pulsation of the superior mesenteric artery.

In the case of intestinal resection, the clearly ischemic segments should be resected. Generally, the experience of the surgeon guides the extension of the resection but in elderly patients it must be kept in mind that there may be concomitant cardiovascular pathologies that increase the risk of ischemia and anastomotic dehiscence.

In restricted cases where there is a high perioperative thromboembolic risk or the functional recovery of intestinal loops is uncertain, or in patients with generalized peritonitis or acute mesenteric ischemia it is possible to perform laparostomy (damage control) with the use of vacuum therapy and definitive closure delayed [38, 39].

Often to allow closure of the abdominal wall it is necessary to decompress the small intestine. This can be done through a naso-intestinal tube if already placed or with a retrograde milking of the intestine towards the duodenum and the stomach and the evacuation of the fluids from the nasogastric tube.

A recently introduced possibility is the application of adhesion barriers. In a recent review, Ten Broeck et al. [40] reported that Oxidised regenerated cellulose and hyaluronate carboxymethylcellulose can safely reduce clinically relevant consequences of adhesions.

As regards the laparoscopic approach in the SBO patient, although the advantages of laparoscopy such as the reduction of hospital stay and postoperative pain would be excellent motivations for use in elderly patients, this should be done only by surgeons skilled in laparoscopic technique and in selected patients.

The presence, in fact, of very distended intestinal loops and the possible presence of adhesions make laparoscopy very complex in these patients with an increased risk of iatrogenic perforation. However, in a review by Sajid et al. [41] laparoscopy appears to have clinical advantages on the open technique in adhesiolysis with a reduction in morbidity and mortality and a clear reduction in postoperative complications such as cardiovascular accidents, respiratory failure, and thromboembolic events.

A tailored approach should be done for elderly patients with SBO due to malignancy.

The prognosis for these patients is poor with a general survival of 5 months which is reduced to 3 months for patients with peritoneal carcinosis or a history of gynecological cancer [24, 42, 43].

In these cases, due to the high frequency of failure of nonoperative treatments, palliative treatments such as percutaneous decompression with jejunostomy should be considered [44].

In patients with peritoneal carcinosis, surgery does not resolve the underlying pathology, increases morbidity and hospitalization, and very often patients present an inoperable re-obstruction in a short time [45].

In the evaluation of elderly patients who must undergo an emergency intervention, the quality of life must be considered.

The decision to operate patients with severe comorbidities, psychiatric illnesses, or dementia is not simple [46].

In the literature there are no references to the quality of life after emergency intervention for SBO in the elderly and the few guidelines do not help because they are based on studies done on the younger general population. The therapeutic decision should always be shared with the patient clearly, especially in the case of possible surgical intervention, exposing the possible complications and postoperative quality of life [47].

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18 Acute Mesenteric Ischemia in the Elderly Patient

Luís Filipe Pinheiro, Henrique Alexandrino, and Beatriz Costa

18.1 Introduction

In 1961, Cokkinis stated that "occlusion of the mesenteric vessels is regarded as one of those conditions in which the diagnosis is impossible, the prognosis hopeless, and the treatment almost useless" [1].

These words reflect the sense of helplessness most surgeons feel in the treatment of acute mesenteric ischemia (AMI), a disease with an increasing incidence [2], accounting for 0.1–0.2% of urgent hospital admissions [3] and 18% of emergency laparotomies [4]. In fact, despite all the advances in diagnosis and treatment in recent years, AMI remains a morbid condition with high short-term mortality rate, ranging from 60 to 80%, and represents one of the most frequent etiologies of short bowel syndrome and chronic intestinal failure [2, 5, 6]. Although no large population-based data have been published, a study from a secondary hospital serving a stable population demonstrated that the incidence of AMI increases drastically from the age of 75 and upward, surpassing the incidence of another seemingly more common acute abdominal emergency, acute appendicitis [7].

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In 1967 in an autopsy series, Ottinger and Austen reported a rate of 8.8 cases of AMI per 10,000 hospital admission [8]. Almost 30 years later, Stoney and Cunningham observed an incidence rate of 1 in 1000 hospital admissions [9]. As the mean age of the population increases and the proportion of older patients in our hospitals grows, AMI will predictably be more common. Unfortunately, as reported in many series, the mortality rate in older patients is significantly greater and carries a relative risk of the mortality rate of 3.0 for those more than the age of 60 years.

Two main determinants of the prognosis of AMI are precocity of diagnosis, before the development of irreversible intestinal damage, and celerity and adequacy of the treatment [2, 10]. These are hampered by the absence of accurate clinical and laboratory diagnostic criteria in the initial phase of evolution and the difficulty of rapid integration and coordination of the distinct therapeutic modalities. Pathogenesis of AMI, affected splanchnic vessel(s), location of the obstruction, degree and the extent of ischemia, and segment of intestine involved are additional prognostic parameters [11].

Clinical presentation of AMI is usually nonspecific at the initial stages and, therefore, early recognition must rely on a high degree of clinical suspicion and an immediate confirmation by an abdominal computed tomography (CT) angiography, to identify signs of splanchno-mesenteric ischemia and intestinal injury [3, 12–14]. Nevertheless, selection of patients requiring CT angiography remains challenging. In fact, although D-lactate, ischemia modified albumin, intestinal fatty acid binding protein (I-FABP), α-glutathione S-transferase, and other biomarkers are considered promising, there is still lack of a specific biomarker to indicate early mesenteric hypoperfusion in the routine clinical practice [15–18].

Duration of evolution, referral patterns, and triage are important prognostic factors. Prolonged symptoms duration (more than 24 h) was an independent predictor of mortality following surgical interventions for AMI [19]. Mortality was reduced if intervention was performed within 12 h of evolution [12]. Presenting first in a nonsurgical emergency room was independently associated with a first door to operation time superior to 12 h, while initial evaluation in a surgical emergency service was associated with a lower 90-days mortality rate and length of stay [20]. This emphasizes the critical role of the emergency surgeon in the initial management of the patient with acute abdominal pain.

This chapter reviews the presentation, diagnosis, and treatment of the four most common causes of AMI: arterial embolism (AE), arterial thrombosis (AT), mesenteric venous thrombosis (MVT), and nonocclusive mesenteric ischemia (NOMI). Although mesenteric vascular disease is more common, albeit not exclusive, of old age, in this chapter we will place focus mainly on particular aspects related to the elderly patient.

Diagnosis of AMI can be challenging but must be recognized early and treated aggressively in order to improve patient survival. However, access to the best care, according to the state of the art, is not universal. For this reason, we also propose an algorithm to treat these patients when full resources are not available. This may prove particularly useful for the emergency surgeon working without full access to endovascular therapy or vascular surgery consultation in a reasonable time frame.

18.2 Definitions, Epidemiology, and Risk Factors

Acute mesenteric vascular diseases are usually considered a rare cause of acute abdomen, with an estimated incidence of 4.5–5.4 cases per 100.000 person-years. However, its incidence may be underestimated, with population-based studies reporting that in patients over 75-years old, its incidence is larger than that of acute appendicitis and 1.5 times more frequent than ruptured abdominal aortic aneurysm [1].

AMI can be classified into four etiological classes [2], namely:

1. Acute embolic mesenteric ischemia (AEMI)
2. Acute thrombotic mesenteric ischemia (ATMI)
3. Venous thrombotic mesenteric ischemia (VTMI)
4. Nonocclusive mesenteric ischemia (NOMI)

These vary in incidence, risk factors, and clinical presentation.

AEMI is characterized by a sudden occlusion of a main visceral artery by a clot, usually embolized from a cardiac source. The superior mesenteric artery (SMA) is the most commonly implicated vessel, probably because of its relatively acute take-off angle from the aorta (unlike the celiac artery) and larger ostium, favoring embolic occlusion [3]. This causes immediate ischemia of a large portion of the embryologically derived midgut, i.e., the jejunum, ileum, and right colon up to the mid transverse colon. However, since an embolus may lodge distally, some sparing of the first branches of the SMA may occur, leaving the proximal jejunum and right colon unaffected [4]. Risk factors for AEMI include atrial fibrillation, valvular heart disease, prosthetic valve, and ventricular aneurysm, diseases highly prevalent in elderly patients. In fact, in developed nations the prevalence of atrial fibrillation is estimated to increase from 6% at the ages of 65–74 to 15% in the population over 75-years old [5].

ATMI can occur in cases of previous chronic atherosclerotic occlusion of visceral arteries, again usually the SMA. In such cases, and similarly to other chronic stenosis in other vascular beds such as the myocardium or the lower limbs, anginal crisis may occur with increased oxygen consumption. Plaque rupture would be a precipitating event, causing sudden-onset occlusion of the vessel and end-organ ischemia, similarly to what occurs in acute myocardial infarction or acute thrombotic occlusion in patients with preexisting peripheral vascular disease. However, since atherosclerosis is frequent at the SMA take-off from the aorta, ATMI will likely affect the entire midgut. Risk factors for ATMI include those usually associated with atherosclerosis, namely adiposity, hypertension, dyslipidemia, and diabetes mellitus, again highly prevalent with increasing age [6].

VTMI consists of venous thrombosis in the portal venous system extending into the superior mesenteric vein. This will cause venous and capillary congestion of the midgut and subsequent mucosal and transmural necrosis. Risk factors can be divided into local or systemic, which may coexist. Local factors include cirrhosis (with portal hypertension and slowed or even reversed splanchnic venous flow), pancreatitis, abdominal surgery (including bariatric surgery), or malignancies [7, 8]. Systemic factors mostly relate to hypercoagulability disorders, either congenital (protein C or S deficiency, factor V Leiden mutation) or acquired (neoplasia, cirrhosis, antiphospholipid syndrome) [2]. Since the progression of ischemia is much slower, so is clinical presentation. Of the four classes of AMI, VTMI is the one with clinical presentation at an earlier age and thus might be rarer and clinically less relevant in elderly patients, when compared with the other classes.

NOMI is a particular subset of AMI in which no mechanical obstacle to visceral arterial flow occurs. Instead, an exacerbated response of visceral small arteries and arterioles to vasoconstrictive stimuli occurs, causing small bowel mucosa ischemia. This can be considered the pathological extreme of the physiologic splanchnic vasoconstriction occurring in systemic hypoperfusion (e.g., in hypovolemic, cardiogenic, or distributive shock), in which visceral blood flow is reduced to preserve oxygenation of critical vascular beds. In NOMI, this response is considered pathological and might initiate a self-feeding loop of gut hypoperfusion. Mucosal ischemia and necrosis cause the release of damage-associated molecular patterns (DAMPs) and translocated bacteria into the mesenteric lymph, inducing a knee-jerk immunoinflammatory response and its systemic consequences, namely aggravated circulatory derangement, which in turn further aggravates bowel hypoperfusion. Patients with NOMI are typically admitted to general, cardiovascular, or surgical intensive care units (ICUs), under vasopressor or digitalis treatment [9]. Patients undergoing on-pump cardiac surgery have an incidence of 5%, increasing the risk with advanced age, depressed renal function, longer operative times, and longer cardiopulmonary bypass time [10]. Enteral nutrition is a common precipitating factor, possibly causing a mismatch between oxygen supply and demand of the bowel mucosa [11]. Given the increasing age of patients admitted to ICUs or undergoing cardiovascular surgery, NOMI is a frequent and likely underdiagnosed clinical condition in elderly patients.

18.3 Diagnosis

Early diagnosis of AMI, in any of its different forms, is universally recognized as the critical prognostic factor, being able to dramatically improve outcomes [19, 21]. The main difficulty lies on the lack of specificity of clinical presentation, as well as on the early recognition of patients at risk (Table 18.1). This is particularly relevant in the geriatric patient, as it is known that the incidence of AMI is likely ten-fold higher in 80-year olds than in 60-year olds [24]. Thus, in the lack of specific clinical or laboratory markers, strong clinical suspicion, i.e., an elderly patient with acute abdominal pain, should prompt the performance of computed tomography angiography. However, in clinical practice, delayed presentation of AMI, usually with established bowel necrosis, is commonplace. This requires a thorough discussion of the most relevant aspects in the diagnosis of AMI: clinical findings, laboratory markers and, most importantly, early imaging. In fact, the key issue in early diagnosis is a strong clinical suspicion [8].

Table 18.1 Clinical presentation and risk factors for the four distinct types of acute mesenteric ischemia. Adapted from [19, 22, 23]

Ethiology	Risk factors	Symptoms	Presentation
Embolic (AE)	Myocardial infarction Atrial fibrillation Prior embolism Congestive heart failure Ventricular aneurysm Recent cardiac surgery	Sudden abdominal pain Hematochezia Diarrhea Vomiting	Peritonitis Hypotension Nausea/vomiting Distention Tachycardia
Thrombotic (AT)	Abdominal angina Coronary artery disease Smokers Prolonged hypotension Estrogen hypercoagulability	Progressive abdominal pain Nausea/vomiting	Pain out of proportion Insidious onset Tachycardia Peritonitis Hypotension
Venous (VT)	Recent abdominal surgery Hypercoagulable state estrogens Polycythemia Sickle cell disease malignancy Pancreatitis	Asymptomatic Vague tenderness GI bleeding Nausea/vomiting Fever	Insidious onset GI bleeding Upper—10% Lower—16% Peritonitis Abdominal distension Tenderness
Nonocclusive (NOMI)	Vasopressors Hypotension Low cardiac output Digoxin Hypovolemia Recent cardiac surgery Hemodialysis Diarrhea	Critically ill patient abdominal pain Hypotension Altered mental status Nausea/vomiting	Tenderness Abdominal distension Feeding intolerance

18.4 Clinical Findings

Although in the embolic AMI the onset of abdominal pain is usually sudden, mimicking other causes of acute abdomen (hollow viscus perforation, acute cholecystitis or acute pancreatitis) [25, 26], and might be accompanied by signs of shock, in thrombotic AMI, collateral circulation formed over the time could decrease the severity of presenting symptoms, leading nonetheless to a dismal prognosis [9].

Several other symptoms may also be present, such as nausea, vomiting, hematochezia, melena, hypotension, fever, and abdominal distension. Unfortunately, these signs and symptoms are clearly insufficient to perform a correct diagnosis, let alone distinguish between the different forms of AMI. For instance, only 15% of patients will present with melena or hematochezia [27]. The association of clinical symptoms with the risk factors, obtained from the clinical history, will however aid in raising a strong clinical suspicion, prompting the performance of more sensitive and specific tests.

Clinical signs of peritonitis, such as tenderness and guarding, will only occur at a later stage and are associated with bowel necrosis. Therefore, their absence is unreliable to exclude the diagnosis of AMI.

Nonocclusive mesenteric ischemia (NOMI), because of the scarcity and little specificity of initial symptoms, is only diagnosed several hours after emergency department admission, or much later in sedated patients admitted to medical or surgical intensive care units. According to Mitsuyoshi et al., NOMI should be suspected in the presence of three clinical signs or symptoms in a critical patient: ileus or abdominal pain; need for vasopressors; and elevated aminotransferases [28].

18.5 Biochemical Markers

Unlike acute myocardial infarction, which is readily diagnosed with noninvasive serum markers of myocardial necrosis such as troponin, no such markers are yet disseminated in clinical practice for the diagnosis of ischemic bowel. Some markers (such as L-lactate, C-reactive protein, lactate dehydrogenase, and amylase) are nonspecifically elevated in many acute abdominal emergencies and might have some relevance in the initial clinical suspicion. However, they lack specificity or are only elevated at a late stage, when full-thickness bowel necrosis supervenes [29, 30].

The ideal laboratory marker would be highly specific, present high sensitivity, and be elevated at early stages of the disease, when diagnosis would allow for timely revascularization and potentially decrease, or altogether prevent, the need for bowel resection. Furthermore, it could be readily performed by standard of care laboratory testing in most emergency departments.

Several putative molecules have shown promise, including intestinal fatty acid binding protein (I-FABP) and α-glutathione S-transferase (α-GST). These are two proteins produced by the mature enterocyte that are readily released into the systemic circulation with cell injury. Given that the mucosa is the earliest layer of bowel wall to suffer from ischemia [31], these two molecules are excellent putative markers for early diagnosis of AMI, with reported sensitivity and specificity of 80% and 85%, respectively for serum I-FABP; and pooled sensitivity and specificity of 68% and 85% for α-GST [15] (Table 18.2).

Table 18.2 Diagnostic sensitivity and specificity of distinct methods in acute mesenteric ischemia. Adapted and modified from [15, 32, 33]

Laboratory test	Sensitivity (%)	Specificity (%)
WBC	65.4–80	42.1–50
Lactate	86	44
D-Dimer	76.9–96	40–57.9
pH	38–57.7	52.6–84
Amylase	23.1	84.2
I-FABP	80	85
α-GST	68	85

I-FABP intestine-fatty acid binding protein, *WBC* white blood cell count, *α-GST* α-glutathione S-transferase

Other serological markers include D-lactate, ischemia modified albumin, and procalcitonin [15, 34, 35]. However, these are more sensitive for advanced forms of bowel ischemia, with established necrosis, and thus lack in clinical value for early diagnosis [34, 35].

D-dimer biomarker is for ruling out acute intestinal ischemia rather than for making a final diagnosis [36].

In the particular case of NOMI arising in the setting of cardiothoracic surgery, two very promising serum markers are endothelin-1 and presepsin (a cleaved product of the CD-14 monocyte receptor), with both diagnostic and prognostic value [37, 38]. Another addition to the already long list of putative molecules is the entero-endocrine cell product, glucagon-like peptide 1 (GLP-1), which is elevated in bowel ischemia. However, it lacks clinical validation [39].

Still, ongoing research continues for more accurate serum markers of AMI that could enable the early diagnosis and timely initiation of therapy. However, although many promising molecules have emerged, they have yet to enter into clinical practice. The discovery and dissemination of such marker would allow it to be easily included in the diagnostic algorithm of AMI, as much as serum amylase, along with other clinical and radiological markers, is for the diagnosis of acute pancreatitis. In the meantime, in the absence of such molecule, clinicians attending the elderly patient with acute abdominal pain must solely resort to strong clinical suspicion and immediate dedicated imaging.

18.6 Clinical Suspicion and Early Computed Tomography Angiography

Given the prevalence of abdominal complaints in the elderly population, lack of specificity of clinical findings and absence of truly specific laboratory markers, the early and timely diagnosis of AMI relies on the presence of strong clinical suspicion, prompting the immediate performance of triphasic (nonenhanced, arterial phase, and portal phase) multidetector computed tomography angiography (CTA).

This is illustrated in an interesting study by the Helsinki group [20]. In a cohort of 81 patients with AMI, the clinician first observing the patient had a significant impact on early diagnosis and subsequently, prognosis. In fact, when a non-surgeon, usually an internist, was the first clinician assessing the patient there was a median delay of admission to CT of 8.4 h. However, in emergency rooms with the surgeon first seeing the patient, there was a median time of the door to CT of only 2.7 h. This had an impact on prognosis, with a reduction in time to operating room (15–10 h) and decrease in mortality (75–50%).

A major concern of clinicians treating elderly patients is the small but significant risk of contrast-induced nephropathy (CIN), which is a sudden deterioration of renal function caused by the administration of intravascular iodinated contrast, such as that used in diagnostic or therapeutic radiological procedures. The risk factors for CIN are highly prevalent in the patients at risk of AMI, such as advanced age, diabetes, and congestive heart failure. Other cofactors causing renal vasoconstriction, such as sepsis and dehydration, also coexist in AMI. Thus, some clinicians might choose to delay the performance of CTA until other diagnosis are excluded. Although this attitude may seem reasonable, it is unsupported by the literature. In fact, a meta-analysis of studies of patients undergoing CT for acute abdomen found an incidence of acute kidney injury (AKI) after contrast-enhanced CT ranging from 2.2 to 10.6%. Importantly, patients undergoing unenhanced CT-scan have similar rates of AKI, possibly given the multifactorial causes for deteriorating renal function in the acute abdomen [40]. Therefore, in face of a strong clinical suspicion of AMI, CTA should be performed earlier rather than later, meaning that the diagnosis of AMI should not be one of exclusion, because this might severely delay the time to treatment. Nonetheless, all measures pertaining to the prevention of CNI, namely adequate intravenous hydration should be scrupulously followed in this population.

Moreover, although inevitably many patients with initial clinical suspicion of AMI might not have this condition, CTA will also reveal many other acute conditions potentially requiring surgical treatment. In fact, while as many as 60% of patients might not have AMI, other emergent diagnoses, such as bowel obstruction or hollow viscus perforation may be detected in 10% and 4% of cases, respectively, without unduly delaying surgical therapy [41].

To diagnose acute mesenteric ischemic disease, the radiologist must be acquainted with both the mesenteric arterial and venous anatomies of the bowel and extravascular signs, as well (bowel wall and mesentery). The three major arteries that supply the small and large bowel are the coeliac trunk, superior mesenteric artery (SMA), and inferior mesenteric artery (IMA) (Fig. 18.1) [42]. The venous system returns

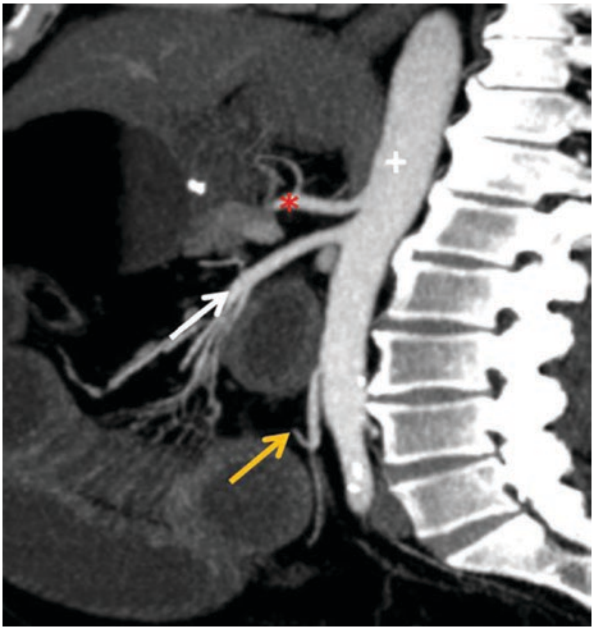

Fig. 18.1 Sagittal view on arterial phase computed tomography angiography (CTA) of the three visceral arteries: celiac trunk (asterix), superior mesenteric artery (white arrow), and inferior mesenteric artery (yellow arrow). (Reprinted with permission from Florim et al. [42])

essentially parallel to the arterial supply. The superior and inferior mesenteric veins run parallel to the arteries and drain the respective part of the bowel. The inferior mesenteric vein (IMV) usually joins the splenic vein, and the splenic vein joins the superior mesenteric vein (SMV) to form the portal vein.

Arterial occlusion most commonly results from thromboembolism, where the embolus originates from the left atrium as a consequence of atrial fibrillation. Emboli from heart origin preferentially affects the SMA because of its small take-off angle, while thrombi and large emboli may occlude the proximal SMA and ostia of major mesenteric vessels, where some images of ostial calcification may be already present, resulting in extensive small bowel and colon ischemia (Fig. 18.2). Smaller emboli may lodge in the distal portions of the vessel and cause smaller regions of segmental ischemia (Fig. 18.3).

Although it is not a specific finding, bowel wall thickness is the most common CT finding in acute bowel ischemia. It is present in 26–96% of reported cases [43].

Bowel wall may be thickened or thinned, depending on the etiological mechanism. In cases of bowel ischemia caused by mesenteric venous thrombosis, bowel wall thickening is more pronounced than in cases caused exclusively by occlusions of mesenteric arteries (Fig. 18.4) and the small bowel may be full of fluid.

Luminal dilatation and air-fluid levels are quite common in acute bowel infarction (56–91% of cases) [44].

Pneumatosis and portomesenteric venous gas have also been reported as one of the more accurate imaging signs of acute bowel ischemia, being present in 6–28% and 3–14% of cases, respectively [45]. Although pneumatosis is not a specific finding of intestinal ischemia when found, bowel ischemia should be considered. Located in the thickness of the bowel wall, it should be differentiated from endoluminal gas. Portomesenteric venous gas may consist only of some small gaseous inclusions within the mesenteric veins or may extend into the intrahepatic branches of the portal vein, where it is typically found in the periphery of the liver (Fig. 18.5).

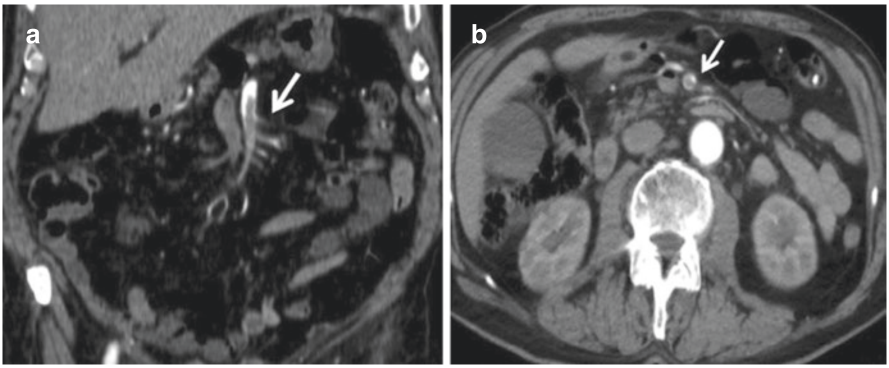

Fig. 18.2 Thrombotic acute mesenteric ischemia. (Reprinted with permission from Florim et al. [42]). (**a**)Coronal view of thrombus in the lumen of the superior mesenteric artery. (**b**)Axial view

Fig. 18.3 Embolic acute mesenteric ischemia. Sagittal view on computed tomography angiography reconstructed images of embolus in the distal superior mesenteric artery, sparing the first branches. (Image courtesy of Prof. Paulo Donato—Coimbra, Portugal)

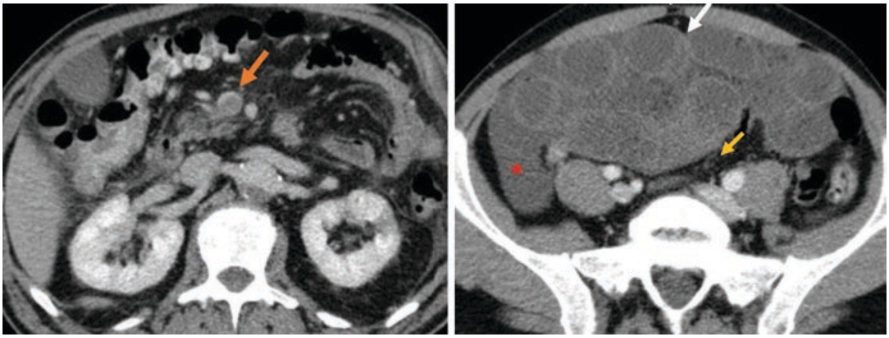

Fig. 18.4 Venous thrombotic mesenteric ischemia. Hypodense thrombus inside the superior mesenteric vein (left) and marked bowel wall thickening (right). (Reprinted with permission from Florim et al. [42])

18.7 Other Imaging Methods

Duplex ultrasound (US) scanning and Doppler flowmetry can be used to evaluate patients with suspected AMI, but these techniques are limited in their clinical use by several factors. First, only the proximal portions of the major splanchnic vessels can be studied reliably, not the peripheral aspect of the vasculature. Secondly, vascular occlusions are not diagnostic of intestinal ischemia, because complete occlusions can be seen in asymptomatic patients. Moreover, blood flow through the SMA is highly variable, which may make interpretation difficult. Finally, NOMI cannot be diagnosed reliably by US studies [46].

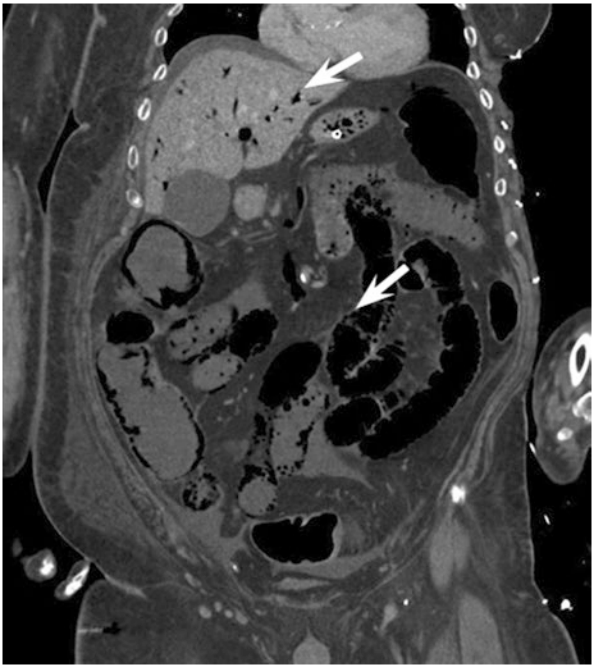

Fig. 18.5 Coronal view in computed tomography angiography of gas in the portal venous system, both at the level of the bowel wall and intrahepatic. (Reprinted with permission from [42])

Plain abdominal radiography has absolutely no role in the early diagnosis of AMI, as it lacks sensitivity and specificity, only demonstrating the signs of advanced bowel necrosis, i.e., pneumoperitoneum and eventually portal venous gas [3, 12].

18.8 Treatment

As with other acute conditions, immediate resuscitation, ensuring oxygenation and peripheral perfusion, is mandatory. Supplemental oxygen by face mask, large bore intravenous lines, and a fluid bolus with crystalloid is warranted since most patients are hypovolemic due to vomiting and ileus. Nasogastric tube is desirable and placement of a Foley catheter, for assessment of hourly urinary output, is paramount. Further resuscitation should be guided by the response to fluid challenge, more accurately assessed by physiologic parameters such as base deficit and arterial lactate. Invasive monitoring, such as a central line, may be required in cases of suspected or proved cardiac dysfunction but can be delayed to after admission in intermediate or intensive care unit. Large spectrum antibiotics, covering enterobacteria and anaerobes, should be given, as well as correction of associated metabolic and electrolyte disturbances [3, 12].

Alongside with resuscitation efforts, immediate attention should be given to revascularization and source control if there are signs of bowel necrosis.

Although the trends in treatment are changing, with an increasing emphasis on endovascular techniques in the management of the different forms of AMI, the reality is that in low- and middle-income countries this approach has not gained popularity. Moreover, even in high-income countries, not all institutions are equipped with all the resources, namely endovascular techniques, and the patients' condition may not allow for safe transfer in a reasonable timeframe. This notorious lack of resources, either in diagnosis or in therapy, still makes the exploratory laparotomy the most used method to confirm the diagnosis and complete the therapy [6].

Usually, the two main factors that prompt the performance of laparotomy are: the presence of peritoneal signs, which are associated with full-thickness bowel necrosis; and the lack of resources, such as CTA and endovascular therapy.

Apart from the peritoneal signs, other factors have also been identified as surrogate markers of bowel necrosis: coexisting organ failure; elevated arterial lactate >2 mmol/L; elevated white blood cell count >10.000/mL; and decreased bowel wall enhancement or dilated loops [47, 48]. When present, these findings will be pivotal in the decision for immediate surgery.

In practical terms, the approach to AMI is totally different if one is working in an environment of full resources (FR) or limited resources (LR).

18.9 Full Resources (FR) Setting

In a center with full resources, all patients with clinical suspicion will undergo CTA for diagnostic confirmation and for assessment of signs of bowel necrosis. If there are no clinical signs of peritonitis, these patients will then undergo endovascular therapy: aspiration of embolus and thrombolysis in embolic AMI (Fig. 18.6); angioplasty (with or without stent placement) in cases of thrombotic AMI (Fig. 18.7); or direct intra-arterial infusion of vasodilator drugs (papaverine, prostaglandin

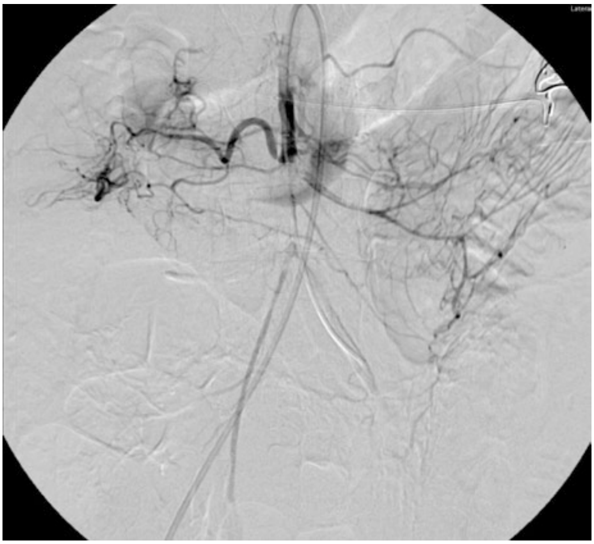

Fig. 18.6 Thrombus aspiration through endovascular approach in acute embolic mesenteric ischemia. (Image courtesy of Prof. Paulo Donato—Coimbra, Portugal)

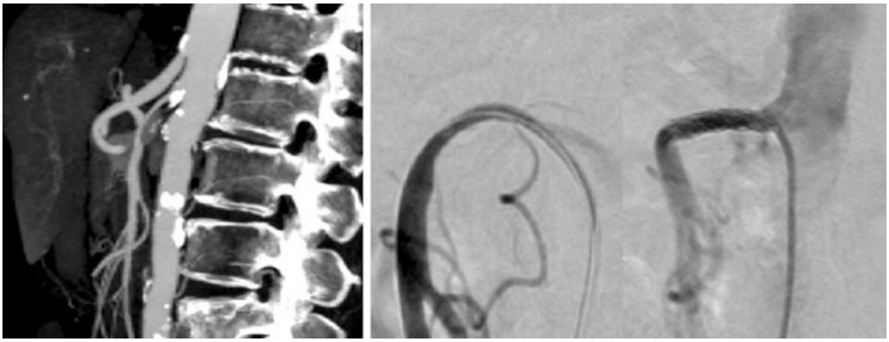

Fig. 18.7 Thrombotic acute mesenteric ischemia managed with angioplasty and stent placement through endovascular approach. (Image courtesy of Prof. Paulo Donato—Coimbra, Portugal)

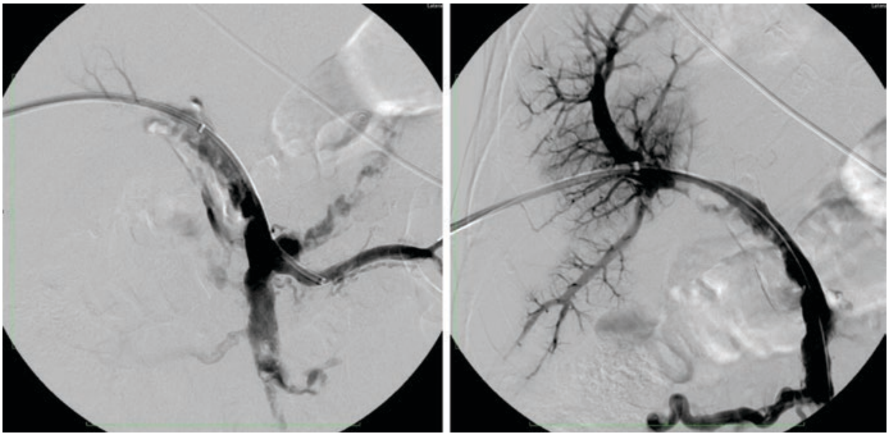

Fig. 18.8 Direct catheter-based percutaneous thrombolysis of extensive mesenterico-portal venous thrombosis. (Image courtesy of Prof. Paulo Donato—Coimbra, Portugal)

E1—PGE1), in cases of NOMI, respectively. In MVTI, continuous infusion of unfractionated heparin is still the first choice [12], with percutaneous transhepatic endovascular therapy as a choice in selected cases (Fig. 18.8).

In 1973, Boley et al. proposed an aggressive plan of management employing early angiography and the intra-arterial infusion of the vasodilator papaverine to interrupt splanchnic vasoconstriction [49]. This approach resulted in the salvage of compromised bowel and improved survival. The authors present a protocol for the use of papaverine through percutaneous selective catheterization of the superior mesenteric artery, adapted from Kozuch et al. [50] (Table 18.3).

When AMI is suspected, treatment includes resuscitation of the patient and correction, as far as possible, of predisposing or precipitating causes. These patients should be admitted to high dependency units (intensive or intermediate care), for close surveillance of signs of organ dysfunction. Should clinical deterioration

Table 18.3 Protocol for the use of papaverine through percutaneous selective catheterization of the superior mesenteric artery, adapted from Kozuch et al. [50]

Papaverine infusion protocol
Use concentration of 1 mg/mL
Infuse bolus of 60 mg papaverine into the SMA through an angiogram catheter
Left the catheter in situ and follow with infusion at 30–60 mg/h
Adjust dose for clinical response for at least 24 h, continued until 12–24 h
Flush catheter with normal saline for 30 min after the initial treatment cycle
Repeat the angiogram
Repeat the entire cycle every 24 h for maximum of 5 days if vasospasm persists

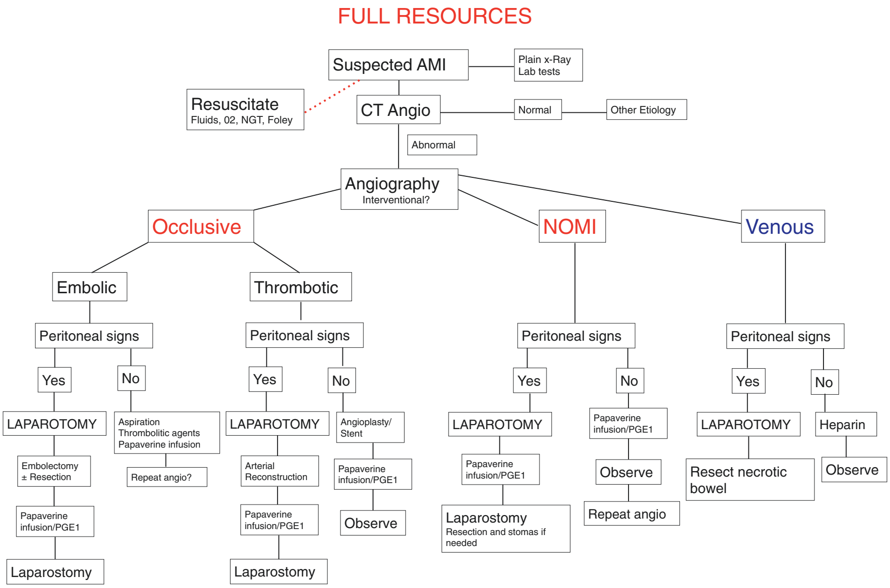

Fig. 18.9 Algorithm for management of acute mesenteric ischemia in a full resources setting

develop, or peritoneal or imagiological signs occur suggesting bowel necrosis, prompt laparotomy should be performed [2].

In this circumstance, the aim of laparotomy is to resect irreversibly affected bowel, along with, if needed, revascularization of the remaining splanchnic territory (embolectomy, thrombectomy, aorto- or ilio-mesenteric bypass, or spleno-mesenteric bypass) [51]. At this stage, it is the authors recommendation that no anastomosis or stoma be performed. The bowel ends should be stapled closed and the abdomen left open, in a damage-control context [52], easily allowing second-look procedures.

The authors propose an algorithm for the management of AMI in a full resources setting (Fig. 18.9).

18.10 Limited Resources (LR) Setting

Unfortunately, not all centers have the full resources to offer the best available treatment to all patients, particularly endovascular therapy. Although interventional cardiologists may be involved in emergent mesenteric revascularization procedures, this approach should be considered the exception rather than the rule [53]. As such, these patients require a distinct approach, based on locally available resources (Fig. 18.10). Given the emergent and life-threatening context of AMI, most patients undergo emergent laparotomy. These patients will present an acute abdomen with peritoneal signs, with or without the preoperative clinical suspicion of AMI, possibly with CT confirmation.

After adequate initial resuscitation, the conduction of the laparotomy should suit the intraoperative findings, especially the presence of bowel necrosis. Should this be present, affected bowel must be resected. However, this resection should be conservative, as the full extension of the affected bowel can only be ascertained after revascularization, which requires direct approach of the SMA.

There are two transperitoneal methods for the exposure of the SMA. In the lateral approach, the transverse colon is reflected superiorly, and the small bowel is retracted to the right upper quadrant. The ligament of Treitz is divided to mobilize the fourth portion of the duodenum. The SMA is palpated at the root of the mesentery over the junction of the third and fourth portions of the duodenum. Its identification can be very difficult due to the absence of pulse. In the anterior approach,

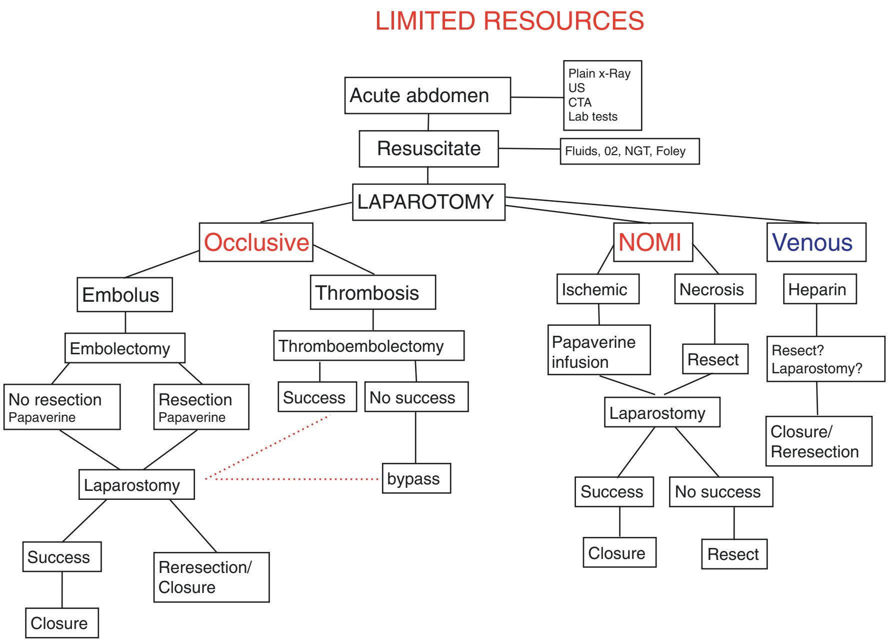

Fig. 18.10 Algorithm for management of acute mesenteric ischemia in a limited resources setting

after superior retraction of the transverse colon, the small bowel is retracted to the right. The middle colic artery is traced proximally, and a horizontal incision at the root of the mesentery is made. The SMA is identified medial to the SMV after careful dissection of surrounding lymphatic and autonomic nerve fibers with proximal and distal vascular control. If a thrombotic etiology is suspected, longitudinal arteriotomy, rather than transverse arteriotomy, is made, and an embolectomy balloon catheter is passed proximally and distally to ensure complete removal of the embolus if possible. When proximal inflow and distal backflow are adequate, an autogenous vein patch is used for closure of the arteriotomy.

If an embolic cause is suspected, then a transverse arteriotomy can be done, followed by a complete embolectomy and transverse closure of the artery. If embolectomy is unsuccessful in reestablishing blood flow, then the arteriotomy can be used for distal anastomoses of the bypass graft or anastomotic site with proximal splenic artery [51].

If this approach is successful, all necrosed segments should be resected and the laparotomy abbreviated as a damage-control procedure, meaning that the bowel stumps should neither be anastomosed nor exteriorized as stomas. A second-look procedure at least after 24 h is mandatory, and the patient should be admitted to an intensive care unit. Vasopressors should be avoided, or at least used in the smallest dosage possible, in order to maximize bowel perfusion.

Prognosis is obviously dependent upon the extent of resection, as well as on the systemic repercussions. Several predictive factors for early (<72 h) have been identified [54]: preoperative heart failure, lactate level over 5 mmol/L, aspartate aminotransferase over 200 IU/L, and total cholesterol level below 80 mg/dL, or procalcitonin level over 40 ng/L. From these results, a mortality prognostic score was derived. Probability of mortality within 72 h was estimated to be 5% for patients with none of these factors and 97% for those with all four.

Regarding NOMI, and since there is no actual arterial obstruction rather a low-flow state with splanchnic vasoconstriction, there is no place for performing SMA arteriotomy. In this instance, the authors recommend papaverine infusion through retrograde approach of the SMA by placing a catheter in the stump of the middle colic artery in patients undergoing colectomy (unpublished data) (Fig. 18.11). The catheter is placed in situ, with an infusion rate of 30 mg/h continued in the ICU and until the second look is performed. In the authors' opinion, this method is particularly useful for three main reasons: it avoids the somewhat difficult direct approach to the SMA; it allows the delivery of the drug in the vascular territories where it is most needed, obviating the systemic effects; and it does not require any particular care in the removal of the catheter, as the artery is anyway ligated at the end of the infusion at the second stage procedure (Fig. 18.11).

In all cases requiring laparotomy, the authors strongly recommend a second-look procedure for the assessment of adequate bowel perfusion. Confection of anastomosis or stomas should be delayed until the patient is fully resuscitated and without any vasopressors [55]. Regardless of the setting (full resources or limited resources), the management as an open abdomen after the first operation has numerous advantages: decreases the risk of intra-abdominal hypertension; improves the perfusion of

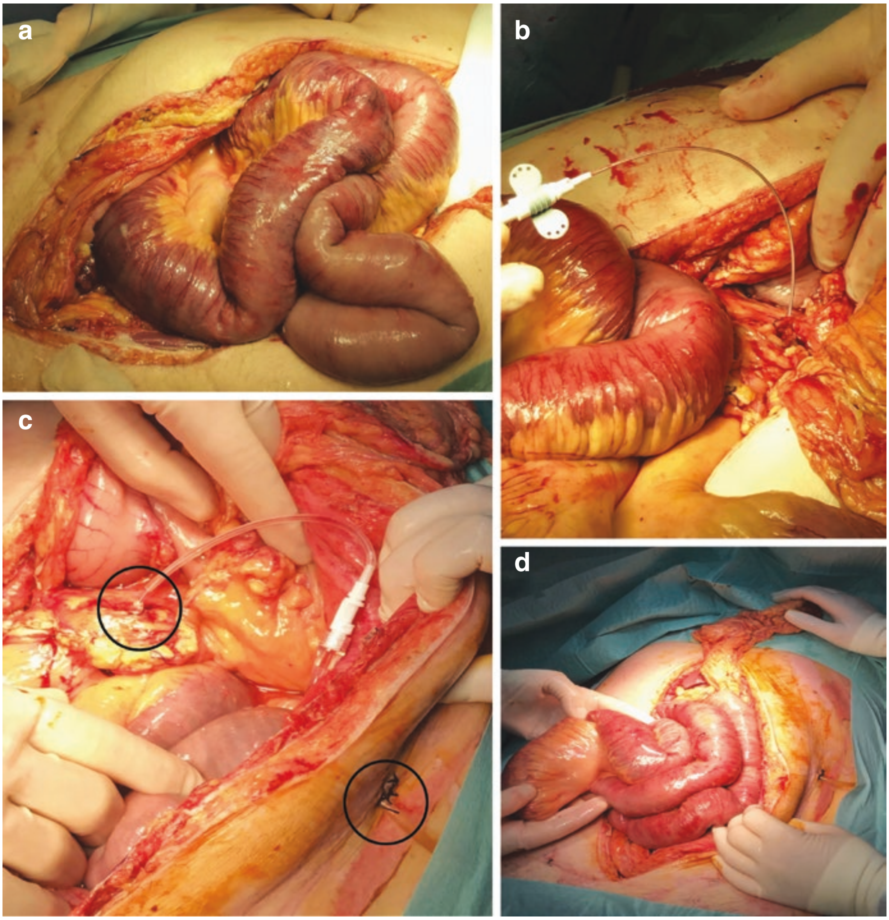

Fig. 18.11 Clinical case of management of nonocclusive mesenteric ischemia (NOMI) in a limited resources setting with damage-control techniques and intraoperative placement of a catheter in the superior mesenteric artery (SMA) through the stump of the middle colic artery for continuous postoperative perfusion of papaverine. (**a**) Intraoperative image of NOMI. Note the dusky bowel and fully viable bowel without a clear demarcation line. (**b**) Placement of catheter in the lumen of the SMA through the stump of the middle colic artery for intraoperative and postoperative perfusion of papaverine (according to the protocol in Table 18.3). Note some clearly ischemic bowel loops, without full-blown necrosis. (**c**) The catheter (black circle) was exteriorized through the abdominal wall and the abdomen temporarily closed. (**d**) Well perfused small bowel at the second-look procedure, 24 h after the index operation. The catheter was removed at this stage, the abdomen definitively closed and the patient ultimately discharged home after 4 days in ICU

bowel; and preserves the fascia for definitive closure after the second-look procedure. Although there are several techniques available, the use of negative pressure wound therapy with mesh-mediated fascial traction seems to present the best outcomes [56].

