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ORIGINAL CONTRIBUTIONS

Options in Bariatric Surgery: Modeled Decision Analysis Supports One-Anastomosis Gastric Bypass as the Treatment of Choice when Type 2 Diabetes Is Present

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Abstract

Background Obesity and type 2 diabetes mellitus (T2DM) represent significant healthcare burdens. Surgical management is superior to traditional medical therapy. Laparoscopic sleeve gastrectomy (LSG) and gastric bypass (both Roux-en-Y (RYGB) and one anastomosis gastric bypass (OAGB) are the most commonly performed metabolic procedures. It remains unclear which gives the optimal quality-of-life pay-off in the context of T2DM. This study compares LSG, RYGB, and OAGB in the management of T2DM and obesity using modeled decision analysis. Alternative approaches were assessed considering efficacy of interventions, post-operative complications, and quality of life outcomes to determine the optimal approach.

Methods Modeled decision analysis was performed from the patent's perspective comparing best medical management (MM), SG, RYGB, OAGB, and LAGB. The base case is a 40-year-old female with a body mass index (BMI) of 40 and T2DM. Input variables were calculated based on published decision analyses and a literature review. Utilities were based on previous studies. Sensitivity analysis was performed. The payoff was quality-adjusted life years (QALYs) 5 years from intervention. TreeAge Pro modeling software was used for analysis.

Results In 5-years post-procedure**,** OAGB gave the optimal QALY payoff of 3.65 QALYs **(reviewer 2)**. RYGB gave 3.47, SG gave 3.08, LAGB gave 2.62 and MM 2.45 QALYs. Three input variables proved sensitive. RYGB is optimal if its metabolic improvement rates exceed 86%. It is also optimal if metabolic improvement rates in OAGB drop below 71.8% or if the utility of OAGB drops below 0.759.

Conclusion OAGB gives the optimal QALY payoff in treatment of T2DM. RYGB and SG also improve metabolic outcomes and remain viable options in selected patients.

Keywords Modeled decision analysis · Obesity · Type 2 diabetes

Introduction

Diabetes mellitus refers to a group of metabolic diseases characterized by persistent hyperglycemia resulting from defects in insulin secretion, action, or both [1]. Type 2 diabetes mellitus (T2DM) is the commonest form, accounting for 90–95% of all cases [2]. Studies estimate a global health burden of $1.3 trillion per annum, with economic strain affecting both developed and developing countries [3, 4]. T2DM is a well-known cause for reduced quality-of-life, and studies demonstrate diabetic patients to have shorter life expectancies compared with nondiabetic counterparts [5]. The link between obesity and T2DM is well-established. Traditionally, T2DM has been managed medically, with intense lifestyle interventions and pharmacological therapy employed to control hyperglycemia and attempt to reduce complications [6]. Best medical management (MM) can decrease incidence of the condition and non-surgical intervention can induce remission in a small minority of patients [7].

Over the last two decades, numerous studies have shown weight loss surgery significantly improves diabetic control,

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rates of remission, weight loss and reduces both complications and diabetic medications compared with MM [8, 9]. Given the extent of evidence detailing these improved outcomes [7, 9–11], the second Diabetes Surgery Summit recommended bariatric surgery be considered to treat T2DM patients in certain scenarios [12].

The fifth International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) global registry report 2019 showed the most commonly performed bariatric surgeries to be Sleeve Gastrectomy (SG), Roux-en-Y Gastric Bypass (RYGB), one-anastomosis gastric bypass (OAGB), and laparoscopic adjustable gastric banding (LAGB) which account for 58.6, 31.2, 4.1, and 3.7%, respectively [13]. Meanwhile, more recent data from the American Society for Metabolic and Bariatric Surgery (ASMBS) demonstrates that SG continues to grow in popularity, accounting for 61.4% of all metabolic procedures in 2018 in the USA [14]. Meanwhile, alternative approaches to RYGB such as OAGB have gained considerable traction [15]. OAGB is widely accepted as a mainstream surgical option [16]. While SG has overtaken RYGB as the most commonly performed procedure, it is unclear as to which strategy gives patients the best combination of weight loss, glycemic control, and quality of life measured by quality adjusted life years (QALYs). QALYs measure disease burden that includes both quantity and quality of life lived. One QALY represents a full year of perfect health.

Decision analysis is a quantitative method to assess efficacy of alternative therapeutic strategies where the optimal approach remains unclear. It allows approaches to be examined under a variety of conditions to determine an optimal strategy. Previous work from our group has used decision analysis to examine short-term QALY outcomes in bariatric surgery. This showed that RYGB and SG offer similar short-term outcomes in terms of QALY [17]. Both gave significant improvements over LAGB and MM.