18.11 Intestinal Stroke Centers and the Multimodal Approach of Acute Mesenteric Ischemia

Despite recent progresses, revascularization rates in AMI remain low. According to the Nationwide Inpatient Sample (NIS) registry, in the United States in 2014, the overall revascularization rate did not exceed 7.9%; only 8.6% and 6.5% of patients received an attempt endovascular or open revascularization, respectively, while most were treated with bowel resection alone or received no intervention whatsoever [57].

Implementation of a systematic, multidisciplinary, and multimodal management of AMI, in a differentiated intestinal stroke center, focused on preserving life and intestinal viability, according to current scientific evidences, seems to improve the vital and functional prognosis of patients [2, 58–60], increasing survival rates and preventing intestinal failure development. In cases of chronic intestinal failure, specialized resources for long-term parenteral nutritional support and dietary, pharmacological, and surgical intestinal rehabilitation programs may be available. Furthermore, a differentiated multidisciplinary approach may also allow accurate detection and proper elective treatment of chronic mesenteric ischemia [61], which has also an increasing incidence, improving the quality of life of affected patients and preventing the occurrence of bowel infarction.

Recently published studies suggest that management of AMI in a specialized center can reduce mortality and intestinal resection rates to less than 20 and 30%, respectively [47].

Intestinal stroke centers should have medical and technical expertise for a timely approach of AMI, including endovascular and open revascularization skills, logistical resources and good accessibility, and be available 24 h a day, 7 days a week, ensuring a proper treatment of this potentially fatal condition. Algorithms for an appropriate and expeditious therapeutic decision, based on the international recommendations [3, 12, 62, 63] and integration in a multi-institutional network with clearly defined referral protocols must be also ensured. Early definition of the objectives of treatment and establishment of criteria for the definition of futile care or non-resuscitation are also necessary.

The multimodal integrated management strategy should involve a quick-response team of digestive and vascular surgeons, diagnostic and interventional radiologists, and intensive care specialists, in close cooperation. A hybrid operation room with interventional radiology facilities, as well as, a surgical intensive care unit equipped with advanced multi-organ function support and surveillance devices should be available.

A standardized “3Rs” treatment strategy is designed to reduce mortality rates and to avoid extended intestinal resections, based on Resuscitation, Rapid diagnosis, and early Revascularization. The coordinated multimodal program, targeting life and intestinal viability preservation, combines three therapeutic objectives: excision of nonviable bowel; reperfusion to limit the extent of reversible ischemia; and prevention of multi-organ failure and ischemia-reperfusion syndrome with a pathophysiological-based medical treatment. An early diagnosis should be achieved and revascularization performed within 12 h from the onset of symptoms. Resection of nonviable bowel should be accomplished promptly [2, 3, 12, 59]. For acute mesenteric arterial occlusive disease, both endovascular and open revascularization techniques are viable options [64]. However, endovascular revascularization confers improved outcomes compared to conventional surgery, as indicated by reduced mortality, risk of bowel resection, and acute renal failure [65]. According to Erben et al. [57], patients treated endovascularly demonstrated one-third the rate of in-hospital mortality, an increased hazard ratio for discharge alive, and a cost saving of $9196 (97.5% CI, $3797–$14,595) per hospitalization. New approaches for intraoperative for evaluation of intestinal viability, implementation of principles of damage control, and liberal use of second-look approach should be included in the treatment [3, 12] (Fig. 18.8).

Extensive resection, with a remaining small bowel length inferior to 200 cm, may lead to a short bowel syndrome (SBS) and intestinal failure, that is, parenteral support dependency. SBS is a complex clinical entity, with variable severity, characterized by dehydration, electrolytic and acid-base imbalance, malnutrition, diarrhea, dysbiosis, and hepatobiliary, renal, and bone complications [1, 2]. Mesenteric ischemia is the second most common underlying disease of SBS in adult patients (after Crohn's disease) and SBS is the most frequent pathophysiological mechanism of chronic intestinal failure [1, 2]. In fact, SBS-associated intestinal failure has been reported in 13–31% of acute mesenteric ischemia survivors [3]. Prognosis of SBS is determined by the anatomy, integrity, and function of in-continuity gastrointestinal tract, including length of remnant small bowel, presence of distal ileum, ileocecal valve and colon, comorbidities, time of evolution and age of patient, among others. Reversibility of intestinal failure and weaning of parenteral support is possible with spontaneous physiological intestinal adaptation, which occurs predominantly during the first 2 or 3 years after resection. Nevertheless, definitive parenteral support dependency is likely in cases of small bowel remnant length inferior to 115 cm, 60 cm, and 35 cm in end-jejunostomy (type I), jejunocolic anastomosis (type II), and jejuno-ileal (type III) SBS, respectively. In this context, long-term parenteral nutrition is a life-saving but also potentially problem-prone therapy. Although considered safe in experienced centers, home parenteral nutrition is associated with non-neglectable risk of morbidity and mortality, including catheter-related complications, intestinal failure-associated liver disease, and metabolic bone disease, significant impact on quality of life and high social and economic costs. Intestinal transplantation may be indicated in cases of life-threatening home parenteral nutrition-related or primary disease-related complications but is not option in elderly patients. SBS-associated chronic intestinal failure requires a multimodal treatment, with highly differentiated multidisciplinary teams, in specialized centers. Pharmacological, surgical, and dietetic rehabilitation strategies may allow the reduction of parenteral support dependency and improvement of the prognosis [1, 2]. In consequence, a massive small bowel resection must be carefully considered, particularly in elderly and frail patients.

In conclusion, prompt diagnosis and intervention included in a multimodal stepwise management, in intestinal stroke centers, may improve the vital and functional prognosis of patients with AMI.

18.12 Other Adjuvant Therapies

18.12.1 Gut Decontamination

Oral antibiotics should be considered an important adjunct to surgical treatment. Decreased bacteria in the bowel lumen may decrease the immunoinflammatory storm that follows gut hypoperfusion and which is, at least in part, responsible for the deranged physiologic status that these patients present. Experimental studies have demonstrated that depletion of gut bacteria decreases intestinal ischemic injury [66] and a prospective cohort study showed that oral antibiotics (gentamicin and metronidazole) could decrease irreversible bowel ischemia and improve survival [67]. However, this was not a randomized control trial and further evidence is needed. Nonetheless, given the simplicity and low risk of this therapy, the authors believe it can be an interesting adjunct to the surgical management of AMI patients.

18.12.2 Direct Peritoneal Resuscitation

Direct Peritoneal Resuscitation (DPR) is a promising therapy in the surgical management of patients with AMI, particularly NOMI. This technique consists of a continuous postoperative infusion of hypertonic dialysis fluid in the abdominal cavity, causing an increase in gut perfusion by a vasoactive effect in small bowel arterioles [68]. When used in the setting of nontraumatic abdominal catastrophes, DPR is associated with improved organ disfunction, decrease length of stay, decreased days in ICU, and reduced time to definitive abdominal closure [69]. However, only 11 and 10 patients in the treatment and control arm, respectively, presented mesenteric ischemia. Although no specific evidence supports its use in AMI, hypothetically DPR could reverse the physiologic derangements associated with bowel ischemia and particularly reverse the self-feeding loop of gut hypoperfusion, release of damage-associated molecular patterns (DAMPs) and bacteria into the mesenteric lymph with its systemic consequences, further circulatory derangement and aggravated bowel hypoperfusion. Further randomized controlled trials are warranted to investigate the full potential of this promising therapy in AMI.

18.13 Concluding Remarks

In spite of the continued improvement in both diagnostic and treatment methods, mortality of AMI is expected to remain high, particularly because the optimal care is yet unavailable in most acute care hospitals managing these patients. Given the expected aging of the world population, not only in developed but also in underdeveloped countries, the number of AMI cases is likely to increase, prompting the creation of dedicated reference centers. In the meantime, vascular skills and a damage-control frame of mind should be a part of the armamentarium of emergency surgeons, especially when the patient transfer is not feasible in a reasonable timeframe.

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19 Acute Diverticulitis in Elderly

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19.1 Introduction

Diverticular disease is a common gastrointestinal disorder and affects a lot of elderly patients. Its prevalence increases for the elderly, but a large majority of patients with diverticular disease remain asymptomatic. Acute diverticulitis is frequently a challenge regarding the diagnosis and treatment for the elderly due to comorbid conditions. The presentation of acute diverticulitis is wide: could be an uncomplicated diverticulitis, which is a relatively benign disease with virtually no mortality and one that could be treated even only with symptomatic treatment or could be with severe sepsis and generalized peritonitis, a highly lethal condition which requires intensive care frequently. Several classifications have been developed. Hinchey classification is the oldest and most widely used classification system. This was developed before the advent of computed tomography (CT) and relied on intraoperative macroscopic anatomic findings alone. Several modifications have been developed to accommodate the classification suitable for CT diagnostics. Most of these patients admitted with acute diverticulitis have a favorable evolution under conservative treatment, but until one-third of patients could benefit after surgery. Surgery for acute diverticulitis conducts significant rates of morbidity and mortality, so conservative treatment is recommended in the elderly without significant risk factors.

19.2 Definitions and Epidemiology

The etiology of the diverticular disease is not clearly understood. Diverticulitis is the most usual clinical complication of diverticular disease, affecting 10–25% of patients with diverticula. Most patients admitted with acute diverticulitis respond to

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conservative treatment, but until one-third require surgery. Predictive factors for severe diverticulitis are sex, obesity, immunodeficiency, and old age [1].

Diverticulosis of the colon is an acquired condition that results from herniation of the mucosa through defects in the muscle layer [2]. The concepts regarding the causes of colonic diverticula include alterations in colonic wall resistance and dietary deficiencies with fibers frequently involved.

Diverticulitis is the result of a micro- or macro perforation of a diverticulum, due to erosion of the luminal wall by increased intraluminal pressure or thickened fecal material in the neck of the diverticulum. Micro perforations can be contained by pericolic fat and mesentery causing small pericolic abscesses. Macro perforations can result in an extensive abscess, which can continue around the bowel wall and form a large inflammatory mass or extend to other organs. Free perforation into the peritoneum causes peritonitis [3].

The pathophysiologic mechanism underlying diverticulitis is not well understood. The long-held belief that diverticulitis is caused by micro perforation and bacterial infection has been challenged by the concept that diverticulitis may be a primary inflammatory process [4]. Other opinion is mucosal prolapse, relative ischemia, bacterial overgrowth, increased exposure to intraluminal toxins, and antigens secondary to fecal stasis [5]. Colonic diverticular disease is common in industrialized country but very rare in developing countries. It is now widely accepted that chronic diverticular formation occurs in westernized societies due to the lack of fiber in the diet [6].

19.3 Incidence

The prevalence is largely age-dependent, as it is uncommon in those under the age of 40. Colonic diverticular disease affects the sigmoid and descending colon in a huge majority of patients in western countries and in contrast cecum and ascending colon in Asia [7]. Probably because of changes in lifestyle its prevalence is increasing throughout the world and left-sided colonic diverticulosis is more common among elderly patients. A dramatic rise in its incidence has been seen in the younger age groups in recent years. Recent evidence suggests that the lifetime risk of developing acute left-sided colonic diverticulitis (ALCD) is only about 4% among patients with diverticulosis [8].

19.4 Clinical Findings and Diagnosis

The clinical symptoms of diverticulitis vary with the stage and the extent of the disease process. Acute pain is the most common symptom of diverticulitis, usually in the lower abdominal part but the location varies depending on the site of the involved segment which may be associated with increased inflammatory markers including C-reactive protein (CRP) and white blood cell count (WBC). Low-grade fever and leukocytosis are generally present [7].

Careful physical examination usually reveals localized tenderness. Bowel sounds are frequently decreased but may be normal in the early stages or increased in the presence of obstruction. Generalized peritonitis may result from the rupture of a peridiverticular abscess or from the free rupture of a non-inflamed diverticulum. Patients with free perforation have peritoneal irritation, including a marked abdominal tenderness that begins suddenly and spreads rapidly to involve the entire abdomen with guarding and involuntary rigidity. Peritonitis is an indication for emergency surgical exploration. Hematochezia is rare in colonic diverticulitis and should suggest frequently other conditions [7].

The diagnosis of acute diverticulitis can often be made on the physical examination and personal history, especially in patients with recurrent diverticulitis whose diagnosis has been previously confirmed. Other diagnoses should be considered to exclude acute diverticulitis like inflammatory bowel disease, ischemic bowel, appendicitis, irritable bowel syndrome, neoplasia, or gynecologic disorders.

Colonic diverticulitis should be considered in differential diagnosis for acute abdomen. Right-sided pain does not exclude diverticulitis because some patients have redundant sigmoid colons and right-sided diverticula can occur, especially in Asian populations. Anyway, sigmoid diverticulitis may appear like acute appendicitis. Clinical diagnosis of acute diverticulitis usually lacks accuracy [9].

Regarding the laboratory findings uncomplicated acute diverticulitis may present with mild to moderate leukocytosis; however, in the elderly they might present normal values. Moderate to high leukocytosis should indicate complicated acute diverticulitis. Also, elevated C-reactive protein (values >50 mg/L) and procalcitonin higher than 0.1 ng/L are good markers to differentiate uncomplicated to complicated acute diverticulitis [10].

In patients with urinary symptoms, the urinalysis could show leukocyturia due to adjacent inflammation or positive cultures with colonic germs as a manifestation of colovesical fistula.

Imaging evaluation in patients with colonic diverticulitis has an important role in diagnosis and evaluation of severity. X-rays of the abdomen should be mandatory for all patients with abdominal pain and suspected diverticulitis. Frequently, this is unspecific and includes small or large bowel dilation or ileus, or evidence of bowel obstruction. X-rays are neither specific nor sensitive however as an initial evaluation can rarely show free perforation or air-fluid levels. The chest X-ray is also useful to identify pneumoperitoneum if perforation is suspected. However, pneumoperitoneum is uncommon and may fail to detect perforation [11].

Barium enema is no longer recommended because in case of any perforation the risk of extravasation of contrast material is higher. A water-soluble agent is mandatory to prevent peritonitis if it is used in an acute setting and perforation is suspected. Another subject to avoid barium enema is the difficulty of exploration if computed tomography (CT) is necessary for a complete evaluation. The barium enema could help to differentiate colonic diverticulitis from colorectal cancer but most important help to identify fistulas.

Ultrasound may be useful in the initial evaluation of patients. It has wide availability and easy accessibility but it may not be practical in patients with abdominal tenderness because the transducer probe requires compression. It may have good sensitivity and specificity when is performed by an expert, but is operator dependent and the utility of ultrasound may be diminished in obese patients. Transabdominal, high-resolution ultrasound could be an alternative imaging modality that may be useful in patients with relative contraindications to CT scannings like pregnancy, renal insufficiency, or contrast allergy.

The best choice to confirm a suspected diagnosis of colonic diverticulitis is CT with intravenous and oral contrast. The imagistic evaluation should standardly include a CT-scan with intravenous (IV) and oral contrast which can make an accurate diagnosis and stage the disease [12]. Also, there are studies to prove that ultrasound in experienced hands can achieve similar sensitivity and specificity compared to CT based on a hypoechoic appearance of pericolic tissues, bowel thickening, abscess, or fistula (proven by air inside the bladder) [13].

The pericolic fat infiltration, bowel wall thickness > 4 mm, or phlegmon is suggestive for diagnostic. Other criteria suggestive of colonic diverticulitis include peridiverticular abscess.

MRI can diagnose acute diverticulitis with similar accuracy like CT-scan but with the advantage of not being irradiating. However, it can prove useful for fistula complications.

Because of the risk of perforation from either the device or air insufflation, endoscopy is generally avoided in the initial assessment of the patient with acute diverticulitis. Its use should be restricted to situations in which the diagnosis of diverticulitis is unclear. In such cases, limited sigmoidoscopy with minimum insufflation can be helpful to exclude other diagnoses, such as inflammatory, infectious, or ischemic colitis [1].

19.5 Classification

Acute diverticulitis could vary in severity from uncomplicated inflammatory diverticulitis to complicated diverticulitis (abscess formation or perforation). For the past three decades, the Hinchey classification has been the most commonly used classification for complicated acute diverticulitis in international literature. Based on the surgical findings of abscesses and peritonitis, Hinchey classified the severity of acute diverticulitis into four grades. Stage I is diverticulitis with diverticular wall thickening and strong wall enhancement or a small pericolic abscess. Stage II is associated with a large peridiverticular abscess pelvic, intra-abdominal, or retroperitoneal. Stage III is diverticulitis with perforated diverticulitis and purulent peritonitis, and stage IV is diverticulitis associated with free rupture of diverticulum and fecal peritonitis. The risk of death is less than 5% for most patients with stage I or II diverticulitis, approximately 13% for those with stage III, and 43% for those with stage IV [14].

In 2005 Kaiser et al. modified Hinchey classification according to specific CT findings:

- Stage 0 mild clinical diverticulitis
- Stage 1a confined pericolic inflammation,
- Stage 1b confined pericolic abscess
- Stage 2 pelvic or distant intra-abdominal abscess
- Stage 3 generalized purulent peritonitis
- Stage 4 fecal peritonitis at presentation [15].

19.6 Management of Acute Diverticulitis

The management of acute diverticulitis has recently changed dramatically in recent years, due to better radiological imaging and availability of nonsurgical treatment options. This is based on the severity and type of complication. Although the treatment of the elderly with acute diverticulitis is similar to the one for general population, there are some particularities that are worth to be mentioned.

For uncomplicated acute diverticulitis, the utility of antimicrobial therapy has been the subject of debate in the medical community. In the last few years, several studies demonstrated that antimicrobial treatment was not superior to withholding antibiotic therapy in patients with mild unperforated diverticulitis, in terms of clinical resolution [16].

The consensus of the World Society for Emergency Surgery is that uncomplicated diverticulitis may be a self-limiting condition in which local host defenses can manage the bacterial inflammation without antibiotics in immunocompetent patients. In this context, antibiotics may, therefore, not be necessary for the treatment of uncomplicated disease. If patients need antimicrobial therapy, oral administration may be acceptable. Patients with uncomplicated diverticulitis symptoms without significant comorbidities, who are able to take fluids orally and manage themselves at home, can be treated as outpatients and they should be reevaluated within 7 days or earlier if the clinical condition deteriorates [9].

Considering that the elderly persons are frailty patients, most of them affected by immunosuppression and multiple other diseases, they should be treated inpatient for acute diverticulitis whether it is complicated or not. Only very well fitted patients without any comorbidities with uncomplicated diverticulitis and no severity factors (fever, peritonitis or severe abdominal pain, moderate or severe leukocytosis, micro perforation, intolerance of oral intake, high inflammatory markers) could be managed outpatient if they give consent and can be surgically monitored daily [17].

For uncomplicated acute diverticulitis, the antibiotic therapy treatment should be adapted for usual gastrointestinal flora (gram-negative and anaerobes bacteria). It can be given orally for those with good intestinal tolerance and without risk factors (ciprofloxacin or amoxicillin-clavulanate plus metronidazole for a 7–10 days course) or on intravenous route (in a single regimen with piperacillin-tazobactam or combination of third generation cephalosporin or ciprofloxacin plus metronidazole). Also, a combination of the two can be made, with antibiotics started on intravenous route and then after the patient partially recovers intestinal function to change on oral route.

Patients without severity risk factors or immunosuppression and clinically fit can be managed in selected cases, under continuous observation without antibiotic therapy. However, considering that there are few elderly patients matching those criteria we recommend no-antibiotic approach only for those having multiple antibiotic allergies or other contraindications [18, 19].

The patients must be hydrated, orally with clear liquids if possible or with IV fluids until the intestinal function is recovered. For pain control, the patient must receive IV or oral analgesics according to VAS scale. The diet can be advanced to soft or regular according to patient's tolerance and clinical evolution. In the first 2- or 3-days ice packs placed on the painful abdominal area can be useful because of their local anti-inflammatory and analgesic action (care must be taken not to put the ice directly in contact with the patient's skin).

Hospitalized patients with well clinical evolution do not need any further imaging follow-up. They can be discharged when they are clinically stable, have low inflammatory markers, and recover digestive function and oral tolerance.

Patients with abdominal pain and colonic wall thickening on CT should have the lumen of the colon evaluated, ideally, after the acute symptoms resolve. The purpose of the investigation is to exclude diagnoses other than diverticulitis, because patients with simple thickening on imaging may be found to have ischemia, inflammatory bowel disease, or neoplasia. Patients with presumed diverticulitis who have not had a recent colon evaluation should undergo colonoscopy, typically within 6–8 weeks following resolution of the acute episode. The absence of neoplasia on colonoscopy may confirm the diagnosis of diverticulitis suspected on CT alternatively, Ct colonography may be used in this situation [20–22]. After resolution of an episode of acute diverticulitis, the colon should typically be endoscopically evaluated to confirm the diagnosis, if this is a first episode or recent colonoscopy has not been performed.

After 6–8 weeks after the attack, patients must be investigated with colonoscopy for colon cancer, especially the elderly patients where the incidence is higher [21].

In long term, patients must take general measures to lower their risk of recurrent disease by consuming more fibers, seeds, corns, and nuts [23]. There are some studies stating that specific intestinal anti-inflammatory drugs (like mesalamine) could lower the symptoms, or prescribing rifaximin and probiotics to prevent recurrence; [24] however, there is insufficient data to recommend them on a clinical daily basis.

Patients with small diverticular abscesses (less than 3 cm) may be treated by antibiotics alone. Patients with large abscesses (>4–5 cm) can best be treated by percutaneous drainage combined with antibiotic treatment. Whenever percutaneous drainage of the abscess is not feasible or not available, based on the clinical conditions patients with large abscesses can be initially treated by antibiotic therapy alone. However, careful clinical monitoring is mandatory [9].

Patients without evident perforation (only micro perforation) signs on CT-scan can be treated with conservative measures, but there is a risk of treatment failure and patient should be continuously monitored in case of an emergency surgery required. Patients who fail to respond despite vigorous medical management or who have a localized abscess should be considered for CT-guided percutaneous drainage (PCD).

Patients with abscesses of ≤3 cm can be treated with antibiotics alone, those with abscesses approaching 4 cm are best managed with PCD followed by a referral for surgical treatment.

The management of diverticulitis continues to be a controversial point in the appropriate selection of patients for elective sigmoid colectomy after recovery from an uncomplicated episode. Based on large retrospective series, it is estimated that, after an initial attack, approximately one-third of patients will have a recurrent episode, and that one-third of those patients are expected to have another recurrence [25].

Despite previous emphasis on the number of attacks dictating the need for surgery, the literature demonstrates that patients with more than two episodes are not at an increased risk for morbidity and mortality in comparison with patients who have had fewer episodes, signifying that diverticulitis is not a progressive disease [26].

Elective surgery is indicated for chronic diverticulitis with symptoms still persistent at 6 weeks or if there are any worries about the presence of malignant disease and biopsies cannot be safely obtained. Delayed emergency surgery is indicated when the conservative management of certain patients is not working and the patient immunity is affected. In this category, most of the elderly could be included due to their low immunity and low resource.

Perforation is the most frequent complication of acute diverticulitis. The surgical treatment is indicated based on the Hinchey classification and the grade of perforation. Those patients presenting with an abscess (Hinchey I or II) should first be evaluated for minimally invasive drainage (transabdominal, transvaginal, transrectal, trans gluteal, etc.). Usually abscesses smaller than 3–4 cm or with deep positioning can be challenging for the interventional radiologist and their management should be based on the patient characteristics, risk of recurrence, and clinical status with antibiotic therapy or surgery if conservative treatment fails [27]. After percutaneous drainage, the patient clinical status usually ameliorates in 48–72 h and the drainage tube should be maintained until the secretion is low. If there is no clinical or biological amelioration after 2–3 days or the drainage persists with high output or suspicious enteral or fecaloid aspect the patient should be referred for surgery.

A subgroup of patients in whom nonoperative management fails do not present as dramatically; these patients just do not improve clinically and continue with abdominal pain or the inability to tolerate enteral nutrition owing to infection-related ileus or bowel obstruction. Although repeat imaging to evaluate possible abscess formation or to otherwise guide management of antibiotic coverage and parenteral nutrition may be useful, clinical judgment determines the need for definitive surgical treatment. Urgent sigmoid colectomy is required for patients with diffuse peritonitis or for those in whom nonoperative management of acute diverticulitis fails [28].

Evident perforation with clinical and imagistic signs of peritonitis are absolute indications for emergency surgery. However, clinical signs in the elderly can sometimes be challenging because of their late abdominal signs and delayed response. Also, most of the old persons present with multiple comorbidities and multiple pills which could interfere with the clinical response and affect renal function thus not allowing intravenous contrast-enhanced CT-scan to be obtained. Similarly, hemodynamic status is difficult to assess and difficult to challenge. Due to these considerations, an exploratory laparoscopy is better than an empiric conservative treatment for an immunosuppressed and low resource senior patient.

If the surgical indication was made, the approach has to be settled. For hemodynamically unstable patients open approach is preferred and three-stage procedure (ostomy first with no resection) or damage control surgery should be chosen. The abdomen can be left open with VAC abdomen system and if the patient becomes stable at 48 h a definitive procedure can be made based on the local situation.

Patients with hemodynamic stability can be operated open or laparoscopically, being subjected to one-stage or two-stage procedure. In the one-stage procedure is included resection with primary anastomosis or lavage and in the two-stage procedure are included Hartmann's procedure or resection with primary anastomosis and diverting stoma. Patients who required urgent surgery or emergent cases, BMI $\geq$ 30, Mannheim Peritonitis index higher than 10, immunosuppression and Hinchey grade 3 or 4 are frequently recognized in the literature as predictors end-colostomy and found that strong predictors of nonrestorative surgery.

Parameters generally favoring proximal diversion include patient and intraoperative factors like hemodynamic instability, acidosis, acute organ failure, and comorbidities such as diabetes mellitus, chronic organ failure, and immunosuppression as well as surgeon preference and experience [29].

Primary anastomosis with proximal diversion may be the optimal strategy for selected patients with Hinchey 3 or 4. The decision to create an anastomosis in the setting of peritonitis should be individualized to each patient based on the factors described above.

Laparoscopic sigmoid resection for diverticulitis is technically challenging and requires training and adequate experience. Laparoscopic colectomy performed by experienced surgeons is safe and results in better short-term outcomes compared with open surgery. Laparoscopy is associated with decreased operative blood loss, less pain, shorter hospitalization, reduced duration of ileus, reduced complication rates, and improve quality of life.

Patients with high index of peritonitis and having a risk of anastomotic failure should be proposed for two-stage procedures. However, due to low reintegration rates after Hartmann's procedure [30], technically demanding operation of reintegrating bowel continuity and higher postoperative comorbidities compared to ileostomy closure we recommend the latter. The exception is when the patient cannot tolerate a longer procedure due to septic shock, major fecal spillage, or bowel edema in which terminal colostomy is recommended.

Regarding patients who would tolerate one-stage procedure they should be selected based on their biological resource, clinical status, peritonitis index, and patients' desire. Considering that most of the elderly patients lack resources, present with multiple comorbidities, that local sepsis is not very well controlled with laparoscopic lavage only [31] and that fecal spillage cannot all the time be excluded, the option of laparoscopic lavage should be rarely used for elderly patients. Resection with primary anastomosis and no diverting stoma is a risky choice for perforated diverticulitis with peritonitis in all settings and can be safely done in elective cases for chronic symptoms after conservative management or percutaneous drainage. Laparoscopic peritoneal lavage and drainage should not be considered the treatment of choice in patients with generalized peritonitis. Among patients with likely perforated diverticulitis and undergoing emergency surgery, the use of laparoscopic lavage vs primary resection did not reduce severe postoperative complications and led to worse outcomes in secondary end points. These findings do not support laparoscopic lavage for the treatment of perforated diverticulitis [32].

Another complication after acute diverticulitis is bowel stenosis. Usually, it is not a complete stenosis and the patient can be prepared for elective resection with primary anastomosis. Besides, chronic symptoms associated with stenosis, another surgical indication is suspicion of a malignant tumor (and impossible to procure biopsy).

Bleeding is associated with diverticular disease and not acute diverticulitis. However, if perforation occurs after angiographic embolization of diverticular bleeding the same treatment as for perforated acute diverticulitis should be initiated.

Fistulas can occur between affected colon segment and close organs like bladder, internal genital organs, and small bowel. In all circumstances, the colon should be resected with primary anastomosis (unless local conditions require otherwise) and the other organ being affected should be resected (if possible like for small bowel, uterus) or sutured and patched with greater omentum (if vagina or bladder are involved). Nonoperative treatment can be offered to those patients not fitted for major surgery and low life expectancy with antibiotic therapy, endo-vacuum sponge, and fistula ligation. Care must be taken to colovesical fistula because of the high risk of urosepsis.

Recurrence of acute diverticulitis is lower than previously thought but after a conservatively treated episode of acute diverticulitis, an elective sigmoid resection should be planned in high-risk patients, such as immunocompromised patients.

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Intestinal Stomas in Elderly

20

Hayato Kurihara and Simona Mei

20.1 Introduction

Intestinal stomas are a common strategy of fecal diversion in the management of a huge variety of conditions. In Europe, approximately 700,000 people are living with a stoma while approximately 100,000 stomas are performed annually in the United States [1].

According to the surgical scope, stomas can be temporary or permanent and, generally, they can be fashioned as "end" or "loop" and be classified, according to the segment of exteriorized bowel, as jejunostomy, ileostomy, or colostomy.

The possibility to create an ostomy in case of clinical conditions requiring abdominal emergency surgery such as small or large bowel obstruction, bowel ischemia, and peritonitis in the elderly population is high and, due to increased aging of the population, the number of elderly ostomy carriers is expected to rise in the coming years; furthermore, a small number of patients need a stoma due to trauma-related conditions.

Despite the variety of high-quality products for stoma management and improvement in surgical techniques, surgical procedures associated with enteral stoma creation still have a complication rate up to 70% and, in adult population, with exclusion of stoma specific problems, complications such as dehydration, skin inflammation, and prolapse range from 33 to 48% [1, 2].

Complications specifically related to stomas are common and are mostly represented by parastomal hernias, mucocutaneous separation, retraction, and stenosis; usually, a careful surgical management can reduce complications' rate, nevertheless

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elderly, represent the most fragile category of people and special considerations must be done while considering a stoma creation.

Reduced physiology reserves, septic conditions, impaired nutritional status, and severe frailty typical of the elderly patients in adjunction to the impact of the emergency surgery procedure itself are conditions for a "perfect storm" in terms of poor outcome for this population of patients; therefore, surgical strategy must be planned meticulously although in an emergency setting this is often challenging.

20.2 Preoperative Counseling and Stoma Site Planning

Although in emergency surgery setting the activation of an enterostomal nursing service is challenging due to time and logistic restrictions, a minimal preoperative counseling should be provided to the patient and relatives in order to explain how the stoma will function and will look like. It is important also to give information regarding site of the stoma and possibility of stoma reversal or if the stoma will be permanent.

An accurate planning of stoma site is mandatory and the patient's abdomen should be examined; previous surgical scars, skin folds, and sitting and supine position must be therefore evaluated. This is of particular importance in the elderly and malnourished patient since skin folds and prominent anterior superior iliac spine in skinny patients might represent a real challenge to provide an optimal attachment of the stoma bag causing discomfort, anxiety, and a stressful postoperative management.

The other way around the creation of a stoma in obese patients presents other difficulties related to abdomen contour and abdominal wall thickness that are linked to higher complication rates such as mucocutaneous separation, stoma retraction, and parastomal hernia [3, 4].

Especially in the emergency setting sometimes it is not possible to select a stoma site beforehand, nor plan if the final ostomy will be an ileostomy or a colostomy and temporary or permanent; for these reasons a second or even third possible stoma site should be planned before surgery; furthermore due to advanced age, comorbidities and frailty, although technically feasible, a potentially reversible stoma might end up as permanent it is therefore advisable to be very meticulous and not consider the surgical act as an annoying and time-consuming procedure. A poorly sited stoma will in fact adversely affect the quality of life of the patient.

The following issues should be taken into account:

- A flat area of skin is required for adequate adhesion of the stoma bag
- Stoma should be visible to the patient and not located at the beltline
- Preexisting disabilities must be taken into account (e.g., neurological impairment, need of wheel-chair, etc.)
- Possible postoperative weight variations.

20.3 Type of Procedures and Technical Aspects

Regarding the choice of procedure there are multiple options; nevertheless, in abdominal emergency surgery it might be very difficult to select the best available technique beforehand. In the elderly patients, postoperative complications, in particular postoperative dehydration with risk of development of acute kidney injury, should be taken into account and therefore guide the intraoperative decision-making process.

The general principles of stoma creation should simply follow the key concepts of intestinal anastomosis such as adequate blood supply and mobilization of the bowel without tension. Impaired vascular insufficiency typical of the elderly patients should be considered carefully since compression against the bowel wall when delivering the bowel through the stoma site could worsen the blood supply causing ischemia of the stoma, therefore attention should be given in order to avoid a too-small hole in the abdominal wall. If these criteria are not respected, then either the bowel should be mobilized further or a new bowel segment should be selected [5, 6].

20.3.1 End Ileostomy and Colostomy

When an end stoma creation is decided the following principles should be respected:

- Circular skin excision at the previously marked site should be approximately 2.5 cm in diameter.
- Excision of fat tissue is not recommended and simple retraction of subcutaneous tissue is sufficient.
- After the incision of the anterior rectus sheath, the rectus abdominis muscle should be divided in the direction of its fibers.
- After the incision of the posterior rectus sheath, the bowel should be gently pushed rather than pull through the abdominal wall hole and bowel tissue perfusion should be assessed meticulously.
- Twisting of the bowel should also be checked.
- Colostomy should protrude 2 cm above the skin, while ileostomy should protrude 5 cm above the skin so that the matured stoma will protrude 0.5–1.0 and 2.0–2.5 cm, respectively.
- Excision of staple line, generally after abdominal closure, should be performed with a scalpel blade; ileostomy should be always everted, while eversion of colostomy is generally optional.
- Interrupted absorbable sutures should be used to perform the final enterocutaneous anastomosis; eversion of ileostomy can be made by using triplicate sutures (from dermis 4–5 cm, from the proximal end of the bowel to the cut-end of the bowel). Usually, three everting sutures, away form the mesentery, should be enough and standard interrupted sutures between the everting sutures will complete the fixation of the stoma.

In case of end colostomy, usually it is not necessary to take down the splenic flexure to mobilize the colon; however, if there are concerns regarding the tension of the stoma, a full splenic flexure mobilization is suggested.

In case of severe intra-abdominal sepsis or other clinical scenario, an open abdomen strategy might be undertaken; in such cases a stoma should be generally avoided until the abdomen is left open, nevertheless it is sometimes necessary to layout a stoma while the abdomen is still open. In such cases the end stoma must be placed very laterally and far from the midline incision in order to avoid spillage of fecal material inside the abdominal cavity; moreover, abnormalities related to fascial and mesenteric retraction must be taken into account since tension at the stoma level might end up with ischemia or retraction of the intestinal bowel loop.

20.3.2 Loop Ileostomy and Colostomy

Loop stoma is most often the procedure of choice in case of need of simple fecal diversion and, particularly in old patients should be performed as much distally as possible; furthermore, it should be underlined that in a significant number of patients this temporary solution might become permanent.

These diverting stoma are generally performed to avoid fecal material to reach a distal portion of the bowel in order to decrease the incidence of distal anastomotic leakage and avoid further complications. The options are a transverse or descending colon loop colostomy or loop ileostomy but surgeons should be aware that the most favorable outcome at least in terms of risk of prolapse and infectious complications is associated with loop ileostomy rather than loop colostomy; also regarding the quality of life loop ileostomy seems to be superior when compared to loop colostomy. Nevertheless, although loop ileostomy seems to provide a better outcome in terms of specific stoma-related complications, patients who underwent this kind of procedure are at higher risk to develop dehydration; this happens particularly in aging population and it is often linked to acute kidney injury with need of hospital readmission.

Loop stoma creation should follow the principles on blood supply and tension previously discussed, furthermore procedure-related key concepts should be considered:

- Marking of the distal bowel with a suture facilitates proper orientation of the bowel and avoiding twisting.
- Circular skin incision should be slightly larger than in end stoma.
- A Penrose drain or Foley catheter might be useful to facilitate the passage of the bowel loop through the abdominal wall.
- Once the loop is well above the skin level, 80% of the circumference of the antimesenteric portion of the bowel is transected, peeled back, and then sutured with three triplicate suture while the gaps among the triplicate suture and opposite part of the stoma will be sutured with simple stitches.

– A rod or a bridge might be used, but if the stoma has been externalized and created without tension, is generally not necessary and, especially in frail patients, might be even more associated with worse outcomes since it can increase the rate of postoperative complications such as bowel necrosis, edema, peristomal dermatitis, and surgical site infections.

20.3.3 End-Loop Stoma

In case a temporary stoma is needed it is preferable, when possible, to bring both proximal and distal bowel ends to the abdominal wall using the same trephine; this solution facilitates the following stoma reversal avoiding a further laparotomy with less risks for the patient. The options might be end-loop ileoileostomy, ileocolostomy, or colocolostomy where the stomas are created from distant intestinal segments. In such cases, a good option is to perform directly an anastomosis at the level of the posterior wall facilitating the following stoma reversal and the stoma will function well even if the stoma would be definitive.

20.3.4 Laparoscopic Stoma Creation

Although very rare in the emergency surgery setting, especially in the elderly population, sometimes stoma creation might be performed with a minimally invasive approach through laparoscopy. The main indication of fecal diversion that might be approached by laparoscopy approach are represented by unresectable cancer of the pelvis, severe perianal disease, and pelvic trauma. Nowadays the main contraindication to laparoscopy in the elderly patient is the tolerance of the patient to increased intraoperative abdominal hypertension induced by the pneumoperitoneum.

In case of laparoscopic approach, the technical key points are represented by preoperative table positioning and port placement that should meticulously be chosen according to the segment of the bowel that will be exteriorized and in general one tracer should be placed at the level of the mark of the planned stoma site.

From a technical point of view one of the main pitfall is represented by the need to get the correct orientation of the bowel and avoid twisting of the bowel loop and kinking of the mesentery; marking the distal bowel prior to exteriorization with a suture or with the felt tip of a marker is a good way to facilitate the proper orientation. Before fixation of the stoma to the skin, reestablishment of the pneumoperitoneum for a final check of the orientation of the bowel should always be performed.

20.3.5 Parastomal Hernia and Stoma Prolapse Prevention

Parastomal hernia are quite frequent mainly after loop colostomy, while are less frequent in case of loop ileostomy and, up to one-third of these patients will require a surgical repair due to pain, incarceration, and obstruction; furthermore, in some cases, parastomal hernia will affect an adequate fitting of the stoma bag causing a poor quality of life and skin disorders. Particularly in the elderly and frail patients, a parastomal hernia should be therefore prevented since advanced age is in fact associated with increased risk of hernia development. Other associated conditions such as hypertension, obesity, and female gender are also associated with parastomal hernia.

The main cause of this kind of hernia is due to the large size of the fascial aperture that is frequently made in emergency surgery cases with severe bowel edema and distension. In such cases, in particular, a smaller fascial aperture would lead to ischemia of the stoma, is therefore often challenging to decide the ideal caliber of the fascial incision, since the “two fingers rule” is sometimes not enough. The passage of the bowel through the abdominal wall might be facilitated by plastic wound protector (e.g., Alexis Wound Protector).

The prophylactic use of a mesh placement has been proposed at the time of stoma creation, but long-term data supporting the routine use of a mesh are still lacking and therefore its use is not recommended.

A simple method to prevent the risk of parastomal hernia is to tunnel the stoma through an extraperitoneal route; this can be done with an incision of the peritoneum laterally to the fascial incision, then the stoma is passed through the preperitoneal tunnel to the anterior abdominal wall. This technique seems to be associated with lower risk of parastomal hernia prevention, but robust data supporting this approach are still lacking.

Another complication related to stoma affecting a patient’s quality of life is represented by stoma prolapse. Also, this complication is mainly associated with loop colostomy and end colostomy rather than loop ileostomy. In terms of stoma prolapse prevention, the above-described technique of extraperitoneal approach is suggested since it seems to be associated with a decreased incidence of prolapse.

20.3.6 Stoma Reversal

Ideally, stoma reversal should be planned at the time of stoma creation, but this is usually very challenging in frail and elderly patients since reestablishment of physiological impairment and nutritional status might take a long period. Timing of stoma reversal is still under debate and the literature focuses mainly on elective colorectal surgery and not in the emergency surgery setting. In general, in elective surgery conditions, such as rectal cancer surgery, if the patient fulfill the physiological and nutritional conditions to face a second surgery, for loop ostomy, closure might be performed within 8–12 weeks in elective cases, but in the emergency surgery elderly population this time frame might be much longer or even never. In case of Hartmann’s reversal surgery should be performed at least 3 months after the index surgery, but usually a 6–8 month period is suggested.

Regarding skin closure, a purse-string closure in stoma reversal should be the preferred skin closure technique since it is associated with a low rate of surgical site infection when compared to other techniques. Another option is represented by the application of a prophylactic negative pressure wound therapy after direct skin closure.

20.4 Complications: General Considerations

Stoma creation can be burdened, in the general population, by several complications such as leakage, skin disorders, dehydration and in the late-term prolapse, parastomal hernia, or stenosis.

Nevertheless while planning the formation of a stoma in the elderly an even more considerable attention must be paid on the peculiar issues that concern this population.

Our efforts must be focused on avoiding, as much as possible, complications and surgical revisions that can compromise the outcomes of this frail population.

It is well known that older people are affected by serious comorbidities as cardiovascular diseases, diabetes mellitus, pulmonary diseases, coagulopathy, and chronic kidney disease that can impair surgical procedure and hinder the healing process of the wound and the stoma; at the same time many physiological and degenerative changes occur with aging and elderly people can be negatively influenced in the management of the stoma and can suffer most for the possible complications stoma-related.

Another key point while considering any procedure on elderly people is frailty. Frailty is the most problematic expression of aging. It is a state of increased vulnerability to poor resolution of homeostasis following stress, which increases the risk of adverse outcomes. Therefore, frailty must be assessed and specific interventions have to be carried out.

In addition to the previous important topics, nutritional status must be taken into consideration. Elderly are frequently malnourished and an accurate nutritional evaluation should be done and a possible condition of malnourishment must be managed.

20.5 Peculiar Issues

20.5.1 Peristomal Skin

Important considerations should be made on peristomal skin. Even if the normal aspect and function of the stoma are well acknowledged by the patients, small changes happen over a long time. These may result in problems such as leakage from the stoma appliance. Leakage and soreness can occur if a stoma appliance does not fit appropriately to the stoma or adhere securely to the skin. For patients, leakage is particularly embarrassing and can deeply concern their psychosocial behavior, body image, and quality of life.

In fact during the old age the loss of skin tone and of subcutaneous fat result in wrinkles and sags. When this happens in the peristomal skin the probability of leakage between the stoma devices and the abdominal is increased. In addition to this while aging the skin becomes thinner and drier and that results in a greater likelihood to be injured by stoma products with a longer time of healing despite the younger. In this case, it is extremely important for the patient to keep in contact with a stoma nurse and to be reevaluated.

20.5.2 Disabilities

While aging some people can develop arthritis or lose their manual dexterity due to neurological illnesses (stroke, Parkinson's disease). Some other people can experience visual impairment in the advanced age and may require support from family members or caretakers. Finally, some older people have memory impairment and can forget they have a stoma appliance to empty. These people may take advantage of written instructions.

20.5.3 Stoma Education

For the reasons abovementioned, even if generally stoma education starts after surgery, it should be considered, as the literature demonstrates, a preoperative education training.

Certainly, this is a challenging issue in case of emergency procedures because of the availability of stoma nurses. In this cases, the surgeon must be aware of the importance of stoma site marking and of the first elements of education.

After discharge, the stoma should be reassessed and the educational training should continue, mainly in the first postoperative period when complications occur most frequently.

In the educational training, it should be considered that the ability of managing a stoma sometimes decreases during the aging process, due to illnesses or disability, even for those older people who have had a stoma for years.

An important aspect of the educational training concerns diet: elderly refer a loss of appetite, due to inactivity and loss of muscle mass, some older people may not feel like cooking. The result of this kind of diet can be constipation or diarrhea. Nurses can prepare a list of foods that can help thicken output or prevent constipation. Patients should be encouraged to take small, well-balanced meals with plenty of fluids to help maintain their weight and manage stoma output.

Ostomates should be reviewed annually by a stoma nurse. They should have a contact number in the local hospital.

20.6 Specific Complications

Stoma complication rate is around 6 and 59%. Several risk factors can increase the likelihood to develop ostomy complications. They can be divided into patient-, operation-, and disease-related factors. Patient-related risks include age, gender, body mass index (BMI), nutritional status, ASA status, and corticosteroid use. The operation-related risk factors include emergency versus elective surgery. The location and type of stoma have also been compared, as well as the disease processes that necessitated creation of the stoma.