The aim of this study is to use decision analysis to examine OAGB, RYGB, and SG as therapeutic interventions for T2DM in obesity. The model used not only incorporates objective parameters such as metabolic improvement and operative complications but also considers patients' experience and reported quality of life. This allows us to examine which variables affect patient outcomes and how these interact. As the proportion eligible of patients who have access to metabolic surgery remains low, MM was included for comparative purposes. Although LAGB is losing popularity as an approach for managing obesity and T2DM, it is included in our analysis as there are still a significant number of proponents and procedures being performed worldwide. Although biliopancreatic diversion/duodenal switch (BPD/DS) is highly effective [18], there are a number of reasons it was not included in this study. This study focusses on primary interventions for T2DM, while BPD/DS is often used as a salvage or second-line surgical intervention [19]. The optimal DS operations are yet to be defined. There are proponents for a number of approaches including "single-anastomosis duodeno-ileal bypass" (SADI), "stomach intestinal pylorus sparing" (SIPS), and "single anastomosis duodeno-jejunal bypass with sleeve gastrectomy" (SADJB-SG). When the rates of nutritional disturbance, revisional procedures, and complications are also considered [20–22], comparing BPD/DS approaches with MM, SG, and more conventional forms of bypass (OAGB and RYGB) is beyond the scope of this decision tree model.

Methods

Modeled decision analysis was performed following published guidelines [23–27] to determine the optimal management strategy. The base case patient is a 40-year-old female with T2DM and elevated body mass index (BMI) of 40 being considered for surgical intervention. This hypothetical patient was chosen to represent a typical diabetic patient who may be considered a candidate for surgical management [28].

Variables studied are based on published literature. Peer-reviewed articles determine the input variables for the model, with a range of studies being used to determine plausible maximum and minimum values of these variables. This allows the model to be tested under a range of conditions. A systematic review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) [29]. A PubMed search was performed from January 2008 to December 2019 to identify articles that examined surgical and conservative management to treat T2DM. The search terms "Bariatric Surgery," "Adjustable Gastric Banding," "Roux-en-Y," "Sleeve Gastrectomy," "Gastric Bypass," "One anastomosis gastric bypass," "Mini-gastric bypass," "OAGB," "Diabetes," "Outcomes," and "Trial" were used in combination with Boolean operators "AND" and "OR." Our search strategy yielded 1717 citations. Records were screened to remove non-human studies, duplicates, systematic reviews/meta-analyses, and irrelevant studies. Suitable articles were critically appraised independently by two authors (CB and JCB). Randomized control trials and high-quality cohort studies were selected using guidelines for including studies in decision analyses [26]. High-quality articles conforming to the standards established by Naglie et al. were included [26]. For the purposes of this decision analysis, only trials with long-term follow-up (a minimum of 5 years) were included (Fig. 1). All studies selected for inclusion are detailed in Table 1.

Variables selected for study were postoperative complications managed conservatively, postoperative complications requiring further surgical intervention, and the likelihood of metabolic improvement (improvement in glycemic control with reduction in medication use) for each approach.

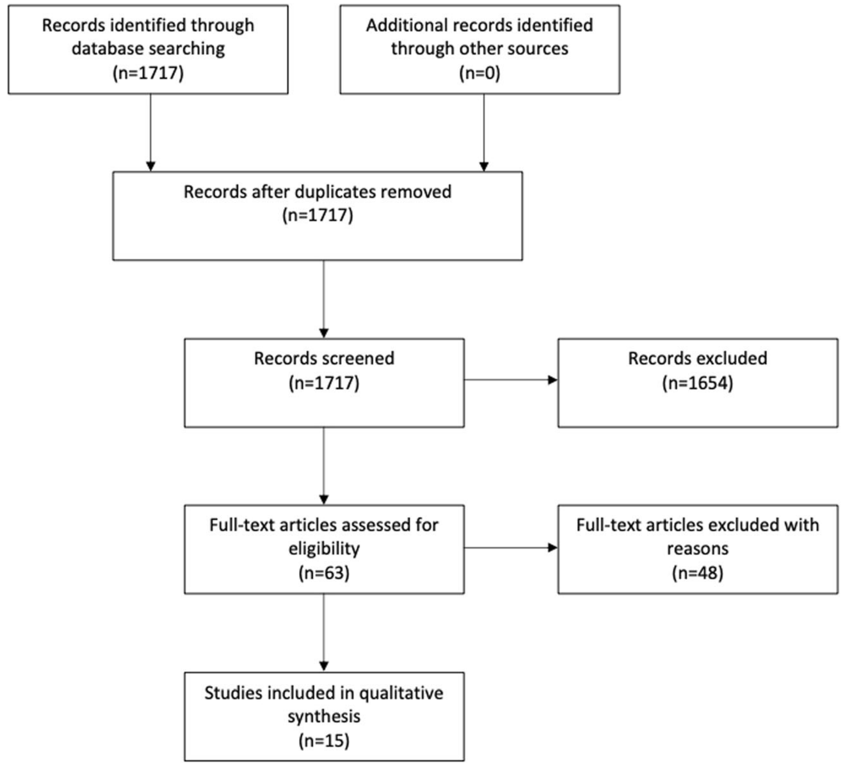


Fig. 1 PRISMA statement of included studies

Perioperative mortality was not included, as it is exceptionally rare with bariatric surgery and had no influence in outcomes on a previous model [17]. Weighted means (based on the sample size of each study) and ranges for data obtained were calculated with the highest and lowest reported figures for each variable used for sensitivity analysis (Table 2).

A utility is a measure of a decision-maker's relative satisfaction with a given outcome. It is expressed as a value ranging from "0" to "1" where "0" represents death and "1" represents being alive in full, normal health [26]. Utilities for other states of health were then estimated based on previously published decision analyses and established literature examining quality of life in obesity, T2DM, and bariatric surgery [7, 30–48]. Time spent in each healthcare state was calculated as previously described [17]. QALY payoffs were calculated based on the time spent in these healthcare states. A 5-year follow-up period was used.

A decision tree was constructed using TreeAge Pro software (v.2019, TreeAge Software Inc., Williamstown, MA, 01267 USA). This tree examines the potential outcomes for our base case patient with a 5-year follow-up of MM, LAGB, SG, and RYGB (Fig. 2). Complications were those that have an impact on quality of life, including hemorrhage, wound infection, dehiscence, staple line leaks, intra-abdominal collections or sepsis, bowel obstruction, and cardiopulmonary compromise [17]. Complications requiring operative or radiologic intervention were noted, such as anastomotic leaks.

Sensitivity analysis is the process of repeatedly testing the decision tree using different plausible values for established variables to assess their impact on the outcome of interest. If changing the value of a variable influences the outcome of the model, it is considered sensitive. All variables were subjected to one-way sensitivity analysis, with sensitive variables subjected to two-way and three-way analysis as appropriate.

Results

Nine randomized controlled trials and six cohort studies identified in the literature review met selection criteria and provided adequate data on outcomes following bariatric surgery in T2DM patients at 5 years. Data from a total of 9757 patients was evaluated. These papers are summarized in Table 1. They provide a range of data pertaining to operative and non-operative complications with bariatric surgery, efficacy of interventions, and quality of life outcomes for each intervention.

The base case analysis showed that overall at 5 years, OAGB provided the optimal strategy with a payoff of 3.65 QALYs. This was followed by RYGB at 3.47 QALYs. SG, LAGB, and MM gave gains of 3.08, 2.39, and 2.30 QALYs, respectively. If we only consider the QALY payoff for patients who had an uncomplicated course and who had a metabolic response, both OAGB and RYGB gave a payoff of 3.91 QALYs, followed by SG at 3.80, with adjustable gastric banding and MM giving 2.62 and 2.45 QALYs, respectively.

The sensitivity analysis and thresholds for sensitive variables are presented in Tables 2 and 3. Overall, three input variables proved sensitive to the whole model: the likelihood

Table 1 Studies included in decision analysis

Author	Country	Year	Journal	Surgery Types	Number of patients	Study Design	Follow up (years)	Conclusion
Arterburn et al. [30]	California, Minnesota USA	2013	Obesity Surgery	RYGB	4434	Cohort Study	5	Bypass improves T2DM, risk of remission.
Lee et al. [31]	Taiwan	2014	Obesity Surgery	OAGB, LSG	60	RCT	5	Bariatric surgery effective at 5 years, bypass more effective than LSG.
Musella et al. [32]	Italy	2014	Surgical Endoscopy	OAGB	224 (T2DM)	Cohort study	5	OAGB is short, simple, low-risk, effective and durable.
Zhang et al. [33]	China	2014	Obesity Surgery	RYGB, LSG	64 (T2DM)	RCT	5	RYGB and LSG both safe and effective, RYGB gives better sustained weight loss.
Mingrone et al. [34]	Italy	2015	Lancet	RYGB	60	RCT	5	Surgery superior to medical management. Potential for relapse in long term
Hsu et al. [35]	Taiwan	2015	JAMA	RYGB, LSG	351	Cohort Study	5	Improvement in glycaemic control with bariatric surgery sustained at 5 years.
Bruzzi et al. [36]	France	2015	SOARD	OAGB	26 (T2DM)	Cohort Study	5	At 5 years, LMGB is safe, effective and provided interesting quality of life results.
Gulliford et al. [37]	United Kingdom	2016	Obesity Surgery	RYGB, LAGB, LSG	1652	Cohort Study	6	Remission continues for at least 6 years. RYGB and LLSG superior to LAGB.
Dicker et al. [38]	Israel	2016	Obesity Surgery	RYGB, LAGB, LSG	2190	Cohort Study	5	All surgical options can lead to remission. RYGB gives best early improvements.
Schauer et al. [7]	Cleveland, USA	2017	New England Journal	RYGB, LSG	150	RCT	5	Surgery plus medical management superior to medical management alone.
Wentworth et al. [39]	Australia	2017	Diabetes Care	LAGB	51	RCT	5	LAGB effective for improving glycaemic control in overweight T2DM
Ikramuddin et al. [40]	USA/ Taiwan	2018	JAMA	RYGB	120	RCT	5	RYGB superior to medical management
Salminen et al. [41]	Finland	2018	JAMA	RYGB, LSG	101 (T2DM)	RCT	5	LSG did not achieve equivalence with RYGB.
Peterli et al. [42]	Switzerland	2018	JAMA	RYGB, LSG	54 (T2DM)	RCT	5	RYGB and LSG both reduced T2DM remission, no significant difference between procedures.
Ruiz-Tovar et al. [43]	Spain	2019	Surgical Endoscopy	OAGB, RYGB, LSG	190 (T2DM)	RCT	5	OAGB achieves superior mid and long term weight loss and DM resolution vs RYGB and SG.