Thus, it is easy to understand that an elderly patient with multiple medical comorbidities undergoing emergency operation for gross intestinal perforation may have a higher likelihood of stomal complications.

Complications can also be divided into early and late events. Early complications are those that present within 30 days of surgery and late complications are those that occur after 30 days. Early complications include hematoma formation, edema of the ostomy, peristomal skin problems, and necrosis of the ostomy. The most frequent between late complications include prolapse, retraction, stenosis of the ostomy, and parastomal hernia. In general, early complications can be treated conservatively. For hematoma and edema of the ostomy, no special treatment is required. Skin complications can be solved with an accurate ostomy care. Retraction and necrosis of the ostomy require a revision surgery only when ostomy function is compromised [7, 8].

Late complications may be related to the patient or to the surgical technique: regarding patient, obesity and elevated intra-abdominal pressure increase the risk of ostomy prolapse and parastomal hernia. On the other hand, about surgical technique, an excessively large trephine can be a predisposing factor for parastomal hernia, in other cases an extended mobilization of the bowel loop used to create the ostomy increases the risk of prolapse.

Another common complication in ileostomy patients is dehydration with electrolyte imbalance. This complication may be observed both immediately after ostomy creation and weeks or months later and is the commonest reason for readmission, comprising 43.1% of cases. The severity of dehydration varies from mild dehydration to renal failure requiring dialysis.

The management of late complications can be carried out both conservatively or surgically. A surgical revision is recommended in case of persistence of symptoms and functional impairment. Despite the advances in medicine, surgery, and postoperative management, little has changed about complications. Patient-related factors must be optimized through weight control, smoking cessation, correction of malnutrition, and medical treatment of comorbidities. In fact, careful planning, meticulous surgery, and optimal care are crucial in ensuring that ostomy patients can live their lives in the best way possible.

According to the literature, although elderly with an ostomy have significantly more limitations in functioning, the impact of an ostomy is more significant in younger patients. Therefore, age itself should not be a reason for withholding an ostomy.

20.6.1 Dehydration and Renal Failure

Even if in the literature there is a lack of studies about dehydration and subsequent electrolyte abnormalities, this can be considered a complication. The general incidence ranges between 0.8 and 16.7%. Due to bowel edema frequently the mucosal surface shows an impairment of fluid absorption that results in high volume output. Therefore, sometimes daily volumes reach 1 L/day, in severe cases they exceed 2 L/day. After adaptation of the bowel, that may require several days or some weeks, one experiences a decrease of the output to 400–800 mL/day. Ileostomies are more prone to high output and patients are at risk for dehydration and electrolyte abnormalities.

This condition is related to an excessive stoma output without an adequate reintegration of water and minerals and can lead to acute kidney failure [7, 9].

We must consider that the prevalence of chronic kidney disease is higher in the elderly population and this condition can be worsened because of the presence of a stoma with a high output.

It is known that aging reduces thirst sensation and fluid intake in older adults and in case of augmented losses of fluids a complete restoration of fluid balance is not always guaranteed.

Therefore, it is fundamental, in order to prevent hospital readmission for acute kidney failure, to give clear instructions to the patients regarding oral hydration with glucose-electrolyte balanced fluids (e.g., commercial sports drinks).

Another important recommendation is to introduce fiber implementation (20–30 g/day) remembering that fiber can thicken the consistency of the waste without changing the water content.

20.6.2 Peristomal Skin Disorders

Peristomal skin disorders are the most common complication for ostomates. It is an issue that involves up to 70% of new estimates and occurs usually in the early postoperative period while the patient is learning the right stoma care techniques. Peristomal skin disorders can vary from skin irritation to ulceration and infection and can be easily managed with an appropriate stoma construction and care. Causes can be mechanical, chemical, allergic, and infectious. Patients with uncomfortable to fit stomas have a major risk of complication and this is associated with poor siting, prolapse, and retraction.

Considering mechanical causes one of the main is the improper use of appliance. Frequent changes in the appliance can cause lesions of the skin. This kind of lesions can be treated with skin sealant and topical wound care products. If the lesions are caused by a device this should be abandoned. Furthermore, patients must be evaluated for their ability in appliance changing.

Chemical lesions are caused by irritation of intestinal waste to the peristomal skin that can appear reddened and moist. The severity of the lesions depends on the quality of the effluent. Contact dermatitis is the most common peristomal skin disorder and the first step of the treatment is preventing progression: in fact, dermatitis can lead to worsening of the leakage with more irritation. Treatment consists of application of hydrocolloids before the appliance.

Allergic dermatitis is caused by the sensitivity to appliance, barriers, powder, or filler and usually interests the skin in contact with one of these agents. This kind of dermatitis can be treated with the topic application of corticosteroids or antihistamines.

Finally, among infectious causes, candidiasis is the most common peristomal skin disorder.

Another cause can be found in a lack of contact with stoma nurses: without a professional assessment even minor issues can require hospitalization and expensive treatment.

It must be remembered that elderly, because of their immunocompromised state, have a greater predisposition to develop serious infections.

20.6.3 Mucocutaneous Separation

The incidence of this complication is between 3.96 and 25.3% and it is more common as an early complication. Mucocutaneous separation can be caused by excessive traction or improperly matured stoma. One of the solutions can be a suture full-thickness stoma to skin in order to avoid separation. This complication can be treated filling the gap between stoma and skin with paste or powder and covering the gap with the stoma appliance.

20.6.4 Ischemia

Ischemia can interest the stoma surface or extend below the fascia. This complication is common with an incidence of 2–20%. One must be careful in the mobilization of the bowel to use as a stoma avoiding excessive traction and maintaining an adequate vascular flow [4].

Even using this caution the stoma may appear darkish due to venous congestion. When the edema reduces in the postoperative period usually the venous congestion improves. In other cases, the stoma may be edematous and congested because of the small size of the aperture through the abdominal wall. These aspects must be checked because ischemia can worsen to necrosis. In such situations the segment of bowel designed for the stoma, might be exteriorized early during the procedure in order to detect in advanced any eventual ischemic demarcation.

One must consider that even minor ischemic problems can result in future poor stomal function with important patient dissatisfaction.

When the extension of ischemia or necrosis regards the subcutaneous level the potential result can be a stomal stenosis. The patient may improve without emergency procedure but a surgical revision may be necessary lately.

20.6.5 Retraction

The incidence ranges from 1.4 to 9% and can interest both ileostomies and colostomies. It is common as early complication but can appear even in the late postoperative time. The cause is usually an inadequate mobilization of the bowel. The result of retraction is that stoma effluent is poured at the level of skin causing peristomal skin irritation.

If it occurs early the result can be a leakage in the mucocutaneous junction with intra-abdominal contamination. Conservative treatment may be unsuccessful and a laparotomy is necessary for a revision of the stoma in order to create one new stoma tension-free.

20.6.6 Parastomal Hernia

Parastomal hernia is an incisional hernia that appears in relation to abdominal stoma. In the early postoperative is quite uncommon (0–3%) but the incidence increases in the late postoperative ranging from 14.1 to 40%. Risk factors for this kind of complication are, as in the other hernias of the abdominal wall, respiratory comorbidities, diabetes, surgery for cancer, and end colostomy. Parastomal hernias are also associated with aging, weight loss and gain. Although the problem can be managed conservatively with a support garment, surgery sometimes must be considered. Surgical treatment consists of primary repair, relocation, or mesh repair. Primary repair is easy to perform because it does not require a laparotomy and a huge dissection but the high rate of recurrence (46–100%) makes this procedure applicable only in those cases where a larger procedure determines a high risk for the patient or where a mesh repair is unacceptable. Likewise, stoma relocation is burdened by a high risk of recurrence at the relocated site (24–40%). Therefore parastomal hernia mesh repair seems the safer solution compared to primary repair and relocation considering that recurrence rate ranges from 6.8 to 17.8%. One of the main aim is however the prevention of hernia.

20.6.7 Stoma Prolapse

This complication has an incidence between 2 and 22%. Usually, prolapse is a late complication. It is associated with both loop and end stomas and it is more common among loop colostomies than among loop ileostomies. One of the preventive measures can be bowel fixation to the fascia. Another solution can be the creation of a small trephine in the abdominal wall, both for ileostomies and colostomies [7, 9].

The treatment of stomal prolapse can be a combination of conservative and surgical measures. Even if the patient can be worried about this issue the function of the ostomy is preserved and prolapse is not an emergency. Reduction of the prolapse can be done manually without effort. Surgical revision can be done through a peristomal incision.

20.7 Conclusion

Stoma creation and management can be accompanied by many problems due to advancing age, disability, and ill health. The role of stoma nurses is fundamental in the educational training both in the preoperative and postoperative time. Stoma education does not end after discharge from the hospital. Patients with stoma should be reassessed periodically and should be reviewed annually by a stoma nurse. Some patients, because of their conditions, need a long-term support from family, caretakers, or healthcare professionals in managing their stoma.

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21 Management of Acute Large Bowel Obstruction in Elderly Patients

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Abbreviations

CRC	Colorectal cancer
IBD	Inflammatory bowel disease
LBO	Large bowel obstruction
SBO	Small bowel obstruction

21.1 Pathophysiology of Large Bowel Obstruction in Geriatric Patients

21.1.1 Physiologic Alterations

Conventionally, “elderly” has been defined as a chronological age of 65 years old or older.

Globally, the population is aging and the World Health Organization (WHO) predicts that the number of people aged 60 years or older will rise from 900 million to 2 billion between 2015 and 2050 (moving from 12 to 22% of the total global population) [1].

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Poor nutritional status, chronic diseases, and physiological changes are a key determinant of morbidity and mortality in the elderly subjects [2, 3].

Bowel habit changes are common in elderly patients. Malnutrition and chronic primary constipation are frequent conditions of geriatric subjects and the result of age-related alterations in the gastrointestinal tract and psychological factors. Aging may affect the signal transduction pathways and cellular mechanisms controlling smooth muscle contraction contribute to the development of constipation. In geriatric subjects, the number of neurons in the plexus is reduced, especially in the myenteric plexus. There is also a reduction of the release of acetylcholine and nitric oxide (NO) synthesis that cut the levels of neuronal NO synthase (NOS) [4, 5]. These physiological changes associated with dysphagia, reduced food intake, limited physical activity, and other pathological conditions like endocrine and metabolic disorders, organic colorectal diseases, neurological and psychiatric affections contribute to the development of constipation and represent an important risk factor for LBO [6].

21.1.2 Pathophysiology of LBO

When an obstruction occurs the large bowel functions (water and electrolyte absorption, vitamins synthesis and absorption, bilirubin breakdown) are compromised. LBOs follow a slower course than SBOs. The obstruction of the right colon has a pathophysiological evolution similar to distal small bowel obstruction, the stool is less dense, and the lumen is bigger than descending and sigmoid colon where obstruction's signs and symptoms manifest earlier.

The early stage of LBO starts with gaseous distension of the colon and progressive increase of endoluminal pressure with normal blood electrolytes concentration, on this phase the colon maintains the absorption capacity of fluid and electrolytes. In the cecum, the distension is faster than other colic segments. This difference is associated with the largest diameter and the greater capacity of distension of the cecum with a lower increase of endoluminal pressure. The continence of the ileocecal valve also influences the speed of bowel dilatation, the ileocecal valve is competent in about 75% of subjects, and it leads to a closed-loop LBO without decompression into small bowel. In the 25% of patients with incontinence of ileocecal valve, the distension of small bowel may mimic a SBO with decompression into small bowel and subsequent distension of small intestine.

In the second stage, the partial or complete blockage of digested products in the proximal bowel leads to emesis onset. Frequent emesis and colon progressive distension with isotonic loss of water and electrolytes lead to hemoconcentration, electrolyte disorders (especially hyponatremia), decrease of CVP, and oliguria. Dehydration of as little as 2% of body weight, corresponding to ~3–5% reduction in total body water can result in impairment in physical and cognitive performances in elderly patients.

The colon has the lowest blood flow of abdominal viscera and consequently it develops a faster and earlier damage of the blood flow in the parietal vessel. At first, the ischemia interests the mucosa. Contemporary blood flow damage and increasing endoluminal pressure can cause perforation and bring to septic peritonitis, especially in intestinal segments with thin walls, like cecum.

A serious and life-threatening complication of LBO is strangulation. Strangulation is more commonly seen in closed-loop obstructions. Without a prompt treatment, the strangulated bowel becomes ischemic and tissue infarction occurs. Tissue infarction progresses to bowel necrosis, and in case of perforation to septic shock [7–10].

21.2 Etiology

LBO etiology can be classified in neoplastic and nonneoplastic pathologies (Table 21.1).

Neoplastic LBO is mostly associated with colorectal cancer (CRC). CRC is the most common cause in elderly patients in about 60% of cases and in approximately 7–29% of cases LBO is the initial presentation of colorectal cancer. Sigmoid colon is the most common site of LBO caused by colorectal cancer [13–17].

Extracolonic malignances can extrinsically compress the bowel resulting in obstruction. Neoplasms can lead to LBO through direct invasion (NET, GIST, gastric, pancreatic, genitourinary cancers), hematogenous, or lymphatic metastasis and intraperitoneal seeding (carcinomatosis) [18].

Diverticulitis and volvulus are the most common nonneoplastic causes of LBOs, respectively in 10% and 10–15% of cases.

Diverticulitis can cause obstruction through fibrosis, adherence, and compression by intramural or extramural abscess [19].

The sigmoid colon is the most common site of colonic volvulus in about 60–75% of all cases of colonic volvulus.

Table 21.1 Causes of LBO in geriatric patients [7, 11, 12]

LBO common cause (>95%)	
Colorectal cancer	60–80%
Volvulus	10–15%
Diverticulitis	10%
LBO uncommon cause (<5%)	
Extra colonic neoplasms	<1%
Adherence	1%
IBD	<1%
Abdominal wall hernia	<1%
Fecal impaction	1%
Intraluminal foreign body	<1%
Enterolith	<1%
Intussusception	<1%
Toxic megacolon	<1%
Ogilvie's syndrome	<1%
Gallstones	<1%
Strictures	<1%
Internal hernia	<1%

Cecal volvulus is responsible for 1% of all adult intestinal obstructions and nearly 25–30% of all cases of colonic volvulus [18–20].

Fecal impact is a common finding in geriatric patients, the absence of any treatment rarely can lead to LBO that is secondary to ischemic pressure necrosis caused by a stercoraceous mass. IBD rarely can cause LBO with adhesions or strictures formation, commonly caused by persistent inflammation [21, 22].

21.3 Evaluation of Large Bowel Obstruction in Geriatric Patients

21.3.1 Geriatric Patient's Assessment

Geriatric patient's physical exam could be difficult to achieve due to comorbidities and psychological diseases of the elderly. The lack of cooperation itself can be an important indication of an underlying medical problem. Comorbidities such as stroke and dementia can result in communication difficulties. Presenting symptoms of geriatric subjects are subtler than youngers. Initially, it is important to recognize the comorbidities, especially psychosocial disorders and specific geriatric conditions such as dementia, falls, or functional disability. Physical examination must include an immediate evaluation of vital signs. Signs of hypovolemic or septic shock must be evaluated (tachycardia, tachypnea, hypotension, obtund or abnormal mental status, cold, clammy extremities, mottled or cyanotic skin, dizziness, weakness, apathy, oliguria, metabolic acidosis, and hyperlactatemia). To identify patients at high risk of mortality due to sepsis qSOFA is used.

Personal history about last defecation, chronic constipation and use of laxatives, abrupt onset of symptoms, previous abdominal surgery, or previous diverticulitis episodes may be diagnostically significant. LBO causes a wide range of uncomfortable symptoms. Typical presentation of LBO includes abdominal pain, distension, nausea, vomiting, and constipation-obstipation. Some symptoms may depend on the location and length of time of the obstruction. Sigmoid volvulus is common in elderly, immobile patients. Volvulus should be suspected in patients with painless and gross abdominal distension.

Pain is usually colicky and poorly localized due to visceral distention of the intestine. Intermittent abdominal pain is typical in the early stage due to increased bowel motility, after this stage the peristalsis reduction leads to a typical continuous pain. LBO's emesis is less frequent than in SBO, it is intermittent and feculent when present.

Abdominal tenderness and distension are the most common signs of LBO. Tenderness is more diffuse than in SBO. Peritonism is associated with bowel ischemia and/or perforation. Distention is marked in LBO with obstipation. An incompetent ileocecal valve producing symptoms similar to the SBO. Bowel sounds can be hyperactive or absent. Abdominal hernias and surgical incision must be examined. Digital rectal examination is important to evaluate active bleeding or the presence of a rectal mass.

Clinical findings of high fever, severe abdominal tenderness, rebound tenderness, severe leukocytosis, suggest possible complications of bowel obstruction with necrosis, bowel perforation, or generalized peritonitis [23–27].

21.3.2 Diagnostic Tests

21.3.2.1 Plain Abdominal Radiography

Abdominal radiography normally is the first diagnostic test in suspected LBO. The examination should include supine and nondependent (upright or left lateral decubitus) radiographs. Abdominal radiographic findings present a diagnostic value in 50–60% of the cases, indifferent in 20–30%, and misleading in 10–20% of patients. The sensitivity and specificity of plain abdominal x-ray for the detection of LBO are respectively of 84% and 72%. Plain radiograph in LBO is potentially useful to evaluate colonic distension, the colon is dilated proximal to the site of obstruction with absence of gas distal to the obstruction (normal colonic caliber ranges from 3 to 8 cm, the colon and the cecum are dilated when the diameter is greater than 6 cm and 9 cm, respectively). Eventual small bowel distension is noted in case of incompetent ileocecal valve. When bowel ischemia or perforation are suspected abdominal x-ray can show intramural gas, pneumoperitoneum, and portal venous gas [28–31] (Fig. 21.1).

21.3.2.2 Contrast Enema

The water-soluble contrast enema usually allows easy distinction between a LBO and colon pseudo-obstruction. Contrast enema can detect the obstruction site and the transition point where colon is dilated. The water-soluble contrast enema sensitivity and specificity are respectively of 96% and 98%. The water-soluble contrast

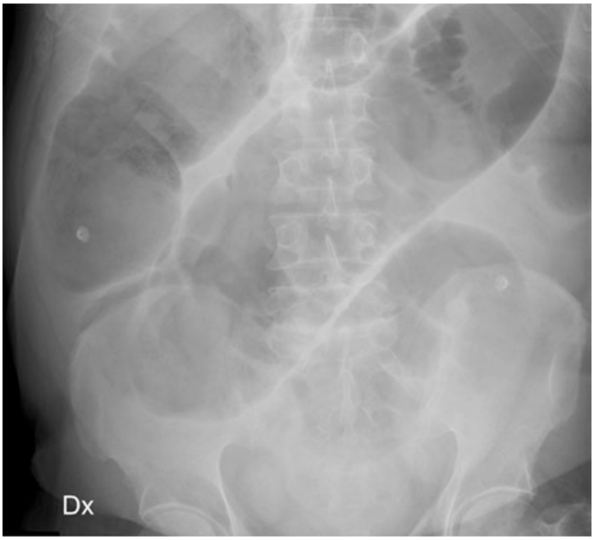

Fig. 21.1 Case courtesy of Emergency Surgery Department, Parma University Hospital, Parma, Italy

material does not cause artifacts on CT scan. In elderly patients, the examination may be an insufficient diagnostic tool due to the difficulty of geriatric patients to be able to rotate on the fluoroscopy table to accomplish the evaluation of the colon [32].

21.3.2.3 Ultrasound

Ultrasound is a noninvasive exam, it can evaluate the obstruction distinguishing mechanical or functional bowel obstruction. Ultrasound and Doppler sonography can detect bowel wall thickness (>4 mm) and perfusion, decreased or absent peristalsis, the presence of free intraperitoneal air and fluid. In conservative treatment, ultrasound is useful to evaluate the progress of LBO [33–35].

21.3.2.4 Computed Tomography Scan

CT with intravenous contrast is the gold standard for the diagnosis of the cause of CT has a superior accuracy than ultrasound and abdominal radiography. CT has a sensitivity and specificity of 96% and 93%, respectively. CT studies intraluminal, mural, and extramural causes of LBO. CT can detect the presence of a mass, signs of inflammation and bowel wall ischemia, or perforation and peritonitis. In colorectal cancers LBO can evaluate the local or regional metastasis. Despite other diagnostic tests abdominal CT can evaluate clinical findings severity and manage the right treatment option [34–36] (Fig. 21.2a, b).

21.3.2.5 Colonoscopy

Colonoscopy in elderly patients can manage diagnosis and treatment. In the absence of clinical, laboratory or radiological signs of bowel necrosis, perforation or peritonitis, diagnostic, and therapeutic colonoscopy is increasing in indications and possibilities. Colonoscopy can lead to a possible diagnosis in case of suspected

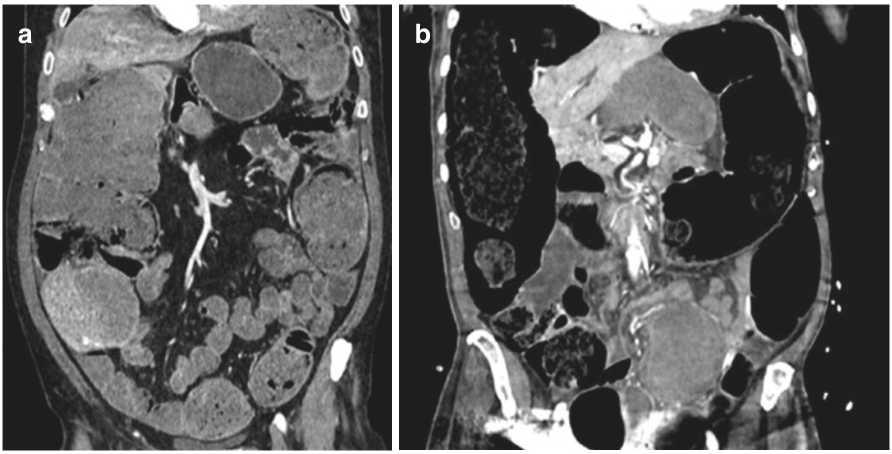

Fig. 21.2 (**a**, **b**) Case of sigmoid volvulus, courtesy of Emergency Surgery Department, Parma University Hospital, Parma, Italy

malignancy, IBD, volvulus, Ogilvie's syndrome, fecal impact or can exclude an unnecessary surgery. When a LBO is suspected carbon dioxide insufflation is preferable to conventional air insufflation due to the faster capacity of the colon to absorption CO2 reducing the risk of bowel ischemia. In elderly patient colonoscopy also can be a definite therapy in 8% of cases avoiding surgery [37, 38].

21.4 Therapy

21.4.1 Initial Management

Initial management must consider the physical status of patients and includes: full blood count, creatinine and electrolytes, liver function tests, amylase, glucose, C-reactive protein (CRP), coagulation profile blood group, ECG, arterial blood gas sample including lactate, placement of urinary catheter, adequate intravenous access, arterial line, CVP monitoring, fluid balance monitoring, vital sign monitoring every 3 h in stable patients, and continuous monitoring of vital signs in critical patients.

Supportive treatment must begin as soon as possible to control symptoms, fluid, and electrolyte loss (hyponatremia) through nasogastric suction, intravenous crystalloids, anti-emetics, and bowel rest. Appropriate preoperative broad-spectrum antibiotics should be considered.

Evaluation of hydration status in geriatric patients is fundamental. Geriatric patients with dehydration and electrolyte disorders are more fragile than youngers. Dehydration is a major predictor of morbidity and mortality causing physical and cognitive impairment with six times greater risk of in-hospital mortality. Dehydration may be a manifestation of disease severity. Iatrogenic overhydration can occur during the management of LBO, especially in renal and/or cardiac insufficiency and it is an independent risk factor for morbidity and mortality in elderly people (congestive heart failure, pulmonary edema, confusion, high blood pressure, and even death).

After appropriate and timely resuscitation, a prompt diagnosis of LBO causes is helpful to reduce delays in treatment. Appropriate preoperative risk assessment for elderly patients is crucial for correct treatment management. It is also important taking account of the patients' wishes and the avoidance of futile surgery. Surgical decision-making for geriatric patients with bowel obstruction is complex due to poor outcomes after emergency surgical intervention and high postoperative complication and mortality rates [39–42].

21.4.2 Nonsurgical Treatment

Conservative treatment should be performed in case of uncomplicated LBO in absence of symptoms and signs of hypovolemic or septic shock or LBO complications (bowel ischemia and necrosis, peritonitis). Conservative management of intestinal obstruction is mandatory in order to avoid unnecessary surgery and unexpected complications due to comorbidities.

The management of LBO with a conservative treatment depends on the etiology and severity of the obstruction. Stable patients with partial or low-grade obstruction resolve with nasogastric tube decompression and supportive measures.

Prompt manual reduction of hernias should always be performed and elective surgery after acute LBO should be considered to prevent new episodes of LBO. Emergency surgery is needed for unsuccessful reductions.

Water-soluble contrast should be initially administrated in LBOs caused by uncomplicated adherences and intussusceptions. Gastrografin can be used for both diagnostic and therapeutic purposes, it is hypertonic and draws fluid from the bowel wall into the lumen, decreasing bowel wall edema and stimulating peristalsis.

Uncomplicated sigmoid colon volvulus benefits of endoscopic decompression and derotation. Nonoperative treatment is successful in 70–91% of cases, with reported complication rates of 2–4.7% in geriatric patients.

In neoplastic obstruction of the colon endoscopic colonic stents have been proposed for palliation or as a bridge to surgery due to a better short-term outcome than emergency surgery.

Diverticular LBO usually is the result of multiple attacks of diverticulitis with marked fibrosis and strictures formation on the colon walls, conservative treatment resolves the obstruction, in the presence of pericolic abscess percutaneous drainage can be performed.

In IBD, colonic obstruction conservative treatment starts with anti-inflammatory medications and high-dose steroids, but fibrotic strictures are often refractory to medical treatment and one or more endoscopic dilatations of strictures are required with a reported success rate between 70% and 90%.

Fecal impaction treatment includes digital manipulation, enema instillation.

Uncomplicated acute colonic pseudo-obstruction is treated with neostigmine or colonoscopic decompression [43–46].

21.4.3 Surgical Treatment

Surgery should be performed only in selected cases. When conservative treatment fails, or complicated LBO is presented with signs of bowel ischemia, perforation, peritonitis, and abdominal sepsis surgery should be considered. The perfect timing to perform nonoperative treatment before surgery is lacking, especially in geriatric patients. A wrong treatment timing can result in deterioration, development of adverse events, and poor outcome. Correct timing for surgery is considered 24–48 h after hospital admission and conservative treatment. Realistic risk prediction and identification of frailty are essential to consider surgery as a treatment option [47, 48].

In presence of sepsis, peritonitis, perforation, and bowel ischemia emergency laparotomy is necessary to control the cause, surgery in elderly patients should be performed following the criteria of damage control surgery to mitigate the negative downstream effects of physiologic insults seen preoperatively. The goal of rapid source control laparotomy is the restoration of physiologic normality and homeostasis [49].

Abdominal wall hernia surgery with prosthetic repair is the treatment of choice, but in presence of contaminated surgical field (perforation, bowel resections) suture repair is preferred for the risk of mesh infection [50].

Treatment of cecal volvulus involves operative reduction of the twist and cecopexy is preferred in elderly patients instead of right colon resection. After endoscopic decompression and derotation of sigmoid colon, volvulus fail sigmoidopexy should be performed instead of colon resection [51, 52].

Diverticular LBOs in elderly patients should be managed conservatively and surgery should be performed only in case of worsening conditions with Hartmann procedure performed in high-risk patients.

Colorectal cancer bowel obstruction surgery should be performed only after endoscopic dilatation or stenting fail or after clinical stabilization with oncological laparoscopic or laparotomic resection. When emergency laparotomy is required formal resection with or without anastomosis, with or without stoma can be performed. In case of severe clinical conditions in left colon cancer, Hartmann's procedure or loop colostomy should be performed. In right colon cancer right colectomy with terminal ileostomy should be considered as the procedure of choice. Severely unstable patients should be treated with a loop ileostomy [53].

21.5 Conclusion

While nonoperative resolution of LBO in elderly patients is ideal, waiting too long may lead to poor outcomes. In uncomplicated LBOs conservative treatment should be always performed. Complicated LBOs need immediate treatment and damage control surgery is the most recommended treatment to control severe complications of LBO like perforation and sepsis in elderly patients. The goal of this procedure consists of restoring physiologic normality and reduces mortality.

"When treating patients in the later years of life, our focus must shift from maximizing survival to maximizing also the quality of life, dignity, and minimizing suffering." [54].

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22 Acute Appendicitis in Elderly: Presentation, Diagnosis, and Treatment

Shahin Mohseni

22.1 Background

Acute appendicitis is one of the most common abdominal surgical emergencies with a lifetime incidence of 7% with a peak incidence between the ages of 10 and 30. Only 5–10% of all appendectomies are performed in the elderly (> 65 years of age) at the time of writing [1–6]. However, population aging is likely to lead to an increased incidence of appendicitis in the elderly population. The liberal use of advanced imaging in this population may also increase the number of patients with a radiological diagnosis of appendicitis of whom some may have resolution of symptoms without appendectomy or may never progress to clinical appendicitis [7–9].

Elderly patients present with perforated appendicitis and abdominal sepsis more often than younger patients [3, 10–12], and also have higher morbidity and mortality rates [5, 13]. Mortality ranges from less than 1% in the general population to 4–8% in the elderly [14–17]. It is well-accepted that emergency surgery in the average elderly patient is likely to lead to higher morbidity and mortality than in younger patients as a consequence of advanced age, increased burden of medical comorbidity, and a loss of physiological reserves. This is shown by the fact that elderly patients account for a greater proportion of hospital costs associated with appendectomies, despite accounting for only 10% of procedures. The need for more complex surgical procedures, a higher incidence of postoperative complications, and longer average hospital stay could explain the higher costs after appendectomy in the elderly population [4]. Therefore, timely diagnosis and treatment are of paramount importance for the best possible outcome in the elderly patient with appendicitis.

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22.2 Clinical Presentation and Diagnosis

Acute abdominal pain is one of the most common symptoms in elderly patients presenting to the emergency departments in the United States [18]. The evaluation of abdominal pain in this patient population is especially challenging since there is a higher prevalence of comorbidities and multi-pharmacy, both of which can give unreliable vital signs and laboratory values; and a higher likelihood of life-threatening pathology that must be taken into account or ruled out at the time of investigation and diagnosis [19–23].

Appendicitis in the elderly is commonly associated with a delayed diagnosis due to atypical presentation, communication difficulties, unreliable physical examinations, and laboratory values. This delay leads to higher rates of perforation and increased risk of morbidity and mortality [11, 12, 19]. Compared to the general population, the rate of perforation is almost double in the elderly, who present with perforated appendicitis in up to 50% of cases [3, 4, 11, 12, 24]. Although the delay in seeking healthcare services remains one of the major risk factors for perforation in elderly patients, a combination of misdiagnosis and delay in surgical intervention also contribute to this finding [12]. The combination of the specific signs for acute appendicitis consisting of lower abdominal pain with tenderness, fever, and leukocytosis is reported in as few as 26% of patients over the age of 60 who have appendicitis [12, 25, 26]. In a cohort of 214 elderly patients (defined as >60 years of age) with appendicitis, Omari et al. reported a perforation rate of 41%. Patients with perforated appendicitis had a significantly longer prehospital delay (79.6 ± 62.4 vs. 47.3 ± 43.7 h, $p < 0.001$). A history of the classical migratory pain was given in 47% of cases. Eighty-four percent of patients had localized right lower quadrant abdominal tenderness on exam. Only 41% of the cohort had a fever (>38 °C), the majority of which were in the perforated group. White cell count was elevated in 63% of the total cohort [24]. These findings are supported by several other studies [12, 27] and leads to the fact that the widely used and validated scoring systems, such as the Alvarado score, should be utilized with higher suspicion when screening elderly patients for the diagnosis of appendicitis [28].

Combining appropriate imaging with history, physical examination and laboratory tests are crucial to achieve the correct diagnosis of the underlying cause of abdominal pain in the elderly. The importance of early and liberal imaging in the elderly population with undifferentiated abdominal pain is stressed in Emergency Medicine literature [29]. CT imaging has been shown to alter decision-making in elderly patients and increase the diagnostic confidence of emergency physicians [8, 9, 30]. In a study by Esses and colleagues, abdominal CT in elderly patients with acute abdominal pain altered the admission decision in 26% of cases (95% CI: 18–34%); the decision of whether or not to operate in 12% of cases (95% CI: 6–18%); the decision to administer antibiotics in 21% of cases (95% CI: 13–29%); and the suspected diagnosis in 45% of cases (95% CI 35–55%) [8]. Similarly, Miller et al. concluded that a CT exam of the elderly with acute abdominal pain influenced surgical decision-making heavily [9]. Storm-Dickerson and colleagues reported a decline in the incidence of perforated appendicitis from 72 to 51% over a 20-year period and the authors attributed this finding to earlier use of CT in elderly patients with abdominal pain [12]. The routine use of IV contrast to enhance the accuracy of CT for the diagnosis of appendicitis is encouraged, since, with this modality, other causes of abdominal pain can either be diagnosed or ruled out [31]. CT scans in elderly patients with abdominal pain does not only aid early diagnosis of appendicitis, but it may also reduce negative appendectomies. Both the sensitivity and specificity of CT in detecting appendicitis in adults is high and consistent among centers compared to ultrasonography [32]. Further, ultrasonography does not exclude other causes of abdominal pain in the elderly population where other pathology must be considered [9, 20]. For these reasons, the use of abdominal ultrasonography in elderly patients with abdominal pain is not recommended.

22.3 Open Versus Laparoscopic Appendectomy

Since its introduction in 1983 by Semm [33], the use of laparoscopic appendectomy has been contentious. Due to its advantages compared to the open surgical approach, the laparoscopic approach has gained more acceptance in clinical settings. Advantages include better navigation and visualization of the intra-abdominal space, decreased postoperative pain, shorter hospital length of stay, faster recovery and return to normal activities, and better cosmetic appearance [11, 34]. However, there have been some concerns with laparoscopic appendectomy. Several studies have reported a higher incidence of intra-abdominal abscesses for laparoscopic appendectomy, compared to open surgery [35]. This adverse finding seems to be decreasing or even to have become reversed during the last decade [36], and some studies suggest it might be associated with surgical expertise [37]. A cumulative meta-analysis by Ukai and colleagues demonstrated that the risk of intra-abdominal abscesses associated with laparoscopic appendectomy disappeared in studies published after 2001 [38]. A more important measure than the surgical approach in decreasing the risk of postoperative deep and superficial infections is the timely initiation of prophylactic antibiotics. In a meta-analysis comparing the use of antibiotics to placebo including 9576 appendectomies from 45 studies, Andersen and colleagues found that withholding antibiotics increased the risk of both deep and superficial infections in patients with acute uncomplicated, gangrenous, or perforated appendicitis. However, they were unable to determine the optimal antibiotic, dosage, and duration of administration [39]. These findings advocate for early initiation of prophylactic antibiotics in patients scheduled for appendectomy. Longer operative time and higher operative costs have also been raised as concerns for the laparoscopic approach. However, a recent meta-analysis demonstrated that laparoscopic appendectomy is associated with decreased postoperative pain, shorter hospital admission, earlier return to physical activity, and to the workplace [40]. The laparoscopic approach can, therefore, lead to an overall cost reduction for both hospitals and society as a whole [37].

The increased use of laparoscopic surgery is also seen in the elderly. Using the Nationwide Inpatient Sample database, Guller et al. reported only 15.6% of all appendectomies in the elderly were performed using laparoscopy between 1998 and 2000 [41]. Analyzing the same database for the years of 2006 to 2008, Masoomi and colleagues found a significant increase of laparoscopic appendectomy in the elderly: overall, 52% of all appendectomies were performed laparoscopically with even a higher rate (61.9%) performed in the non-perforated subgroup. Interestingly, the utilization of the laparoscopic approach increased within the two-year study period by 24%, from 46.5% in 2006 to 57.8% in 2008 [11]. The same advantages of laparoscopic appendectomies have been shown in elderly patients as in the general population. In a study conducted by Ward and colleagues including over 250,000 appendectomies in patients 65 years and older, the authors found a significant decrease in postoperative morbidity and mortality with shorter hospital stay in patients who were operated on laparoscopically [42]. In a recent meta-analysis by Wang et al., including 12 studies with a total of 126,237 patients in the laparoscopy group and 213,201 patients in the open surgery group, the same positive findings could be detected [43]. In this elderly study population, laparoscopic appendectomy was associated with fewer postoperative complications (Odds Ratio [OR]: 0.65, 95% CI: 0.62–0.67), mortality (OR: 0.33, 95% CI: 0.28–0.39), and shorter hospital stay (Mean Days: −2.72, 95% CI: −3.31 to −2.13). There was no significant difference in the risk of intra-abdominal abscess development (OR: 0.44, 95% CI: 0.19–1.03). However, laparoscopic appendectomy was associated with a decreased risk of superficial wound infections (OR: 0.27, 95% CI: 0.22–0.32) [43]. More importantly, comorbid elderly patients and those with complicated appendicitis seem to benefit more from laparoscopic appendectomy compared to the open approach with decreased postoperative complications, mortality, and hospital length of stay [44–46]. In a cohort of 32,680, elderly patients with perforated appendicitis where 13,765 (42.1%) underwent laparoscopic appendectomy and 18,915 (57.9%) open surgery and appendectomy, laparoscopic appendectomy was associated with lower overall complication rates (36.3% vs. 46.9%, $p < 0.01$), in-hospital mortality (1.4 vs. 2.6%, $p < 0.01$), shorter hospital length of stay (5.8 vs. 8.7 days, $p < 0.01$), and lower hospital charges (mean cost: $43,339 vs. $57,943, $p < 0.01$) [11]. After adjusting for differences in patient characteristics, comorbidities, and type of appendicitis, the laparoscopic approach remained associated with decreased risk of overall complication rate (adjusted OR [AOR] 0.67; 95% CI: 0.67–0.73; $p < 0.01$), in-hospital mortality (AOR 0.53; 95% CI: 0.45–0.62; $p < 0.01$), and shorter hospital stay (AOR 0.39; 95% CI: 0.37–0.41; $p < 0.01$). Also, all of the evaluated complications were lower in the laparoscopically operated group, except urinary tract infection and pulmonary emboli, but no statistically significant difference was found between the groups [11].

Finally, with the obesity epidemic seen in recent decades, more elderly patients with appendicitis will inevitably be obese (BMI > 30). The advantages seen with the laparoscopic approach is even more pronounced in obese patients [47]. Hence, this approach should be the first choice in elderly obese patient with appendicitis.

22.4 Antibiotic Treatment "Only"

During the previous decade, there has been an increased interest in the nonoperative treatment for uncomplicated appendicitis which has led to several investigators looking at the possibility of antibiotic treatment instead of surgery [48]. Despite the lack of consensus about which patients should be offered such treatment, the preferred antibiotic regime, the route of administration, and the length of antibiotic treatment, such therapy for uncomplicated acute appendicitis has been introduced in several practices over the world.

The APPAC (Antibiotic Therapy versus Appendectomy for Treatment of Uncomplicated Acute Appendicitis) trial, randomized 273 patients to appendectomy and 257 patients to antibiotic treatment for CT-verified uncomplicated appendicitis. The recurrence rate with subsequent appendectomy at 1-year follow-up was 27% in the antibiotic group [49]. At 5-year follow-up, the authors found that 39.1% of patients among those who had been treated initially with antibiotics for their acute appendicitis had been subjected to an appendectomy [50]. The result of the APPAC trial is in line with previous studies. Varadhan et al. performed a meta-analysis including four randomized controlled trials with a total of 900 patients, 470 in the antibiotic treatment arm and 430 in the appendectomy arm, respectively. The failure rate during the follow-up periods was 47% in patients who had received antibiotic treatment for their acute appendicitis with subsequent appendectomy [48]. In the cohort of patients initially treated with antibiotics up to 20% were operated on due to complicated appendicitis, i.e., perforated or gangrenous, giving an overall risk of 7.4% for complicated appendicitis following the nonoperative approach [48].

In a review on the subject by Flum published in the New England Journal of Medicine, the author concludes that appendectomy should be considered as the first-line therapy in uncomplicated appendicitis and recommended as such to the patient [51]. Further, the author suggests that in patients with the equivocal clinical picture, or equivocal imaging, or in those who have strong preferences for avoiding an operation, or those with major comorbid medical problems where general anesthesia or surgery is contraindicated, it is reasonable to treat with antibiotics first [51]. One would argue that this statement has always been the practice of most surgeons.

Finally, the cost-benefit of antibiotic treatment only for uncomplicated acute appendicitis has also to be considered when discussing treatment options both with patients and in medical societies. Sceats et al. reported that nonoperative management in a cohort of 2620 patients (4.5% of the study cohort) was associated with higher rates of abscess, readmission, and higher overall cost of care [52]. This is not supervising since up to 40% of patients treated with antibiotics had a subsequent appendectomy which means re-seeking healthcare providers, repeated clinical exams, tests, advanced imaging, and finally surgery [53].

The abovementioned findings should be interpreted also in light of the fact that the mean age of all study populations was significantly lower than what is considered elderly or geriatric age. The high incidence of recurrence, with the known increased risk of perforation in elderly patients, and the lack of studies specifically investigating the antibiotic treatment "only" in the geriatric population makes appendectomy the first choice in these instances if no absolute contraindication to general anesthesia or surgery exists.

22.5 Interval Appendectomy

For perforated appendicitis with abscess, i.e., complicated appendicitis, nonoperative management with antibiotic treatment with or without percutaneous drainage has been accepted as the first-line of treatment. A meta-analysis by Simillis et al. including 17 studies (one randomized prospective and 16 retrospective) with a total of 1572 patients where 725 (46%) had the same index admission appendectomy, revealed that nonoperative management was associated with significantly less complications. No significant differences were found in the duration of the first hospitalization, the overall hospital stay, and the duration of intravenous antibiotic use between groups [54].

Although the overall risk of appendiceal malignancy is low, the risk progressively increases after the age of 40 years and has been associated with perforated appendicitis [55–57]. Colonic screening should be performed in elderly patient where nonoperative management has been undertaken for complicated appendicitis [58]. However, the role of interval appendectomy after nonoperative management for complicated appendicitis is yet to be settled. Although the Eastern Trauma Association made a conditional recommendation against interval appendectomy in their Guidelines from 2019 [59], they do acknowledge the increased risk for appendiceal neoplasm associated with increased age and they state that "the decision to proceed with interval appendectomy versus surveillance testing or watchful waiting should be thoroughly discussed with the patient, keeping in mind the patient's age and potential for perioperative complications with interval appendectomy." The World Society of Emergency Surgery Guidelines makes the same recommendation against routine interval appendectomy. However, they state that in cases where recurrent symptoms are present interval appendectomy should be performed. The authors do, however, not specify the symptoms in any great detail [58]. Based on the data available today, the decision for interval appendectomy after complicated appendicitis in the elderly patient should be individualized.

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23 Damage Control and Open Abdomen in the Elderly

Joshua Klein and Rifat Latifi

23.1 Introduction

Since first being described in 1983, Damage Control Laparotomy, which has since been adapted into Damage Control Surgery (DCS) over the subsequent decades, has become an integral component of general and trauma surgery [1]. The principals applied in DCS prioritize not only control of hemorrhage and intra-abdominal contamination, but also the correction of metabolic derangements that comprise the lethal triad of hypothermia, metabolic acidosis, and coagulopathy, over the definitive operative repair. Damage control concepts have been part of our clinical armamentarium in trauma for decades, but in recent decades DCS has expanded into other surgical disciplines, including: emergency general surgery, neurosurgery (craniectomies), orthopedics surgery (particularly for trauma), thoracic surgery, vascular surgery, and liver transplant surgery. DCS is characterized by termination of surgical intervention after control of bleeding and contamination, followed by continued hemostatic resuscitation and subsequent definitive management delayed until the patient has met endpoints of resuscitation. It is a staged approach that takes into consideration the physiologic reserves of the patient, and it is designed to avoid or treat the lethal triad of hypothermia, acidosis, and coagulopathy. The decision to perform DCS is complex and takes into account associated injuries and comorbid conditions. Moreover, it takes complete situational awareness regarding the patient's physiology and resuscitative endpoints, and demands decisive decision-making in conjunction with coordinated surgical team dynamics that of course include anesthesia team.

With the aging population, there is an increasing number of patients over the age of 65 who undergo DCS every year. With aging, there are physiologic changes that occur throughout the body that must be taken into account when managing these

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patients. Both the stress of surgery and surgical complications can push an already diminished physiologic reserve past its limits. Increasing age has been directly correlated with higher mortality rates in the adult surgical patient population [2]. Understanding the implications of these physiologic changes can not only allow for the surgeon to tailor management on an individual basis, but can additionally assist in conversations with the patient and family regarding realistic expectations and potential outcomes.

23.2 Open Abdomen

While first introduced in the 1940s, the concept of open abdomen began to gain traction several decades later with studies looking at open abdomen as an option for trauma patients and patients with generalized peritonitis [3]. These early studies noted both a high morbidity and mortality rate, with some series having mortality rates that exceeded 50% [4]. Complications of excessive fluid loss, evisceration, fistulization, intra-abdominal contamination, and inability to subsequently re-approximate the fascia were routinely seen in these patients; therefore, leaving an open abdomen was only performed when all other options were exhausted. Nonetheless, DCS has seen a rise in recent years, despite a warning that this technique is overused, and significantly to the overall cost [5]. As surgical techniques and surgical technology evolved, the indications for open abdomen have broadened. A recent international study on open abdomen (OA) performed by the World Society of Emergency Surgery (WSES) and the Pan-American Trauma Society (PTS) found that out of 649 adult patients with OA, 58 (8.9%) developed entero-atmospheric fistula (EAF). The study's overall mortality rate was 29.7%, with EAF having no impact on mortality [6]. The need for high-quality studies is best demonstrated in another systematic review and meta-analysis of the open abdomen and temporary abdominal closure techniques in non-trauma patients, with a total of 4358 patients, of which 3461 (79%) had peritonitis. The conclusion from this study is that the overall quality of the available evidence is poor and thus prospective studies are badly needed [7].

23.3 Damage Control Surgery

One of the main indications for the open abdomen is after DCS following abdominal trauma or a major visceral catastrophe. While we do not have exact data on the frequency of DCS in the elderly following a visceral catastrophe, anecdotally we have seen this more in this group of patients than in trauma. In order to minimize physiologic derangements, an abbreviated surgery which aims to control hemorrhage and ongoing abdominal contamination is performed, with subsequent operations performed once the patient has been adequately resuscitated. For patients with the "lethal triad" of hypothermia, coagulopathy, and metabolic acidosis, the abbreviated surgery is mandatory. Once these metabolic derangements have become established, they become increasingly more difficult to correct [8, 9]. Age-related changes that are seen on structural, functional, and molecular levels lead to diminished physiologic reserve in the elderly patient. Injury and insults to the body which disrupt normal homeostasis can be amplified in the elderly thus leading to profound morbidity and increased mortality that may not be seen in a younger patient population with similar injuries [10].