T2DM type 2 diabetes mellitus, *LAGB* adjustable gastric band, *LSG* laparoscopic sleeve gastrectomy, *OAGB* one anastomosis gastric bypass, *RYGB* Roux-en-Y gastric bypass, *RCT* randomized controlled trial of a metabolic improvement with RYGB, the likelihood of a metabolic improvement with OAGB, and the utility of OAGB. SG surpassed RYGB if the likelihood of metabolic improvement reached a threshold but did not surpass OAGB. The likelihood of metabolic improvement in adjustable gastric banding, the utility of adjustable gastric banding, and the utility of failure to improve with therapy all altered whether adjustable gastric banding or MM gave better outcomes.

OAGB gives the best QALY payoff in most circumstances. However, there are several sensitive input variables. If the likelihood of metabolic improvement of RYGB exceeds 86% (range 22–87.5%), RYGB becomes the optimal intervention for metabolic improvement and weight loss (Fig. 3b). If the likelihood of metabolic improvement with OAGB drops below 71.8% (range 60–95.7%), RYGB becomes the optimal intervention for metabolic improvement and weight loss (Fig. 3c). If the utility for OAGB drops below 0.759 (range 0.69–0.93), then RYGB becomes the optimal strategy for metabolic improvement and weight loss (Fig. 3d).

Three-way sensitivity analysis is presented in Fig. 4, with utility of OAGB set at three representative levels: 0.69, 0.81, and 0.93. These represent a range of plausible utilities for OAGB. The graph plots likelihood of improvement with RYGB on the x-axis against likelihood of metabolic improvement with OAGB on the y-axis. As the utility value for OAGB increases, it occupies a greater area of the graph, becoming a more favorable option. Our data shows that SG remains a viable alternative strategy. When the likelihood of metabolic improvement with SG exceeds 79% (range 23.4–89%), SG becomes a superior treatment strategy to RYGB (Fig. 3a), although in this model it does not surpass OAGB.

Regarding other treatment strategies, LAGB and MM offer similar, but inferior outcomes to OAGB, RYGB, and SG. Once the likelihood of metabolic improvement became less than 19% (range 18.3–55.6%) with LAGB, then MM was a better management option. If the utility of failed treatment exceeded 0.5, then MM was preferable to adjustable gastric banding.

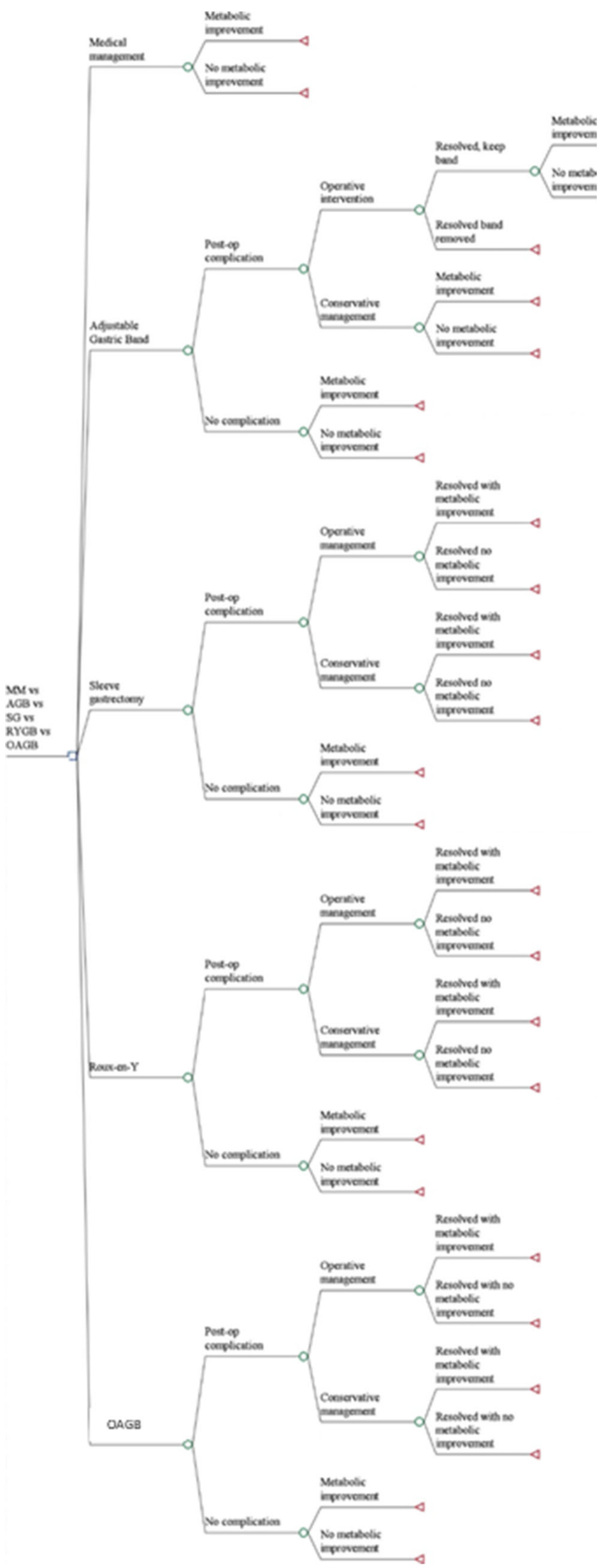
Discussion

Obesity and its sequelae such as T2DM will present an ever-increasing challenge in the years ahead. In spite of overwhelming evidence for the efficacy of bariatric surgery, access to care and utilization of bariatric interventions remain exceptionally low [45]. OAGB, RYGB, and SG give sustained weight loss and improvement in glycemic control in a large proportion of patients, with evidence accruing from a number of well-designed RCTs with good follow-up as well as from population-based cohort studies [7, 30–43, 46, 47]. However, the optimal strategy in terms of improving quality of life and giving sustained metabolic improvement has yet to be definitively established. We used modeled decision analysis to attempt to provide an insight to this question.

Table 2 input variables

Variable	Weighted mean	Range	Reference	Sensitive	Threshold
Medical metabolic improvement	3.25%	0–8.7%	[7, 34, 35, 37, 39, 40]	N	N/A
LAGB: complication not requiring operation	13.9%	7.4%–42%	[17]	N	N/A
LAGB: complication requiring operation	27.8%	12.5%–36%	[17]	N	N/A
LAGB: likelihood of keeping band	59%	0–80%	[17]	N	N/A
LAGB: likelihood of metabolic improvement	51.3%	18.3%–55.6%	[37–39]	N (but worse than medical management if < 19%)	N/A
SG: complication not requiring operation	7.2%	6%–8.2%	[17]	N	N/A
SG: complication requiring operation	4.6%	3.4%–9%	[17]	N	N/A
SG: likelihood of metabolic improvement	51.2%	23.4%–89%	[7, 31, 33, 35, 37, 38, 41, 43]	N (but exceeds RYGB at 79%)	N/A
RYGB: complication not requiring operation	10.5%	4%–21%	[17]	N	N/A
RYGB: complication requiring operation	3.3%	0%–5.6%	[17]	N	N/A
RYGB: likelihood of metabolic improvement	73.7%	22%–87.5%	[7, 30, 33–35, 37, 38, 40, 41, 43]	Y	86%
OAGB: complication not requiring operation	4.9%	1%–13%	[31, 32, 36, 43]	N	N/A
OAGB: complication requiring operation	3%	2%–6.9%	[31, 32, 36, 43]	N	N/A
OAGB: likelihood of metabolic improvement	84%	60%–95.7%	[31, 32, 36, 43]	Y	71.8%

LAGB laparoscopic adjustable gastric band, *SG* sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass, *OAGB* one anastomosis gastric bypass



◀ **Fig. 2** Decision tree used in modeled decision analysis showing decision (square), chance (circular) and terminal (triangular) nodes. *MM* medical management, *LAGB* laparoscopic adjustable gastric band, *SG* sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass, *OAGB* One anastomosis gastric bypass

When all input variables are at their baseline, our model suggests OAGB is the optimal management strategy in obesity with T2DM, giving an increase in QALYs gained when compared with RYGB and SG, and more than one extra QALY when compared with LAGB and MM. Overall superiority of OAGB compared with RYGB and SG is consistent with a number of the studies used to derive our input variables [7, 31, 32, 36–38, 41, 43]. OAGB is gaining traction as a primary intervention for T2DM. We include four studies that examine 350 OAGB patients with 5-year follow-up. These patients come from cohort studies and some small RCTs. In spite of this heterogeneity, there appears to be consistent metabolic improvements [31, 32, 36, 43]. Although there is a broader range of improvement reported for RYGB and SG, RYGB offers remission rates up to 87.5% [33]. There is conflicting evidence as to relapse rates, although it has been suggested in at least one study that the benefits from SG may endure for longer than RYGB [38]. Although there is evidence supporting OAGB, further trials with long-term follow-up (5 + years) are needed to give reliable estimates of metabolic improvement.