DCS is oftentimes incorrectly interchangeably used with the term damage control resuscitation. In practice however, while different, they are routinely used in conjunction with one another and are integral principals in the management of trauma patients. Damage control resuscitation emphasizes strategies that focus on minimizing and correcting the lethal triad. Early rewarming, correction of coagulopathy, and the use of blood to prevent hypotension begin in the prehospital care setting. While resuscitative measures have improved over the last two three decades, ongoing hemorrhage and intra-abdominal contamination can worsen a patient's coagulopathy and acidosis which ultimately leads to further bleeding and physiologic consequences. Resuscitative measures are continued upon arrival to the trauma department and rapid assessment including treatment of any immediate life-threatening injuries are performed. Large bore intravenous lines and intubation can additionally be performed in the trauma department with the goal of transporting the patient to the operating room in an expeditious fashion.

Implementation of DCS should be a decision that is made early on in the management of the trauma patient, with several variables precipitating this surgical approach. Most of us agree that hemodynamic instability, hypothermia (<35 °C), coagulopathy, severe metabolic acidosis (pH < 7.2 or base deficit >8), multiple injuries, massive transfusion requirements (>10 units packed red blood cells), and long operative time (>90 min) for trauma or emergency are basic indications for abbreviating the procedure and proceeding with some sort of temporary abdominal closure [11].

DCS in the elderly is not any different from DCS in younger patients. Priorities are the same. Pack the abdomen quickly, control any ongoing hemorrhage and contamination, and perform definitive surgery if you can as the physiology of the patient allows. Blood vessels that have ongoing hemorrhage should be rapidly managed with isolation followed by subsequent repair, ligation, or temporary shunt. There should be no attempt at a complex repair with interposition graft placement as these repairs are time-consuming leading to further physiologic consequences in the hypothermic, coagulopathic patient. Contamination is managed by stapling, ligation, or single-layer suture closure of the bowel injury. Attempts at reestablishing gastrointestinal continuity or creation of an ostomy should be managed at future operations. If you decide to perform abbreviated surgery, temporary abdominal closure of the abdomen should be performed and the patient should be brought to the intensive care unit to continue resuscitation, with plan to bring the patients to OR as soon as possible for definitive surgery and definitive closure.

Following the initial operation, the primary goal in the intensive care unit should be restoration of a normal physiologic state. Even with surviving the index operation, trauma patients and those who survived visceral catastrophe are at high risk of developing multiple organ dysfunction syndrome or even death. The use of traditional markers of resuscitation is not enough, and true resuscitation is not completed until there is no longer an oxygen debt and the tissue acidosis has cleared. Patients with normal vital signs and adequate urine output may still be in a state of compensated shock—this can progress to rapid clinical deterioration, especially in elderly patients with minimal physiologic reserve [12]. One thing that we surgeons have to remember is that often, until the final and definitive surgery is performed, it is difficult to achieve full resuscitation.

Since standard hemodynamic parameters will not fully reveal the degree of physiologic derangements in trauma patients, measurements of base deficit, arterial lactate, and pH have been investigated. Initial levels obtained in the trauma bay can be used for prognostication and it has been shown that time to normalization of these measurements is predictive of overall survival [13]. Additional parameters including right ventricular end-diastolic volume index and measurements of tissue O_2 and CO_2 concentrations have been examined; however, have not been universally accepted as metabolic endpoints of resuscitation [14].

Once resuscitative endpoints have been met, even partially, or if the patients do not progress as expected, need to be brought back to the operating room for another look or definitive surgery must be reassessed. In many cases, when we return to the operating room, for whatever reason, one should remember to place definitive feeding access through placement of a gastrostomy tube or gastro-jejunal feeding tube. During this stage of the management, it is also important to determine whether or not it is safe to close the abdomen. While fascial closure should be performed as soon as possible, a temporary abdominal closure may need to be performed as bowel edema and mobilization of interstitial fluids may preclude closure during the second operation.

23.4 Intra-Abdominal Hypertension and Abdominal Compartment Syndrome

While trauma patients are certainly at a high risk for intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS), other patient populations have risk factors which predispose them to IAH and ACS and would benefit from an open abdomen. Diagnosing the IAH and treating expeditiously is the first line of action [15, 16].

IAH has significant effects on all organ systems, with manifestations of end-organ injury and failure being seen once the patient has progressed to ACS. Increased intra-abdominal pressures have direct effects on the cardiopulmonary and renal function of patients. In elderly patients with comorbid conditions, not only can gastrointestinal and hepatic dysfunction occur, but further stress upon the heart and lungs can lead to cardiopulmonary collapse [17–19]. The 2013 World Society of the

Abdominal Compartment Syndrome guidelines recommends routine measurements of intra-abdominal pressure every 4–6 h when there are two or more risk factors present [20].

Any intra-abdominal and retroperitoneal fluid collections or abscesses may benefit from percutaneous drainage, and any large volume ascites that may be contributing to increased abdominal pressures should undergo a paracentesis. Lastly, adequate patient sedation and pain control are imperative in order to keep the abdomen sufficiently relaxed; patients may even require a neuromuscular blockade to allow for maximum relaxation of the abdominal wall. Patients with refractive intra-abdominal pressures that do not respond after implementation of these preventative strategies require a decompressive laparotomy.

23.4.1 Abdominal Sepsis and Pancreatitis

In cases of severe peritonitis leading to abdominal sepsis, the strategy of a staged surgical approach can be beneficial. While all age groups have the potential to progress from severe peritonitis to septic shock, advanced age is an independent risk factor for increased postoperative morbidity and mortality following emergency surgery [21]. Patients may clinically worsen throughout the initial surgical procedure which may require an abbreviated surgical approach. In these cases, there may be incomplete source control and/or inability to complete the definitive operation. A re-laparotomy should be planned once the patient has been appropriately resuscitated and stabilized in the intensive care unit. The application of open abdomen in these situations allows for not only an abbreviated surgical time, but can also act as a way to irrigate and drain the abdomen in order to better facilitate source control.

Patients with severe acute pancreatitis are at a higher risk of developing IAH and ACS. Upon hospital admission, patients with pancreatitis are often given large volumes of crystalloid fluid during resuscitation. With severe pancreatitis, there can be a significant capillary leak and associated visceral edema, as well as development of pancreatic ascites [22]. These fluid shifts will lead to an overall increased intra-abdominal pressure that needs to be taken into account. Once a patient with severe acute pancreatitis develops IAH there is an overall increased incidence of progressing to multisystem organ failure with associated increased ICU and hospital lengths of stay [23]. More on management of pancreatitis you can find in the Chapter on the management of pancreatitis in the elderly.

23.5 Vascular Catastrophes as Indication for FCS

Open abdomen has been successfully used following vascular emergencies. Patients with ruptured abdominal aortic aneurysms (AAA) have a significant likelihood of developing IAH and ACS, with studies showing upwards of 20% of patients developing ACS following surgical intervention [24]. Patients who develop ACS following a ruptured AAA have worse outcomes than their counterparts, with intestinal ischemia, renal failure, and acute myocardial infarction being the most common complications. ICU and hospital length of stay are noted to be significantly longer and the 30-day mortality among ruptured AAA patients is higher when ACS develops [25]. Even patients who undergo endovascular repair of a ruptured AAA have a risk of developing ACS; however, this is far less common than following open repair [26].

In patients with mesenteric ischemia, open abdomen may be necessary once perfusion has been restored. In cases where there is ischemic bowel that necessitates resection, the abdomen may be left open to facilitate a second look operation prior to performing a definitive anastomosis. Even in cases where there is no ischemic bowel, after perfusion is restored there may be significant bowel and visceral edema that will lead to increased intra-abdominal pressures.

23.6 Temporary Abdominal Closure Techniques

Various techniques and modalities have been described in the management of open abdomen. The goals of temporary abdominal closure (TAC) have evolved over the past two decades as new technologies have emerged. While abdominal visceral coverage is still a primary goal, the management of intra-abdominal fluids as well as the facilitation of fascial closure must be the main goals.

23.6.1 Skin-Only Closure

The simplest and most expeditious temporary closure involves a running suture to approximate the dermal and epidermal layers. This allows for the rapid closure of the abdomen in patients who are unstable or progressively becoming unstable during the operation. Once suggested as closure technique, towel clipping of the skin (Fig. 23.1) has been abandoned completely and should never be used.

Fig. 23.1 Towel clipping (Courtesy of Dr. Latifi)

23.6.2 Bogota Bag Closure

While first utilized in the 1980s by Oswaldo Borraez in Bogota, Columbia, but popularized Mattox in the 1990s, the silastic bag is another form of temporary closure [27]. Initially performed by suturing a 3 L irrigation bag to the fascia or skin, the technique has since been modified and can incorporate additional sheets, sterile towels, and irrigation/suction tubing. Other sterile bags such as X-Ray cassette covers can be utilized as well. The sterile bag should be cut in a fashion that will allow for coverage of the incision and abdominal viscera. Sterile towels can be placed over the irrigation bag in addition to drains, which can help with the management of fluid balance, prior to securing the temporary closure with an adherent plastic drape. Bag closure allows for easy inspection of the abdomen and can be replaced in a sterile fashion at bedside in the intensive care unit. We have not used the Bogota closure in our practice or a number of other fascial prostheses reported in the literature.

23.6.3 Additional Closure Techniques

While there have been a number of descriptions of TAC, many suggesting expensive wound VAC systems for the initial TAC, we use the so-called “poor man VAC.” If you expect to bring the patient back to the operating room within 12–24 h, do not use expensive VAC systems. Instead, you can cover the intestines with a sterile intestinal bag. A number of cuts on the bag need to be made to allow for fluid egression through the bag. Two Kerlix gauzes cover the intestinal bag and two to three drains are placed (usually JP # 10 or larger) between the gauzes which will exit the dressing superiorly, so they are easily able to be connected to wall suction. The gauze is covered with a sterile adhesive material and the drains are placed to low continuous wall suction.

On very rare occasions, or in patients with ongoing bowel edema, you may use mesh (Vicryl™) to isolate the viscera. The mesh can be sutured to the fascial edges in order to prevent lateral retraction of the aponeurosis and can be opened and reclosed in either the operating room or in a sterile intensive care setting. In situations where it is not possible to perform a delayed primary fascial closure, an absorbable mesh can facilitate granulation tissue and skin grafting. While temporary mesh closures have yielded high fascial closure rates, the incidence of fistula formation is increased compared to alternative techniques [28, 29].

Biologic graft closure is similar to mesh closure in the sense that the graft is sutured to the fascial edges, which provides coverage to the abdominal viscera as well as prevention of lateral retraction of the fascia; the difference lies in the composition as well as cost. Biological grafts are composed of an acellular dermal matrix that acts as a biologic scaffold for cell repopulation. These grafts derive their tissue from porcine, bovine, or human sources and can be cross-linked which inhibits the degradation of collagen [30]. If you use biologic mesh, a complex abdominal wall reconstruction (CAWR) should be performed. In our practice, open abdomen has been abandoned in certain circumstances and we will perform CAWR in the acute phase setting.

23.7 Negative Pressure Therapy

Initially designed for use in the treatment of superficial wounds, negative pressure therapy has evolved and has seen widespread use in the management of an open abdomen. Negative pressure therapy is frequently used in conjunction with the previously mentioned modalities and assists in keeping traction on the fascia and subcutaneous tissues with the goal of eventual abdominal closure. After temporary bag closure or temporary mesh closure, a VAC system can be applied overlying the previously placed bag or mesh (Fig. 23.2). In the combination closure utilizing

Fig. 23.2 Negative pressure wound therapy can assist with maintaining traction on fascia and subcutaneous tissues and has shown to have high rates of eventual fascial closure when used in conjunction with an additional temporary abdominal closure technique (Courtesy of Dr. Latifi)

negative pressure wound therapy, there are high rates of fascial closure with studies reporting between 76 and 100% success rates [31, 32].

23.8 Definitive Closure Post Damage Control

Throughout the management of the patient with an open abdomen, the end goal is always to achieve fascial closure with the least amount of tension possible. A detailed description of definitive abdominal wall reconstruction can be found in the chapter of abdominal wall reconstruction. The goal, as stated above, should be closure of fascia as soon as possible and avoidance of delayed skin closure with skin grafts. A large case series demonstrated that the best outcomes occur when the fascia is closed prior to day 8 following an open abdomen. There were noted to be less wound complications, fewer transfusion requirements, and significantly lower costs associated with the initial hospitalization [33]. Closure of the fascia should be performed with the least amount of tension in order to prevent IAH/ACS, fascial dehiscence, and subsequent ventral hernia.

When the decision is made that it is safe to close the patient's abdomen, several techniques can be employed to minimize tension if interrupted or continuous suture closure is not feasible. Component separation, a concept first introduced in the 1950s by Albanese, is a technique that utilizes muscle as an advancement flap [34]. Anterior or posterior component separation techniques can be utilized, and if there is still insufficient advancement of the flap towards the midline then a secondary component release can be performed. Anterior component separation is performed by incising the external oblique aponeurosis just lateral to the semilunar line from the costal margin to the inguinal ligament. Once dissected free from the underlying internal oblique muscle there can be as much as 10 cm of advancement gained on each side in the mid-abdomen. A secondary release, performed by dissecting the rectus muscle from its posterior sheath can add up to an additional 2 cm if there is still insufficient advancement. Posterior component separation (PCS) involves incising the posterior rectus sheath to expose the transverse abdominis muscle, with the transverse abdominis then divided along its length in order to facilitate the advancement flap [35]. We have changed almost exclusively to PCS and transverse abdominis realease (TAR) in all our CAWR, irrespective of the timing when the CAWR is performed, that is in the acute or elective settings (Fig. 23.3).

The use of mesh as a fascial bridge should be utilized in cases where there is insufficient length to perform a tension-free fascial closure with suture. Nonabsorbable synthetic mesh such as polypropylene was initially used as the mesh of choice; however, numerous studies noted that while adequate fascial closure was achieved, there was a significantly high rate of visceral adhesions and fistulous complications [36, 37]. Biologic mesh, which is constructed from allogenic or xenogeneic sources, has seen an increased utilization for abdominal closure over the past two decades. Biologic meshes act as a scaffolding where host tissue ingrowth can occur and can be either cross-linked or non-cross-linked. Collagen cross-linking

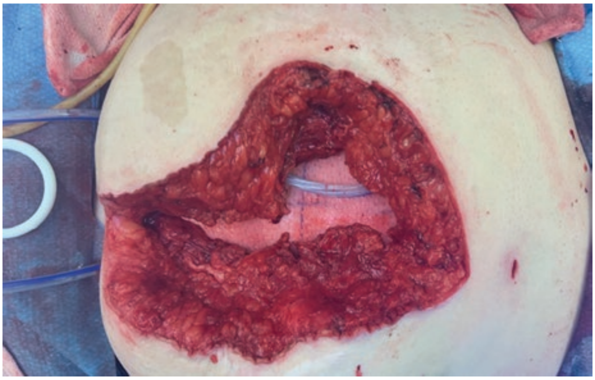

Fig. 23.3 Definitive CAWR with biologic mesh closure prior to fascial closure and placement of negative pressure therapy device. The picture depicts after the mesh was placed and before the fascia was closed. (Courtesy of Dr. Latifi)

prolongs the resorption of mesh thus giving it a higher tensile strength; however, the presence of cross-linking makes tissue integration more difficult due to the impedance of fibroblast proliferation and angiogenesis. Non-cross-linked meshes will allow for quicker tissue integration, but have a lower tensile strength as the resorption rate is faster [38]. Overall bio-prosthetic meshes have shown to be less adhesiogenic as well as noted to allow for better delivery of cytokines and growth factors, increased blood flow during tissue ingrowth, and better outcomes in contaminated/infected fields [39].

23.9 Conclusion

Damage control surgery is an integral component of both trauma and general surgery. While the nonanatomic situation does carry the potential for serious complications, there is no shortage of literature showing how effective an open abdomen can be in managing the physiologic derangements associated with trauma and critical illness. Advances in medical technology as well as our understanding of the physiology and pathophysiology associated with trauma and surgical disease have allowed for increased utilization of the concept of open abdomen. With the aging population, there will continue to be an increase in the number of elderly patients who are treated in this fashion. Physiologic changes that come with aging need to be taken into account in order to alter management strategies to best suit the individualized patient.

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24 Abdominal Wall Reconstruction in the Elderly During the Acute Phase: Principles and Techniques

Shekhar Gogna, James Choi, and Rifat Latifi

24.1 Introduction

The abdominal wall is probably one of the most important, but unfortunately the most underrated, and dynamic "organ" of the human body. This is the first "organ" to be encountered while obtaining access to the abdominal cavity. The strength and dynamic biomechanics of the abdominal wall may not return to baseline after any surgical intervention. The intact abdominal wall is a major factor in determining the satisfactory quality of life after any surgical intervention. The abdominal wall pathology can be divided into two types based on the acuity of presentation; acute and chronic. Slow growing masses, chronic ventral hernia including planned ventral hernia, entero-cutaneous or entero-atmospheric fistula, and elective surgery all give time to plan the restoration by primary closure or reconstruction using novel techniques such as component separation. However, during surgical management of acute intra-abdominal pathology the dilemma lies in deciding whether to discharge the patients with temporary abdominal closure, or perform some sought after definitive abdominal closure. The real surgical challenge lies in reconstructing the abdominal wall after acute pathologies, such as after damage control surgery for trauma/non-trauma, incarcerated or strangulated ventral hernia, or necrotizing soft tissue infections.

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Despite the growing prevalence of these problems, there is still paucity on a general consensus regarding the criteria to define a “complex” abdominal wall [1]. The decision to perform primary closure or abdominal wall reconstruction during the acute phase depends on patient-specific risk factors, or disease-specific risk factors, or both. Advanced age, frailty, and high comorbidity burden are considered risk factors in performing surgical procedures and predict higher postoperative mortality and complications [2].

By 2050 in the USA, the population aged 65 and over is projected to be 83.7 million, double the estimated number of 43.1 million in 2012 [3]. This demographic shift in the population will have implications in terms of a higher proportion of elderly undergoing major emergent or elective abdominal surgery. However, mortality in emergency surgery is approximately 15–30%, and it is doubled if associated with complications and notably higher in patients over 75 years [4]. The increase in the proportion of emergent surgery in the elderly will translate into the need of managing abdominal wall closure more aggressively to negate the excess morbidity due to open abdomen.

This chapter is an evidence-based pragmatic approach to the concept of early abdominal wall closure using abdominal wall reconstruction in the elderly during the acute phase. We will begin with some basic definitions of abdominal wall surgery followed by the basic surgical technique of AWR specifically in the acute phase in the elderly. The last section will delve upon the discussion on the limited literature on this topic.

24.2 Definitions

The understanding and knowledge of basic terminology related to abdominal wall surgery are of paramount importance while managing the elderly patients admitted with abdominal wall surgery.

Ventral hernia vs. *incisional hernia:* Ventral hernia is defined as a hernia of the abdominal wall excluding the inguinal area, the pelvic area, and the diaphragm that was present at birth or that developed spontaneously without trauma to the abdominal wall [5].

An incisional hernia is defined as “any abdominal wall gap with or without a bulge in the area of a postoperative scar perceptible or palpable by clinical examination or imaging” [6].

Open abdomen: “Open abdomen” (OA) refers to a surgically created defect in the abdominal wall that exposes abdominal viscera leaving an abdominal cavity temporarily open [7]. The surgical technique of OA is commonly employed by trauma and acute care surgeons to manage severely injured or physiologically deranged patients.

Fascial dehiscence (Fig. 24.1): also known as “Burst abdomen” or “Evisceration” is a dreadful complication of laparotomy incisions. Fascial dehiscence is an acute wound failure at the level of the fascia. This is a postoperative complication after primary closure of a laparotomy incision [8].

Fig. 24.1 Fascial dehiscence or burst abdomen; a dreadful complication of midline laparotomy (Courtesy of Dr. Rifat Latifi)

Abdominal wall reconstruction (AWR): This is a complex reconstructive surgery primarily used for hernia repair, scar repair, and repair of previous surgical damage [9]. Although there is no true definition, this procedure involves the closure of the fascia at the midline by releasing various muscular layers often with reinforcement using mesh prosthetics [10]. There are numerous reconstructive options available in the market, but treatment must be personalized and based on preoperative and intra-operative surgical decision-making.

The terminology of the location of mesh placement: Across the globe, there is very little consistency in the taxonomy of the location of mesh placement [9]. Recently, a call for formalizing the taxonomy of mesh location has been introduced (Fig. 24.2, Table 24.1) [5, 11].

Component separation technique: Albanese was the first to develop the concept of CST to address the issue of tension-free repair of complex abdominal wall defects [12]. The procedure involves dividing the external oblique aponeurosis and muscle, dissecting the rectus abdominis muscle from its posterior rectus sheath, and then mobilizing the myofascial flap consisting of the rectus, internal oblique, and transversus abdominis medially [13].

Anterior component separation: Midline scar excision is followed by extensive adipocutaneous flap mobilization and at a point 1 cm lateral to the rectus, the external oblique aponeurosis and muscle are divided from the inguinal region to the

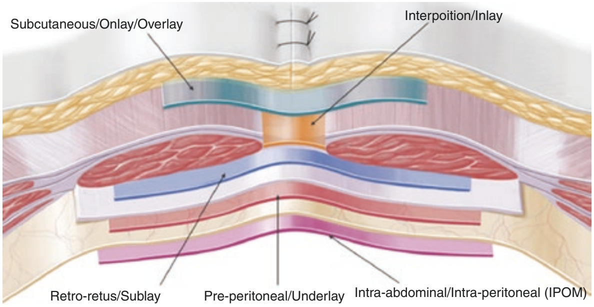

Fig. 24.2 Illustration clearly showing the planes of the anterior abdominal wall (Reprinted with permission from; Parker SG, Wood CPJ, Sanders DL, Windsor ACJ (2017) Nomenclature in abdominal wall hernias: Is it time for a consensus? World J Surg. https://doi.org/10.1007/s00268-017-4037-0)

Table 24.1 Defining the planes of the anterior abdominal wall

Detailed anatomical description	Abbreviated anatomical terms	Ventral hernia nomenclature
Mesh is laid on top of the external oblique over the defect	Subcutaneous/onlay/overlay	Onlay/overlay
Mesh is the same size as the hernia defect and the edges have sutured the hernia neck	Inlay/interposition (always bridging)	Inlay (always bridging)
Posterior to the rectus muscles and anterior to the posterior rectus sheath[a]	Retro-rectus	Sublay
Anterior to the peritoneum and posterior the rectus sheath[b]	Pre-peritoneal	Underlay
Mesh is inserted into the abdominal compartment and laid on the anterior abdominal wall deep to the peritoneum. Often bridging especially in laparoscopic surgery	Intra-abdominal/intraperitoneal onlay mesh (IPOM)	Intraperitoneal/(IPOM)

With permission from Parker SG, Wood CPJ, Sanders DL, Windsor ACJ (2017) Nomenclature in abdominal wall hernias: Is it time for a consensus? World J Surg. https://doi.org/10.1007/s00268-017-4037-0

[a]Below the arcuate line this layer is between the rectus abdominis muscles and the transversalis fascia. After TAR this layer extends laterally between the transversalis fascia (posteriorly) and the transversus abdominis muscle (anteriorly)

[b]Below the arcuate line the peritoneum is posterior and the transversalis fascia is anterior. Lateral to the posterior rectus sheath this layer is between the peritoneum (posteriorly) and the transversalis fascia (anteriorly)

costal margin. Lateral dissection deep to the external oblique allows the creation of a "sliding myofascial flap" consisting of the internal oblique and transversus muscles. The midline is then suture approximated to close the defect [14]. This technique is relatively easy to perform, but one has be cognizant on sparing the perforating vessels (Fig. 24.3).

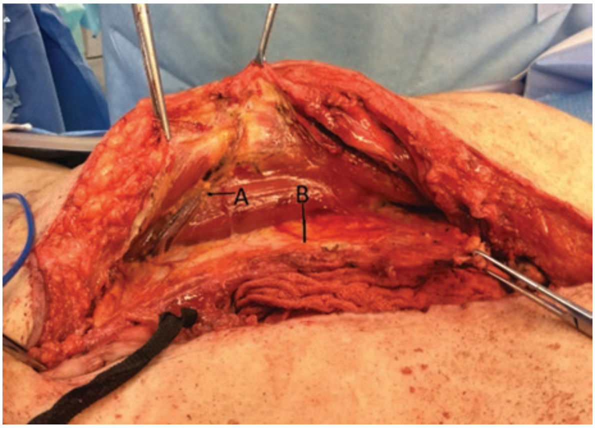

Fig. 24.3 Retro-rectus dissection; (**a**) Sparing of neurovascular perforators. (**b**) Posterior rectus sheath (Courtesy of Dr. Rifat Latifi)

24.3 Posterior Component Separation with Transversus Abdominus Release (TAR)

The retrorectus repair for large midline hernias has become a technique of choice for many of us for a multitude of reasons, but the reduction of complication is the main one. Although many surgeons are familiar with anterior component separation (ACS), recently posterior component separation (PCS) with Transversus Abdominus release (TAR) has become popular. Detailed technical aspects of this procedure with particular attention to the surgical anatomy have been recently outlined [15].

The main principle of PCS is that the perforating vessels are spared, and the mesh is placed between the rectus muscle anteriorly and posterior rectus fascia/peritoneum/preperitoneum posteriorly. Once you have dealt with all adhesions and other concomitant procedures, such as reconstitution of GI tract or other procedures, the posterior approach to the retrorectus space is performed by incising the medial edge of the posterior rectus sheath at the medial edge of the rectus abdominis muscle. The edge of the transected posterior rectus sheath is grasped with clamps and retracted medially and posteriorly, allowing easy lateral dissection of the retrorectus space. During this stage of the operation, one has to be cognizant not to injure intercostal nerves that perforate the rectus muscle. The posterior lamina of the internal oblique aponeurosis is incised just medial to the entry of the intercostal nerves as they enter the rectus muscle posteriorly [13].

You should start this segment of the dissection as cranially as you can. At the point of transition of posterior lamina of the internal oblique fascia, you will be able to see the medial aspect of the transversus abdominus muscle (TAM). The muscle fibers and fascia of TAM can be separated from the underlying thin posterior transversus abdominis fascia and peritoneum with a right-angle clamp. However, this separation requires a careful dissection under the muscle fibers of TAM. One has to be careful not to enter peritoneum, but if you do, make sure to identify and close with an absorbable suture. Transection of TAM can be done in a number of ways, although I agree with these authors that the transection of the TAM should start as far cranially as possible where these muscle fibers are prominent and progressing caudally aids markedly this part of the component separation. This extraperitoneal space now can be extended laterally and caudally in order to make space for the prosthesis. This dissection is facilitated greatly with a sweeping move of your hand. I prefer that this space extends to the costal margin and join the central tendon of the diaphragm in the midline. Once the space is created to your satisfaction, the posterior rectus sheaths are approximated with a running absorbable suture. Fixation of the mesh superiorly, inferiorly, and laterally with sutures will help you position the mesh appropriately. A number of techniques can be used to place the rest of the sutures. I prefer to use a Carter-Thomason suture passer, but other suture passers are just as good to fix the mesh to the anterior abdominal wall.

The benefits of PCS with TAR have been demonstrated with the superiority when compared with ACS by a 50% decrease in wound morbidity with the posterior approach [16]. Most large series report significant lower morbidity with the PCS approach [17]. Moreover, this technique has been suggested for patients who previously had ACS, but also have a recurrence of hernia [18]. Retromuscular space is developed by incising the posterior rectus sheath and dissecting the rectus muscle anteriorly. Once the lateral edge of the rectus sheath is reached, the posterior rectus sheath is incised to access to the plane between the internal oblique and transversus abdominis muscle. The posterior rectus sheath is then reapproximated in the midline with a running suture [19].

The technique of PCS with transversus abdominis release (TAR) [20] deviates from the "classic PCS" by the step that the retro muscular plane is developed towards the linea semilunar, visualizing the junction between the posterior and anterior rectus sheaths. The perforators supplying the rectus muscle are preserved under vision. The muscle is then divided along its entire medial edge using electrocautery to enter into the avascular space between the transversalis fascia and the divided transversus abdominis muscle. Once a similar release is performed on both sides, the posterior rectus sheath is reapproximated in the midline.

24.4 The Technique of Abdominal Wall Reconstruction in the Acute Phase

In this section, we will describe the technique step-by-step. This concept is based on early complex abdominal wall reconstruction after open abdomen management for trauma or intra-abdominal catastrophe, and acute fascial dehiscence resulting in evisceration during the same hospital admission once the patient is free of any sepsis and has achieved "physiological homeostasis."

In our experience, the outcomes after CAWR are similar to PCS/TAR as compared to ACS; however, skin-related complications are less, although the drains seem to stay longer since in our practice we keep the drain until the output is less than 25 cc/24-h period. Hence, in this section, we will describe CAWR with PCS/TAR using biological mesh in the acute phase along with some tricks and tips to manage atypical abdominal wall reconstruction as well.

The CAWR operation in the acute phase is different from the elective cases, as the skin incision is very recent from the prior surgery, and that can be used to commence the reconstruction promptly.

24.4.1 Step 1

The first key step in PCS/TAR is defining the avascular retro-rectus space. This is done by making an incision into the most medial aspect of the posterior rectus sheath about 1 cm lateral to the linea alba (Fig. 24.3). This is the most difficult part of the procedure, as one can "get lost" easily and venture on the anterior portion of the rectus muscle. Once you identify the proper space, the rest of the dissection is relatively easy.

24.4.2 Step 2

We then proceed with this dissection along the lateral edge of the rectus abdominis muscle, or we release the transversus abdominus muscle more laterally from the posterior rectus sheath (TAR). The posterior sheath is then approximated in the midline with a continuous suture (Fig. 24.4). This part of the procedure, while surgically elegant, may damage the blood vessels very easily if one is not careful with retraction either by hand or by a retractor. The operating surgeon should be very careful in determining the position of the assistant while minding every move of the assistant's hands.

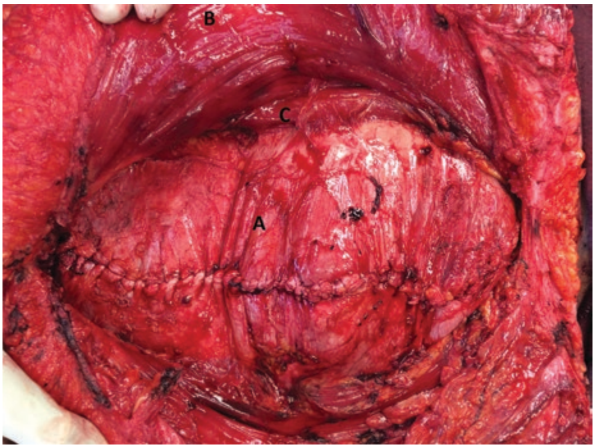

Fig. 24.4 Completed PCS/TAR; (**a**) Approximated midline fascia, (**b**) Posterior surface of rectus Abdominis muscle. (**c**) Lateral edge of Transverses Abdominis muscle (Courtesy of Dr. Rifat Latifi)

Importantly, the retro-rectus space can be anatomically extended as far as the lateral border of Psoas muscle and superiorly up to the central tendon of the diaphragm, by using a subxiphoid and retrosternal dissection and inferiorly to the retropubic space [21]. Nonetheless, how far laterally one goes depends on the size of the defect and the ability to close the posterior rectus sheet. For larger defects, one has to perform complete TAR. We do not transect longitudinally the TA muscle unless we really must. However, if one does, should be careful not to enter the posterior sheet of the TA.

Once the dissection is done, then the posterior rectus sheet is closed primarily. The inferior portion of the space is closed by bringing together the peritoneal layer. We use 0.Vicryl suture. You should try to use a small needle if possible, so you do not create defects that will later potentially leak peritoneal fluids. Once this portion is complete, one may use a few more sutures to invert the "bump" created from the bladder and peritoneum.

24.4.3 Step 3

A sublay mesh is then placed and fashioned based on the space that needs to be covered into the retro-rectus space between the rectus abdominis muscle and the approximated posterior rectus sheaths medially, and in the space between the transversus abdominis muscle and the peritoneum laterally. We place a minimum of 4–6 trans-fascial U-shaped sutures to anchor the mesh using the Carter-Thompson needle passer (Fig. 24.5). The anterior fascial layer is closed in the usual fashion using continuous sutures, but before we close the anterior fascia, we place two large drains (Blake # 19) and secure them with 2.0 silk sutures. Every effort should be made to achieve healthy fascial closure after adequate debridement of any poor quality, scarred, or nonviable fascial tissue. This provides a dynamic abdominal wall leading to much lower rates of hernia recurrence.

During the closing of the abdominal wall, we measure airway peak pressure. The increase of up to 5 cm of H_2O change from the open state to closed Linea Alba is deemed acceptable. If those thresholds are reached, we usually leave the fascia open and apply negative pressure wound therapy (NPWT) and return for fascial closure once edema has subsided, or rarely we place a bridge mesh.

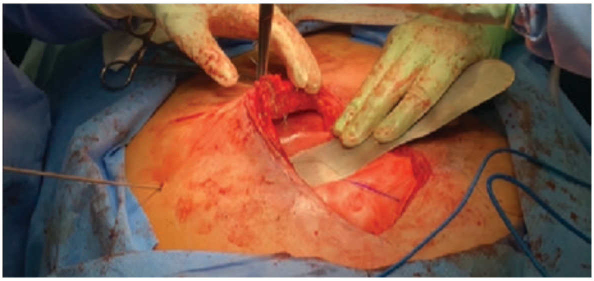

Fig. 24.5 Sublay mesh placement and anchoring with U-shaped stitch using Carter-Thompson needle (Courtesy of Dr. Rifat Latifi)

24.5 Abdominal Wall Reconstruction in the Elderly in the Acute Phase

A ventral hernia is one of the most common consequences after laparotomy and often requires complex abdominal wall reconstruction (CAWR). Yet, there are only a handful of studies determining outcomes after complex abdominal wall reconstruction (CAWR) in the elderly population [22, 23].

In the senior author's (Dr. Rifat Latifi) practice, the elderly population is the biggest subgroup of patients undergoing CAWR. In a recently published paper [22], we have shown that the outcomes of CAWR in the elderly are equivalent to the non-elderly population. Advanced age does not translate into increased postoperative mortality or morbidity after CAWR with biological mesh. However, our study [2] included both emergent and elective CAWR in the elderly, while Giordano et al. [23] included only elective CAWR in the elderly.

There is evidence of performing CAWR early in acute settings in patients after intra-abdominal catastrophe or trauma. Eastern Association for the Surgery of Trauma (E.A.S.T) recommends that in the acute setting, once intra-abdominal injuries have been addressed, visceral edema has subsided, and the degree of bacterial contamination has minimized, the abdomen should be closed [24]. There has been no study so far evaluating the outcome of CAWR in the acute phase exclusively in the elderly. However, the application of this concept seems plausible in the elderly population as well. This is an important area of research as many questions on this topic are still unanswered.

The question on the type of mesh to be used as reinforcement in the clean-contaminated, contaminated, or infected surgical field during CAWR has been asked many times. We feel that the biologic meshes have certain advantages in this setting because of their ability to resist infection, lack of mesh erosion, and mesh migration. There is a piece of evidence that these meshes form a scaffold for the tissue and vascular in-growth. This revascularization process is the main mechanism behind resistance to infection [25, 26]. These inherent properties make them a very viable option in high-risk cases [22].

24.6 Optimizing the Outcomes

Every question has an answer/s, but in the surgical discipline, we strive for an optimal answer. To enhance the outcomes of CAWR in high-risk patients, such as malnourished, enterocutaneous, or entero-atmospheric fistula, a six-step management strategy known as "SOWATS" (S = Sepsis Control, O = Nutrition Optimization, W = Wound Care, A = Anatomy, T = Timing, and S = Surgery) has been suggested [27]. We have expanded this aproach to a nine-step strategy, and call it "ISOWATS PL" where I = Identification and diagnosis of the postoperative fistula; S = Sepsis and Source Control; O = Optimization of Nutrition, W = Providing and Ensuring Wound Care; A = Redefining the anatomy and understanding the pathology at hand;

T = Timing of definitive surgery and/or takedown of fistulas; S = Definitive surgery and surgical creativity; P = Postoperative care; and L = Long-term follow-up [28]. Adhering to all nine steps of the "ISOWATS PL" may be difficult at times as certain patients often require emergency surgery, and you do not have the luxury to plan the entire process; however, all attempts should be made, and the process of reoperations should be planned, structured, and executed carefully. Obviously this is done in more elective or semi-elective cases, rather than in an acute setting with an open abdomen. The elderly population has different protoplasm and aggressive measures are needed to optimize the physiology and biology. We are implementing Geriatric-SOWATS to achieve early "physiological homeostasis" for stable and dynamic closure after CAWR.

24.7 Conclusion

The elderly will be the major subgroup of the population undergoing emergent surgical procedures. Subsequently, there will be an increased demand for surgical management of abdominal wall defects. The application of early CAWR in the acute phase in the elderly with attention to the type of prosthetic reinforcement will offer a plausible solution. However, future prospective studies are still needed to provide concrete evidence.

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Emergency Hepatobiliary Surgery in Elderly

25

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With the increase in life expectancy, hepatic and biliary diseases have become common problems in the elderly. Most acute presentations can be the effect of infectious, inflammatory (gallstones, cholangitis, hepatic abscess), and traumatic (common bile duct, liver) etiologies [1–3]. Among the elderly, bile duct stones are a common cause of clinical problems, such as acute cholecystitis and acute cholangitis. Because of the increasing prevalence of morbidity that accompanies the aging process, urgent and aggressive treatment is required for elderly patients with severe infectious conditions or with traumatic injuries. Many of the hepatobiliary emergencies present with overlapping symptoms, but treatment options can be different [4] and they may include percutaneous, endoscopic, and surgical procedures.

25.1 Acute Calculous Cholecystitis

Old age (>65 years), by itself, does not represent a contraindication to cholecystectomy for acute calculous cholecystitis [5]. However, increased age is associated with increased comorbidities and a decreased life expectancy. As the concept of frailty is becoming more and more common in surgery, several frailty scores have been recently introduced [6–8]. Frailty scoring systems may help in stratifying the risk for patients requiring surgery. However, a consensus about the superiority of one system over the others has not reached yet. ASA, P-POSSUM, and APACHE II have shown the best correlation with surgical risk, but there is no validated way of stratifying risk in elderly patients, even though age is one of the factors taken into account for the calculation of P-POSSUM and APACHE II score [9]. In order to avoid surgery for

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elderly and high-risk patients (often these two groups are mixed together), alternative treatments such as the percutaneous drainage of the gall bladder (cholecystostomy) or, less commonly, the drainage of the gallbladder by retrograde endoscopic procedure, have been developed. The results regarding the drainage of the gallbladder are not conclusive and we have to wait for prospective studies to throw some light on this issue [10, 11]. The laparoscopic approach to acute cholecystitis is safer than the open approach: morbidity and mortality, in the case of laparoscopic procedure, are 10% and 1%, respectively compared to 25% and 2% for the open procedure [9]. On the other hand, aged patients are at increased risk of conversion from laparoscopy to open procedure, and this may produce a worsening impact on the final outcome [12–15]. The current opinion is that elderly patients presenting with acute cholecystitis should be offered a laparoscopic approach unless contraindicated by anesthesiologic reasons or by the presence of a septic shock. Laparoscopic cholecystectomy is safe, feasible, with a low complication rate and it is associated with a shortened hospital stay. Early laparoscopic cholecystectomy should be performed as soon as possible but can be safely and reasonably delayed up to 10 days from the onset of symptoms if comorbidities need to be addressed and managed. However, although the historical rule of 72 h to perform cholecystectomy for acute cholecystitis is no longer mandatory, surgery performed as soon as possible is associated with a better outcome [16–21]. The role of routine intraoperative cholangiography (IOC) has been evaluated in patients undergoing elective cholecystectomy [22]. Eight randomized trials (including 1715 patients) were analyzed in a recent systematic review and the conclusion was that there is no clear evidence to support its routine use [23]. Moreover, there are no randomized studies focusing on the use of intraoperative cholangiography during laparoscopic cholecystectomy for acute cholecystitis. As in younger patients, in the elderly IOC should be performed selectively. When no preoperative CT scan with contrast or MR cholangiography has been done before surgery for acute cholecystitis, IOC may be pursued if the patient shows elevation of the liver biochemical tests (including ALT, AST, bilirubin, ALP, GGT), US finding of common bile duct dilatation, or has suffered a recent episode of acute pancreatitis. On the other hand, it should not be forgotten that the dissection-free of the cystic duct may be very challenging in the contest of an inflammatory scenario, and that the diagnosis and the management of common duct stones, if the case, should not be addressed as a first priority. It could be much safer in elderly patients presenting with acute cholecystitis to achieve first the source control of infection by quickly removing the gallbladder and to demand the search and the management of bile duct stones in the course. To reduce the risk of biliary injuries, it has been demonstrated the relevance of the "critical view of safety" (CVS), that is a method of identification of the cystic duct and cystic artery during laparoscopic cholecystectomy [24]. CVS identification requires a few methodic steps. Firstly, the hepato-cystic triangle, that is formed by the cystic duct, the common hepatic duct, and inferior edge of the liver, is cleared of fat and fibrous tissue. The common bile duct and common hepatic duct do not need to be exposed. Secondly, the lower one-third of the gallbladder is separated from the liver to expose the liver bed of the gallbladder. Eventually, only two structures should be seen entering the gallbladder: the artery and the cystic duct. Achieving the steps sequence for CVS may result in easier said than done in some situations, such as local severe inflammation, gangrenous gallbladder, adhesions, and bleeding, all conditions that make CVS not easy to be identified. In these contexts, laparoscopic anterograde cholecystectomy and laparoscopic subtotal cholecystectomy may be valid and safe options. Nonetheless, in case of inability to proceed safely in laparoscopy, conversion to open surgery is mandatory [25, 26].

The Tokyo guidelines have recently been updated to recommend early laparoscopic cholecystectomy in patients with severe cholecystitis (Severity grade III) if appropriate experience is available and if the patients do not have any high-risk predictive factor for morbidities such as jaundice, neurological dysfunction, or respiratory failure [27]. However, some elderly patients with ASA III/IV, performance status 3 to 4, or septic shock remain unfit for surgery. Laparoscopic cholecystectomy is associated with a mortality rate of 0–0.8% in the general population but mortality increases dramatically up to 14–30% in elderly or critically ill patients with comorbid diseases [28]. For elderly patients presenting with AC and unfit for surgery, the first initial approach should be aggressive and based on antibiotic therapy, pain control, careful fluids administration, oxygen supplementation, and monitoring of vital signs. Those responding to medical management are evaluated the following days in order to reassess the risk for surgery. If the re-evaluation confirms the high risk for surgery, patients are considered as patients with chronic cholecystitis and enter a follow-up program. Surgeons should always keep in mind that cholecystolithiasis is a benign condition and that surgery should not be offered at every cost. For those patients in which the initial medical management fails, the drainage of the inflamed gallbladder becomes the next step. Current guidelines recommend percutaneous cholecystostomy for moderate (grade II) or severe (grade III) acute cholecystitis as an effective life-saving method in older or in frail patients who are deemed unfit for surgery [15, 28, 29]. Nevertheless, the percutaneous cholecystostomy is a procedure which may lead to potential and dangerous complications. In a study by Wiggins et al. on 47,500 patients over the age of 80 admitted as an emergency with acute cholecystitis, 89.7% of patients were treated conservatively, 7.5% had cholecystectomy, and 2.8% underwent cholecystostomy. As short-term results, 30-day mortality was significantly increased in the emergency cholecystectomy group (11.6%) compared to those managed conservatively (9.9%). However, this was offset by the long-term benefits of cholecystectomy that showed a lower 1-year mortality (20.8 vs. 27.1% for those managed conservatively). Patients managed by percutaneous cholecystostomy had the worse 30-day and 1-year mortality results (13.4 and 35.0%, respectively). The recent CHOCOLATE study by Loozen et al. analyzed 142 high-risk patients with acute calculous cholecystitis that were randomly allocated to laparoscopic cholecystectomy ($n = 66$) or to percutaneous catheter drainage ($n = 68$) management. They observed that the rate of death did not differ between the laparoscopic cholecystectomy and percutaneous catheter drainage group (3% vs 9%), but major complications (12% vs 65%), reinterventions (12% vs 66%), and recurrent biliary disease (5% vs 53%) all were significantly more frequent in the percutaneous drainage group. In addition, the authors found that the median length of hospital stay was also longer in the latter group (9 days vs

5 days). The conclusion was that laparoscopic cholecystectomy compared with percutaneous catheter drainage has a reduced rate of major complications in high-risk patients with acute cholecystitis [30].

Due to the limits of percutaneous drainage, the decision to place a cholecystostomy should be carefully evaluated case-by-case. When drainage of the gallbladder is advised, a percutaneous transhepatic route under local anesthesia is the preferred method. Specific complications of this procedure account for 3.4% and include bile duct leak, biliary peritonitis, portal or parenchymal vessel injury and bleeding, catheter dislodgement, colon injury, and vagal reaction. The transhepatic route should not be employed in patients with severe liver disease and coagulopathy [28]. The cholecystostomy catheter can be removed between 4 and 6 weeks after its placement, once the biliary tree patency has been proved by a cholangiogram [31, 32].