Although OAGB was the superior strategy in this study, RYGB and SG should also be considered as viable and competitive treatment strategies. When patients undergo uncomplicated recoveries, the QALY gain for OAGB and RYGB are similar. The advantage with OAGB appears to lie in its improved metabolic outcome on a background of a similar utility. This is down to a similar approach to altering the digestive tract, with a combination of restriction and malabsorption. Popularity of SG is rapidly increasing and is likely multifactorial. The learning curve is less steep than bypass, there are no internal anastomoses, and there are minimal alterations in internal anatomy, reducing the risk of a long-term surgical complication [28]. It must be acknowledged that both RYGB and SG offer excellent and enduring weight loss in obesity and offer a significant prospect of reducing or fully eliminating hypoglycemic agents.

Utilities for different healthcare states can only be estimated based on published quality of life data, or, where this is unavailable, based on expert opinion. The utility of OAGB proved sensitive in this model, at 0.759. Although there was initial skepticism about the benefit of OAGB [49], it is now widely well-received and commonly practiced. OAGB does have some potential downsides, estimating the impact of these in this type of model is challenging. OAGB is associated with a more radicle malabsorptive element and consequently

Table 3 Analysis of utility outcomes

Utility	Value	Range	Reference	Sensitive	Threshold
Medical QoL	0.49	0–0.55	[7, 17, 34, 39]	N	N/A
Utility of adjusting to LAGB	0.49	0.45–0.7	[17, 39]	N	N/A
Utility of LAGB	0.53	0.45–0.7	[17, 39]	N (but worse than medical if <0.5)	N/A
Utility of adjusting to SG	0.57	0.5–0.85	[7, 17]	N	N/A
Utility of SG	0.78	0.6–0.85	[7, 17]	N	N/A
Utility of adjusting to RYGB	0.63	0.5–0.85	[7, 17, 34]	N	N/A
Utility of RYGB	0.805	0.6–0.85	[7, 17, 34]	N	N/A
Utility of adjusting to OAGB	0.63	0.5–0.93	[36, 48]	N	
Utility of OAGB	0.81	0.69–0.93	[36, 48]	Y	0.759
Utility of complication	0.2	0–0.65	[17, 44]	N	N/A
Utility of operation	0.15	0–0.65	[17, 44]	N	N/A
Utility of post-op state	0.25	0–0.77	[17, 44]	N	N/A
Utility of re-operation	0.15	0–0.65	[17, 44]	N	N/A
Utility of failed treatment	0.49	0–0.55	[7, 17, 34, 39]	N (but medical surpasses LAGB at 0.5)	N/A

QoL quality of life, *LAGB* laparoscopic adjustable gastric band, *SG* sleeve gastrectomy, *RYGB* Roux-en-Y gastric bypass

patients suffer from malnutrition more commonly, and increased risk of osteoporosis and in some cases, iron deficiency anemia have been reported. Marginal ulcers also occur more frequently in this population [50]. Our decision analysis does not explicitly include these elements in our modeling, and their adverse effects may be underestimated. If the impact of adverse effects from surgery is greater than our utility estimate, then RYGB may be a better long-term management plan. Our three-way sensitivity analysis (Fig. 4) captures the dynamic relationship between utility of OAGB and likelihood of metabolic improvement for OAGB and RYGB; it demonstrates that subtle shifts in each of the input variables can greatly impact QALY outcomes.