25.2 Common Bile Duct Stones

The presence of obstructive jaundice needs to be carefully assessed because it reflects a wide spectrum of potentially benign and malignant conditions. These include, but are not limited to, common bile duct (CBD) obstruction from external compression (cholangiocarcinoma, periampullary cancers, gallbladder cancer), choledocholithiasis, and liver failure (e.g., secondary to sepsis). Common bile duct stones occur in about 5–10% of patients with acute cholecystitis [33–36]. The routine use of biochemical tests should be used for the suspicion of common bile duct stones with some limitations. Preoperative magnetic resonance cholangiopancreatography (MRCP), endoscopic US, intraoperative cholangiography, or laparoscopic ultrasound should be performed depending on the local expertise and availability. Common bile duct stones can be removed preoperatively, intraoperatively, or postoperatively according to the local expertise and the instrumentation availability. Endoscopic retrograde cholangiopancreatography (ERCP) and laparoscopic common bile duct exploration (LCBDE) represent the two dominant methods for CBD clearance [37, 38]. Currently, many different strategies have been described for the management of common bile duct stones in patients scheduled for laparoscopic cholecystectomy. The bile duct can be cleared during the same cholecystectomy procedure by a surgical exploration of the duct (LCBDE) or by performing an intraoperative ERCP (iERCP); alternatively, the ERCP may precede or follow the laparoscopic cholecystectomy procedure. LCBDE and iERCP carry the benefit of being performed as a single procedure [39, 40]. The laparoscopic CDB clearance could be done via a trans-cystic or a trans-choledochotomy access depending on the diameter of the CBD, the size and the number of stones, the level of the junction between the CBD and the cystic duct, and the grade of the inflammation of the hepatoduodenal ligament. Choledochoscopy may help surgeons to ascertain the successful clearance of the common bile duct. Although no consensus exists on which between LCBDE and ERCP is the best strategy for the management of common bile duct stones, a decreasing use of LCBDE in the common surgical practice has been recently observed [41, 42]. Surgeons are often reluctant to perform biliary tract surgery in elderly patients with gallstone disease and in these cases ERCP may suffice [43, 44]. Zheng et al. compared 253 patients younger and 123 patients older than 70 years undergoing LBCDE. They showed that LCBDE was equally successful with a high clearance rate (100% in elderly patients and 98.8% in younger group) and with no significant differences in terms of operating time, intraoperative blood loss, postoperative hospital stay, total costs, overall complication, major bile duct injury, and death. They concluded that LCBDE is safe and effective even in elderly patients [45]. From a practical point of view, the feasibility of LCBDE depends on several factors including surgical expertise, adequate equipment, a patent and not inflamed cystic duct, and common duct stones not larger than the caliber of the cystic duct. Moreover, LCBDE extends the time of the surgical procedure. Thus, it appears reasonable that where the expertise in operative endoscopy is available, ERCP rather than LCBDE becomes the daily practice [46]. The need to place biliary drains such as T-Tubes could reduce the quality of life of an elderly patient and this may be an additional point to favoring ERCP respect to a surgical approach to the main bile duct.

25.3 Acute Cholangitis

Acute cholangitis is defined as acute inflammation and infection of the biliary tree. The dominant cause of acute cholangitis is choledocholithiasis, followed by benign biliary stenosis and cancer [47]. This clinical condition may present with a wide variety of symptoms, ranging from nonspecific findings to severe infection and fatal septic shock. According to the most recent Tokyo guidelines, the severity of acute cholangitis is graded in acute, mild, or severe depending on the patient's general clinical condition and the dysfunction of one or more organs/systems [48]. Most frequently, patients present with grade I disease (54%), while only 11% develop a grade III [47]. The only way to minimize morbidity and mortality is an early diagnosis and a timely and proper treatment. Due to the improvement in the therapeutic options, the mortality of acute cholangitis has been declined and currently is less than 5%. Severe sepsis with multiorgan failure is the main cause of death [3]. An aggressive therapy including NPO, intravenous fluids, antibiotics, and analgesia is the initial step in the management of this life-threatening condition [47]. Large-board antibiotic coverage should be addressed against gram-negative, gram-positive bacteria, and anaerobes. Antibiotics can be tapered on the basis of final culture results. Medical treatment may be sufficient in selected cases of acute cholangitis, but biliary drainage should be considered for all nonresponders to the initial management [29].

Biliary decompression may be achieved by endoscopy, percutaneous drainage, or surgery. The choice of the approach must be based on the etiology of the cholangitis and on the patient's physiological status [49, 50]. Elderly patients with acute cholangitis are often critically ill and emergency decompressive interventions are necessary. Compared to percutaneous transhepatic biliary drainage and emergency surgery (including laparoscopic or open choledocholithotomy) endoscopic retrograde cholangiopancreatography (ERCP) is the most common and effective interventional method for biliary decompression [51]. Emergency ERCP biliary drainage in older with severe comorbidities is not a procedure free from risks [52]. Complications of ERCP include pancreatitis, hemorrhage, perforation, cholangitis, and cardiorespiratory problems and may occur from 7 to 15% of cases [53]. Emergency surgery decompression of the common duct and T-Tube placement is however burdened by higher rates of morbidity and mortality [54]. Thus, surgery should be offered as a last option therapy. The rate of ERCP-related complications in the elderly are comparable with those of younger patients [55–57], but only a few reports address the role of emergency ERCP for the management of elderly patients with acute cholangitis [54]. Endoscopic retrograde cholangiopancreatography (ERCP) with sphincterotomy has been established as an effective method to treat patients with acute cholangitis [58], but, as already said, it is not a procedure free of adverse events [59]. In elderly patients presenting with acute cholangitis and critically ill, ERCP should be limited to quick drainage of the common duct with a biliary stent insertion, without any attempt to remove the stones. These will be eventually removed by a second endoscopic procedure once the source control has been achieved and the patient's conditions have been restored [60]. In their retrospective review, Tonda et al. compared patients under versus over 80 years old with acute cholangitis undergoing biliary drainage by stent insertion with or without endoscopic sphincterotomy as an initial treatment, and repeated ERCPs for the extraction of residual biliary stones in the patients whose clinical conditions had improved. As a result, the technical success and ERCP-related complication rates were comparable between the two groups except for post-ERCP pancreatitis that was significantly lower in the elderly group [61]. Emergency ERCP for acute cholangitis is a safe and effective procedure in elderly patients. Advanced age is not a contraindication to ERCP. However, informed consent, adequate monitoring during the procedure, prompt detection, and management of ERCPrelated complications are crucial.

ERCP cannot be performed in some circumstances, for example, in case of complete biliary obstruction, in patients who have a Roux-en-Y reconstruction, or a periampullary duodenal diverticulum. In such situations, a percutaneous transhepatic biliary drainage could be an option, especially if the biliary tree proximal to the obstruction is dilated. This procedure is rarely used, and it may carry important complications like intraperitoneal hemorrhage, haemobilia, and bile peritonitis. The open surgical approach with drainage of the biliary tree in patients with acute cholangitis should be considered only as a last resort procedure, as it carries a mortality rate of around 30% [31].

Because a scheduled laparoscopic cholecystectomy following emergency ERCP for acute cholangitis secondary to choledocholithiasis has a not negligible risk of complications, the need for definitive surgical treatment should be carefully evaluated and perhaps limited only to patients fit to surgery which suffer recurrent episodes of acute cholangitis [62]. Patients presenting with acute cholangitis due to cancer require different management and should be referred for a definitive treatment following emergency biliary drainage.

25.4 Liver Abscess

Pyogenic liver abscess (PLA) is collection of pus within the liver as a result of an infection. The causes of PLA are thought to be ascending infection from the biliary tract and hematologic spread via the portal vein and hepatic artery. It accounts for almost half of the visceral abscess cases. PLA usually appears in patients with predisposing conditions such as diabetes, hepatobiliary malignancy, or immunosuppression [63]. Life-threatening sepsis can develop in these patients. Along with the rapid aging population, both the incidence of PLA and the mean age of PLA patients have increased steadily in the past several decades [64, 65]. About half of PLAs do not have an identified etiology. Several links between gastrointestinal tract malignancies and PLA have been found [66, 67]. Furthermore, diverticula disease of the colon and hepatobiliary pathology (gallstones, strictures, congenital disease, and cancer) are recognized as causes of PLA [68]. Despite recent improvements, differentiating PLA from hepatic metastasis by imaging studies is still difficult. The differential diagnosis of these two conditions is of paramount importance because the treatment strategies are completely different [69]. Clinical characteristics and outcomes of PLA in elderly patients are insufficiently elucidated. A few studies attempted to investigate the role of age in PLA and have yielded controversial results [70–76]. PLAs may present with atypical symptoms and signs on admission. In elderly patients, lower body temperature and a higher heart rate could be the only clinical manifestations [77]. The most common pathogens are *Escherichia coli*, *Enterococcus,* and *Streptococcus*, being commonly polymicrobial in oncological patients. Infection with *Klebsiella pneumoniae* is the most prevalent in Asia, but it has been increasing in the occidental population [78, 79]. Elderly PLA patients appear to have a slightly lower positive rate on both pus and blood culture than young ones [77]. Imaging studies (ultrasound, CT scan, and MRI with gadolinium) play a crucial role in making the diagnosis. The treatment should be based on the patient's condition and his response to antibiotic therapy, but it depends also on the number and the size of the abscesses, the degree of colliquation, and the presence of septs inside the abscess cavity. Preferred methods of treatment include intravenous broad-spectrum antibiotics and when appropriate, the drainage of the abscess. The most commonly used antibiotics are fluoroquinolones or third-generation cephalosporin in combination with metronidazole [80]. If it is not possible to isolate the agent to obtain a cultural examination and antibiotics sensibility test, empiric antibiotics should be the first choice. Surgical drainage may be required in case of larger and multilocular abscesses, failure of percutaneous drainage, or when surgical treatment of the underlying cause of PLA is needed [80, 81]. Surgical drainage or resection could be performed via open or laparoscopic approach, according to the grade of experience of the surgeon, available resources, and patient's clinical conditions.

The impact of aging on outcomes of patients with PLA remains unclear. Zhang et al. showed from a cohort of 332 patients that there were no significant differences in the therapeutic procedures performed between young and elderly PLA patients (antibiotics alone vs percutaneous drainage vs surgical drainage). Moreover, the authors demonstrated that older and younger PLA patients had comparable results [77]. If untreated, PLA may reach a 100% mortality. Moreover, around 40% of cases with PLA may develop local or systemic complications, the most common being generalized sepsis and pleural effusion. Other complications include rupture of the liver abscess to the peritoneal cavity, thrombosis of the portal vein or of the hepatic veins, IVC occlusion, development of pseudoaneurysm of the hepatic artery, haemobilia, and, very rarely, the appearance of a fistula to the portal vein or to the hepatic veins. When the PLA is properly treated, complications are contained between 2.5 and 14% [82]. Thus, surgeons need to be on high alert when a PLA in elderly patients is diagnosed. A multidisciplinary approach may be reasonable in order to achieve source control and to address comorbidities. If adequately managed, older PLA patients have outcomes comparable to their younger counterparts with a high rate of cure achieved in both groups.

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26 Emergency Cholecystectomy in the Elderly

Michael Sugrue, Huilun Huan, Brendan Skelly, and Angus Watson

26.1 Introduction

Cholecystitis is one of the most common emergency presentations to hospitals. In general, the incidence of biliary disease is 19% in women and 10% in men [1]. Left untreated, 25% of patients who had biliary colic develop biliary complications within the first year. These include acute cholecystitis, gallstone pancreatitis, and obstructive jaundice.

The prevalence of gallstones increases with age, rising from 20% in those in their 70s to 30% of 90-year olds. In nursing home patients >50% over the age of 80 and 80% over 90 have gallstones [2].

Globally, there is an ever-increasing aging population where those older than 60 will increase from 25 to 35% by 2050, a *"silver tsunami"* thus making the optimum management of symptomatic biliary disease increasingly important. This is further confounded by the increasing burden of dementia [3].

Many guidelines on the management of acute cholecystitis [4] exist but few deal with the elderly population [5]. The challenge of caring for elderly patients with cholecystitis is balancing the risk of comorbidities against the failure to perform emergency cholecystectomy.

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Defining the term “elderly” can be problematic and the concept of the super elderly (>90 years of age) is being increasingly recognized. This chapter will focus on emergency cholecystectomy in the elderly (≥65 years), its indication, and outcomes.

26.2 Presentation and Triage

In general, elderly patients present with more advanced cholecystitis than younger patients. Right hypochondrium and epigastric pain is the only symptom definitively associated with cholecystitis in this age group [1]. Atypical pain or no pain has been reported in 12% and 5%, respectively [5]. In the elderly, symptoms may be less obvious and cholecystitis may only be identified during imaging, often performed for unexplained sepsis.

While a fever is reported in 50% of patients with cholecystitis, less than 10% will have a temperature of >38 °C. With calculous cholecystitis in the elderly, about 10% will have assorted choledocholithiasis.

In the elderly, cholangitis often presents as Charcot’s Triad and obtaining a clear history of rigors is essential to making the diagnosis. This is despite a suggestion from Rumsey and colleagues that Charcot’s Triad was of little specific clinical value [6]. Many studies evaluating cholangitis have reported fever rather than rigors as a cardinal symptom of Charcot’s Triad. If untreated, cholangitic patients, especially in the elderly, may progress to Reynold’s Pentad, with its associated confusion and hypotension [7, 8]. Morrow suggested there was a delay in diagnosis and surgery in 33% of elderly patients with cholecystitis [9]. A rising trend of CRP or an absolute value of 200 mg/L in elderly patients with right upper quadrant pain suggests fulminant cholecystitis and impending failure of a nonoperative approach.

To facilitate an optimal outcome and timely discharge to home, community, or institutional health care facility, an early diagnosis is important in facilitating a clear management path. The keys to making initial decisions are shown in Table 26.1.

Table 26.1 Keys to defining a management plan in the elderly patient

		Goal
History and physical exam		Simple or complex Cholecystitis
Frailty and comorbidity assessment		Assess suitability for surgery Review medications
Bloods focusing on; inflammatory markers	WCC CRP LFTs Procalcitonin (rarely) Amylase (always)	Support simple or complicated Identify CBD stones
Imaging assessment	POCUS	Rapid diagnosis
	Radiology US	On same day or next morning
	CT	Complicated case or diagnostic doubt
	MRCP	Detection of CBD stones
	EUS/ERCP	Therapeutic only

26.3 What Is the Optimal Management of Acute Cholecystitis in the Elderly; Intervene or Observe?

Having made the diagnosis of cholecystitis, what is optimal care?

Elderly patients who present with cholecystitis tend to show less spontaneous resolution than younger patients, with increased risk of gangrenous cholecystitis, (as shown in US in Fig. 26.1), biliary peritonitis, and complex CBD disease with either stone in the CBD or fistulae. During the index admission, semi-urgent (emergency) laparoscopic cholecystectomy is preferred unless there are contraindications to surgery. Some but not all series in the elderly have shown high failure rates of nonoperative management [9, 10], anesthetic risk and surgical difficulty increase with age, with 50% of >70 years demonstrating frailty. The relative contraindications to proceeding with cholecystectomy are shown in Table 26.2.

Patients with gallstone ileus are not infrequent in the elderly and in general a laparoscopic or laparoscopic-assisted relief of small bowel obstruction is adequate.

Riall, in a US study of almost 30,000 patients, found that 25% of patients did not undergo cholecystectomy during the index admission [11]. Lack of definitive therapy was associated with a 27% subsequent cholecystectomy rate and a 38% gallstone-related readmission rate in the 2 years after discharge.

Failure to perform a cholecystectomy on initial hospitalization was associated with a worse 2-year survival (hazard ratio 1.56, 95% CI 1.47–1.65). However,

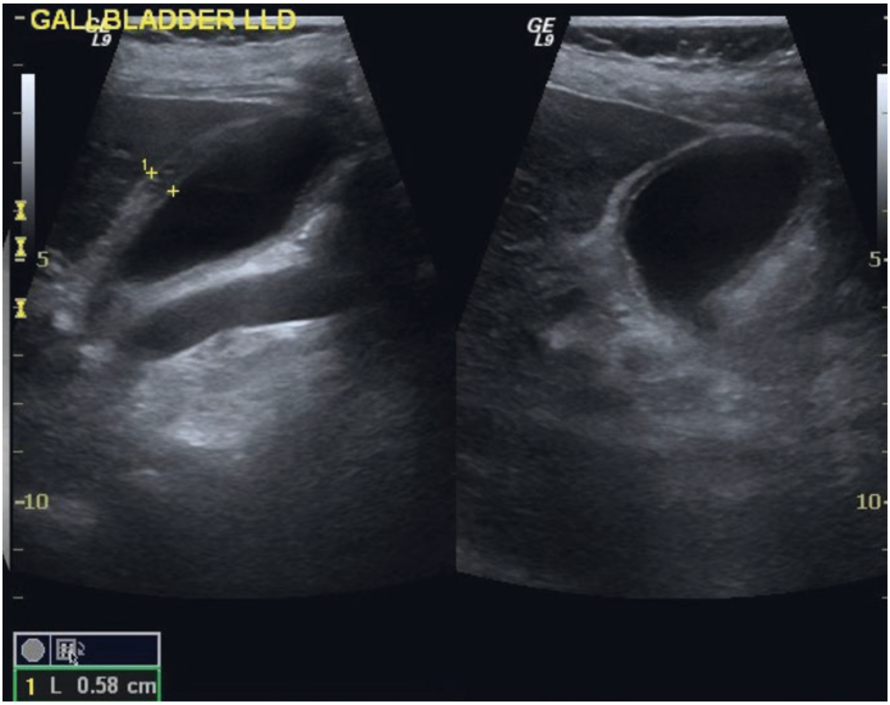

Fig. 26.1 US showing severe cholecystitis in elderly patient

Table 26.2 Potential contraindications to urgent laparoscopic cholecystectomy

Patient in severe cardiac failure
Moderate to severe dementia
Presentations with gallstone ileus
Uncontrolled anticoagulation
Multiple previous laparotomies with known adhesions
Uncontrolled sepsis with hypotension

medical management with an interval cholecystectomy performed only for recurrent acute cholecystitis may be appropriate in selected patients especially where there are no CBD stones [10].

Patients presenting with acute cholecystitis had a 30% higher chance of being readmitted in comparison to those presenting with chronic cholecystitis. Similar findings are described by Giger et al. [12] Also, patients undergoing surgery on a weekend were associated with significantly increased readmission rates. Interestingly, the risk of readmission was reduced by around 15% when intraoperative cholangiogram was implemented, supported by the findings of Halawani et al. [13] following an analysis of the National Surgical Quality Improvement Program Database (NSQIP). Due to the potential seriousness of biliary complications, it begs the question of the current global approach to intraoperative cholangiography and single-stage bile duct clearance. A recent meta-analysis by Pan et al. found performance of intraoperative cholangiography to have superior outcomes in managing choledocholithiasis [14]. McIntyre, in a recent meta-analysis of factors associated with readmission, identified a readmission benchmark of 3.3% accounted for mostly by uncontrolled postoperative pain, nausea and vomiting, and surgical complications, particularly bile duct obstruction. Intraoperative cholangiography may reduce readmission rates [15].

26.4 Preoperative Preparation

Given the variable conversion rate from laparoscopic to open (ranging from 0 to 65%) [16], formal risk assessment should be done. P Possum, Apache II, and NELA scoring may assist [15, 17].

Predicting the risk of conversion is intuitive, but can be aided by preoperative imaging showing a grossly thickened GB wall or a shriveled gallbladder [18]. In addition, male patients with long-standing symptoms, previous ERCP for CBD stone clearance, previous cholecystostomy, and patients with multiple upper midline laparotomies are more likely to be converted.

A postoperative high dependency bed should be organized and surgery should be performed on the next available OR list, following some prehabilitation, including a geriatric internal medicine review. Group and crossmatching of blood are generally not necessary. In the elderly, careful multimodality DVT prophylaxis should be used, with dose and risk-adjusted heparin given into the thigh rather than the abdomen. Care should be used in the super elderly with thromboembolic stockings as they may not be appropriate due to the delicate nature of the skin and potential presence of peripheral vascular disease. The operative decision tree is shown in Fig. 26.2.

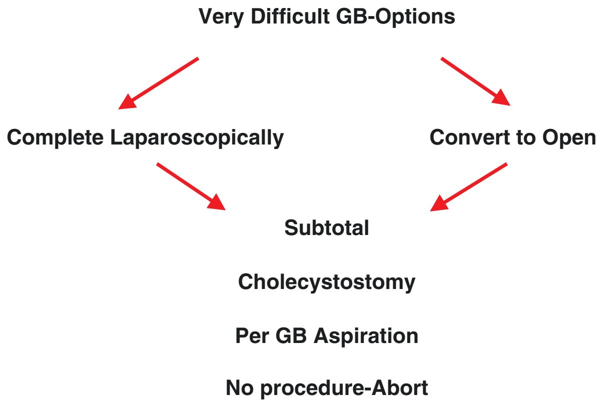

Fig. 26.2 Operative strategy when encountering a difficult GB

Table 26.3 G10 score and conversion rates

G10 score	Conversion to open cholecystectomy (%)	
	No	Yes
1	96.6	3.4
2	97.5	2.5
3	87.6	12.4
4	81.7	18.3
5	70.4	29.6
6	66.7	33.3
7	68.4	31.6
8	33.3	66.7

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Recently, the AAST scoring system has been validated and it has been suggested that it is superior to the 2013 Tokyo classification in part due to the greater number of grades of cholecystitis with the AAST classification [19]. The G10 10-point operative scoring system of cholecystitis severity has been validated as a good predictor of the need to convert (Table 26.3). This, or another grading system, should be used to document intraoperative findings [16].

26.5 Surgical Strategy at Cholecystectomy

The laparoscopic approach for the elderly patient will be similar to that utilized in younger patients, influenced by personal preference but in general, a 4 port approach, three 5 mm ports, and one 11 mm. Other options include; SILS, 3 mm mini ports, or use 3 ports. Certainly, if you are using two 10/11 mm ports with two 5 mm ports you should change your technique. The use of two 10/11 mm ports is not necessary and the GB can be removed through the umbilical port using a camera interchange with a 5 mm telescope. The laparoscopes used should be angled either at 30 or 45 degrees.

Fig. 26.3 Obtaining a CVS or Line of Safety is impossible in this case

There should be a facility to do an operative cholangiogram, so positioning of the patient on the operating room (OR) table is checked before draping. Failure to diagnose and deal with CBD stones will result in increased complications, bile leaks, and recurrent cholangitis.

Obtaining adequate view of the CVS may not be possible and in this situation, there are a number of options (Fig. 26.3). A fundus first approach can be used but may be associated with more hemorrhage and risk of damage to the right hepatic radicles [20]. Rouviere's sulcus or a line of safety similarly may not be clear, so a subtotal cholecystectomy can be undertaken and Purzner's recent classification of this is shown in Fig. 26.4 [21, 22]. If a subtotal cholecystectomy is performed on the gallbladder (Fig. 26.5), then every attempt should be made to remove any residual gallstones. If a fenestrating subtotal cholecystectomy is performed, a drain should be placed as bile leaks occur in over 10%. The infundibular approach will increase the injury rate to the CBD.

When performing a subtotal cholecystectomy an intraoperative cholangiogram (IOC) is generally not possible, so if there has not been preoperative visualization of the CBD a postoperative MRI should be considered.

26.6 Traps During Procedure

The OR ambiance must assist the surgeon, especially when approaching difficult or critical stages of dissection. The commonest traps are shown in Table 26.4. The decision to convert or abort should be proactive rather than reactive to secondary hemorrhage or visceral injury. A great device for a difficult and stuck GB is a laparoscopic peanut. This will facilitate tissue dissection and identification of the window between cystic duct and artery.

Many elderly patients undergo laparoscopic cholecystectomy as an emergency procedure and as such their incidence of CBD stones is >10%. Failure to detect and

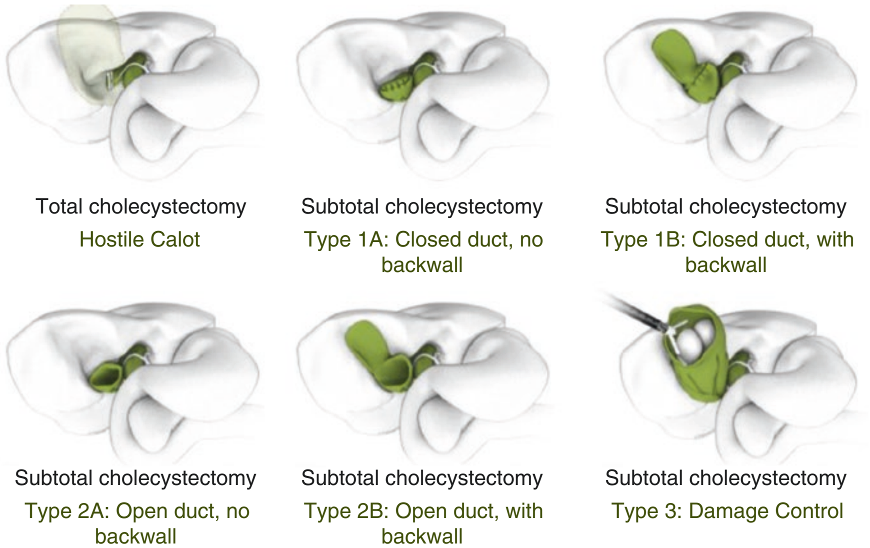

Fig. 26.4 Purzner's classification of subtotal cholecystectomy [21] (Source: Toronto Video Atlas of Surgery www.tvasurg.ca) [22]

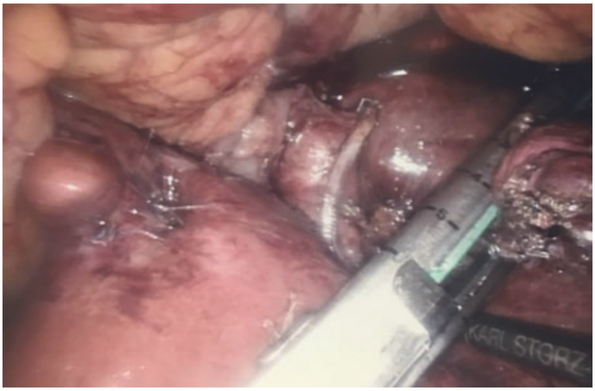

Fig. 26.5 Reconstituted Type 1A subtotal cholecystectomy (Making sure to remove stone before closing the GB)

clear these will result in increased readmission and complications [15]. Preoperative MRI may help but access may be limited. Fluorescent cholangiography, which has some benefit in identifying the extrahepatic bile duct anatomy, does not detect CBD stones [23].

An intraoperative cholangiogram (IOC) is best done with a Reddick Olsen Forceps and a size 4 (or 3 if smaller) ureteric catheter via the cystic duct. There should be no side holes on the ureteric catheter and it should be primed with dilute contrast (Fig. 26.6). Once the control image has been identified, correct positioning of the image intensifier should capture the images in a continuous mode to allow the

Table 26.4 Traps made during laparoscopic cholecystectomy

Port incision incorrect size; not in skin crease
Second Grasper on GB instead of retracting duodenal downwards at initial dissection
Failure to look for and document CVS, Line of Safety, Rouviere's Sulcus
Aggressive diathermy to control bleeding points
Failing to convert to open or abort when "impossible"
Not picking up "dropped" stones
Failing to get a second consultant to help/advise if needed

Fig. 26.6 Intraoperative cholangiogram

dilute contrast to outline the stones clearly in the CBD. If a CBD stone is discovered, a single procedure transcystic clearance is optimal. This should be done only if the operator is experienced. The success of a transcystic CBD clearance will be aided, where there is a large cystic duct, by using a "no-tip" Dormia basket and small choledochoscope. A CBD clearance should not be attempted if there is a small CBD, a large single stone, and a small cystic duct or multiple stones (>6) as the procedure is unlikely to be successful and risk damage to the CBD. Intraoperative ERCP will be increasingly used in the elderly as more centers take up its use [24].

26.7 Closure and Postoperative Care

If the patient has been converted to an open cholecystectomy using a Kocher incision, fascial closure should be done in small bites, utilizing a wound bundle, with antibiotic wash, wound protector, and consideration for onlay prophylactic mesh to reduce dehiscence and incisional hernia [25].

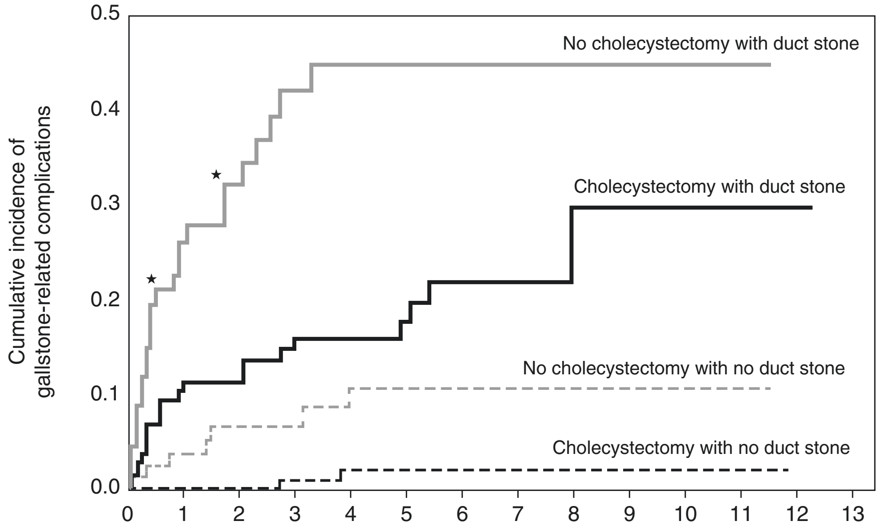

Fig. 26.7 Gallstone-related complications in subgroup analysis according to a history of bile duct stones. (Source: Yoichi Matsui World J Surg (2019) 44:721–729) [26]

The elderly have less physiological reserve and a higher complication rate. If a drain has been used, especially in a difficult case, it is best left in for 48 h as occasionally bile leaks will not declare themselves until the second postoperative day. Matsui has clearly identified the pivotal importance of CBD stones and their effect of dramatically increasing the cumulative incidence of gallstone-related complications [26].

26.8 Conclusion

The fine art of decision before incision is particularly required when treating the elderly with cholecystitis. The elderly with cholecystitis are less likely to settle and do not have a great outcome with cholecystostomy. The procedure of choice is same admission cholecystectomy where possible and particular attention should be paid to identify and clear CBD stones if present before or during the index procedure, or with a postoperative ERCP (Fig. 26.7).

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Management of Acute Pancreatitis in Elderly

27

Asad Azim, Gregory Veillette, and Rifat Latifi

27.1 Aging Pancreas

In the US, pancreatitis is a major cause of morbidity and mortality based on the severity of the the diease [1]. Age-related changes in the pancreas include fatty infiltration, parenchymal atrophy, fibrosis, and ductal ectasia. These changes have a varying degree of impact on the functional ability of the pancreas resulting in a very limited or marginal exocrine and endocrine capacity of the pancreas in elderly patients [2]. Poor structural integrity and a limited functional reserve of the pancreas in addition to comorbidities contribute to the severity of pancreatitis. A complicated disease course leads to higher complication rates including multi-organ failure, diabetes, and exocrine insufficiency, and significantly higher mortality rates. Hastier et al. have reported that only one-third of the patients with an age >70 without a history of pancreatic pathology have duct diameters within normal defined limits [3]. These structural changes can pose a challenge in the diagnosis and management of acute pancreatitis in the elderly. These changes should be taken into account and are of prime importance while making the diagnosis or managing patients with pancreatitis.

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27.2 Etiology and Pathophysiology

27.2.1 Gallstones

Gallstone is the leading cause of acute pancreatitis in the US at any age. Approximately 35% of acute pancreatitis cases have an underlying biliary etiology. In the elderly, gallstones account for up to 75% of cases of acute pancreatitis. Old age is associated with lithogenicity of the bile hence a higher incidence of gallstones and resulting gallstone pancreatitis. It is proposed that blockade of the ampulla by a gallstone or edema induced by a passing gallstone is the inciting factor in the pathogenesis of acute pancreatitis [4].

27.2.2 Alcohol

Only 5% of the episodes of acute pancreatitis are related to alcohol use, which is significantly lower as compared to younger adults. However, alcohol is still the most common cause of chronic pancreatitis in the elderly. A potential mechanism by which alcohol induces pancreatitis include, spasm of the sphincter of Oddi, obstruction of small pancreatic ductules by proteinaceous material, metabolic abnormalities, and direct impact of alcohol and its metabolites [5].

27.2.3 Other Etiologies

Acute pancreatitis associated with metabolic and medication-induced etiologies is much higher in comparison to younger patients. This is related to a higher comorbidity burden, polypharmacy, and hence extensive drug interactions that are very difficult to manage. Common drug classes that are known to cause pancreatitis include ACE inhibitors, statins, diuretics, antiretroviral, anti-seizure, and hypoglycemic agents. Unfortunately, with advancing age, the probability of being on one or more of these above inciting medications increases exponentially. New onset of pancreatitis in the elderly with no obvious cause should also raise the suspicion of underlying carcinoma and a clinician should have a low threshold to rule out malignancy in elderly patients [6].

27.3 Clinical Presentation

The most prevalent features in patients presenting with acute pancreatitis are abdominal pain, nausea, and vomiting. Pain is usually localized to the epigastrium; it classically radiates towards the back and patients report relief with sitting up and leaning forward. The most common sign is epigastric tenderness. Depending on the severity of pancreatitis, patients may present hemodynamic lability, which can be drastic in the elderly due to limited reserve. Although it is not very common, patients with necrotizing pancreatitis and retroperitoneal hemorrhage can present with Grey Turner sign (bruising of the flanks), Cullen sign (bruising in the periumbilical region), or Fox sign (bruising in the inguinal region resulting from blood dissection into subcutaneous tissues of the respected areas).

27.4 Diagnosis

27.4.1 Lab Workup

Pancreatic injury results in the release of a variety of digestive enzymes from acinar cells that escape into the systemic circulation. Amylase is one of the most commonly assayed enzymes to confirm the diagnosis of acute pancreatitis. Amylase levels rise within several hours after the onset of symptoms and typically remain elevated for 3–5 days during uncomplicated episodes of mild acute pancreatitis. Amylase has a short half-life of about 10 h; the downside to this is that levels can normalize as soon as 24 h after onset of the disease. The sensitivity of this test depends on what threshold value is used to define a positive result (90% sensitivity with a threshold value just above the normal range vs. 60% sensitivity with a threshold value at three times the upper limit of normal). Specificity is limited because a wide range of disorders can cause elevations in serum amylase concentration.

Serum lipase concentrations have similar kinetics as those of amylase. As compared to amylase, serum lipase has a longer serum half-life; however, it may be useful for diagnosing acute pancreatitis late in the course of an episode. Generally, lipase is more specific than amylase in the diagnosis of acute pancreatitis.

27.5 Imaging

27.5.1 Ultrasonography

Ultrasonography can be useful in visualizing the pancreas in thin and lean patients, but this is highly dependent on expertise. Ultrasonographic images can reveal a diffusely enlarged, hypoechoic pancreas. However, overlying bowel gas (Ileus) severely limits the visualization of the pancreas in a large percentage of cases. Although Ultrasound has poor sensitivity and specificity for detecting pancreatic pathology, ultrasonography plays a vital role in the identification of the etiology of pancreatitis, i.e., the detection of gallstones.

27.5.2 Computed Tomographic Scan

The most important imaging test in the evaluation of acute pancreatitis is CT scanning. CT scan images obtained with intravenous contrast provide vital information based on which pancreatitis can be classified as either interstitial edematous or necrotizing pancreatitis. Findings of mild acute pancreatitis include pancreatic enlargement and edema, effacement of the normal lobulated contour of the pancreas, and stranding of peripancreatic fat. Whereas necrotizing pancreatitis is characterized by hypo-enhancing areas within pancreatic parenchyma or surrounding tissue. Furthermore, CT scans later in the course of the disease help in making the diagnosis of local complications including infected necrosis or pseudocyst and walled-off necrosis [7].

27.6 Assessment of Severity

Approximately, 70–80% of acute pancreatitis are mild and generally resolve within 5–7 days with minimal therapy. Overall mortality with the mild disease is less than 1%. About 20% of the patients present with a severe disease, either a severe local disease or a severe systemic disease leading to multi-organ failure. In severe disease, the mortality rate goes as high as 20% or even higher in elderly patients due to limited organ reserve and poor overall resilience. Age is one of the most important factors that is associated with adverse outcomes in patients with acute pancreatitis. Friability of the pancreas and limited organ reserve put the elderly patient at a higher risk of both severe local disease as well as multi-organ failure. Moreover, failure to rescue once the elderly patient suffers from severe disease is much higher as compared to their younger counterparts. Multiple scores and criteria exist for early prediction of the severity of disease and hence appropriate triaging and resource allocation. Two of the most commonly used criteria for severity assessment, i.e., Ranson and APACHE use age as a major factor to stratify patients who are at higher risk of developing serve disease and resulting complications [8, 9].

27.6.1 Revised Atlanta Criteria

The Atlanta Classification system was developed at a consensus conference in 1992 to establish standard definitions for the classification of acute pancreatitis. Revision of the Atlanta Classification provides a detailed system that emphasizes disease severity and includes comprehensive definitions of pancreatic and peripancreatic collections. According to revised Atlanta Criteria, the diagnosis of AP requires two of the following three features: (1) abdominal pain consistent with acute pancreatitis; (2) serum lipase activity (or amylase activity) at least three times greater than the upper limit of normal; or (3) characteristic findings of acute pancreatitis on contrast-enhanced computed tomography (CECT). In addition, based on the CECT criteria, acute pancreatitis is divided into two distinct types: acute interstitial edematous pancreatitis and acute necrotizing pancreatitis (ANP) (Figs. 27.1 and 27.2). ANP is further subdivided into pancreatic parenchymal necrosis, or peripancreatic necrosis or both combined. Local complications refer to the presence of peripancreatic fluid collections which are classified as acute peripancreatic fluid collection (APFC), pancreatic pseudocyst (Fig. 27.3), acute necrotic collection (ANC), and walled-off necrosis (WON) (Fig. 27.4). Characteristic and CT appearance of these findings are

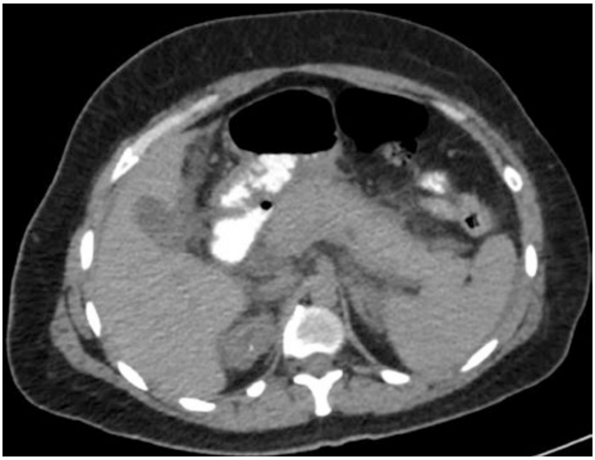

Fig. 27.1 Acute interstitial edematous pancreatitis

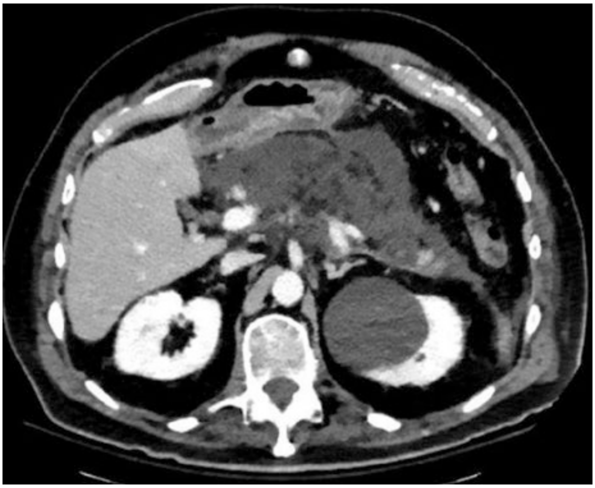

Fig. 27.2 Necrotizing pancreatitis with ccute necrotic collection

summarized in Table 27.1. Systemic complications are defined as exacerbation of preexisting comorbidities, i.e., chronic obstructive pulmonary disease (COPD), chronic kidney disease (CKD), congestive heart failure (CHF), and chronic liver disease (CLD). Organ failure is defined based on the Modified Marshall Scoring system, which evaluates the dysfunction of three major organ systems, respiratory, renal, and cardiovascular based on PaO2 to FiO2 ratio, serum creatinine, and systolic blood pressure, respectively. Each organ system is scored from 0 to 4 based on the degree of dysfunction. According to Revised Atlanta Criteria, mild acute pancreatitis is defined as the absence of organ failure and local or systemic complications. Moderately severe pancreatitis is characterized by transient organ failure (lasting less than 48 h) and/or local or systemic complications. Severe acute pancreatitis is associated with persistent organ failure (>48 h) single or multiple [7].

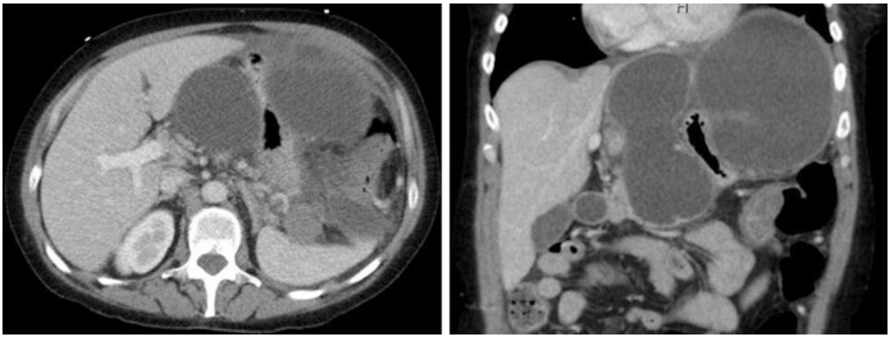

Fig. 27.3 Pancreatic pseudocyst

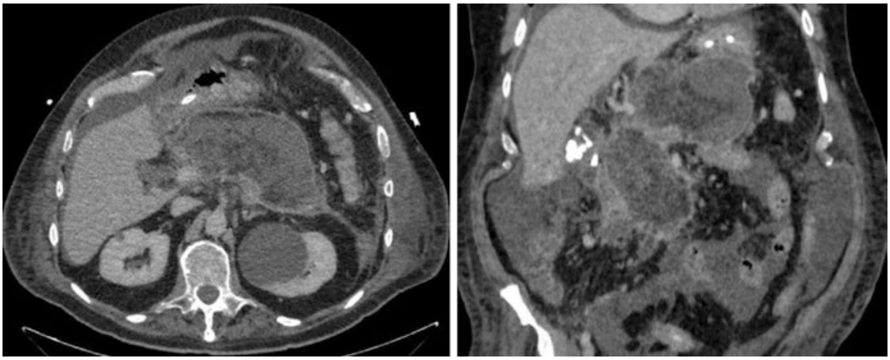

Fig. 27.4 Walled-off necrosis

Table 27.1 Types of fluid collections

Type of collection	Type of pancreatitis	Description	CT scan characteristics
Acute peripancreatic fluid collection (APFC)	Acute interstitial edematous pancreatitis	Within 4 weeks after onset.	Homogeneous fluid density collection surrounded by normal peripancreatic fascial planes. No definable wall or encapsulation
Pancreatic pseudocyst	Acute interstitial edematous pancreatitis	>4 weeks after onset	Homogeneous fluid collection, well-circumscribed. Encapsulated with no solid component or septa
Acute necrotic collection (ANC)	Acute necrotizing pancreatitis	Within in 4 weeks after onset	Heterogeneous collection with solid (necrotic component) and liquid components. No definable wall encapsulation
Walled-off necrosis (WON)	Acute necrotizing pancreatitis	>4 weeks after onset	Heterogeneous, with varying degree of solid and liquid components. Encapsulated with well-defined wall

Modified Atlanta Criteria

27.6.2 Ranson Criteria

Ranson Criteria is based on age, white blood cell count, glucose, serum lactate dehydrogenase (LDH), aspartate aminotransferase (AST) determined on admission, and drop in hematocrit, blood urea nitrogen (BUN), serum calcium, PaO2, base deficit, and fluid requirements measured 48 h post-admission shown in Table 27.2. Based on the abovementioned variables, the score is calculated correlating with morbidity and mortality related to acute pancreatitis. Limitations to Ranson criteria are that the score cannot be calculated until after 48 h and it can only be used once [8].

27.7 Treatment Strategies

27.7.1 Initial Resuscitation

The most important component of initial management is the assessment of fluid deficit and resuscitation. Due to widespread systemic inflammatory response, third space fluid losses can be immense and often underestimated. In elderly patients special care should be taken as over resuscitation can exacerbate CHF, which can further complicate the problem and sometimes can be fatal. Frequent reassessment of intravascular volume, aggressive fluid administration, and electrolyte replacement should be ensured. Patients with severe acute pancreatitis or those who failed to respond to initial fluid resuscitation are best managed in an intensive care unit setting with close cardiopulmonary monitoring. The degree and intensity of monitoring are tailored to disease severity and a comorbidity burden especially in the elderly. Urinary catheter should be inserted to monitor adequacy of urine output and watch for impending renal failure. Nasogastric tubes have been previously advocated to avoid pancreatic stimulation. There is no clinical data that supports this practice and hence should only be limited to patients with altered mental status, increased risk of aspiration, or present with paralytic ileus and intractable vomiting.

Table 27.2 Ranson's criteria

Ranson criteria and prognosis	
At admission	At 48 h
• Age >55 years • Leukocyte count >16 × 10^3/mcL • Blood glucose >200 mg/dL • Serum LDH >350 IU/L • Serum AST >250 IU/L	• Decrease in hematocrit >10% • Increase in BUN of >8 mg/dL • Serum calcium less than 8 mg/dL • PaO_2 < 60 mmHg • Base deficit >4 mEq/L • Estimated fluid sequestration >6000 mL
Score < 3 = mortality 0–3%, score < 3 = mortality 0–3%, score ≥ 6 = mortality 40%	

27.7.2 Nutritional Support

Traditionally, in patients presenting with acute pancreatitis, enteral feeding was limited to provide “pancreatic rest” as it was believed that enteral feeding stimulated the secretion of proteolytic pancreatic enzyme thus exacerbating the inflammatory process. However, on the other hand, limiting nutritional intake can have grave consequences. Inflammatory stress is a state of increased nutritional demand leading to catabolism and negative nitrogen balance.

Patients with mild acute pancreatitis generally need no or minimal nutritional support, as their disease typically resolves within 1 week. In contrast, patients with severe pancreatitis usually have a more prolonged disease course and should begin to receive nutritional support as early as feasible. Although these patients traditionally have been administered total parenteral nutrition (TPN), recent evidence suggests that enteral nutrition is safe, is less costly, and is associated with a lower complication rate as compared to parental nutrition. Administration of enteral nutrition supports the integrity of the intestinal mucosal barrier thus limiting or preventing bacterial translocation. A meta-analysis of eight randomized trials comparing enteral vs parenteral nutrition for acute pancreatitis revealed that enteral nutrition significantly reduced mortality, multiple organ failure, systemic infections, and the need for operative interventions compared to those who received TPN [10]. Traditionally, feeds have been delivered to the jejunum through nasojejunal tubes to avoid stimulating pancreatic exocrine secretion; however, recent studies have shown that continuous feedings through nasogastric tubes are equally safe and effective.

27.7.3 Endoscopic Retrograde Cholangiography (ERCP)

The benefit of early ERCP in acute pancreatitis has been studied extensively. Studies have shown that early ERCP with stone extraction and sphincterotomy clearly benefits the subset of patients with gallstone pancreatitis who present with cholangitis and biliary obstruction. Current recommendations for patients, with cholangitis, consist of performing ERCP urgently (within 24 h). The timing of ERCP in patients with biliary obstruction is not clear (24–72 h). It is reasonable to wait up to 48 h for biliary obstruction to resolve [11]. Magnetic Resonance Cholangiopancreaticography (MRCP) and endoscopic ultrasound (EUS) can be helpful to look for persistent choledocholithiasis in equivocal cases to prevent unnecessary intervention. In patients with no signs and symptoms of cholangitis or biliary obstruction, ERCP is associated with high complication rates and no apparent benefits; therefore, it is not recommended.

27.7.4 Cholecystectomy

The guidelines recommend that cholecystectomy should ideally be performed at the index admission, and should not be delayed by >2 weeks for patients with mild acute gallstone pancreatitis who are good surgical candidates for the procedure. Laparoscopic Cholecystectomy should be the procedure of choice considering less postoperative pain and shorter hospital length of stay with comparable procedure-related morbidity and mortality compared to open procedure. The incidence of recurrent pancreatitis or associated gallstone complications during the 6-week period after an episode of gallstone pancreatitis is 18% in patients who do not undergo cholecystectomy [12]. Even the risk of recurrent pancreatitis is substantially high within 2 weeks after the initial episode of biliary pancreatitis who are discharged without cholecystectomy [13].

Therefore, current recommendations are to perform cholecystectomy in the same hospital admission once the acute phase of the episode has resolved which can be followed by analyzing the overall clinical condition, physical exam, and down-trending laboratory markers. This strategy does not increase operative complications, conversion to open procedures, or mortality [14].

27.7.5 Approach to Infected Necrosis

Surgery used to be the mainstay treatment for acute pancreatitis, this is no longer the case and surgical management has largely been replaced by more conservative and supportive care. However, surgery is still an integral component of treatment in patients with acute pancreatitis with gallstone pancreatitis and local complications.

27.7.6 Percutaneous Drainage

Invasive management is usually indicated in the presence of infection. Infected pancreatic necrosis/collection is suggested by clinical signs such as persistent fevers, leukocytosis, and radiological evidence of gas in peripancreatic collection. Drainage alone is the initially recommended intervention for infected pancreatic necrosis [15]. This is most often accomplished through a percutaneous image-guided approach, which is technically feasible in the vast majority of cases and is also the first step of step-up approach [16, 17]. The minimally invasive nature of this technique allows intervention even in the early phase of severe necrosis, as compared to an open approach which is associated with significantly higher mortality. It can be used as the primary treatment, as an adjunct to other techniques, or to reduce post-operative persistent fluid collections. The preferred approach for percutaneous drains is retroperitoneal so that the drain tract can later be used to perform video-assisted retroperitoneal debridement.

27.7.7 Video-Assisted Retroperitoneal Debridement (VARD)

VARD procedure is part of a “step-up” approach, it is the second-line therapy and usually follows percutaneous drainage when it fails to show an impact on clinical condition of the patient. A small incision is made in the left flank in proximity to the previously placed percutaneous drain, which is used as a guide to accessing the retroperitoneum. The cavity is cleaned for better visualization using standard suction and irrigation. All necrotic tissue that is easily visualized is carefully removed until the deeper cavity is reached and further dissection and debridement cannot be performed under direct visualization. At this point, a long laparoscope trocar is placed from the incision followed by a zero-degree video scope. The cavity is then insufflated via the percutaneous drain. Under video scope guidance further debridement of retained necrotic tissue is performed. Complete necrosectomy is not the ultimate goal of this procedure, so only loose necrotic tissue is debrided thus keeping the risk of tearing of underlying blood vessels to a minimum. Once the debridement is completed, the percutaneous drain is removed and replaced with two large-bore drains. Irrigation is usually continued postoperatively through surgically placed drains. In a multicenter randomized controlled trial, patients with infected pancreatic necrosis were randomized to undergo primary open necrosectomy or a step-up approach consisting of percutaneous drainage followed by VARD. Open necrosectomy was rarely used only in cases where VARD could not be accomplished. Although there was no difference in mortality between the two groups, primary open necrosectomy was associated with a higher rate of major complications and increased cost [18].

27.7.8 Direct Endoscopic Nacrosectomy (DEN)

DEN is performed via transmural puncture into a necrotic collection with the help of an endoscope. The prerequisite to this technique is that the collection must be in close proximity or abutting either stomach or duodenum. With the help of transluminal endoscopic ultrasound, the collection is visualized and accessed using the FNA needle. The track into the collection is then dilated and large-bore stents are placed. Mechanical debridement can be performed by passing the endoscope via stent into the cavity and by using a snare, net, or a basket. Typically, multiple sessions are necessary to completely debride the cavity. The use of hydrogen peroxide has also been described in the literature and has been shown to decrease the number of sessions required to clean up the necrosis. This endoscopic approach can be used as a step-up approach replacing VARDS or as a primary treatment for walled-off necrosis [19].

27.7.9 Minimally Invasive Nacrosectomy

Minimally invasive necrosectomy was first described in 1996 by Ganger. Three minimally invasive approaches were initially described, retrogastric debridement, full retroperitoneal approach, and transgastric drainage with a success rate of about 75% [20]. Retrogastric technique is a preferred approach for acute necrotizing collection. Retrogastric debridement can be performed by either a transgastrocolic or transmesocolic/infracolic approach. In a transgastrocolic approach, the gastrocolic ligament was opened to access the necrosed tissue. This approach is preferable for necrosis involving the head and body of the pancreas. In the transmesocolic or infracolic approach, the mesocolon was opened near the ligament of Treitz, between the middle colic artery and left colic artery. It is the preferred approach in necrosis involving the tail region of the pancreas. Necrotic tissue is dissected and removed using blunt dissection. The cavity is copiously irrigated with normal saline followed by placement of two large-bore surgical drains in the cavity. The transgastric approach is mostly used for walled-off pancreatic necrosis [21].

The minimally invasive approach is associated with less surgical trauma in these severely ill patients and there is substantial data suggesting a significant reduction in the incidence of new-onset organ failure compared to open approach.

27.7.10 Open Necrosectomy

Open necrosectomy used to be the standard approach for the treatment of pancreatic necrosis. Historically, early necrosectomy was recommended for all patients with necrotizing pancreatitis. However, its role has undergone resolution and is now only recommended for patients with infected necrosis not amenable to endoscopic and/or minimally invasive approaches or in centers with a lack of expertise in these techniques (Fig. 27.5).

Midline or bilateral subcostal (Chevron or Rooftop) incisions are used to access the abdomen. The lesser sac is approached by dividing the gastrocolic ligament. If the inflammatory reaction is intense and dissection planes are obliterated alternate route is opted by dividing the avascular portion of the transverse mesocolon. Loose nonviable necrotic tissue is removed by blunt dissection without performing anatomic resections. Special care should be taken to avoid injury to underlying vessels that are at high risk of rupture secondary to an intense inflammatory reaction. Any

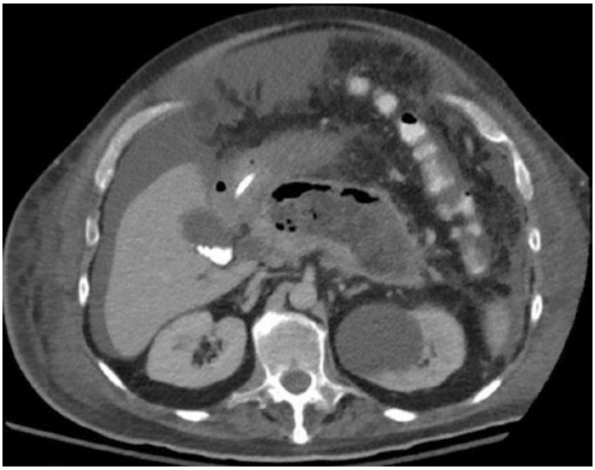

Fig. 27.5 Infected pancreatic necrosis (Courtesy of Dr. Latifi)

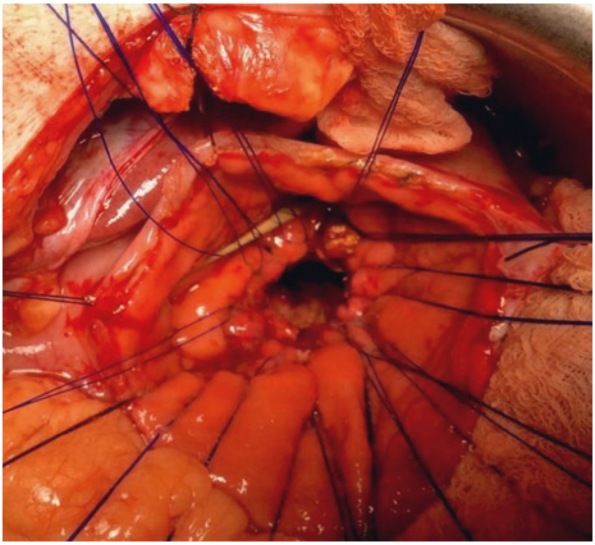

Fig. 27.6 Transgastric cystogastrosotomy (Courtesy of Dr. Latifi)

injury to surrounding major vessels including splenic, superior mesenteric vessels, or portal veins can result in massive hemorrhage that is difficult to control and can be fatal. Once the necrosectomy is performed, the cavity is lavaged with normal saline and surgical drains are left in place with the intent to continue irrigation via drains during the postoperative period [22].

Often times, the lesser sac cannot be entered at all, due to vascularization and inflammation. In this situation, the surgeon should select arriving at the necrotic tissue through anterior and posterior stomach. Care should be taken to stay in the midbody of the stomach. Anteriorly, the incision should be made longitudinally. The posterior opening of the stomach should be large as well, at least 5–6 cm, enough to allow gentle but complete evacuation of a dark clay-like necrotic material. One has to be careful and gentle during this process. The posterior stomach wall and pseudocyst wall are sutured with interrupted, slow absorbing sutures (Fig. 27.6).

The procedure has been modified in an attempt to achieve optimal results. Sometimes the abdomen is left open with packing and planned staged re-laparotomies for subsequent debridements and packing changes to ensure the adequacy of debridement. In other modifications, the drains are used for continuous lavage of the cavity to minimize stasis and risk of infection. Open necrosectomies for acute infected pancreatic necrosis are considered as a last tier therapy due to high morbidity, mortality, and debilitating complications including enteric-cutaneous and pancreatic-cutaneous fistulas [17].

27.7.11 Pseudocyst and Walled-off Necrosis

About 30–50% of patients developed acute collections with acute pancreatitis. Without evidence of any infection, most of these collections remain asymptomatic and spontaneously resolve without any intervention. However, based on size and location they can cause upper abdominal pain, gastric outlet obstruction, or obstructive jaundice. Pseudocysts are typically round, unilocular, and have a dense wall. In contrast, walled-off necrosis is typically heterogeneous with liquid and non-liquid density, with varying degrees of loculations, and is encapsulated by a well-defined wall. Previously, it was believed that walled off collections that existed beyond 6 weeks rarely resolve and are associated with high complication rates; hence, it was recommended that all walled off collections (pseudocyst/walled-off necrosis) that persist beyond a period of 6 weeks should undergo drainage. This concept has now evolved and the natural history of asymptomatic walled off collections follows a benign course, especially those with less than 6 cm diameter that have a high tendency for spontaneous resolution. Currently, indications of surgical drainage in the absence of any infection are persistent symptoms, i.e., intractable pain, gastric outlet obstruction, and obstructive jaundice. However, any intervention of a symptomatic patient without evidence of infection should be delayed 4–6 weeks to provide adequate time for the maturation of the cyst wall.

Multiple treatment options are available including percutaneous drainage and internal drainage either trans-abdominally or endoscopically. Percutaneous drainage that is obsolete is avoided due to high failure rates especially in patients with ductal abnormalities [23]. The endoscopic approach is feasible in patients when the collection is in close proximity to the stomach or duodenum. (Refer to DEN for description) [19]. A small single-center study has shown equal efficacy of open vs endoscopic cystogastrostomy for pseudocyst with advantages of no general anesthesia, shorter hospital length of stay, and decreased cost for patients undergoing an endoscopic approach [24]. However, for walled-off necrosis due to the presence of a solid component endoscopic approach, a multistage procedure in order to achieve complete evacuation of debris is required. No high-quality data exists to show any advantages if any of the endoscopic approaches compared to the transabdominal approach.

Transabdominal procedures for pseudocyst or walled-off necrosis include cystogastrostomy, cystoduodensotomy, and Roux-en-Y cystojujenostomy. These can be performed open, laparoscopically, or robotically depending upon the feasibility, complexity of the collection, and expertise of the surgeon. The internal drainage of the cyst is achieved by creating communication between the cyst wall and the gastrointestinal tract. For transgastric cystogastrostomy, an anterior longitudinal gastrostomy is made to enter and palpate the lumen posterior gastric wall. The location of the cyst wall can be confirmed using an intraoperative ultrasound or by needle aspiration which also determines the distance of the cyst wall to the posterior gastric wall. The cyst is entered by incising the posterior gastric wall. Intraoperative ultrasounds can be used to evaluate the complete extent of the cavity. Necrotic tissue within the cyst cavity is evacuated. Cyst cavity s explored for any loculations and are lysed. A generous cystogastrostomy (Fig. 27.6) is done 5 cm or more ensuring a wide patent connection between the cyst and stomach wall, and finally, the anterior gastrostomy site is closed. Extra gastric cystogastrostomy can also be performed by approaching the lesser sac and identifying the spot where the posterior gastric wall

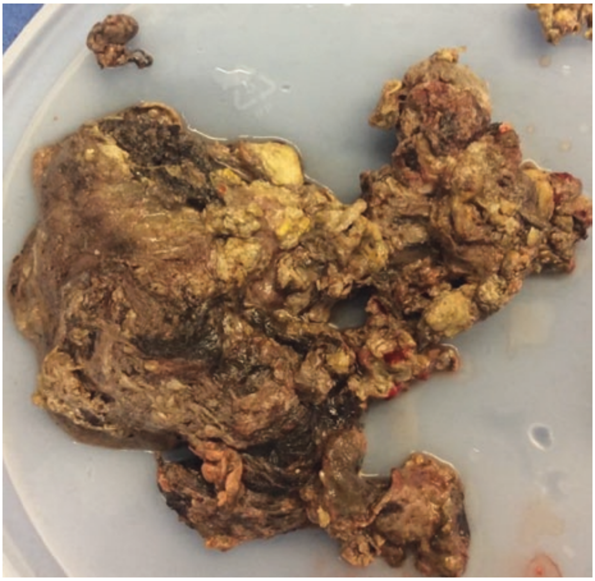

Fig. 27.7 Pancreatic necrosum (Courtesy of Dr. Latifi)

and pseudocyst wall lie in close proximity. Cystogastrostomy can be performed between the posterior gastric wall and anterior cyst wall either by stapler or in a hand-sewn fashion (Fig. 27.7).

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Skin and Soft Tissue Infections in the Geriatric Patient

28

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28.1 Introduction

The world is aging. The number of individuals aged 60 years and over is expected to increase globally from 841 million in 2013 to more than 2 billion by 2050 [1]. More than 20% of the United States population will surpass the age of 65 years by 2030 [2]. Skin and soft tissue infections are potentially dangerous and unfortunately all too common in this aging population. There is a danger of these infections progressing rapidly to necrotizing soft tissue infections with associated systemic toxicity and high morbidity and mortality.

28.2 Epidemiology

The incidence of skin and soft tissue infections has been shown to increase by 44% per decade of life and be recurrent in up to 20% of patients [3, 4]. Skin and soft tissue infections are the fourth leading cause of emergency hospital admissions for patients over age 65 years and increasing [2, 3]. The mortality has been reported to range from 12% to 21% [5, 6]. The presence of wounds, skin sores, and decubitus ulcers predispose to skin and soft tissue infections. The presence of incontinence, whether urinary or fecal, has not been shown to increase the risk of these infections [7].

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Table 28.1 Risk factors for skin and soft tissue infections and their associated pathogens

Diabetes mellitus	*S. aureus*, group B *streptococci*, anaerobes, gram-negative bacilli
Cirrhosis	*E. coli, K. pneumonia*, gram-negative bacilli, *V. vulnificus*
Neutropenia	*P. aeruginosa*
Human bite	Aerobic and anaerobic oral flora
Dog bite	*C. canimorsus, P. multocida*
Cat bite	*P. multocida*
Whirlpool	*P. aeruginosa*
Seawater exposure	*V. vulnificus*
Injection sites	Anaerobes

Multimorbidity and malnutrition are present in more than half of older Americans. Table 28.1 lists risk factors for skin and soft infections and common bacterial pathogens [8] The presence of two or more chronic medical conditions in one individual often coexists with polypharmacy [9, 10]. Venous stasis and lymphedema, often following surgical disruption of the lymphatics during saphenous vein harvesting or axillary node dissection, can also increase the risk for skin and soft tissue infections in the extremities.

28.3 Classification

Skin and soft tissue infections have been described according to the anatomic location and depth of infection. Many names have been applied to these serious infections such as synergistic gangrene and Fournier gangrene for the scrotum. Necrotizing soft tissue infection represents the most severe form and manifests as necrotic lesions within any layer of the soft tissue compartments. It is more useful to characterize these based on the deepest tissue layer involved by necrosis. Involvement of only the skin and subcutaneous tissue is necrotizing cellulitis, whereas the involvement of the fascia is referred to as necrotizing fasciitis, and involvement of underlying muscle is referred to as necrotizing myositis or sometimes myonecrosis.

Classification of necrotizing soft tissue infections according to the microbiological etiology is also clinically useful [11, 12]. Type I infections are the most common type occurring in 55–80% of patients. Type I infections are mixed infections, involving aerobic and anaerobic bacteria. *Streptococcus* and *Bacteroides* are the most common aerobic and anaerobic bacteria, respectively. Diabetes mellitus, obesity, immunosuppression, chronic kidney disease, cirrhosis, malignancy, and alcohol abuse are common risk factors.

Type II infections are the second most common type of necrotizing soft tissue infection and are associated with either beta-hemolytic *Streptococcus* or *Staphylococcus aureus* infection. There is a history of trauma to the area, including surgery and intravenous drug use, which supplies the initial inoculation. The bacteria involved in type II infections produce exotoxins and may result in an intense proinflammatory cytokine release that produces the septic shock associated with necrotizing soft tissue infections. The inflammatory response also causes widespread thrombosis of blood vessels leading to necrosis of the tissues [13]. The natural state of immunosuppression commonly presents in the geriatric patient because of immunosenescence frequently blunts or suppresses this response. Other varied exotoxins produced by the bacteria in type 1 and type II infections break down connective tissue structural components and decrease viscosity of the purulent fluid so that it transmits rapidly along fascial planes [11].

Infections caused by *Clostridium* species and *Vibrio vulnificus* are associated with exposure to warm coastal seawater or consumption of raw oysters. They are classified as type III infections and have a mortality ranging between 30 and 40% [14]. Aeromonas hydrophila and fungi are the etiology of type IV infections. *Candida* species are typically found in immunocompromised patients and zygomycetes in immunocompetent patients. Frequently these fungal infections are a result of penetrating traumatic injury. Type IV infections are rare, but aggressive and associated with high mortality, especially in the immunocompromised patient [15].

28.4 Pathophysiology

This increased risk has been attributed to a number of factors. Atrophy and reduced elasticity, turgor, turnover, and perfusion render aging skin prone to tears and pressure ulcer formation, particularly in the setting of comorbid diabetes mellitus, peripheral vascular disease, and impaired mobility. The compromised skin serves as a portal of entry for bacterial pathogens [16].

To develop a skin and soft tissue infection the pathogen must evade the host defenses after invading the tissue. The aging immune system is a complex phenomenon that we have yet to fully comprehend [17–19]. Immunosenescence in the geriatric patient creates a natural state of immunosuppression characterized by a compromised primary T-cell response to antigens impairing the effectiveness of the cell-mediated immune response. Humoral immunity is likewise blunted as the number of naïve B-cells necessary for new antibody formation is decreased. Polymorphonuclear neutrophils exhibit reduced chemotaxis, phagocytosis, and intracellular killing of pathogens. Similarly, age-associated decreases in macrophage, natural killer, and dendritic cell function are present. Other comorbid conditions, including diabetes mellitus, chronic kidney disease, cirrhosis, and malignancy may also contribute to immune dysfunction.

The final step in the development of skin and soft tissue infection is the elaboration of toxins. There are two main classes of toxins—endotoxins and exotoxins. Endotoxins are lipopolysaccharide chains found abundantly in gram-negative bacterial cell walls. In modest quantities, lipopolysaccharides may be beneficial in immunocompetent patients by activating the immune system leading to the release of chemoattractants and enhancing T-lymphocyte activation. Massive elaboration of liposaccharides may, however, lead to detrimental hyperactivity of the patient's immune and inflammatory systems leading to rapidly progressive necrotizing soft tissue infections and overwhelming sepsis.

Table 28.2 Examples of bacterial toxins

Bacteria	Toxin	Action
S. pyogenes	Fimbrillae	Adherence to epithelial cells
	M protein	Prevents phagocytosis
	Protein F	Allow access to epithelial cells
S. aureus	Clumping factor	Adherence to host epithelial cell
	Protein A	Prevents opsonization and phagocytosis
	Serine protease	Digest desmosome proteins and cause bullous disease
	Lipases	Digest skin fatty acids to disrupt skin barrier
Clostridium species	Collagenases	Digestion of connective tissue
	Hyaluronidases	Matrix protein digestion
	Alpha-toxin	Cell membrane and nerve sheath degradation
E coli	Nonspecific exotoxin	Intracellular signaling disruption leading to cell death

Exotoxins, on the other hand, are actively secreted proteins that cause direct tissue damage and subsequent cell lysis through various mechanisms including enzymatic reactions, cellular dysregulation, or pore formation. Superantigens are produced by some virulent strains of *S. aureus* and *S. pyogenes*. These antigens bind to T-cell receptors and enable a massive release of cytokines which causes a grossly exaggerated inflammatory response. Necrotizing soft tissue infections caused by these strains are associated with severe tissue necrosis. Table 28.2 lists examples of bacterial toxins [8].

The immunologic and inflammatory response to the necrotizing soft tissue infection may be attenuated or absent in the geriatric patient because of the lack of inflammatory mediators associated with physiologic and/or iatrogenic immunosuppression discussed earlier. In immunocompetent patients the septic response includes fever, confusion, functional decline, and hypotension and can be divided into four stages. In the first, stage A, patients experience a small increase in cardiac output and oxygen consumption associated with a normal or slightly increased arteriovenous oxygen difference. The peripheral vascular resistance is slightly decreased and with appropriate volume resuscitation, the serum lactate level is normal. This can progress to stage B where there is a marked increase in cardiac output and a dramatic decrease in the peripheral vascular resistance. The oxygen consumption is usually decreased with a narrowing of the arteriovenous oxygen difference. The serum lactate level is elevated usually without systemic acidosis. With further progression, stage C occurs where there is a profound loss of peripheral vascular resistance which cannot be compensated by increased cardiac output resulting in hypotension. Lactic acidemia increases and systemic acidosis develops. Stage D is the final stage and is usually preterminal. Patients have profound systemic acidosis and left ventricular failure with associated reduced cardiac output and perfusion pressures with resultant multisystem organ failure [20].

Elderly patients frequently do not pass sequentially through each of the stages of the septic response. The transition from stage A to B is dependent on the patient having adequate cardiac reserve to compensate for the decreased peripheral vascular reserve. Older patients with intrinsic cardiac disease or those taking cardiac or antihypertensive medications may not have the capability to increase the cardiac output and decompensate rapidly from stage A to C without any apparent stage B interval.

28.5 Diagnosis

The diagnosis of skin and soft tissue infections is based primarily on the history and physical examination. The presence of skin erythema, induration, edema, fluctuance, and purulent wound drainage suggest less serious skin and soft tissue infections. The more common differential diagnoses of skin and soft tissue infections are listed in Table 28.3 [21]. The initial manifestations of necrotizing soft tissue infections in the geriatric patient can be subtle and result in the potential for a delay in diagnosis. One notable early characteristic is a complaint of severe pain that is disproportionate to local physical findings. Necrotizing soft tissue infections should always be included in the differential diagnosis whenever a patient presents with severe pain, particularly of the perineum or an extremity that is out of proportion to any physical findings.

Table 28.3 Differential diagnoses of skin and soft tissue lesions

Diagnosis	Risk factor	Findings
Superficial thrombophlebitis	Intravenous site may become secondarily infected	Red, indurated area; tender, palpable vein
Deep venous thrombosis	Venous stasis, hypercoagulability	Erythema, edema, warmth; mild fever, leukocytosis
Drug reactions	Allergies to medications; associated with sulfur-based antibiotics and anti-inflammatory agents	Pruritic or burning, well-demarcated plaque that recurs at the same site and spreads slowly
Pyoderma gangrenosum	Inflammatory bowel disease, leukemia, monoclonal gammopathies, rheumatoides	Papule or pustule progressive to ulceration with violaceous or vesiculopustular borders
Polyarteritis nodosa	Inflammatory bowel disease, leukemia, monoclonal gammopathies, rheumatoides	Subcutaneous, inflammatory plaques along affected artery Often bilateral and involve lower extremities
Erythema nodosum	Associated with IBD, sarcoidosis, and Behçet's syndrome	Raised, painful lesions, usually in arms and legs bilaterally
Foreign body reactions	Hypersensitivity to nickel, chromium, and cobalt	Overlying cellulitis-like erythema of the skin
Gouty arthritis	Elevated uric acid	Erythema, warmth, and tenderness; mild fever, chills, and leukocytosis; urate crystals
Idiopathic dermatitis (Well's syndrome, Sweet's syndrome)	Myeloproliferative, immunological and infectious disorders	Recurrent; multiple, pruritic, erythematous plaques

Inspection of the overlying skin may yield a few early clues. The subcutaneous fat and fascia are more likely than the overlying skin to develop necrosis. Thus, there may be little or no early cutaneous evidence of underlying infection. Edema and tenderness that extend beyond the margin of erythema, skin blistering, crepitus, bullae, hemorrhagic blebs, and the absence of lymphangitis and lymphadenitis and obvious necrosis are the typical "hard signs" of necrotizing soft tissue infection that occur as a result of thrombosis of the cutaneous microcirculation. As infection progresses, cutaneous anesthesia develops along with clinical manifestations of sepsis. The early recognition and treatment of sepsis is a major international outcomes improvement effort through the Surviving Sepsis Campaign [22]. Screening programs for sepsis while not specific for necrotizing soft tissue infections can point the clinician toward that diagnosis.

A high index of suspicion for anyone who evaluates the older patients with a skin and soft tissue infection is essential to avoid a delay in definitive therapy; the major risk factor for mortality in cases of necrotizing soft tissue infections. The clinical suspicion of a necrotizing soft tissue infection is sufficient to warrant surgical consultation. Further diagnostic approaches are usually unnecessary and should not lead to a delay in definitive diagnosis and management.

Some common laboratory studies may be useful for the evaluation of skin and soft tissue infections in the appropriate clinical context. A white blood cell count less than 15,400/μL or serum sodium greater than 135 mEq/L on admission has demonstrated a negative predictive value for necrotizing soft tissue infections of 99% [23]. C-reactive protein, procalcitonin, and serum creatinine and lactate have been found useful to assess the severity and monitor the progress and response to treatment for patients with skin and soft tissue infections.

The Laboratory Risk Indicator for Necrotizing fasciitis (LRINEC) score has been proposed as an adjunct for clinically detecting early cases of necrotizing soft tissue infections. (Table 28.4) The score includes total WBC count, hemoglobin and serum sodium, glucose, creatinine, and C-reactive protein. Scores are given to each value and a total score of 6 or above is suspicious for necrotizing soft tissue

Table 28.4 The Laboratory Risk Indicator for Necrotizing Fasciitis Score (LRINEC)

Laboratory parameter	Value	Score
Hemoglobin	<11.0 g/dL	2
	11.0–13.5 g/dL	1
	>13.5 g/dL	0
Leukocyte count	>25,000/mL	2
	15,000–25,000/mL	1
	<15,000/mL	0
CRP	≥150 mg/L	4
	<150 mg/dL	0
Sodium	<135 mEq/L	2
	≥135 mEq/dL	0
Glucose	>180 mg/dL	1
	≤180 mg/dL	0
Creatinine	>1.6 mg/dL	2
	≤1.6 mg/dL	0

infections. A score of 0–5 has a risk of a necrotizing soft tissue infection of less than 50%. A score of 6–7 has a risk of a necrotizing soft tissue infection of 50–75% and should lead to a high suspicion of a necrotizing soft tissue infection. A score of 8 or greater has a positive predictive value of 92% and is strongly suggestive of necrotizing soft tissue infection [6]. LRINEC has been criticized because it does not include the patient's clinical findings or other laboratory values including the serum lactate. A recent modification of the LRINEC has been proposed by Borschitz to include different laboratory (hemoglobin level, leukocyte count, erythrocyte count, C-reactive protein, fibrinogen level, and creatinine) with the addition of clinical parameters (pain, fever, tachycardia, and acute renal injury). A score of 8 or greater has a positive predictive value of 83% and is strongly suggestive of necrotizing soft tissue infection. A score less than 6 has a negative predictive value of 91% and makes the presence of a necrotizing soft tissue infection much less likely. A score of 6–7 should raise the suspicion of a necrotizing soft tissue infection [24]. Both the LRINEC and modified LRINEC do not include the patient's age or comorbidities. The mean age of the patients included in the validation of the modified LRINEC was 57 ± 17 years; thus, the usefulness if LRINEC and modified LRINEC in elderly patients had not been established.

If the diagnosis is not obvious by physical examination and laboratory testing, then radiographic studies may be obtained. Subcutaneous emphysema may develop as a result of anaerobic wound conditions that allow proliferation of gas-forming organisms, including *C. perfringens, B. fragilis, E. coli, Klebsiella pneumoniae, P. aeruginosa*, and *Proteus* species. These bacteria produce insoluble gases such as hydrogen, nitrogen, and methane, which remain in the tissue to a variable degree. Plain radiographs may demonstrate gas in the soft tissues in the absence of crepitus depending on the pathogens involved in 17–30% of patients [13].

The presence of soft tissue gas on computed tomography (CT) has a high specificity but low sensitivity for necrotizing soft tissue infections [25]. CT may also demonstrate the nonspecific finding of asymmetric edema of tissue planes. A CT scan can be helpful in the evaluation of the obese patient with a deep-seated infection, for whom the physical examination is unreliable. The absence of gas in the tissues by clinical or radiological examination does not exclude the presence of a necrotizing soft tissue infection. Gas in the tissue tends to be a late finding in non-clostridial polymicrobial infections and to be absent in infections caused by S. pyogenes. In general, to the extent that obtaining any imaging study will delay the operative management of the patient, they should be avoided.

Point-of-care ultrasound (POCUS) is becoming more ubiquitous given its portability and rapidity, especially in the field of emergency medicine. It is readily available but relies heavily on operator experience. There have been limited case series using point-of-care ultrasound to assess soft tissue infections. There is no compelling evidence for their routine and additional data are needed before POCUS can be considered a mainstream diagnostic modality [26, 27].

Other adjuncts that have been proposed when the diagnosis is not obvious by physical examination and laboratory testing include fine-needle aspiration and incisional biopsy of questionably affected areas. Gram stain of the material obtained can demonstrate causative organisms and an inflammatory cell infiltrate. Frozen section demonstration of pathogens in tissue or microvascular thrombosis with necrosis are diagnostic. However, clinical suspicion is sufficient to explore the patient with suspected necrotizing soft tissue infections and these less-invasive diagnostic approaches are usually unnecessary and should not lead to a delay in definitive diagnosis and management.

28.6 Treatment

The management of a necrotizing soft tissue infection is a true emergency. Delay in diagnosis and treatment should be avoided at all costs. The elapsed time between the onset of symptoms and the initial operative treatment is the single most important factor influencing morbidity and mortality [6]. Unfortunately, these patients frequently present to healthcare facilities that have limited capabilities. Many rural and community hospitals do not offer surgical services or do not have the immediate availability of an operating room and personnel. In these circumstances, the provider caring for these patients must make a judgment as to the optimal approach, mobilizing local resources or transfer to another facility where definitive therapy, surgical debridement can be accomplished in a more expeditious manner. While the technical aspects of the surgical debridement are within the capabilities of most surgeons, the system components necessary to care for a critically ill patient; intensive care unit, intensivists, invasive monitoring, etc., may not be available. The iatrogenic component of managing several coexistent diseases coupled with polypharmacy cannot help but increase the complexities encountered in managing geriatric patients with skin and soft tissue infections.

Interhospital transfer introduces another layer of complexity and risk to these already complex patients with a high morbidity and mortality. The risks associated with the transfer of these patients are not insignificant and are the responsibility of the referring provider and facility. Transfer can take a prolonged time to arrange and transfer teams frequently have limited resources and experience. When selecting the management strategy, the provider's primary consideration should be to minimize the interval to surgical debridement. If transfer is selected, clear communication with the receiving hospital and provider is essential.

Regardless of the management strategy, mobilization of local resources or transfer for a higher level of care, adjuvant therapies should be initiated while awaiting definitive cate. Clinical diagnosis alone is sufficient to begin broad-spectrum antimicrobial therapy. The use of imaging studies as "confirmatory" tests cannot be justified. Sepsis is a major component of necrotizing soft tissue infections. Resuscitation should be promptly implemented using the guidelines and sepsis management bundles as described in the Surviving Sepsis Campaign [22].

Considering that these infections progress rapidly, the initial surgical debridement should not be unduly delayed for complete resuscitation and correction of fluid and electrolyte abnormalities. Clinical diagnosis alone is sufficient to undertake surgical exploration and debridement; the definitive diagnostic test as well as therapeutic intervention. Geriatric patients with necrotizing soft tissue infections not uncommonly present with advanced stages, stages C and D, of shock for the reasons described earlier. Proceeding with the surgical debridement in a patient in advanced stages of shock without adequate resuscitation must be balanced against the knowledge that delay in the initial operative treatment is associated with high morbidities and mortality. It is our practice to employ a "damage control" strategy with these patients where the aim of the initial surgical procedure is to obtain source control of the infection. The patient is subsequently taken to the intensive care unit for aggressive resuscitation and correction of fluid and electrolyte abnormalities. An early return to the operating room, usually within 4–6 h, is planned for more definitive excision.

The objective at the first surgical debridement is a thorough wound exploration to confirm the presence and extent of infection. Debridement of all infected, devitalized tissue must be aggressive. Exposure must be wide and dissection should extend beyond the boundary of tissue viability even at the cost of additional deformity or disability as the underlying tissue necrosis usually extends far beyond the boundary of the skin involvement. Excised tissues should be submitted for comprehensive microbiologic testing. Fasciotomies should be performed if compartment syndrome is suspected. Frozen section examination of the limits of resection can occasionally be helpful when the margin of viability is indistinct to limit the excision but should not prevent the excision of any areas of questionable viability [28, 29].

Following initial excision, temporary wound coverage is accomplished with saline moistened dressings. Planned reexploration in the operating room is routine after 12–24 h to excise any additional necrotic tissue that may have developed [30, 31]. The interval before the planned reexplorations is less if the patient shows continuing or worsening signs of sepsis including deteriorating hemodynamic parameters or worsening renal function and longer if there is steady clinical improvement. The planned reexplorations continue until no further infected tissue remains. Definitive closure with tissue flaps and skin grafts, if possible, is only considered after all infected tissue has been debrided. Rarely extremity amputation or urinary or fecal diversion may be necessary to manage severe infections of the extremity or perineum, respectively.

Antibiotics are an adjunct to early surgical debridement, not a substitute for it. Early and aggressive use of antibiotic therapy is essential and should be performed concomitant to the patient undergoing surgical evaluation and treatment. Antimicrobial therapy should be continued until further debridement is no longer necessary, the patient has improved clinically, and fever has been absent for 48–72 h. Approximately half of the necrotizing soft tissue infections will be polymicrobial in nature [29, 32]. Initial empiric treatment should include agents effective against both aerobes, including MRSA, and anaerobes. Among the many choices, vancomycin, linezolid, or daptomycin combined with either; piperacillin-tazobactam, a carbapenem, ceftriaxone plus metronidazole, or a fluoroquinolone plus metronidazole is appropriate. Blood cultures, and where possible, deep tissue, abscess and/or operative cultures should be obtained during the initial surgical debridement to help tailor antibiotic therapy. Once the microbial etiology has been determined, the antibiotic coverage should be appropriately modified. Empiric antifungal therapy is unnecessary in most cases. Necrotizing fasciitis caused by group A *streptococci* should be treated with both clindamycin and penicillin [29].

Hyperbaric oxygen has been proposed as an adjunctive therapy after surgical debridement for necrotizing soft tissue infections. The fascia is known to be a relatively hypoxic environment owing to its tenuous blood supply when compared to surrounding muscle or skin. Among the putative benefits of hyperbaric oxygen are inhibition of exotoxin production, increased tissue oxygen tension, and improved neutrophil function [33]. There are conflicting results from multiple retrospective studies, with some showing decreased mortality and others showing no effect [34, 35]. Despite theoretical benefits, the greatest barrier to the practical use of this modality is the inability to adequately monitor critically ill patients with necrotizing soft tissue infections. The majority of hyperbaric chambers and society guidelines do not recommend its routine use in these infections [36].

Immunoglobulins have been studied in streptococcal infections that cause toxic shock syndrome. Because streptococcus is known to cause many necrotizing soft tissue infections, it is reasonable to hypothesize that immunoglobulins may aid in the treatment of these infections. The most recent INSTINCT study, a Danish multicenter randomized controlled trial, evaluating the effect of therapy with immunoglobulins for patients with necrotizing soft tissue infections found no benefit on survival at 6 months [37].

After the sepsis is controlled, postoperative management of all patients with necrotizing soft tissue infections is complicated and resource intensive requiring the availability of a large number of specialized clinical resources that are not available at many hospitals. This is especially true for the elderly patient where multimorbidity, polypharmacy, and malnutrition are frequently present as discussed earlier [9, 10]. The soft tissue loss and disabilities resulting from the appropriate surgical management of necrotizing soft tissue infections are usually severe. Definitive closure with tissue flaps and skin grafts, if possible, requires surgical expertise and wound care capabilities that may only be available at a regional burn center. It is recommended that when the clinical status of the patient allows, transfer to a burn center be considered for all patients with necrotizing soft tissue infections if any of the criteria in Table 28.5 are present.

Table 28.5 Criteria for referral to a designated burn or wound care center

• Full-thickness tissue loss involving more than 10% body surface area
• Any full-thickness tissue loss involving the face, hands, feet, genitalia, perineum, or major joints
• Patients with preexisting medical disorders that could complicate management, prolong recovery, or affect the outcome
• Patients who will require special social, emotional, or long-term rehabilitative intervention

28.7 Summary

Necrotizing skin and soft tissue infections are challenging to diagnose in the geriatric patient and associated with high morbidity and mortality. A high index of suspicion is essential for the diagnosis and appropriate management of these infections. Prompt surgical intervention is the cornerstone of therapy. Delays in the diagnosis and management are associated with increased morbidity and mortality.

In our institution, we promote early surgical exploration, "damage control," for any patient suspected of a necrotizing soft tissue infection. This is followed by frequent returns to the operating room for any patients with continuing signs of sepsis or deterioration. Early enteral nutrition is crucial to help maintain muscle mass. In the setting of critically ill patients, we advocate continued feeding until the time of surgery if the airway is protected. Once source control is achieved, assessment of tissue loss, disabilities, and functional preservation are paramount to successful care of elderly patients.

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Incarcerated Inguinal Hernia in Elderly

29

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29.1 Introduction

At a time of unpredictable challenges for health, one trend is certain: the rise of the elderly population worldwide [1]. According to the World Health Organization (WHO) guidelines, the elderly is defined as the population aged 65 years and above [2]. In the coming years, the elderly population will be the major consumer of healthcare resources with a concurrent increase in the demand for surgical services.

An inguinal hernia is one of the most frequently encountered emergent surgical pathology in old age [3]. Inguinal hernias (IH) are common in the elderly because of the loss of strength of the abdominal wall and conditions with increased intra-abdominal pressure [4]. Unfortunately, the evidence on the management of incarcerated inguinal hernias in the elderly is very limited and the quality of that evidence is very low. Hence, in this chapter, we have amalgamated the treatment guidelines from the hernia societies on the management of incarcerated IH in this "high-risk" age group.

Before embarking on the details, we shall revisit the basic definitions on this topic. "Inguinal hernia" is defined as a protrusion or projection of an organ or a part

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of an organ through the body wall that normally contains it. “Incarcerated inguinal hernia” refers to trapping of hernia contents within the hernia sac such that reducing them back into the abdomen or pelvis is not possible. In “Strangulated inguinal hernia” blood supply to the herniated tissues is compromised leading to infarction, gangrene, or necrosis of the tissue [5]. This chapter will begin with the brief anatomy of the inguinal region. We will then delve upon the diagnosis and the surgical options for incarcerated inguinal hernia in elderly patients.

29.2 History

Anatomical and surgical history of inguinal hernia is a lengthy record of publications, research, and different techniques in an effort to cure this condition, which has haunted humanity from its very beginning until modern times. The term hernia stems from the ancient Greek word hernios, which means bud of off-shoot.

Ogilvie has described inguinal hernia as the disadvantage of the mammals and stated: “there is no doubt that the first appearance of the mammal, with his unexplained need to push his testicles out of their proper home into the air, made a mess of the three layered abdominal wall that had done the reptiles well for 200 million years” [6]. In fact, posterior rectus sheath is absent below the arcuate line of Douglas in the mammals as well as in Homo sapiens. This anatomical feature does not impose quadrupeds to any functional anatomic difficulty as their inguinal canal is directed “uphill” during ambulation. However, erect posture has led to gravitational stress of intra-abdominal organs towards lower abdomen in humans, resulting in a significant number of pathologic inguinal hernias [7].

The evidence of hernia repairs dates as far back as the days of the Egyptian pharaohs. The mummy of Ramses V (1157 BC) had a bulge in the groin (either scrotal hernia or hydrocele or both). An incision over inguinal region with one testicle removed is present in the mummy of the pharaoh Merneptah (1224 BC). Ancient Greeks and physicians in Alexandria used tightly fitting bandages to treat groin hernias (approximately 900 BC) [8]. Hippocrates referred to hernia as “etru rhexis”, which means rupture of the abdominal wall [9]. Hippocratic School used transillumination to distinguish an inguinal hernia from hydrocele.

Galen (129-199), the most prominent physician of the Greco-Roman era, hypothesized (and later discarded) that hernia was caused by the rupture of the peritoneum and aponeuroses of abdominal muscles [10]. In 1363, De Chauliac, who was the first to differentiate inguinal and femoral hernia, disputed this concept [11].

Ambroise Parre described the hernia repair in detail and advised the use of a “Golden Ligature” in case of a rupture of the sac in the renaissance era. In 1559, the German herniotomist Caspar Stromayr made the first distinction between direct and indirect hernias [12].

Significant progress was made in anatomic knowledge in seventeenth and eighteenth centuries. During these centuries, Antonio Scarpa described the deep layer of superficial fascia of the lower abdomen (later named after him); Pieter Camper described Camper fascia and processus vaginalis testis; John Hunter described gubernaculum testis; Antonio de Gimbernat described the lacunar ligament and its division to enlarge femoral ring in the treatment of strangulated femoral hernias (later named after him); August Gottlieb Richter described partial strangulation of the intestinal wall (later named after him); and Sir Astley Paston Cooper described the cremasteric fascia, the transversalis fascia, and the superior pubic ligament (later named after him) [12].

Anatomic and surgical knowledge and the technique of inguinal hernia repair further improved in the twentieth century after the implementation of Lister's concept of antisepsis. Two surgeons are rightfully considered "fathers of modern herniorrhaphy", Edoardo Bassini (1844-1924) and William Stewart Halsted (1852-1922). Besides them, it is noteworthy to mention Rene Stoppa, who used a large unslit Dacron prosthesis to replace the transversalis fascia in 1984 [13]; Lichtenstein, who introduced tension-free inguinal hernia repair in 1986 [14]; Ralph Ger, who performed the first laparoscopic transabdominal inguinal hernia repair in 1982 [15]; and Kugel, who performed preperitoneal inguinal hernia repair in 1994 [16].

29.3 Anatomy

An indirect inguinal hernia is caused by the failure of the obliteration of processus vaginalis (the peritoneal extension which accompanies the testicle in its descent into the scrotum). This type of hernia is always lateral to the inferior epigastric artery. A direct inguinal hernia is caused by a weakness or defect in the floor formed by transversalis fascia. This type of hernia is located medial to the inferior epigastric artery. The direct inguinal hernias have distinct borders and are more prone to incarceration [17]. The thorough knowledge of surgical planes and critical structures in the vicinity of hernia are important for positive outcomes after emergency surgery.

29.4 Epidemiology

A large nationwide study from Denmark on five million patients who underwent IH repair showed that there is a bimodal peak for IH in early childhood and in old age [18]. Male gender predominates up to 75 years of age, while females prevail in later age and have a higher propensity to develop incarceration [19]. The estimated incidence of the anterior abdominal wall hernia in patients aged ≥65 years is 13 per 1000. Incarcerated IH account for about 20% of all small bowel obstructions in the elderly [20].

29.5 Diagnosis

Inguinal hernias have a variety of clinical presentations ranging from an asymptomatic bulge to emergent, life-threatening presentations with bowel strangulation. An incarcerated hernia can present either as a sudden onset of new non-reducible swelling in the groin or as the development of incarceration/strangulation in already diagnosed reducible IH.

Incarceration and strangulation are usually diagnosed in clinical features supported by laboratory data. One of the largest studies on 30-day mortality after groin hernia repair from the Swedish registry concluded that the "groin examination" of patients presenting with bowel obstruction is of utmost importance in order to minimize delay to hernia surgery [21]. In the elderly, strangulated hernia should be regarded as a possible diagnosis in cases of acute small bowel obstruction, especially when no previous laparotomy has been performed.

The most common presenting clinical findings are an irreducible mass in the groin and localized pain suggesting incarceration. In addition to these features, peritonitis, fever, leukocytosis, elevated lactate, or any other SIRS criteria suggests a more sinister diagnosis of strangulation. Importantly, it should be kept in mind that the elderly often show atypical signs and symptoms of incarceration and strangulated IH.

Ultrasound (USG) has been shown to be helpful when the clinical picture is inconclusive. In a prospective study analyzing the utility of USG in diagnosing IH on 149 consecutive abdominal wall hernias, the sensitive signs that were indicative of acute incarceration were; (a) free fluid in the hernia sac, (b) bowel wall thickening in the hernia, and c) dilated bowel loops in the abdomen [22].

International hernia society considers USG to be appropriate for detecting incarceration or strangulation in patients with atypical clinical presentations [5]. However, the recommendations on the use of USG in diagnosing incarcerated IH are based on weak recommendations and RCTs are warranted in the future.

The timely diagnosis is of paramount importance as morbidity and mortality are increased among patients with incarcerated or strangulated IH with the following risk factors; age (≥65 years), especially octogenarians [23, 24], time from admission to start of surgery, incarceration for more than 24 h, and symptoms of bowel obstruction [25].

29.6 Treatment

This section will address the key questions on timing, best surgical approach (open anterior, posterior, or laparoscopic), and repair options (e.g., mesh versus non-mesh) in the elderly.