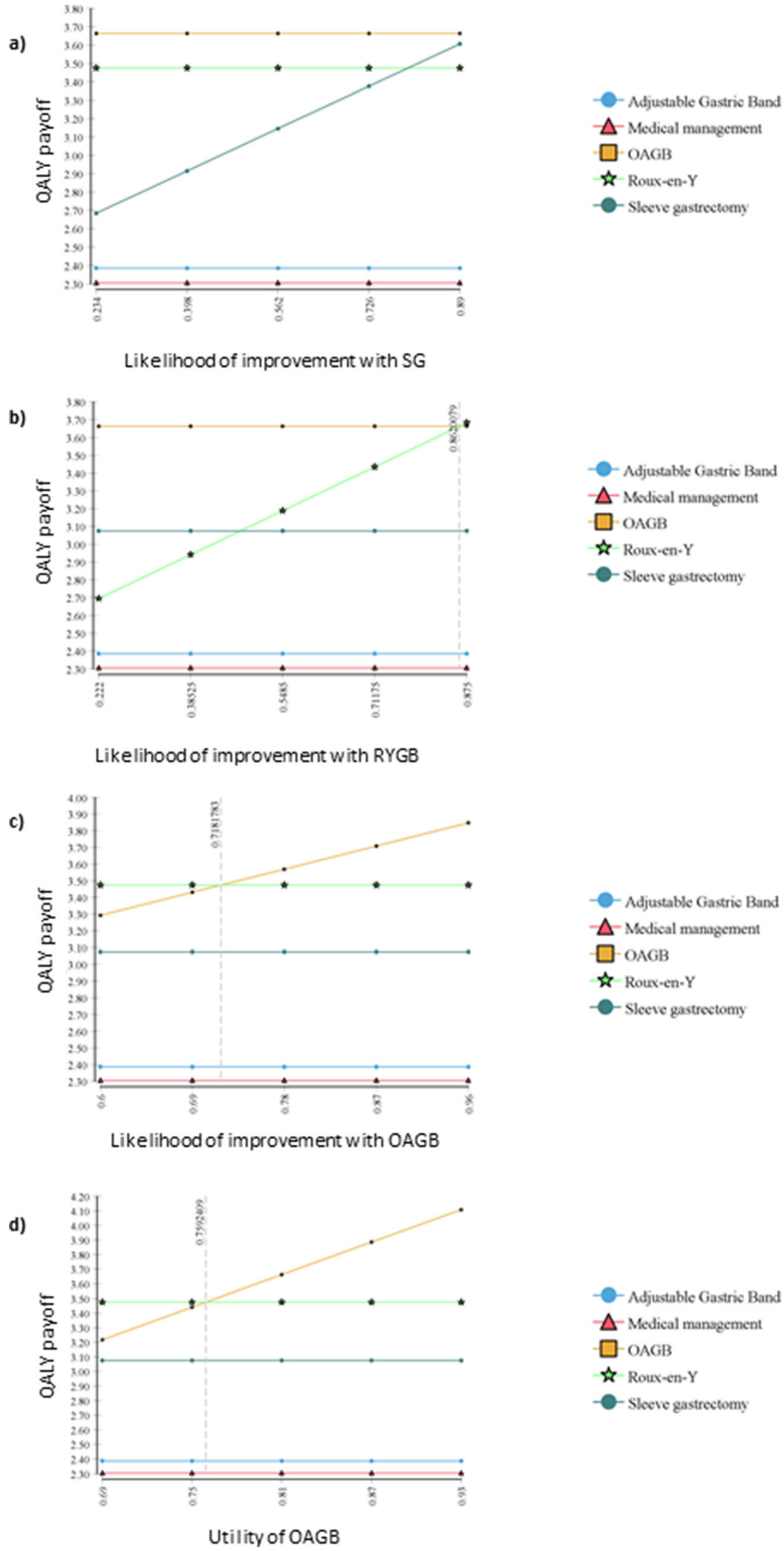
All of the competing approaches can carry long-term complications. Bypass procedures can lead to long-term issues such as internal hernias, intestinal obstruction, and malnutrition [50]. SG also has potential long-term issues, with emerging concerns about gastroesophageal reflux disease and a significant increase in Barrett's esophagus [51]. Whether this will result in an increase in esophageal malignancies has yet to be established. Similarly, the need for routine surveillance endoscopy has not been established, although this would also clearly impact on quality of life if it is established.

As shown in our short-term QALY analysis, LAGB performs poorly when compared with OAGB, RYGB, and SG. In this analysis, it only performs marginally better than MM and indeed is worse under certain scenarios. Need for repeated hospital attendance, band adjustment, and high risk of band removal often render LAGB inferior to MM. There is some evidence that it improves glycemic control in T2DM if correctly utilized [40, 41, 45]. The authors feel that the QALY payoff is insufficient for LAGB to recommend its routine use in managing obesity with T2DM. Similarly, the QALY payoff for MM is poor by comparison with OAGB, RYGB, and SG. This study provides further evidence that optimal patient outcomes can be achieved with OAGB, RYGB, and SG. Of note, none of the perioperative parameters such as complications impacted on outcomes in this study. This would suggest that even when in a low utility healthcare state, such as a serious operative complication, over an extended period, the impact on long-term patient quality of life can be very small. This is useful for counseling and advising patients who experience perioperative complications.

Decision analysis has limitations. The quality of a study is only as good as the input variables that are available in the published literature. We used 9757 patients to calculate our inputs and have tested a wide range of plausible estimates. Although OAGB is the optimal strategy in this model, those treated with OAGB accounted for only 3.58% (350) of the patients studied. More RCTs with long-term data on morbidity and quality of life would be useful to improve the quality of input variables.

This type of model is most useful in examining the impact of variables on disease outcomes and aid overall decision-making. It is not an individualized decision-making tool. The model does not account for duration or severity of T2DM in patients included, factors which strongly influence remission. We also recognize that most RYGB operations were based on the study by Arterburn et al. and the majority of SG operations were based on the study by Dicker et al.

Fig. 3 (**a**) One-way sensitivity analysis for likelihood of improvement in type 2 diabetes (T2DM) with sleeve gastrectomy (SG). (**b**) One-way sensitivity analysis for likelihood of improvement in T2DM with Roux-en-Y gastric bypass (RYGB). (**c**) One-way sensitivity analysis for likelihood of improvement in T2DM with one anastomosis gastric bypass (OAGB). (**d**) One-way sensitivity analysis of the utility of OAGB