29.6.1 Timing of Surgical Intervention

Elderly with incarcerated/strangulated IHs should undergo emergent repair as benefits outweigh risks. The incidence rate of strangulated inguinal hernias is relatively low, but it is still a common cause of acute abdomen in the elderly patients, in whom the hernia is not always diagnosed until strangulation. World Society of Emergency

Surgery (WSES) recommends emergency hernia repair immediately when intestinal strangulation is suspected (grade1C recommendation) [26].

A large-scale retrospective study by Koizumi et al. on the importance of early surgery also concluded that to minimize the mortality and morbidity of emergency surgery in the elderly with comorbidities, early diagnosis and treatment are essential [27].

29.6.2 Preoperative Antibiotics and Type of Anesthesia

The knowledge of bacteriology is important in deciding the course of antibiotics in the perioperative period. In elective or incarcerated hernia repair, *Staphylococcus aureus* is a typical source of infection. When intestinal strangulation ensues, the bacteriology of the surgical field changes as the bacteria translocates from the bowel or after bowel resections [28, 29].

In a high-risk environment (defined by a 5% incidence of wound infection) there is a significant benefit of antibiotic prophylaxis [30]. The risk of antibiotic resistance and additional infections such as *Clostridium difficile* should be kept in mind. We routinely employ preoperative prophylactic antibiotics followed by 5 days of broad-spectrum antibiotic regimen if the degree of contamination was deemed to be high (source control).

Local anesthesia (LA) is one of the most commonly used anesthetic methods in inguinal hernia repair [31]. Local anesthesia is recommended for elective inguinal hernia repair in elderly patients and in patients with comorbidities [32]. European Hernia Society Guideline (EHS) recommended that patients with an incarcerated hernia should be excluded from operation under LA [33]. However, there is a weak recommendation from WSES that LA can be used for emergency IH repair in the absence of bowel gangrene; LA provides effective anesthesia with less postoperative complications (grade 1C recommendation) [26]. In our practice, the decision on the type of anesthesia to be employed in critical situations is made on the case-to-case basis with an overall emphasis on clinical exam, the burden of comorbidity, and frailty.

29.6.3 Type of Surgical Approach

Table 29.1 shows the current IH repair techniques; however, there are modifications of every technique that are beyond the scope of this chapter. The choice of repair in incarcerated IH is based on the contamination of the surgical field, the size of the hernia, and the experience of the surgeon [5]. After exhaustive literature research, we found that there are no randomized trials, systematic reviews, or comparative cohort studies that can answer this question. Incarcerated IH has been routinely managed with open surgery. Laparoscopic approach for incarcerated IH has been described by several authors and WSES recommends the laparoscopic approach in the absence of strangulation and low suspicion of the need for bowel resection

Table 29.1 Current inguinal hernia repair techniques [5]

Non-mesh techniques	Shouldice Bassini (and many variations) Desarda
Open mesh techniques	Lichtenstein Plug and patch Prolene hernia system [PHS (bilayer)] Variations
Endoscopic techniques	Totally extraperitoneal (TEP) Trans abdominal preperitoneal repair (TAPP) Single incision laparoscopic repair (SILS) Robotic repair

(grade 2C) [26]. Most studies agree that laparoscopic extraperitoneal (TEP) or transabdominal preperitoneal (TAPP) repair is feasible and safe in patients with incarcerated IH [34, 35]. We do recommend that in carefully selected elderly, laparoscopic repair can be performed at high volume centers.

Open anterior repair (Bassini, Shouldice, or Lichenstein) can be quickly performed if strangulation or bowel ischemia is suspected. Other indications for open surgery in the elderly are hemodynamic instability or a patient being unfit for laparoscopic surgery.

Hernioscopy (hernia sac laparoscopy) is an effective armamentarium that is easy to perform, accurate, and safe with the potential to prevent unnecessary laparotomies after spontaneous incarcerated IH reduction [36]. General surgeons, acute care surgeons, and hernia surgeons should utilize the potential advantage offered by this procedure to verify the viability of the herniated loop after its spontaneous reduction, especially in elderly as they do not offer much leverage if left undiagnosed with questionable bowel viability.

Another important issue is the use and choice of mesh. Evidence-based information is based on the Center for disease (CDC) wound class. Elective hernia surgery is considered a clean case (CDC wound class I). There is evidence that when compared to direct tissue repair, long-term complications and recurrence rates in clean low-risk groin mesh repair (viable bowel and no required bowel resection) are lower [37].

For CDC grade II wound (clean and contaminated), there is a grade 1A recommendation by WSES that emergent hernia repair with a synthetic mesh can be performed in case of intestinal strangulation and/or concomitant bowel resection without gross enteric spillage (without any increase in 30-day wound-related morbidity) and is associated with a lower risk of recurrence, regardless of the size of the hernia defect. An RCT by Elsebae et al. concluded that the use of Lichtenstein "tension-free'" technique in the emergency treatment of strangulated inguinal hernia is safe and effective with an acceptably low rate of postoperative complications and without recurrence. However, the results should be interpreted with caution that patients with preoperative peritonitis, inflammatory hernia, and for those in whom bowel resection was performed for ischemic necrosis caused by strangulated inguinal hernia were excluded from the study [38].

At this point, we would like to emphasize the importance of the surgical decision-making process (DMP). The anticipation of the complications based on a case-to-case scenario before or during surgery may be of vital importance in enhancing the positive outcomes in the elderly undergoing emergent IH surgery [39, 40].

There are no evidence-based recommendations regarding mesh use in emergency hernia repair in "contaminated–dirty surgical field" (CDC wound classes III and IV) [5]. All the retrospective and prospective studies on IH repair in the elderly in CDC II/IV wound class are based on individual opinions and conclusions.

There are weak recommendations from WSES that in stable patients with strangulated hernia with bowel necrosis and/or gross enteric spillage during intestinal resection or peritonitis from bowel perforation (contaminated, CDC wound class III, dirty surgical field, CDC wound class IV), primary repair is recommended when the size of the defect is small (<3 cm) (grade 2C recommendation) [26].

29.6.4 Role of Biological Mesh in IH Repair

Literature does support the use of biologic mesh in contaminated fields, but it consists of low levels of evidence of case series and case reports. Inguinal hernias can be repaired with biological meshes with a reasonable recurrence rate, also as an alternative in a potentially contaminated field [41]. In a small retrospective case series by Franklin et al., biological meshes were used with reasonable success in a contaminated field for incarcerated inguinal hernia, coincident with a laparoscopic cholecystectomy or colectomy in a setting grossly contaminated with pus or fecal spillage [42]. In the absence of any concrete evidence, the use of biological mesh in IH repair in the CDC III/IV wound class might seem reasonable but further studies are warranted.

29.7 Conclusions

Emergency repair of incarcerated IH remains one of the most common emergencies worldwide. The bigger proportion of these emergent procedures will be performed on the elderly population. There is a very big lacuna in the evidence-based literature addressing this topic especially in the elderly and further prospective studies are warranted.

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Laparoscopic Approaches to Emergency General Surgery

30

J. E. Waha and S. Uranues

30.1 Introduction

By definition, those aged 65 years and older are often referred to as "elderly." In general, there is a differentiation between "early elderly" from 65 through 74 years old and those over 75 years old as "late elderly," although the evidence on which this definition is based is unknown [1]. Laparoscopy is increasingly used, not only in the younger population but also in both groups of the elderly. It is the preferred approach for many abdominal and thoracic surgical procedures. Not only in the elective surgical setting but also in emergency settings, the laparoscopic approach has justifiably gained importance and has emerged in many cases as the technique of choice. The advantages of minimally invasive surgery (MIS) are well studied and supported by the literature. Nevertheless, there are still doubts whether MIS is the right procedure in an emergency setting for the surgical treatment of elderly patients. This doubt may be fuelled by anesthetists' concerns about establishing a pneumoperitoneum and perhaps even more so about changing the elderly patient's posture and positioning on the surgical table, which often is mandatory for laparoscopy. This chapter will elucidate on the basis of the current literature the advantages and disadvantages of a laparoscopic approach within the cohort of the elderly patient in emergency surgery settings.

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30.2 Challenges of Laparoscopy and the Pneumoperitoneum in the Elderly

According to recent literature, laparoscopic approaches to abdominal surgery are associated with shorter length of hospital stay, less mortality, and less morbidity [2]. Knowing that the elderly can profit from MIS, the question is raised: How to find the suitable patient for laparoscopy in emergency settings? To answer this question, it is vital to understand the underlying physiological effects of the pneumo-carboperitoneum.

Absorbed by the peritoneum, CO_2 diffuses by gradient into the blood vessels easily, leading to hypercapnia and acidemia. The CO_2 is then eliminated physiologically by the airway. This process may be disturbed in the elderly patient suffering from chronic obstructive pulmonary disease (COPD) due to restricted ventilation, low cardiac output, and impaired microcirculation. These impaired mechanisms can be particularly striking for the septic patient [3]. Sepsis is characterized by impairment of these mechanisms on the cellular and organ level [4]. On the other hand, oxygenation will not be disturbed during carboperitoneum and does not seem to be of significant clinical relevance.

The intra-abdominal pressure (8–12 mmHg) increases during insufflation, limiting the diaphragmatic excursion. Peak airway pressure rises, while pulmonary compliance and vital capacity drop, resulting in a ventilation perfusion mismatch. A Trendelenburg position, if needed, may aggravate those physiological changes [3].

The carboperitoneum has several cardiovascular effects. CO_2 modulates the vascular resistance directly or by inducing vascular mediators like epinephrine, norepinephrine, and angiotensin. Consequently, blood pressure, cardiac output, and heart rate rise, but renal perfusion drops due to vasoconstriction.

Increase in abdominal pressure (IAP) during laparoscopic operations leads to an increase of the cardiac output by 25%, a decrease in splanchnic perfusion, a decrease in venous return, a decrease in stroke volume, an increase in heart rate, an increase in systemic vascular resistance, and an increase in myocardial oxygen consumption [5]. These effects can be counteracted by the patient, but the extent to which elderly patients can compensate these derangements depends on the individual cardiovascular and pulmonary situation. Elderly and frail patients might not be able to mobilize their cardiopulmonary reserve sufficiently to counterbalance a deficit, especially when they suffer from sepsis or septic shock. Even a slight increase in the IAP during laparoscopy might destabilize the fragile patient. There have been several reports of patients with preexisting cardiovascular or renal conditions who developed small bowel ischemia after laparoscopic procedures [6]. Increasing complexity of the surgery may go along with longer operating time, which might endanger organ perfusion even more. Low-pressure pneumoperitoneum or abdominal wall lift might put less strain on elderly patients' cardiovascular system but this has not gained broad attention [7].

30.3 Common Laparoscopic Procedures in the Elderly Population

In oncological surgery, there are promising data for laparoscopic approaches in the elderly or frail patient, for example, for laparoscopic liver resection in hepatocellular carcinoma, colorectal cancer, and gastric cancer [8–11]. These data prove that complex long-duration surgical procedures are being safely performed on elderly patients.

30.4 Laparoscopic Emergency Procedures

The following emergency surgical procedures have been well studied and shown to be safe and applicable even in the elderly population.

30.5 Laparoscopic Appendectomy

One of the most frequent operations in the elderly population is the appendectomy. The lifetime risk ranges between 8.6% for males and 6.7% for females for developing acute appendicitis. Several studies have shown that laparoscopy in acute appendicitis is safe in elderly patients. A recent review by Wang et al. including 12 retrospective studies with more than 300,000 patients undergoing laparoscopic appendectomy versus open appendectomy showed that postoperative mortality was significantly lower, while postoperative complications and wound infection were reduced following laparoscopy. The average length of hospital stay was shorter. Both groups had a similar incidence of intra-abdominal abscess. Although the laparoscopic operation was significantly longer, the postoperative outcome was better for the laparoscopic group [12].

30.6 Laparoscopic Cholecystectomy

Another frequent and urgent operation in the elderly population is the cholecystectomy for acute cholecystitis with a prevalence of gallstones at the age of 70 years between 15% and 24% for male and female. A systematic review by Loozen et al. reviewed the outcome of 592 patients. They conclude that elderly patients should undergo early laparoscopic cholecystectomy for acute cholecystitis with the limitation that surgery should be performed by an experienced laparoscopic surgeon or at a center that specializes in laparoscopic surgery [13].

The World Society of Emergency Surgery (WSES) and Italian Society for Elderly (SICG) conclude in their guideline of 2017 on acute calculous cholecystitis in an elderly population that the procedure should always be attempted laparoscopically first, unless there are absolute anesthetic contraindications or septic shock. The laparoscopic approach is safe and feasible even in the acute setting and offers elderly patients the advantages of shorter hospital stay and reduced risk for nosocomial infections. As the laparoscopic approach in the elderly is associated with an increased conversion rate, subtotal cholecystectomy should be considered in difficult situations [14].

30.7 Laparoscopic Management of Perforated Peptic Ulcer

The perforated peptic ulcer is a frequent emergency worldwide with a high mortality of 30%. A national cohort study in England included 13,022 patients, of whom 895 patients underwent MIS. In the age group of over 70 years, the length of hospital stay of patients treated with MIS was significantly reduced. That study also shows a reduction of the 30-day and 90-day mortality in that age group compared to open surgery. Patients with a Charlson Comorbidity Score > 2 were mostly treated by open surgery [15].

In conclusion, performing emergency surgical procedures on elderly patients is safe and feasible. Age greater than 65 years per se does not correlate with disqualification for laparoscopic surgery. The increasing number of studies reflects the growing interest of surgeons in treating elderly patients with minimally invasive surgery. Lower postoperative mortality, shorter hospital stay, and fewer wound infections justify that interest. Further studies will report on the outcome of each emergency laparoscopic procedure applicable to elderly patients, pointing out specific characteristics linked to the constantly growing elderly population, and so providing surgeons with robust evidence.

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Part III

Post-operative Critical Care in Elderly

Surgical Intensive Care of the Elderly

31

Mayur Narayan, Matthew Bronstein, and Jeffry Kashuk

31.1 Introduction

Although no formal definition or age exists to definitively define elderly, the consensus in the literature suggests that anyone over the age of 65 fits this category and anyone over the age of 80 is considered very old [1]. In recent years, the geriatric population has become the most rapidly growing population as the baby boomer generation continues to age. The boomers are projected to live longer than previous generations as access to modern healthcare and prevention strategies have improved. Between 2000 and 2010 there was a 15.3% increase in the American population over the age of 65, which was more than double (8.7%) the population increase below the age of 65. By the year 2030, the number of Americans considered elderly (65+) is expected to double and will encompass more than 70 million people. This includes 18 million people who will be over 80 years old or considered very old [2].

The elderly population represents nearly 40% of all hospitalized patients despite representing only 13% of the total American population [3]. Furthermore, 55% of all ICU beds in the United States are occupied by patients 65 and older. The proportion of very old (>80) patients accounts for more than 20% of total ICU admissions and is the fastest growing cohort of patients admitted to the ICU [4].

The admission of elderly patients to the ICU has a very high cost burden. A Canadian study found that the average cost of a person over 80 years old admitted

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to the ICU was more than $36,000 [5]. The aging population will undoubtedly place tremendous strains on healthcare systems that are already stressed. This cost burden does not only affect healthcare providers but also impacts the patients themselves. The elderly spend over 13% on their total health expenditure which is more than twice that of patients under 65 [6].

31.2 Admission Criteria to the ICU

The most crucial step to managing ICU patients is initial triage to determine if an individual will need ICU care. More specifically, it is important to have early discussions with patients and family members to determine if ICU-level care, including mechanical ventilation is something they would want. Several factors and decisions are made prior to an ICU admission, including bed availability, institutional protocols, cultural norms, as well as actual disease process and pathology. The Society of Critical Care Medicine's (SCCM) 2016 guidelines for ICU admission criteria are summarized in Table 31.1 [7].

Several studies have suggested using vital signs as a metric or triage tool for higher priority admission to the ICU. Others have suggested using different metrics such as GCS and other scoring systems. One example is the Swedish Adaptive Process Triage that uses vital signs and chief complaints to create a triage score for ICU admission [8]. However, it is important to note that due to the physiologic changes of aging, geriatric patients may not mount an appropriate inflammatory response to a critical illness which can cause the severity of the illness to be greatly underestimated.

31.3 Scoring Systems

Several clinical scoring systems have been developed from ICUs around the globe. These systems can aid in the assessment of the severity of the illness. This is done by generating a numerical score which can be used to help predict mortality and morbidity. The majority of these scores include several physiologic parameters such

Table 31.1 Represents a summary of the 2016 guidelines published by the Society of Critical Care Medicine (SCCM) for admission to the ICU

– Specific patient needs that can only be addressed in an ICU, such as life-supportive therapies
– Availability of clinical expertise
– Prioritization according the patient's condition
– Diagnosis
– Bed availability
– Objective parameters at the time of referral, such as respiratory rate and other vital signs
– Potential for the patient to benefit from interventions
– Prognosis

Table 31.2 Select list of ICU scoring systems that are available

APACHE II	Acute physiology and chronic health evaluation
SAPS II	Simplified acute physiology score
SOFA	Sequential organ dysfunction assessment
MODS	Multiple organ dysfunction score
LODS	Logistic organ dysfunction

as vital signs as well as laboratory data. The ICU scoring systems currently in practice are listed in Table 31.2.

The Acute Physiology and Chronic Health Evaluation (APACHE) II is one of the more common scoring systems used in the screening of acutely ill patients. The scoring system uses age, previous health status, and 12 other physiologic measurements:

- Temperature
- Mean arterial pressure
- PaO2
- pH
- Heart Rate
- Respiratory rate
- Serum sodium
- Serum potassium
- Mean arterial pressure
- Creatinine
- Hematocrit
- White blood cell count
- GCS

These are calculated during the first 24 h of admission. The score, calculated from 0 to 71, ranks patients in a manner where the higher the number assigned, the more critical the patient is and the higher their probability of mortality. However, the APACHE II score has limitations as it does not consider comorbidities and only focuses on one diagnosis [9]. The Sequential Organ Failure Assessment (SOFA) is another popular scoring system used in practice which tends to focus on morbidity and organ dysfunction rather than mortality. Six variables are included in this score representing six organ systems:

- Cardiovascular
- Neurological
- Respiratory
- Liver
- Coagulation
- Renal Systems

The Simplified Acute Physiology Score (SAPS) II is another scoring tool which incorporates 17 total variables. Of these, 12 are physiologic and the remaining 5 include age, admission type (medical, elective surgical, emergency surgical), chronic disease state, GCS, and P:F ratio [10]. Scoring ranges from 0 to 163 and the probability of death is calculated using logistic regression.

31.4 Comorbidities

As age increases, the proportion of patients with comorbidities as well as their number of comorbidities also increases. The average number of comorbidities in patients aged 65–84 years old is 2.6, and in patients over the age of 85 the mean number of comorbidities rises to 3.6. The most common comorbidities include hypertension, diabetes mellitus, COPD, heart disease, cancer, and cognitive impairment [11]. In ICUs, specifically, comorbidities are associated with higher mortality rates both in hospitals and long term. The Charleston Comorbidity Index (Table 31.3) is a reliable tool and model which is predictive of mortality in critically ill patients.

31.5 Frailty

Frailty has been described as both a “state” and a “syndrome” that aims to capture multidimensional aspects of declining physiologic systems which results in cumulative impairment of homeostatic reserve (energy, cognition, physical ability, etc.). This in turn predisposes patients to a disproportionate vulnerability to adverse outcomes from acute stressors such as trauma and emergency surgery

Table 31.3 The Charleston Comorbidity Index (CCI) is a weighted grading system based on several underlying diseases that is predictive of mortality in critically ill patients

Condition	Weight
Myocardial infarction	1
Congestive heart failure	1
Peripheral vascular disease	1
Cerebrovascular disease	1
Dementia	1
Chronic pulmonary disease	1
Connective tissue disease	1
Ulcer disease	1
Liver disease, mild	1
Diabetes	1
Hemiplegia	2
Renal disease, moderate or severe	2
Diabetes with end-organ damage	2
Any malignancy	2
Liver disease, moderate or severe	3
Metastatic solid malignancy	6
Acquired immunodeficiency syndrome (AIDS)	6

[12]. Fried et al. defined frailty as a clinical syndrome in which three or more of the following were present: unintentional weight loss (10 lbs. in 1 year), slowed walking speed, low physical activity, self-reported exhaustion, and weakness (grip strength) [13].

Multiple scales have been developed to help assess the presence and degree of frailty. These include, but are not limited to the Rockwood Clinical Frailty scale, Edmonton Frail Scale, frailty phenotype, and gait speed test. Rockwood et al. described the frailty index as a detailed inventory of 70 clinical deficits based on the notion that frailty is a result of interacting physical, psychological, and social factors. The frailty index is calculated as the number of deficits the patient has divided by the number of deficits considered [14, 15]. Due to the complexity of the Rockwood scale frailty index, it has limited value in clinical practice. However, the modified frailty index (mFI) is one of the most common scales used in practice. This scale is derived from mapping 11 variables within the NSQIP database, which are contained within the original 70 deficits from Rockwood et al. Canadian study. Nine of the 11 variables are comorbidities and the remaining two include altered sensorium and functional status. The advantage of using this scale is its ability to create rapid, automated calculations to produce a value. However, several limitations exist with the mFI, as it does not assess communication, mood, nutrition, behavior continence, or cognitive impairment, all of which are crucial in frailty assessment [12].

Measuring frailty in the geriatric population is especially important for risk assessment. Several studies have shown that frailty results in increased perioperative and intensive care morbidity and mortality. Bagshaw et al. found that almost one-third of patients over the age of 50 are qualified as frail. The majority of patients who were labeled as frail were older in age, of female gender, had a greater number of comorbidities, and had greater functional dependence. Frail patients have higher in-hospital mortality than non-frail patients. Additionally, frail patients were found to be more likely to suffer adverse effects, have a higher rate of readmission, need rehabilitation, and become functionally dependent leading to a lower quality of life than non-frail patients [16].

31.6 Physiologic Changes in the Elderly

As people age, their physical appearance as well as their physiologic reserve begin to change. The loss of physiologic reserves occurs in all geriatric patients and this decline varies from person-to-person and organ-to-organ. In a non-stressed state, elderly patients can generally overcome their physiologic decline and compensate in order to meet their physiologic needs. When intense stress occurs, such as a trauma or acute surgical pathology, an individual may no longer be able to compensate, as the demand may be too overwhelming. This often leads to inadequate perfusion, which eventually creates a downward spiral of organ systems causing multisystem organ failure [17].

31.6.1 Central Nervous System

Cerebral blood flow and cerebral oxygen consumption decrease with age [18]. With age also comes the loss of total brain mass, with an estimated total loss of 6–11% by the age of 80 [18]. As a result of decreased brain mass, cerebral blood flow and cerebral oxygenation, there is an increased risk for cerebrovascular accidents. The human senses also become blunted, as the number of receptors in the eyes (retinal, rods, cones) and ears (hair cells, labyrinth cells) decline as a part of the aging process. This can lead to a decrease in reflex time. Cortical atrophy lowers the threshold to neurodegeneration in patients. Perioperative insults, such as hypotension, hypoxia, hypothermia, and malnutrition, pose a greater risk to the central nervous system of elderly persons compared to those below 65 years old. The blunted sympathetic and parasympathetic responses to stimuli result in more moderate responses to stress and typically longer recovery times to baseline functionality. The most common postoperative neural complications are cerebrovascular accidents and delirium [19].

31.6.1.1 Delirium

Delirium is a reversible, transient syndrome of cognitive impairment with an acute onset and fluctuating course. Although the exact etiology of delirium is unknown it is believed to be abnormalities in brain neurotransmitters. Delirium occurs in more than 60% of elderly adults admitted to the ICU and upwards of 80% of patients who require mechanical ventilation [20]. One study found that seven out of 10 patients admitted to the surgical/trauma ICU experience delirium during their ICU stay [21].

Three types of delirium have been described which include hyperactive, hypoactive, and mixed type. Hyperactive delirious patients typically exhibit several of the following symptoms; hypervigilance, restlessness, fast and/or loud speech, anger, irritability, combativeness, impatience, uncooperativeness, swearing, singing, distractibility, nightmares, persistent thoughts, and wandering [22]. Hypoactive delirium, the most difficult type of delirium to identify, generally manifests in patients as the following symptoms: unawareness, lethargy, decreased alertness, decreased motor activity, staring, sparse and/or slow speech, and apathy [23]. Patients with mixed delirium, the most common subtype of delirium, experience features of both hyperactive delirium and hypoactive delirium [22].

Delirium has been shown to increase mortality rate in several prospective studies. Mortality rates range from 1 to 8% in in-patient populations. These patients also have a 15–34% 6-month mortality rate after an ICU stay [20, 24]. The overall costs of delirium are huge and can range from $38 to $152 billion per year. Despite the shorter survival duration of elderly with delirium as compared to those without delirium, delirious elderly had significantly higher adjusted costs over 2.5 times that of patients without delirium. Overall costs per delirious patient ranges from $16,303 to $64,421 across the US [25].

The risk factors and causes of delirium can be divided into modifiable and nonmodifiable risk factors. Potentially modifiable risk factors include surgery, pain, acute neurological diseases, medications, immobilization (even by catheters or restraints), sensory impairment of hearing or vision, metabolic derangements (acid-base derangements, electrolyte derangements), environment, emotional distress, and sustained sleep deprivation. Non-modifiable risk factors include dementia or cognitive impairment, age over 65, chronic renal or hepatic disease, multiple comorbidities, and a history of delirium, stroke, neurological disease, falls, or gait disorder [21]. Mechanical ventilation is a well-known risk factor for delirium. Medications have the ability to cause delirium, with benzodiazepines and anticholinergics having the highest incidence of causing delirium [22, 26].

Delirium often times mimics other illness and can go undiagnosed. Reports in the literature suggest that as many as 65–84% of delirium cases go undiagnosed [22]. Despite this, there are a wide range of screening tests which exist to diagnose delirium. One of the most well known and most used tests in American ICUs is the Confusion Assessment Method (CAM-ICU). The CAM-ICU effectiveness is well-supported by numerous studies and has a sensitivity of 94–100%, and a specificity of 89–95% [27]. The CAM has both a long and short version which has nine and four clinical features, respectively. The majority of CAM scoring is done by bedside ICU nurses and includes the short version which encompasses:

1. Acute changes or fluctuating course in mental status,
2. Inattention,
3. Altered level of conscious, and
4. Disorganized thought.

CAM scoring takes less than 2 min and can be used in mechanically ventilated patients [28]. Other scoring systems include but are not limited to, cognitive tests of delirium, a delirium index, and delirium detection scores among others [22].

Treatment for delirium can be difficult, but prevention is key. Addressing underlying causes such as pain, infection, hypoxia, and other metabolic derangements are paramount. Additionally resetting the normal sleep-wake cycle is key. This can be done by keeping the patient awake during the day with the TV on and shades upon surrounding windows. Constant reorientation and reassurance can help as well as frequent visits from family and friends. Several medications have historically been used to treat delirium, especially hyperactive. The typical (haloperidol) and atypical (Quetiapine, Olanzapine) antipsychotics are generally used as first-line treatment options. Newer agents such as Dexmedetomidine, a centrally acting alpha-2 agonist, have shown to reduce the duration of delirium. In a recent Cochrane Review meta-analysis found that all pharmacologic treatments of delirium except for Dexmedetomidine were no better in reducing the duration of delirium compared to placebo [29].

31.6.2 Cardiovascular System

Changes in the heart as a result of aging effects the anatomical, physiological, and the electrical activity of the heart [11]. Geriatric patients have decreased contractility and ventricular compliance. Increase in systolic blood pressure is common due

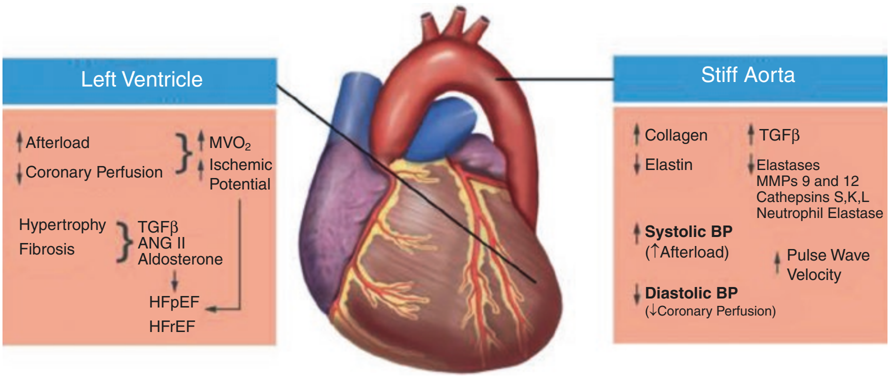


Fig. 31.1 Visual representation of the pathophysiology of the aortic and left ventricle as a process of physiologic aging. (Chan E.D., and Welsh C.H.: Geriatric respiratory medicine. Chest 1998; 114: pp. 1704–1733)

to a decrease in compliance of the outflow tract leading to an increase in afterload. This increase can result in decreased ejection fraction (EF) and cardiac output. Heart rate also can decrease as much as 30% in the elderly, which hinder the ability for the heart to compensate with a tachycardic response during time of intense physiologic stress [30]. Furthermore, aged myocardium has a poor response to catecholamines (both endogenous and exogenous) [31]. As a result, the elderly patient often needs to be volume resuscitated to maintain adequate cardiac output and stroke volume. When giving large volume resuscitation, especially in the elderly it is important to be mindful of the potential for flash pulmonary edema [32] Fig. 31.1.

Cardiac complications are one of the highest causes of mortality in elderly surgical patients. Cardiac complications occur in 12–16.7% of geriatric patients [33, 34]. Myocardial infarction (MI) is the leading cause of postoperative death in patients over the age of 80 [34]. Postoperative MI typically occurs within 72 h of operation and has a prevalence of 0.1–4% in patients over the age of 65 [34]. Beta-blockers have historically been used to help prevent postoperative cardiac events in the elderly. However, there is little consensus on the use of perioperative beta-blockers. The current guidelines set by the ACC/AHA state that those taking beta-blockers at the time of surgery should continue them, and suggest that high-risk patients be started on one [35].

Atrial fibrillation (AF) is the most common arrhythmias and its incidence increases as one ages [36]. AF is common in postsurgical patients and is the most prevalent arrhythmia in the geriatric population admitted to the ICU. As the heart ages, it develops myocardial fibrosis and atrial dilation, both of which can aid in the progression of AF. A higher prevalence of AF is seen in elderly patients with underlying cardiovascular conditions such as hypertension, cardiomyopathy (ischemic, dilated, or hypertrophic), and valvular disease. Other independent risk factors for AF that further increase risk in elderly patients include obstructive sleep apnea and obesity. AF is associated with longer ICU stays and overall increased length of stay

[36–38]. When considering treatment options for AF, it is important to consider underlying causes such as electrolyte abnormalities, thyroid dysfunction, and acute cardiac ischemia. Initial workup should include a physical exam and determine if the patient is hemodynamically stable or not. In hemodynamically unstable patients, cardioversion is the treatment of choice. In stable patients, treatment should focus on rate control, rhythm control, and prevention of veno-thrombo embolism. Rate control is often achieved using beta-blockers, calcium channel blockers, Amiodarone, and Digoxin. Patients with new onset AF without conversion to sinus rhythm after 48 h have an increased risk of atrial thrombus formation and anticoagulation should be considered [37].

31.6.3 Pulmonary System

Age-related changes to the pulmonary anatomy and physiology puts geriatric patients at an increased risk for pulmonary complication post injury and emergent surgery. As we age, pulmonary compliance decreases, while pulmonary vascular resistance increases. As a result of decreased compliance, Burr et al. showed that the FEV_1 and the forced vital capacity declined progressively with age, while Knudson et al. estimated that the FEV_1 decreases by 30 and 23 mL/year in nonsmoking men and women respectively, with an even greater decrease after the age of 65 years [39, 40]. This is equivalent to an 8–10% decline in FEV_1 each decade. Mucociliary dysfunction is often present which may hinder the ability to clear secretions as does reduction in intercostal and diaphragmatic function. Additionally, specific age-related changes which include decreased dead space ventilation, decreased diffusion capacity, and reduced respiratory drive make weaning them from the mechanical ventilator more difficult [41] (Fig. 31.2).

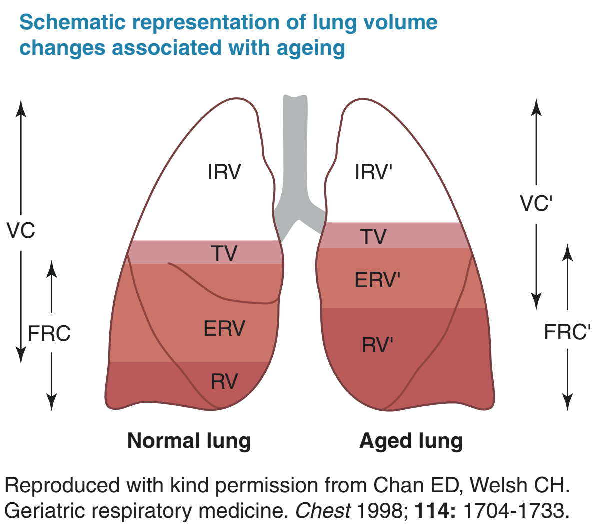


Fig. 31.2 Schematic representation of lung volume changes associated with ageing. (Paneni F, Diaz Cañestro C, Libby P, Lüscher TF, Camici GG. The Aging Cardiovascular System: Understanding It at the Cellular and Clinical Levels. J Am Coll Cardiol. 2017;69(15):1952–1967. https://doi.org/10.1016/j.jacc.2017.01.064)

Respiratory failure leading to mechanical ventilation is a common problem among elderly surgical patients. Certain principles apply to elderly patients admitted to the hospital but are especially pertinent post injury. These include: optimizing gas exchange, preventing aspiration, prevention as well as early diagnosis and treatment of pneumonia, early detection of respiratory failure, assistance with ventilation (noninvasive or invasive), and extubation when appropriate [42].

Pneumonia that is considered is hospital-acquired (HAP) appears 48 h after admission to the hospital. Ventilator-associated pneumonia is a type of HAP that occurs when patients are admitted for more than 48 h and require mechanical ventilation. VAP is more common in the surgical ICU and is significantly more common in patients who have undergone emergency surgery rather than elective surgery (11.1% vs 2.9%) [43]. Under normal physiologic conditions the lower respiratory tract is considered sterile; however, due to an impaired host and weakened defenses in the elderly, this is not the case. This may cause the introduction of bacteria to the lower airway via bacterial colonization of the aerodigestive tract and lead to pneumonia. Several factors promote these mechanisms which include presence of invasive devices, alterations in gastric emptying and pH (surgically or via medications), and contamination of devices.

Diagnosis in the elderly is especially challenging because they may not mount the appropriate fever response or leukocytosis. Additionally, infiltrates on chest x-rays may be secondary to other conditions such as cardiac or pulmonary contusions in a trauma setting. Quantitative culture analysis via bronchoalveolar lavage (BAL) is the preferred method for the diagnosis of VAP. Depending on institution protocols, VAP is diagnosed with a positive culture of 10^4 or 10^5 CFU/mL [44]. Broad-spectrum empiric antibiotics should be initiated and tailored based on culture results. Debates exist on the exact duration of treatment but according to Chastre et al. who published a randomized control study in JAMA found that optimal duration should be 8 days of therapy and there was no difference in outcomes for treatment at 15 days [45]. Prevention of VAP is crucial, and several bundles have been developed and are effective in reducing VAP rates in the ICU.

31.6.4 Gastrointestinal System

As the human body ages, changes occur throughout all portions of the gastrointestinal tract. These changes are typically broken down into three categories; neuromuscular function, structural changes, and changes in secretory and absorptive function [19]. Age-related changes of the esophagus are typically the result of impaired neuromuscular function that leads to motility issues and often results in prolonged transit times. Impaired sphincter relaxation is common. The cricopharyngeus muscle (the primary muscle of the upper esophageal sphincter) is particularly susceptible to alterations in motility and may lead directly to problems such as aspiration and dysphagia [46]. As we age, structural changes are also seen throughout many portions of the GI tract including in the stomach where atrophic gastritis is present. In the small intestine, there is a progressive loss of villi height starting

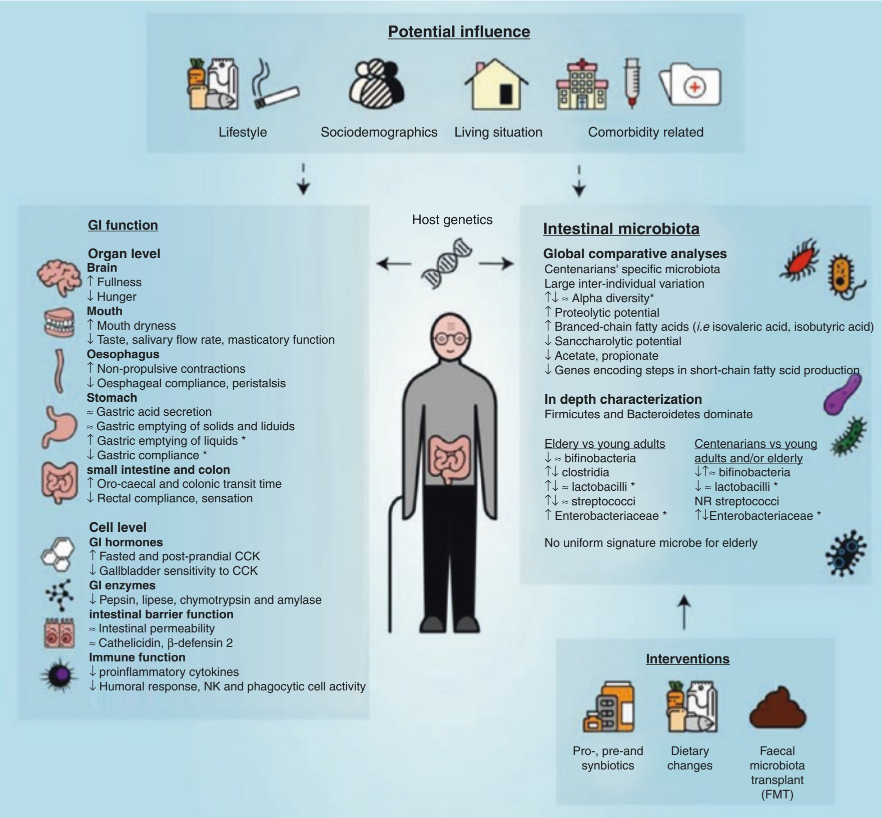


Fig. 31.3 Represents several factors which can influence the gastrointestinal system as ageing occurs. (An R, Wilms E, Masclee AAM, *et al.* Age-dependent changes in GI physiology and microbiota: time to reconsider? *Gut* 2018;**67**:2213–2222)

around age 60 which leads to decreased surface area and therefore decreased absorption [47]. Structural changes in the colon are the most common portion of the GI tract to be affected by aging. Thickening of the muscular layers is present all throughout life but more rapidly thicken in individuals over the age of 60. The thickening is due to elastogenesis and is not a result of myocyte hypertrophy or hyperplasia. This thickening often leads to hard stool, constipation, and fecal impaction [19] (Figs. 31.3 and 31.4).

31.6.5 Nutrition in the SICU

Geriatric patients are at a very high risk of malnutrition. It is estimated that up to 10% of the elderly population living at home and up to 70% of elderly patients who are admitted to acute care hospitals suffer from protein-energy malnutrition. As humans age, basal metabolic rate decreases by more than 16%. There is a redistribution of body fat and a decrease in lean muscle mass [48]. Several risk factors related to age include psychological, social, and environmental factors such as depression, grieving, financial hardship, and admission to long-term facilities including nursing homes. Oral, dental, and swallowing disorders as well as dementia and other neurological disorders can contribute to malnutrition. Acute trauma and surgery also increase the risk of malnutrition in the elderly [49].

The elderly are at a greater risk than the general population for deficiencies in many vitamins and minerals. Vitamin D deficiency is common in the elderly and is a result of multifactorial causes including increased incidence of lactose intolerance, decreased intake, decreased sunlight exposure, and decreased renal conversion to active vitamin D. As a result, elderly individuals may experience vitamin D deficiency and feel bone pain and muscle weakness, especially in the proximal muscle groups. This may lead to frequent falls [50]. Recommended treatment is 600 IU daily [51, 52]. Vitamin B12 is another common deficiency among the elderly. This deficiency is often a result of decreased dietary intake. Red meat is one of the primary sources of B12 and is typically omitted from an elderly person's diet. This can be due to increased costs of red meat as well as difficulty physically chewing the meat. This can lead to anemia, neuropathy, and dementia. The recommended daily amount of B12 is 2.4 μg and elderly patients should try to obtain this from supplements or fortified foods. Vitamin K deficiency is less common in the geriatric population. However, this may occur with the administration of several medications such as anticoagulants, most notably Warfarin, as well as antibiotics, and sulfa-containing drugs [51, 53]. Calcium deficiency may also be seen in the elderly and can result in osteoporosis, especially in females. If wound healing for a specific patient is a concern then supplements with vitamin C, Vitamin A, and zinc should be given [54].

Several screening tools exist for malnutrition. These include evaluating risk factors, appetite and food intake, trending weights, and calculating body mass index (BMI). France's Mini Nutritional Assessment (MNA) has become a standard screening tool for geriatric malnutrition. The Assessment addresses 18 various areas including appetite, meals, and weight loss, in addition to objective measurement such as calf circumference. The maximum score is 30, with normal scores falling between 24 and 30. Scores indicating potential malnutrition and malnutrition are those between 17 and 23.5 and those less than 17, respectively [55]. Several shorter modified scales have also been developed. Objective lab data such as albumin, transferrin, prealbumin, and total lymphocyte count can also help aid in the screening and diagnosis of malnutrition.

According to French guidelines, the diagnosis of malnutrition is based on one or more of the following criteria: weight loss ≥5% in 1 month or ≥10% in 6 months, body mass index <21, serum albumin concentrations <35 g/L, and MNA score <17. Severe malnutrition may be diagnosed by one or more of the following criteria: weight loss of ≥10% in 1 month or ≥15% in 6 months, BMI <18, and serum albumin <30 g/L [54].

The ASPEN/SCCM guidelines recommend the use of indirect calorimetry to estimate resting energy expenditure and caloric needs in ICU patients. Since indirect calorimetry is often not available due to costs or other reasons, the weight-based equation 25–30 kcal/kg/day should be used [56].

The current ASPEN/CCM guidelines suggest early initiation of enteral nutrition (within 24–48 h) in high-risk, critically ill, and trauma patients [56]. Enteral nutrition is the preferred route as the old saying in surgery goes "if the gut works, use it." Since many critically ill patients are not able to take in food by mouth, nasoenteric tubes, gastrostomy, or jejunostomy allow the administration of enteral nutrition. The use of the GI tract for feeding has many pros that include the decreased rate of infection comorbidities (as compared to parenteral nutrition), decreased length of patient stay, and preservation of mucosal integrity. Risks associated with enteral nutrition include aspiration, tube feeds associated diarrhea, and tube dislodgement. Parenteral nutrition is an alternate way to deliver calories via the vein to patients who are unable to tolerate enteral feeding [54]. Typically, Total Parenteral Nutrition (TPN) is initiated at the 5–7-day mark in the ICU; however, newer literature is suggesting that TPN should be initiated as soon as 24 h into one's ICU stay [57, 58]. TPN can help to restore the nitrogen balance and an anabolic state. Parenteral nutrition is not without complications and can be directly related to infections, venous thromboembolisms, hemothorax, and pneumothorax. Additionally, electrolyte derangements and hepatic dysfunction is commonly seen in patients on TPN [54].

The risk of malnutrition skyrockets in hospitalized geriatric patients. It is therefore important to identify age-related risk factors early, perform good screening exams, and obtain objective lab data, so early nutrition can be employed. This will help decrease the length of stay and improve overall morbidity and mortality.

31.6.6 Renal System

The kidneys perform several key functions and help maintain homeostasis by regulating acid-base status and excreting by products of the metabolism. As aging occurs, several morphological changes directly affect renal function. Renal blood flow peaks around 20-years old and declines by 50% by age 80. Each decade of life after 20, there is a progressive decline in glomerular filtration rate (GFR) which is manifested by decreasing creatinine clearance (CCR). On average CCR declines by 6.5 mL/min per decade after age 20 [59]. Aging leads to a reduction in glomerular capillary flow rates, reduction in afferent arteriolar resistance, and an increase in glomerular hydraulic pressure. Other morphological changes which occur are loss of renal mass (20–25% by age 80), glomerulosclerosis (40% of nephrons are sclerotic by age 85), decreased tubular number, and thickening of basement membranes. Despite age-related changes, serum creatinine is typically preserved in the elderly. Serum creatinine is reflective of muscle mass and protein intake, both of which are typically decreased in the elderly. This often results in an unreliable measurement of serum creatinine as an assessment of renal function in the elderly [60–62] (Fig. 31.4).

Acute kidney injury (AKI) which can lead to acute renal failure is a common problem encountered in the ICU especially among the geriatric population. Due to

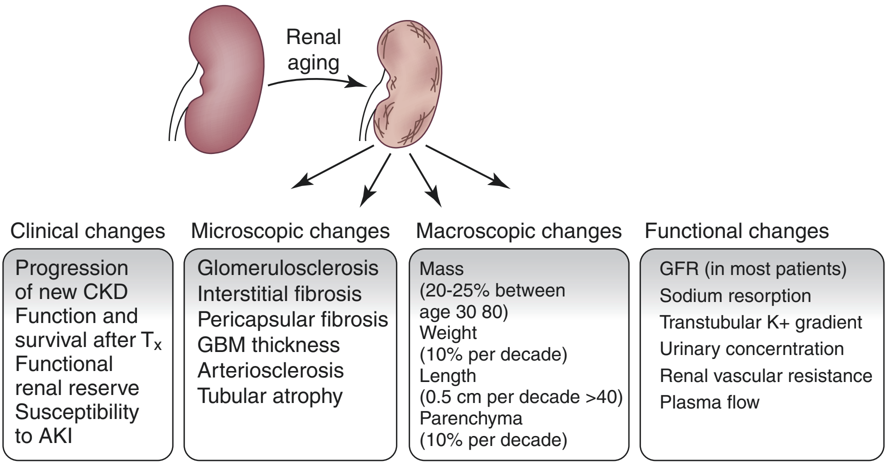


Fig. 31.4 Aging on the kidneys lead to clinical changes, anatomical and histological as well as functional changes. (Renal Aging: Causes and Consequences Eoin D. O'Sullivan, Jeremy Hughes, David A. Ferenbach. JASN Feb 2017, 28 (2) 407-420. https://doi.org/10.1681/ASN.2015121308)

Table 31.4 RIFLE (Risk, Injury, Failure, Loss of kidney function, and End-stage kidney disease) classification defines and stratifies the severity of acute kidney injury (AKI)

Stage	Decrease in GFR	Urine output
R (risk)	>25%	<0.5 mL/kg/h for 6 h
I (injury)	>50%	<0.5 mL/kg/h for 12 h
F (failure)	>75%	<0.3 mL/kg/h for 24 h
L (loss)	Complete loss of renal function >4 weeks	
E (ESRD)	Failure lasts for >3 months	

This system relies on changes in the serum creatinine (SCr) or glomerular filtration rates and/or urine output enables monitoring of AKI severity, and is a predictor of patient outcome

physiologic changes as well as underlying comorbidities such as diabetes and hypertension, elderly patients are more susceptible to insults to the kidneys during states of shock. Additional risk factors for developing AKI include medications and contrast. Typically, AKI and renal failure are associated with oliguria; however, renal failure can be present in the setting of normal urine output [63, 64]. The RIFLE criteria encompasses a spectrum of renal dysfunction that includes both urine output and metabolic dysfunction [65]. The RIFLE criteria is summarized in Table 31.4.

AKI can broadly be classified into three categories that include prerenal AKI, renal AKI, and post-renal AKI. The large majority (>75%) of patients with AKI in the surgical intensive care unit (ICU) are either hypovolemia causing prerenal AKI or acute tubular necrosis (ATN) causing renal AKI. When working up AKI in the ICU it is important to attempt to establish the type of AKI which can be deduced by assessing volume status, signs of uremia, laboratory values (including CBC, BMP, urine electrolytes, urinalysis), and imaging such as renal ultrasounds [64]. Treatment is often based on cause and type of AKI. Renal AKI is treated with fluid resuscitation. However, one must be cautious as to the amount of fluids elderly patients receive, as fluid overload in the elderly often can lead to pulmonary and cardiac complications. A thorough comb over of the patient's medications should be reviewed, nephrotoxic medications should be stopped, and correct renal dosing is crucial to preventing worsening AKI.

Renal replacement therapy (RRT) is a common practice in the ICU. Typically, continuous renal replacement therapy (CRRT) is preferred for the critically ill as compared to intermittent hemodialysis (IHD), as there are less fluid shifts and better hemodynamic stability with CRRT. There are several indications for RRT in the ICU. Severe hyperkalemia, refractory acidosis, and volume overload are the most common indicators [61].

31.6.7 Skin and Soft Tissue

As humans age, skin changes occur that lead to the increased risk of skin breakdown as well as the decreased ability of skin to heal. Structural changes which occur as we age include thinning of the epidermis, decrease in the number of sebaceous glands which leads to skin dryness, and decrease of lipids in the stratum corneum which interfere with normal barrier function [66]. The dermal-epidermal junctions become flattered, which weakens the resistance to shear and results in an increasing number of superficial skin infections in the elderly [67]. Aging also leads to the thinning of the dermis and disorganization of collagen fibers. UV rays which mainly alter the dermis can lead to collagen degradation resulting in decreased tensile strength and decreased dermal hydration [67]. This ultimately results in less elastic skin, wrinkles, and skin that is more prone to tearing and laceration. In addition to structural changes in the skin's cellular makeup, aging causes a decrease in generalized sensation (especially in temperature), decreased vascularity, and impaired lymph flow [66, 68].

Lastly changes beneath the epidermis can contribute to injuries to the skin. As we age muscle mass is often lost as a result of decreased exercise or activity. Fat stores are typically reduced with aging secondary to malnutrition which impairs wound healing. The loss of these fat stores, affect areas where fat acts a padding on boney prominences. This increased pressure increases the risk of injury in older adults. Additionally, incontinence which is often seen in the elderly increases the risk for maceration which in turn increases the risk of shear injury [66] (Figs. 31.5, 31.6 and 31.7).

31.6.8 Endocrine and Immune System

Age-related changes in various endocrine functions are well documented. As women age, they experience menopause. Geriatric female patients enter a post-menopausal or estrogen-deficient state. This can lead to a myriad of symptoms including the loss of calcium homeostasis. This in turn can lead to osteoporosis and bone loss associated with pathological fractures, decreased levels of HDL

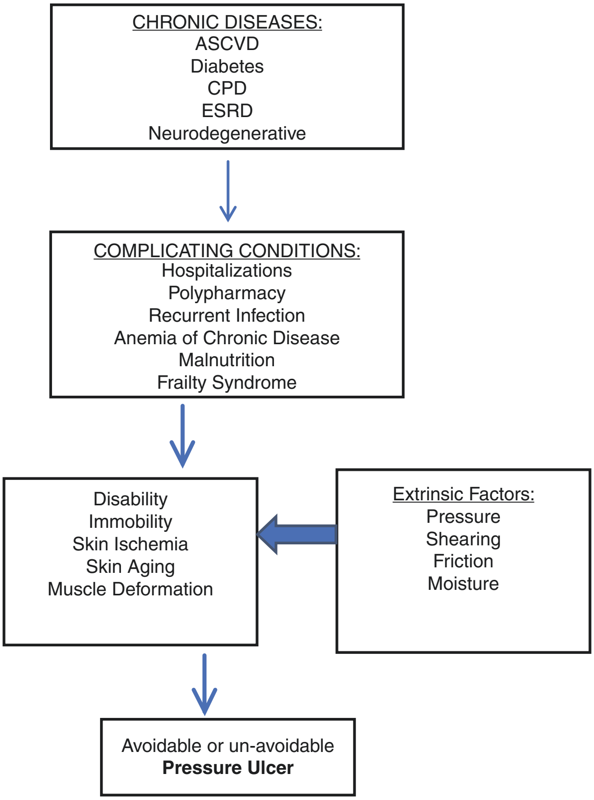


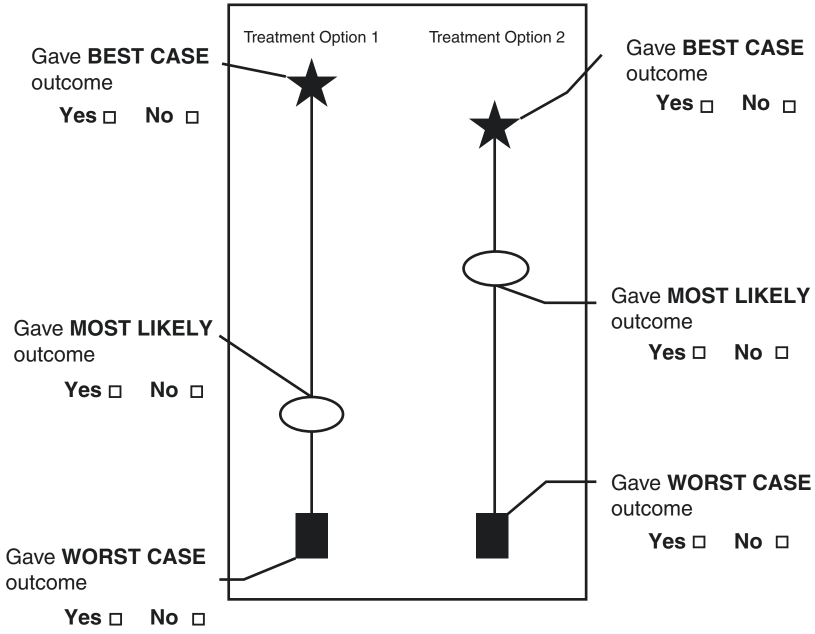
Fig. 31.5 Flow chart of underlying disease process and risk factors which ultimately lead to pressure injuries. (Jaul, E., Barron, J., Rosenzweig, J.P. et al. An overview of co-morbidities and the development of pressure ulcers among older adults. BMC Geriatr 18, 305 (2018). https://doi.org/10.1186/s12877-018-0997-7)

and increased levels of LDL, mood swings, urogenital atrophy, and loss of libido [19, 69, 70]. Similarly, as men age, testosterone levels fall which can lead to decreased libido, decreased hematocrit, muscle atrophy, and osteoporosis [69].

In nondiabetic individuals, there is a progressive impairment of glucose tolerance that comes with advanced age [19]. The thyroid gland undergoes atrophy and fibrosis, which leads to less peripheral conversion of thyroxine to triiodothyronine, decreased uptake of iodine, and overall lower levels of thyroxine and free thyroxine [47]. Adrenal function in the elderly leads to changes in the diurnal pattern of cortisol through a shift to an earlier cycle. This results in high evening cortisol levels, demonstrated by earlier bedtime and earlier wake time in the elderly. Although a positive correlation between aging and levels of norepinephrine and epinephrine exists, the response to these catecholamines is often blunted and manifests as cutaneous vasoconstriction to cold, resulting in increased susceptibility to hypothermia [70, 71].

Aging also results in impairment of T-cell mediated immunity and increased susceptibility to infections [72].

Best Case/Worst Case Tool Skills Checklist & Observation Form



Written diagram complete/ used patient-friendly terminology	Yes ☐ No ☐
Used narrative/ told a story when describing cases	Yes ☐ No ☐
Included patient's chronic medical conditions in discussion	Yes ☐ No ☐
Used questions or phrases to encourage deliberation	Yes ☐ No ☐
Made a recommendation	Yes ☐ No ☐

SURGEN ID: ___________

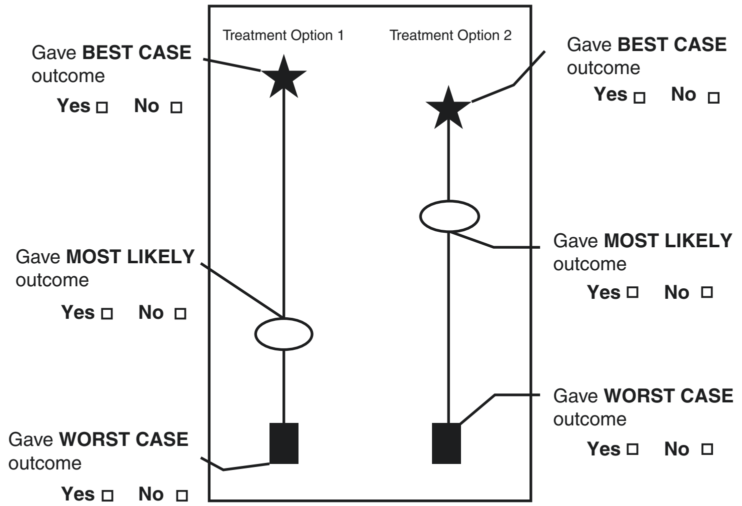
TOTAL SCORED POINTS: _________ **/11**

ADDITIONAL COMMENTS:

Fig. 31.6 Best case/worst case scenario: a framwork for difficult decision-making in surgical patitints who are cirtically ill. (Kruser et al JPSM April 2017 Volume 53, Issue 4, Pages 711–719.e)

a

Best Case/Worst Case Tool Skills Checklist & Observation Form



Written diagram complete/ used patient-friendly terminology	**Yes** ☐ **No** ☐
Used narrative/ told a story when describing cases	**Yes** ☐ **No** ☐
Included patient's chronic medical conditions in discussion	**Yes** ☐ **No** ☐
Used questions or phrases to encourage deliberation	**Yes** ☐ **No** ☐
Made a recommendation	**Yes** ☐ **No** ☐

SURGEN ID: ___________

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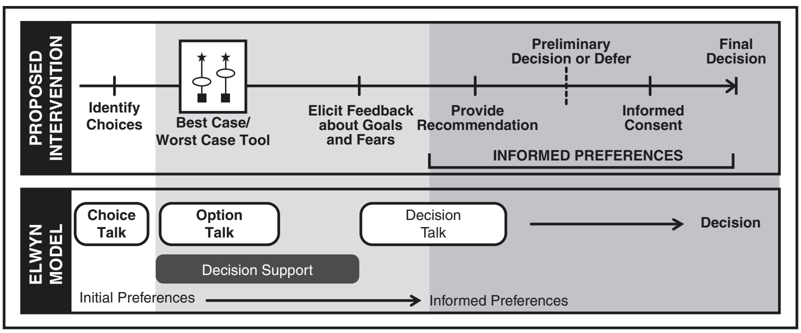

Fig. 31.7 How the "best case/worst case" tool is used within a complete clinical decision-making process. The proposed use of "best case/worst case" builds on a conceptual model described by Elwyn et al that promotes shared decision making and facilitates the development of informed preferences. (Kruser et al JPSM April 2017Volume 53, Issue 4, Pages 711–719.e)

31.7 Common Geriatric ICU Pathology (Issues, Disease?), Management, and Treatment

31.7.1 Communication/Goals of Care/End of Life

When a geriatric patient requires admission to the ICU it is extremely important to clarify their wishes with them or their family members. The importance of communication, especially with medical decision-makers and/or family, cannot be overstated to aid decision-making. It is imperative that intensivists describe the course of an elderly patient's care as simply as possible. Multidisciplinary rounds including family members can help alleviate some of the anxiety surrounding lack of information. Jacobowski et al. found higher satisfaction scores regarding the frequency of physician communication when conducting daily interdisciplinary family rounds p ($p = 0.004$) [73]. The authors also stated that structured family rounds could negatively impact the time for critical decision-making. Therefore, more than one or two direct questions should prompt the intensivist to suggest a private family meeting at the conclusion of rounds to prevent interruptions in caring for other potentially sick patients. At Weill Cornell Medicine/New York-Presbyterian Hospital, we have found it is particularly helpful to hold weekly multi-disciplinary meetings with the family for our sickest patients.

Advanced directives such as living wills and health care proxy forms can help to clarify ones wishes and help to avoid unnecessary treatment. Unfortunately, many elderly patients (upwards of 70%) who are admitted to the ICU have not discussed their medical preferences and goals for care regarding the end of life issues with healthcare providers or family members. Often this leads to unnecessary prolongation of life through life-sustaining interventions, and unwanted procedures and surgeries. In many of these instances, patients would rather focus on improved quality and comfort near the end of life [74, 75]. These unnecessary admissions utilize billions of dollars, significant resources, and large amounts of healthcare providers' time.

When advanced directives are in place, they are often vague and limited by the fact that they cannot encompass every possible clinical scenario that may arise [76]. This has the potential to lead to confusion. An example of the difficulties providers can have with advanced directives is the story of one of the pioneers of cardiac surgery, Dr. Michael Debakey. He was diagnosed with a type 2 aortic aneurysm (a classification he himself developed) up to 7.5 cm. At age 97 at the time of the diagnosis and before he was unresponsive, he had stated that he did not want surgery and would rather die. He had signed a standard form directing that he cannot be resuscitated if his heart stopped and a note in the chart saying he did not want surgery for the aortic dissection and aneurysm. Yet despite the directive, he went on to receive an operation that took nearly 8 h to repair his aorta. He spent another month in an intensive care unit eventually requiring a tracheostomy and gastrostomy feeding tube and an additional 7 months in the hospital for total recovery. When asked about the decision to operate despite his signed directive, he simply stated, "It was the right thing to do."

Narayan et al. described that patients and families who are undecided as to their wishes in a cardiac arrest scenario should be reminded that in the absence of any documented advanced directives, the intensive care team is obligated under law to perform life-saving procedures including compressions, shock, medications, etc. [77]. They also stated the importance of emphasizing that designating an ICU patient *Do Not Resuscitate* or *Do Not Intubate* [DNR/DNI] does not translate to **do not treat**. These orders are to be employed only after treatment has failed. Patient families also struggle with difficult decision-making, particularly in the elderly. Not uncommonly, the intensivist is told, "please do everything." Tools to assist with in-the-moment decision-making focusing on communication and global assessment can help with this difficult process. An example is the best case/worst case tool initially described by Schwarze et al. [78]. The tool promotes a shared decision-making model and can help the intensivist facilitate the development of informed preferences versus preconceived notions. Patients and their families are encouraged to verbalize their choices and options at the outset of the decision-making process, allowing them greater autonomy as well as improved understanding of the varying treatment options (Figs. 31.6 and 31.7).

The proposed use of "best case/worst case" builds on a conceptual model (bottom) described by Elwyn et al. *that promotes shared decision-making and facilitates the development of informed preference*s.

The role of palliative care in the intensive care is evolving. Mercadante et al. and other proponents suggest that palliative care specialists have the potential to encompass symptoms control and end-of-life management, communication with relatives, and setting goals of care ensuring dignity in death and decision-making power [79]. Others taking a more holistic approach believe that general palliative care issues should be the responsibility of all ICU clinicians, who need basic knowledge and skills for symptoms management, appropriate techniques of communication, capability in sharing decision-making based on patients' values, goals, and preferences.

Toevs et al. state that the goal of palliative medicine is to support patients and families during serious life-limiting illness. Specifically, palliative care input can be provided alongside disease-directed therapy to optimize symptom management and adhere to a plan of care that remains patient-concordant. The typical palliative care team often consists of a physician, nurse practitioner, and/or physician assistant (advance practice provider), social worker, and chaplain who provide interdisciplinary comprehensive whole-person care. Toevs encourages intensivists to stay engaged in these discussions but feels that a designated palliative team can help with more complex decision-making, conflict among decision-makers, uncontrolled refractory symptoms, and ongoing needs in an inpatient and outpatient setting [80].

At the time of this chapter submission, the World Health Organization (WHO) declared the novel coronavirus (COVID-19) outbreak a global pandemic in 2020. Given the sheer numbers of critically ill patients on the ventilator, many of them elderly patients, it became increasingly impossible for intensivists to work with individual families. Palliative care teams were formed and, in consultation with intensivists, were able to reach out to families to drive decision-making [81]. Beyond the scope of this chapter is deciding on when to withhold potentially life-saving technologies (ventilation, hemodialysis, and/or extracorporeal membranous oxygenation) given a patient's age, comorbidity, and prognosis.

31.8 Summary

Care of the elderly patient in the intensive care requires a thorough understanding of the underlying physiologic changes to be expected. Elderly patients have a much narrower margin of error compared to younger patients. Careful attention to ideal body weights, volumes of distributions, neuro, cardiac, pulmonary, and renal function will be key to successful management. Implementing ICU bundles will help in liberating patients off of machine support and further move them towards discharge. Physiologic scoring systems can help predict outcomes. Many tools are available to assist the intensivist in the decision-making process on which elderly patients will require care based on physiology, anatomy, and other factors. The importance of consistent communication, offered in a multidisciplinary manner, as often as possible can help families cope with the amount of information they will need to process to make difficult decisions. Inviting palliative care team members to serve as partners in the care of elderly patients may provide additional comfort for patients and their families.

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32 Postoperative Rehabilitation of the Elderly

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With our aging population, improvement of surgical techniques and perioperative care, more elderly patients are undergoing and surviving aggressive surgeries that were not performed even 10 years ago. Because of an increased prevalence of pre-existing medical conditions among the elderly group, they are more at risk for complications following surgery, either elective or an emergency basis. Those complications often lead to longer hospital stays, longer ICU stays, and extended usage of the ventilators with increased mortality [1, 2].

Physicians have recognized the benefits of early ambulation, and that unnecessary bed rest and immobility lead to physiologic changes in individuals who are sick, aged, or disabled and are particularly susceptible to the adverse effects of immobilization. Immobility reduces the functional reserve of the musculoskeletal system and functional capacity of the cardiovascular system, resulting in weakness. Early rehabilitation intervention may prevent deconditioning thus maximize function and improve the quality of life in older adults; the main goal is to help achieve independence. Early mobilization of these elderly patients includes positioning, dangling of their legs static and dynamic standing balance exercises, transfer training, ambulation on postoperative day one [1, 3, 4].

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The new enhanced rehabilitation strategies improve the functional outcome in the elderly patients following abdominal surgery, especially those done on an emergency basis without optimal pre-habilitation.

The scope of this chapter is to review some physiologic changes in the elderly that one must consider in any rehabilitation strategy for this group of patients. We will also cover all rehabilitation interventions in the Intensive Care Unit (ICU), in the acute or subacute rehabilitation services, and as outpatient following their discharges.

32.1 Definition of Terms

Rehabilitation is defined as the development of a person to the fullest potential, consistent with his or her impairment, and environmental limitations.

Impairment disability and handicap definitions, according to the World Health Organization, are provided in Table 32.1 [1].

There are differences in health risk factors, life expectancy, and patient goals among the different elderly subgroups (65–75 years of age) who may still be working, (categorized as old) persons over the age of 85 years (oldest-old), and those over the age of 90 years (nonagrian).

32.2 Physiology of Normal Aging

32.2.1 Musculoskeletal System

Normal aging influences the skeletal muscle in both structure and function: muscle mass decreases, strength diminishes, the rate of concentration slows, and the resistance to fatigue is reduced [5].

Muscle endurance relative to maximum strength does not appear to diminish with age. The loss of muscle mass has been related to a reduction in the total number of muscle fibers or a reduction of the size of type fibers [6].

The decline of muscle strength may be due to the reduction in the number of functioning motor units and change in the pattern of activity, leading to disuse of certain muscles. This may be reversible if older adults are physically active. Stiffness is usually present due to changes in the connective tissue of tendons, ligaments, joint capsules, and muscles. The bone mass is affected by bodyweight loading and

Table 32.1 Definitions according to the World Health Organization

Term	Definition
Impairment	Any loss or abnormality of function
Disability	Any restriction resulting from an impairment the ability to perform an activity, which is considered normal for a person
Handicap	Any disadvantage resulting from impairment or disability that limits or prevents the fulfillment of a role that is normal for an individual

the tensile forces that the muscles exert on the skeletal structure. Insufficient load-bearing activity will result in bone demineralization [7].

Changes in the endocrine system also lead to bone loss, which is more significant in women after menopause. Increased or excess osteoclast activity which occurs during aging activity, possibly due to the results of vitamin D deficiencies leading to an imbalance in the bone remodeling and ultimate weakening of the Cortical and trabecular bone. Risk factors for osteopenia and osteoporosis include increasing age, smoking, family history, and glucocorticoid therapy. Bone mineral density measurements with dual-energy x-ray absorptiometry (DEXA) scans are used to diagnose and track osteopenia and osteoporosis.

The high prevalence of osteoporosis and degenerative joint disease (osteoarthritis) in the elderly raises the question concerning normal physiological changes versus pathology. Degenerative joint changes in weight-bearing joints are essentially a universal occurrence in both sexes by the age of 60. These changes include biochemical alteration of cartilage with decreased ability to bear weight without fissuring, focal fibrillation, and ulceration of cartilage leading eventually to exposure of subchondral bone. This is not simply an issue of wear and tear, but an end-stage phenotype of an abnormal balance of the breakdown repair of analogous to the failure in other organs. Fortunately, significant symptoms and disability occur only in a fraction of those with radiographically identifiable degenerative changes. There is a poor correlation between radiographic findings and clinical picture.

32.2.2 Cardiovascular System

Several changes have been documented in the aging cardiovascular system. Particularly of major importance regarding activity tolerance are a decrease in maximal oxygen consumption (V02max) which decreases 5–15% per decade after the age of 25 years old and a decrease in the maximal heart rate by approximately 6–10 beats per minute per decade. This results in reduced capacity for work [8].

Aging is also associated with progressive gradual increase in both Systolic and Diastolic blood pressure, apparently owning more to loss of arterial elasticity than neurogenic factors (e.g., increase in circulating norepinephrine). This leads to a decrease in arterial compliance, left ventricular hypertrophy with impaired filling. There is also a decrease in beta-adrenergic receptors stimulation response, decreased sinoatrial node automaticity, and decreased number of myocytes [9].

Another important age-related physiological change with significant clinical applications is the decreased baroreceptor sensitivity. This results in a diminished reflex tachycardia upon rising from a recumbent position and accounts in part along with blunted plasma renin activity and reduced angiotensin II and vasopressin levels, for the increased incidence of symptomatic orthostatic hypotension in the elderly.

Orthostatic hypotension, also common after prolonged bed rest is in part due to intravascular volume depletion, compounded by an increase in venous pooling from the lower extremities. Immobilization is a risk thrombotic complication from stasis due to reduced muscle pumping of blood from the lower extremities and increased blood viscosity.

32.2.3 Neurological System

Numerous changes have been noted in relation to the functioning of the neurological system with aging. The three most important areas of dysfunction accompanying normal aging include loss of short-term memory, loss of speed of motor activities (with slowing in the rate of essential information processing), and impairment in stature, properception, and gait. There are altered neurofunctional and structural organization in the aging brain. Functional neuroimaging studies have shown a shift in brain activity from the posterior to the anterior regions with aging, as well as a decrease in cortical thickness, which is more pronounced in the frontal lobe followed by the parietal, occipital, and temporal lobes.

Widespread changes in the white and gray matter areas of the brain have been reported with aging [9]. There are decreased brain volume, frontal gray matter lost, and decreased cerebral blood flow. With aging, there is a decline in episodic memory. By contrast, procedural and semantic memory is stable and may even improve. The fluid intelligence decreases with age.

Rates of cognitive decline vary between individuals and may affect the ability to live independently. The vision declines with age as a result of changes in all the tissues of the eye. Age-related hearing loss is a common condition in the elderly adults [10]. In the peripheral nervous system, a decline in nerve conduction velocities have been well documented. The elderly in general demonstrates a progressive decline in coordination and balance. Perhaps related in part to impaired proprioception [11]. Progressive loss of nigrostriatal neurons with advancing age may also contribute to these changes. The basal ganglia play a major role in control of movement and regulation of muscle tone. This explains the fixed posture, muscle rigidity, akinesia, tremors, weak voice, and shuffling gait which is occasionally seen in older individuals [12].

32.2.4 Pulmonary System

With aging, an enlargement of the distal airspaces due to loss of supporting tissue can be found, a condition for which the terms “senile lung” or “senile emphysema” have been proposed [13]. This results in impaired pulmonary gas exchange and ventilation/perfusion (V/Q) mismatch. In addition, there is a loss of elastic recoil and lung stiffening resulting in increased lung compliance and decreased thoracic wall mobility in the elderly. Respiratory muscle strength also decreases. These changes lead to increased residual volume and functional residual capacity. Compensation during exertion can occur even in healthy older adults to a limited extent [14]. Further morphological changes with aging are progressive calcifications of the airways and the rib cage. Like other muscles, there is a loss of diaphragmatic muscle mass [13].

32.2.5 Gastrointestinal System

The primary changes in the aging intestine involve decreased motility and a relatively hypotonic colon, leading to longer stool transit time, greater stool dehydration, and commonly constipation [15].

Esophageal motility is also often decreased with aging, with a decreased peristaltic response, increased non-peristaltic response, or decreased relaxation of the lower esophageal sphincter.

Gastric compliance decreases with aging causing early satiety and prolonged postprandial satiety. There is also a hypochlorhydria and subsequent impaired absorption of vitamin B12, calcium, iron, zinc, and folic acid.

Hypochlorhydria can also lead to bacterial overgrowth in the small intestine. Several age-related changes in the gastrointestinal tract potentially can alter drug absorption. There is a less effective surface area available for absorption, decreased motility, and reduced splanchnic blood flow [16].

32.3 ICU-Acquired Weakness

ICU admission following major surgery is considered a standard of care in many healthcare systems [17]. The goal of intensive care is to decrease short-term mortality. Furthermore, advances in technology and medical knowledge have led to an improvement in survival rates following critical illness. Nonetheless, there are important complications of care in the intensive care unit (ICU) consisting of infections including ventilator-associated pneumonia, catheter-associated bloodstream infections, and urinary tract infections; venous thromboembolism, delirium, myopathies, and neuropathies related to critical illness and stress ulcers. Furthermore, ICU-acquired weakness is common following prolonged immobilization, high doses of corticosteroid, and or neuromuscular blockers which are frequently used in the ICU plan of care [18, 19]. The etiology of ICU-acquired weakness is multifactorial [20, 21], with critical illness polyneuropathy and or myopathy known to be a well-known cause [22, 23].

Bed rest is commonly prescribed in the ICU setting. Lack of physical activity and prolonged bed rest have significant physiologic effects on musculoskeletal system. Healthy muscle is maintained through a balance of protein breakdown and synthesis. In contrast, muscle wasting occurs when the breakdown is increased relative to synthesis. With bed rest evidently, muscles are not being used and thereby atrophy occurs. Muscle responds quickly to use and disuse by altering diameter length types of contractile fibers and vascular supply [24]. Atrophy begins within 72 h of immobility and even healthy well-nourished individuals show loss in muscle mass and strength within 10 days of bed rest [25, 26]. With the reduction in muscle mass, up to 40% of muscle strength can be lost with the first week of immobilization [27]. There is a 1.3–3% daily loss of muscle strength during immobility [27]. The resultant deconditioning caused by bed rest can be independent of the primary disease and physically debilitating.

The muscle atrophy found with aging and disuse has been studied and found to be very similar suggesting that similar processes are occurring [28]. Elderly patients with muscle mass reduce from aging are particularly vulnerable to muscle dysfunction from disuse [24]. Furthermore, immobilization can result in joint contractures and peripheral nerve injury.

Anti-gravity muscles such as leg extensors and trunk musculature are preferentially affected by the loss of mechanical loading compared to hand and upper limb musculature [27, 29]. Furthermore, in chronic ventilated patients proximal muscles are more affected than distal muscles and larger muscle groups were more severely affected than smaller muscle groups [30].

The skeletal system also reacts quickly to bed rest and mechanical loading [27]. There is greater bony resorption than formation resulting in reduction in bone integrity and demineralization [29] which primarily affects trabecular bone [27]. Consequently, patients on bed rest are at an increased risk of fractures. As opposed to muscular changes the skeletal system responds more slowly. In his study, Le Blanc reported just after 1 week of immobility there was a 1% reduction in bone density within the vertebral column [31].

The respiratory system is also negatively affected by immobility with the risk of developing atelectasis and increased likelihood of developing respiratory complications such as pneumonia [32]. Reduced respiratory muscle strength is a common feature in patients with prolonged mechanical ventilation. Lung-derived inflammatory mediators, e.g., tumor necrosis factor is associated with muscle wasting in chronic lung disease [33].

Bed rest also leads to cardiac deconditioning. There is a reduction in stroke volume by 30% within the first month of bed rest. On the other hand, heart rate is increased and orthostasis can develop within 72 h of immobility [34]. To a large extent, these changes are secondary to a decrease in blood volume [35].

Moreover, even though it is more important to improve outcomes in critically ill patients, one should also consider the economic burden of the cost of ICU patients who are critically ill with respiratory failure and thereby require mechanical ventilation [36]. In the North American region ICU, approximately 40% of the patients are on mechanical ventilation [37]. Overall critical care costs account for approximately 1% of the US Gross Nation Product or 90 billion dollars [38].

32.4 Early Mobilization

Early mobilization of ICU patients may directly modify the negative effects of bed rest. Early ambulation of hospitalized patients was first introduced late during World War II in order to hasten the recovery of soldiers in order to return to the battlefield

[39]. Implementing aspects of physical medicine and rehabilitation within days of ICU admission is an ICU care strategy to improve patient recovery and minimize potential complications. The aims of mobilization include [40]:

1. Improving respiratory function by optimizing ventilation/perfusion matching increasing lung volumes and improving airway clearance
2. Reducing the adverse effects of immobility
3. Increasing levels of consciousness
4. Increasing functional independence
5. Improving cardiovascular fitness
6. Increasing psychological well-being

Additionally, mobilization may decrease the risk of pulmonary complications speed recovery decrease the duration of mechanical ventilation and decrease the length of ICU or hospital stay [40]. In Morris et al. prospective cohort study, although not statistically significant ($P = 0.262$) the total direct inpatient costs for protocol group inclusive of mobility team salaries were less than the usual care group. This was believed to be secondary to the length of stay related cost reduction [41].

Yet early mobilization is not practiced on a widespread basis in the ICUs. Needham et al. reported that only 27% of ICU patients had received physical therapy and exposure to physical therapy had occurred on only 6% of all ICU days [42]. Safety concerns were a major barrier to the implementation of early mobilization in the ICU. There may be a fear of endotracheal tube or drain dislodgment or need for sedation [43]. Clinicians are also concerned for significant changes in hemodynamic parameters such as increases in heart rate and blood pressure and decrease in oxygen saturation, especially with the more demanding activities. Moreover, pain and or anxiety associated with mobilization may also increase hemodynamic parameters. Furthermore, there is a time constraint for nurses and physicians [43] and increase in staff members' workloads. Other barriers brought down include lack of knowledge and training [44].

Stiller provides ICU practitioners a comprehensive guideline to be used to assess the safety of mobilizing critically ill patients. He states that the main safety factors to be addressed include the intrinsic factors which are the patient's medical background and cardiovascular and respiratory reserve vs the extrinsic factors such as patient attachments environment and staffing. Prior to mobilization, the patient's medical background should be reviewed including past medical history. As with all physiatrist evaluation, one should also consider the patients' premorbid functional status and thereby ascertain if his or her current condition is preexisting, caused by the current problem or a combination. The history of present illness and current symptoms will help the ICU practitioner gain an indication of what systems are likely to limit mobilization. This also includes a patient's current medications such as sedating agents [40].

Other intrinsic factors listed include the patient's cardiovascular reserve more specifically the heart rate and blood pressure. As with heart rate, there are no published clinical data concerning safe levels of resting blood pressure when deciding whether to mobilize critically ill patients. Stiller and Phillips considered an acute increase or decrease in blood pressure of 20% or more represented hemodynamic instability and would delay mobilization. Furthermore, they state in many instances where inotropes are required to maintain blood pressure, mobilization should be deferred. We can apply the American College of Sports Science and Medicine list of cardiac conditions that preclude performance of exercise test to early mobilization [40]:

Recent significant change in the resting ECG, suggesting significant ischemia recent myocardial infarction (within 2 days) or other acute cardiac events

Unstable angina

Uncontrolled cardiac arrhythmia causing symptoms or hemodynamic compromise

Severe symptomatic aortic stenosis

Uncontrolled symptomatic heart failure

Acute pulmonary embolus or pulmonary infarction

Acute myocarditis or pericarditis

Dissecting aneurysm

Acute infections

Additional intrinsic factor includes the respiratory reserve. Stiller and Phillip recommend calculating the patient's partial pressure of oxygen in the arterial blood/inspired fraction of oxygen. As a second choice, the patient's SpO_2 can be used as an indicator of oxygenation. A SpO_2 of 90% or more accompanied by a recent fluctuation of less than 4% is suggestive of adequate respiratory reserve for mobilization. Hypercapnia may be indicative of respiratory failure which should caution for mobilization. Respiratory pattern should also be observed including respiratory rate, chest wall and abdomen pattern, usage of accessory respiratory muscles, and presence of wheezing. Clearly, mechanical ventilation is not a reason to prevent or even modify mobilization. Stiller also recommends that patients should remain on the most supportive level of ventilation during mobilization to maximize their respiratory reserve. Moreover, in cases with limited respiratory reserve it is preferred to increase the level of ventilatory support during mobilization to increase mobilization tolerance [40].

Another intrinsic factor includes hematological and metabolic factors. For example, hemoglobin, platelet counts, white cell count, body temperature, and blood glucose level. Instead of relying on the absolute low level for hemoglobin of 7, the clinician should be aware of an acute drop in hemoglobin as an indication of active or recent bleeding. Even though there are no absolute clinical guidelines regarding the minimum for platelet count, 20,000 may be considered a safe lower limit. An abnormally high or low white cell count is a possible marker for infection. Acute infection by itself does not disallow mobilization. However, infection can increase the need for the patient's oxygen use which may be further increased during mobilization [40].

Other intrinsic factors to consider are the patient's appearance, neurological status, orthopedic condition, and nutritional status. Factors to pay attention in the patient's appearance include facial expressions, conscious state, emotional status, level of pain and anxiety, presence of central or peripheral cyanosis, pallor, flush, sweatiness or clamminess, over or underweight, and muscle bulk. Both a decreased and increased level of consciousness (such as agitation, restlessness, or confusion may affect the patient's participation with therapeutic exercise. Inclusive in the neurological status is the assessment of patient's muscle strength. Inclusive in the early mobilization approach is the minimization of heavy sedation. The presence of high intracranial pressure or low cerebral perfusion may preclude mobilization. Weight-bearing status and orthopedic precautions should be investigated prior to mobilization therapy. Furthermore, as per the hospital protocol, extra caution should be considered with surgical conditions such as split skin grafts or myocutaneous flaps [40].

Comparatively, there are also numerous extrinsic factors to be aware of. Except for the need to ensure that attachments should not be dislodged, ECG lead, arterial lines, venous lines, central venous catheters, pulmonary artery catheters, urinary catheters, pulse oximetry, and drains should not prevent mobilization. Tracheostomy may ease mobilization of mechanically ventilated patient as compared to endotracheal tubes. Clinicians should consider that longer length of tubing increases the risk of dislodgement and/or movement which may cause vocal cords trauma. Likewise, similar care should be applied to patients under noninvasive ventilation. Epidural line does not preclude mobilization either. Granted that dialysis tubing does not preclude mobilization clinical practice is that mobilization is deferred during dialysis. An intra-aortic balloon pump used in patients with critically low cardiac output and blood pressure is indicative of hemodynamic instability and thereby may contraindicate mobilization. On the other hand, secondary, the risk of dislodging pacing wires, a temporary pacemaker also precludes mobilization. Mobilization with Sengstaken-Blakemore/Minnesota tubes used for managing bleeding esophageal varices is also contraindicated secondary to the risk of dislodgement of esophageal and or gastric balloons and could result in rupture of the esophagus or stomach. Intracranial pressure monitor is commonly used in the setting of major brain injury and thereby the underlying neurological condition may preclude mobilization [40].

There has been ongoing research on early mobilization therapy in intubated patients proving it to be feasible and safe. Retrospective cohort analysis found that increased physiotherapy intervention in patients with sepsis resulted in less ICU mortality [45].

Peter Nydahl et al. in a systematic review and meta-analysis demonstrated that early mobilization and rehabilitation in ICU is safe. The sturdy safety profile of mobilization of critically ill patients may have several potential reasons including simultaneous effort and attention of multiple clinicians during a session along with continuous cardiorespiratory monitoring and specialized equipment to support mobility [46].

Mobilization therapy may involve activities such as sitting on the edge of the bed or in a chair and ambulating which have proven to prevent or minimize the weakness and reduce the duration of mechanical ventilation and ICU/hospital length of stay [30, 41, 47–50]. Studies have shown that oxygenation improved significantly with mobilization therapy thereby atelectasis also improved. During mobilization, oxygenation was expected to improve because of anticipated beneficial effects of sitting in an upright position on lung volumes and ventilation perfusion distribution [51, 52]. The most important factor in uneven ventilation and blood flow distribution in the healthy lung is gravity [43]. In the erect seated position, the base to apex ratios for ventilation and perfusion distribution is increased as compared to supine position. Body positioning and mobilization optimize airway secretion clearance and oxygenation by improving ventilation alveolar recruitment and ventilation/perfusion matching [53]. In one study following several weeks of the whole body and respiratory rehabilitation, patients had a significant increase in whole-body and respiratory muscle strength and were weaned off the ventilator and functionally improved. Upper extremity strength significantly correlated with weaning time [30]. Upper extremity strengthening exercises facilitate the respiratory actions of the pectoralis muscle and other accessory respiratory muscles.

Whole-body rehabilitation conducted by a multidisciplinary team appears to improve both motor strength and functional variables and should therefore be considered an important part in the care of chronically ventilated patients. With the current research studies, we see how important it is to change the traditional ICU culture in which ICU patients are not encouraged to move until they have recovered from severe illness.

32.4.1 Acute Rehabilitation Phase

A team approach to the rehabilitation of the elderly patient is essential following emergency surgery. Regular physical exercises in older adults can improve strength, endurance, balance, coordination, and range of motion [54]. This can also reduce the risk of hypertension, cardiovascular disease, diabetes, and stroke. The physical therapy program must be tailored to the patient diagnosis, nature of surgery, and restrictions. This will be followed by a home exercise program as outpatient.

Resistance training can lead to improved muscle strength, power, and endurance. There is also increased muscle cross-sectional area, muscle volume, decreased body fat, and improvement of body composition. Resistance exercises can be performed with or without equipment. Some well-known resistance exercises include push-ups, sit-ups, squats, and pull-ups. Isometric exercises can strengthen muscle without joint motion which may be useful in patients with arthritis. Weight training machines with equipment may increase the risk of injuries and require good balance and coordination.

Aerobic exercises can lower the resting heart rate and the blood pressure. They also improve the muscle oxygen uptake, increase the VO_2 max, and cardioprotective effects in older patients after 3–4 months of regular exercise. Those exercises also improve glycemic control, postprandial lipid clearance, and slows the age-related decline in bone mass density.

Exercises such as yoga and tai chi are very important to improve balance in the elderly, both standing static balance and dynamic balance. Falls in the elderly remain a big epidemiologic concern since an elderly patient dies every 20 min in the United States as a consequence of a fall. These exercises improve also the flexibility and the strength. Even elderly patients without medical issues should follow a regular exercise program to decrease the incidence of eventual falls. Weight-bearing exercises are recommended for a patient with osteoporosis. All exercise programs should have beneficial effects on lower extremity function (balance, walking speed, ability to rise from a chair) which are factors associated with possible future disabilities [55].

For training effect, the best exercise is the task itself. Ambulation training with or without the appropriate walking aid will also improve strength and endurance. Those gait aid may include cane, quad cane, hemi walker, walker, rollator, platform walker, etc. Stair training should also be an integral part of the rehabilitation strategy for those elderly patients before going home.

Muscle endurance can be defined as the ability to produce work overtime or the ability to persist or maintain an effort. Endurance can be measured in several ways depending on the particular kind of activity studied. Anaerobic endurance is measured under stimulated anaerobic conditions, with the high intensity or isometric activity decreasing the oxygen availability. Aerobic endurance must be measured under conditions that use an aerobic metabolism, such as low-intensity dynamic exercise. Isotonic endurance is measured by the number of repetitions with given weight. Isokinetic endurance is the number of repetitions at certain angular velocity before a specified decrease in torque develops. Isometric endurance is the time that a certain weight could be maintained in a static position or a certain force exerted against a strain gauge. To compare endurance between individuals, it is most appropriate to use a percentage of individuals' maximum force capability for testing rather than a fixed load, because of the relationship between strength and absolute endurance which is hyperbolic. This hyperbolic relationship may be related to the relative contributions from aerobic and anaerobic metabolism.

Before prescribing an exercise program, several factors should be considered.

32.4.2 Type of Exercise

If an exercise is done passively, it implies that all the effort must come from the therapist and none from the patient. Usually, this is done to maintain the range of motion as the patient may be unable to provide the necessary effort. Exercises can also be done actively or with some assistance.

Exercises can be also done by engaging in functional activities such as mobility training, activity of daily living, stairs training, and leisure activities. All involved strength, endurance, control, balance, and range of motion.

Activity recommendations in older adults with no limitation
• Moderate intensity aerobic activity enough to result in a noticeable increase in heart rate and breathing for at least 30 min 5 days a week
• Resistance training (calisthenics, weight training) at least 1 set 10–15 repetitions of an exercise that trains the major muscle group on 2 or 3 nonconsecutive days each week
• Flexibility at least 10 min of stretching major muscle and tendon groups at least 2 days each week: 10–30 s of static stretches and 3–4 repetitions for each stretch. Ideally performed every day that aerobic and resistance training is performed
• Balance exercise 3 times a week (ideal type, frequency and duration has not been defined).
Adapted from American College of Sports Medicine and the American Heart Association 39: 1435–1445, 2007

Assessment of the patient performance of the activities of daily living by the occupational therapist is critical. Appropriate therapy program will be instituted and all needed adaptive equipment will be provided. Those adaptive equipments enable the patients to perform a functional task, help make those tasks easier, or may prevent complications. They may include a tub bench, a reacher, a raised toilet seat, grab bars, etc. Wheelchair allows for long-distance mobility in the community if not use within the home.

Extensive preparation for discharge must be performed. This requires planning and forethought by the physiatrist, therapist, social worker, and case manager. Additionally, the patient or caregivers may need to alter their homes to create optimal conditions for receiving a patient with a liability that was not present prior to hospitalization. Modifying the environment can have a positive impact on health, injury prevention, and quality of life. Design of larger spaces within the home for better accessibility while a rolling walker is used can have a beneficial impact on comfort and safety. Adequate lighting, decreased bed height, and removal of area rugs can contribute to reduce the incidence of falls.

The patient should leave the acute rehabilitation service with all the pertinent information regarding their hospitalization, pathological condition, and surgical intervention. For more complex patients as in patients with colostomy, complex wounds, they should have the support of a team that visits the home and manages some of these aspects (complex wounds, drains, bladder catheterization, VAC dressing, etc.)

This information is necessary for a health professional who provides continuity of care to integrate it into their assessment and management of those diseases' circumstances.

Finally, the outpatient follow-up should not be neglected. Outpatient physical and occupational therapy may be needed for the patient to reach full functional potential. Reobservation of patients until treatment consolidation is essential.

32.5 Conclusion

Urgent Surgical treatment of the elderly patients is associated with higher morbidity and mortality rates than those of younger patients and there is room for improvement. A multimodality rehabilitation program, particularly if started early, as early as the intensive care unit is a good working model for achieving this improvement.

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Correction to: Acute Mesenteric Ischemia in the Elderly Patient

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This chapter was initially published with incorrect Figure 18.9. This figure has now been updated with this erratum.

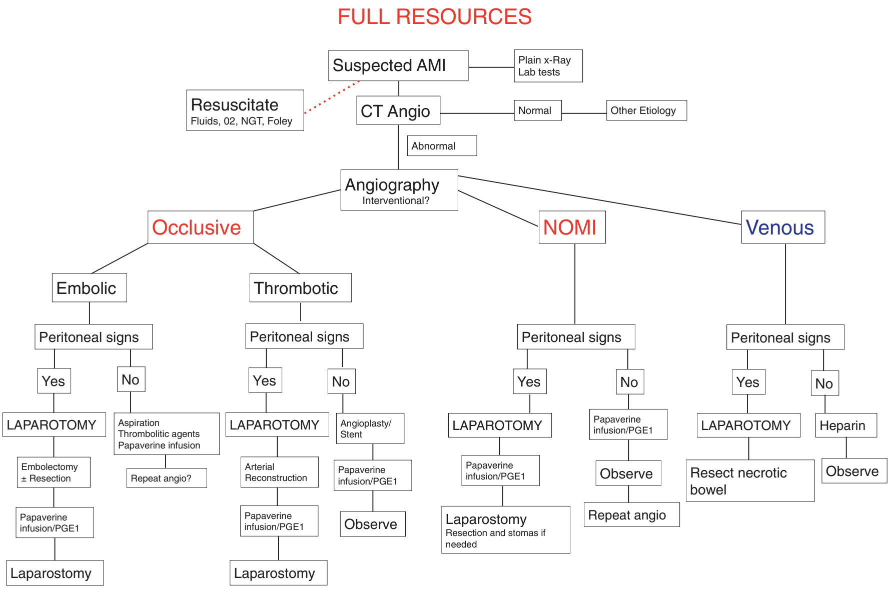

Fig. 18.9 Algorithm for management of acute mesenteric ischemia in a full resources setting

The updated online version of the chapter can be found at https://doi.org/10.1007/978-3-030-62215-2_18

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