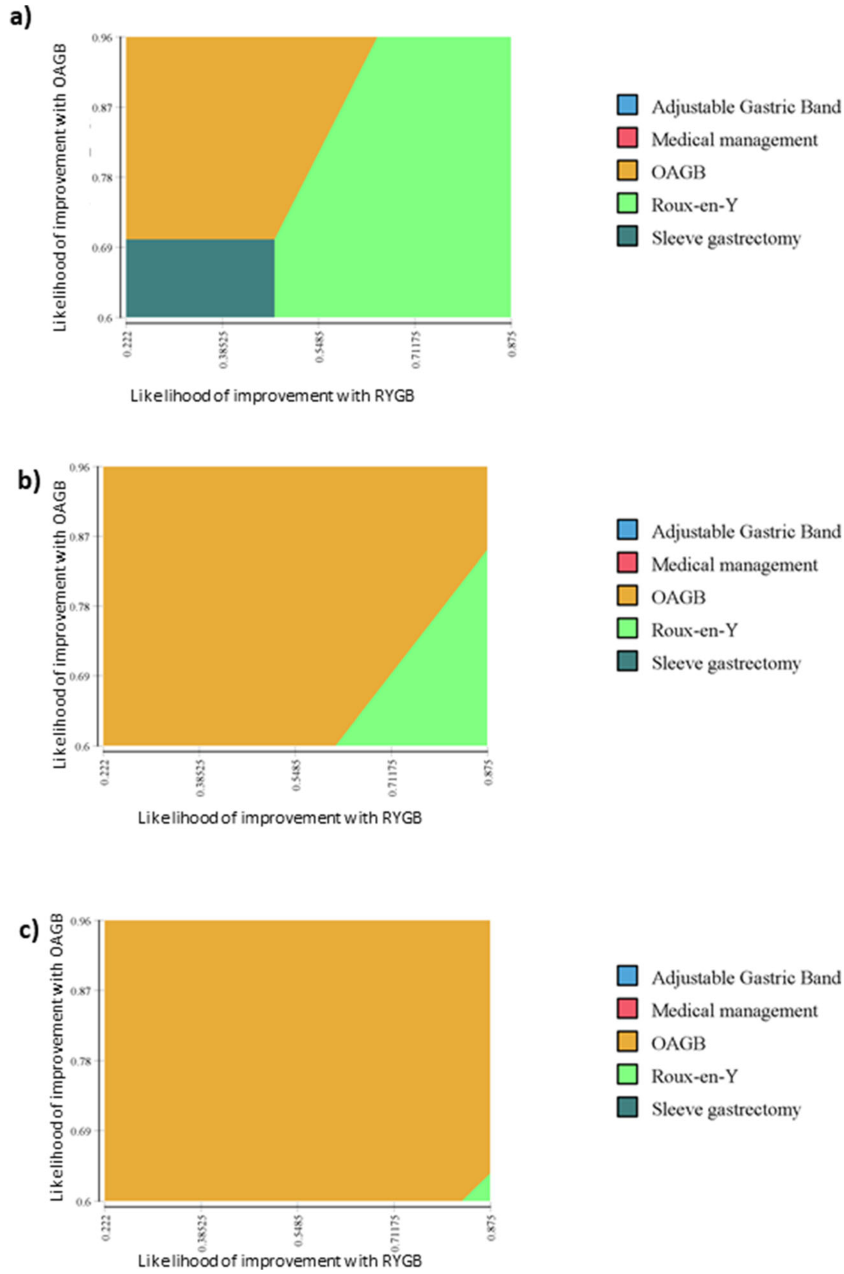


Fig. 4 Three-way sensitivity analysis of improvements in type 2 diabetes (T2DM) analyzing the likelihood of improvement with SG, RYGB, and OAGB, with the utility of OAGB displayed at (**a**) 0.69, (**b**) 0.81, and (**c**) 0.93

Despite both studies being of high quality, they were conducted in different healthcare systems, which may influence outcomes [35, 46]. Furthermore, the literature is relatively consistent in recommending bypass as a superior option for weight loss and possibly for treatment of T2DM when compared with SG.

Overall, this study has shown that in the setting of obesity with T2DM, OAGB gives the best patient quality of life outcome. RYGB and SG also give excellent QALY payoffs. Where all treatment options are available, bypass using OAGB or RYGB is the superior treatment option in terms of QALY payoff. SG remains a viable treatment choice and may be more acceptable to some patients than bypass procedures.

Conclusion

Bariatric surgery is effective in treating obesity with T2DM. OAGB gives superior outcomes in terms of QALY payoffs for patients with T2DM. Patients with obesity and T2DM should be offered bariatric surgery and ideally a bypass procedure. This study adds to the literature, providing a different perspective to what is a well-studied area. This is the first paper to the authors' knowledge that uses modeled decision analysis to integrate patient reported outcomes as well as objective parameters in comparing OAGB, RYGB, and SG. Previously published studies have established all three procedures to be effective treatment strategies for T2DM and obesity. Our model demonstrates OAGB to be a significantly superior procedure in many settings and may also be used as a tool to provide institutions with broad recommendations to aid in the decision-making process.

Compliance with Ethical Standards

Conflict of Interest All the above authors declare no conflict of interest.

Ethical Approval For this type of study formal consent is not required.

Informed Consent Does not apply.

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