45 Long-Term Mortality After Bariatric Surgery

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Abbreviations

AGB	Adjustable gastric banding
BMI	Body mass index
CVD	Cardiovascular disease
DM	Type II diabetes mellitus
DYS	Dyslipidemia
HTN	Hypertension
RYGB	Roux-en-Y gastric bypass
VBG	Vertical banded gastroplasty
VSG	Vertical sleeve gastrectomy

"Corpulence is not only a disease itself, but the harbinger of others." @ How true are the words of fourth-century BC physician Hippocrates, which have been illuminated by the statistics of modern man. Worldwide obesity rates have doubled since 1980, and excess body weight has surpassed malnutrition as a major cause of mortality in over 65 % of the world's countries [1]. According to the 2008 World Health Organization (WHO) fact sheet, more than 1.4 billion adults age 20 and older were overweight [1].

Health and Financial Burden of Obesity

In the United States, the rate of obesity (defined by a body mass index (BMI) of 30 kg/m^2 or greater) has doubled since 1980, has increased by 50 % since 1994, and has only recently shown signs of leveling for specific subpopulations [2]. As of 2010, obesity affected more than 84 million American adults, corresponding to an overall incidence of 35.5 % in men and 35.8 % in women [3]. Furthermore, class II obesity (BMI 35–39.9 kg/m^2) has an incidence of 11.4 % (32 million individuals), and class III obesity (BMI ≥40 kg/m^2) has an incidence of 6.3 % (17 million individuals) [3]. The current model estimates that, by 2030, 42 % of the US population will be obese and that over 11 % will exhibit class III obesity [2]. This represents a predicted 33 % increase in overall obesity and a 2.2 factor increase in class III obesity over the next 20 years [2].

Obesity continues to place a significant financial burden on American healthcare. In 2009, healthcare expenditure related to obesity was estimated at $139 billion and corresponded to direct costs of $75 billion and indirect costs of $64 billion [4]. This estimate represents approximately 5 % of the total US healthcare expenditure [4]. If current trends continue, this cost is expected to top $344 billion by 2018 [5]. This would represent an average increase of $395 per person per year in costs for inpatient and ambulatory care, surpassing healthcare cost increases associated with smoking ($230), aging ($225), and excessive alcohol intake ($150) [6]. Obese individuals have annual medical care costs that are almost $1,500 higher than patients with normal weight [7].

The cost impact of obesity is due, to a significant extent, to the cost associated with its many comorbidities. Obesity increases the incidence of known metabolic conditions such as dyslipidemia (DYS), type 2 diabetes (DM), and related metabolic syndrome with its cardiovascular consequences. Additional conditions such as hypertension (HTN), sleep apnea syndrome, nonalcoholic steatohepatitis, major depression, and osteoarthritis also contribute to the increased mortality related to obesity. There are more than 40 medical diseases which have been linked to severe obesity [8]. A recent study of the German population indicated that obese men have a 4.5 times higher incidence of HTN, a threefold increase in cardiovascular disease (CVD) and DM, and an equal incidence of cancer [9]. Obese women exhibited an incidence of HTN that was five times higher, a risk of CVD that was increased 3.6 times, significantly higher incidence of DM (6.5 times), and a 1.3-fold increase in the incidence of cancer [9].

Studies also support the notion that obesity poses a significant risk for developing malignancy. The additional cancer risk in obese individuals ranges from 25 to 120 % [10]. The relative risk (RR) of cancer in obese patients is higher for esophageal adenocarcinoma (RR 2.10) as well as endometrial (RR 2.20), renal (RR 1.61), colorectal (RR 1.36), pancreatic (RR 1.28), and postmenopausal breast cancer (RR 1.25) [10]. Other studies have shown a 10 % increase in cancer-related deaths in obese patients [11].

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According to the 2009 US Centers for Disease Control and Prevention vital data report, a total of 2,437,163 deaths occurred in the United States. Of those deaths, 24.6 % were related to heart disease, 23.3 % to malignant neoplasm, 5.6 % to respiratory disease, 4.8 % to accidents, 2.8 % to diabetes, 1.5 % to suicide, 1.3 % to liver disease, and 1.1 % to hypertension [12]. As indicated, a number of these leading causes of mortality are associated with severe obesity and are more prevalent among obese individuals than among non-obese individuals. It is inherently difficult to ascertain a singular risk of mortality for a given comorbidity, because all-cause mortality is multifactorial and likely results from the interaction of various comorbidities. Furthermore, mortality is not only a function of the incidence and prevalence of disease, but of the severity of illness at diagnosis and the effectiveness of treatment.

Therefore, the relationship between body mass and mortality is not always readily discernable. This is well-illustrated by CVD, the primary disease-related cause of death in the United States. The major risk factors for CVD are DM, HTN, DYS, and renal impairment. DM is one of the more significant risk factors for CVD and, alone, increases the morbidity and mortality of CVD as much as 29 times compared to non-diabetics with CVD [13]. In addition, metabolic syndrome marks the "perfect storm" of comorbidities for CVD and is defined by increased serum triglycerides (TG), low serum high-density lipoprotein cholesterol (HDL-C), elevated blood pressure, increased fasting plasma glucose, and increased waist circumference [14]. Clearly, the obese patient is at significant risk for metabolic syndrome and CVD.

Furthermore, body mass, as an individual factor, can significantly impact mortality. According to recent estimates, life expectancy may be reduced by 7.1 years in nonsmoking obese women and by 5.8 years in nonsmoking obese men as compared to their normal-weight counterparts [4]. Individuals with BMI $\geq$ 30 kg/m^2 have a 20–179 % increase in premature death compared to a healthy-weight cohort [15, 16]. Obesity accounts for a 40 % increase in mortality attributable to CVD, a 60 % increase in mortality from DM, and a 10 % increase in cancer-related deaths [17]. Thus, obesity increases the incidence of most major causes of death [12].

Comorbidity Response to Bariatric Surgery

Currently bariatric surgery is the only effective treatment for obesity class II or greater. The annual number of bariatric operations increased exponentially from 12,775 cases in 1998 to over 220,000 cases in 2008 [18, 19]. During this time period, the proportion of operations performed laparoscopically has increased, and overall morbidity and mortality have decreased [20]. Patients who undergo bariatric surgery can experience resolution of the major comorbidities related to obesity [21]. Bariatric surgery results in individual remission of HTN in 61.7 %, DYS in 83.6 %, DM in 76.8 %, and obstructive sleep apnea in 61.7 % of patients [22]. In the specific context of patients with metabolic syndrome, Roux-en-Y gastric bypass (RYGB) has been shown to reduce the severity of DM in 75 % of patients, HTN in 69.4 %, and DYS in 76.4 % of patients as early as 2 months postoperatively [23]. Complete remission, among these patients, was observed in 65.3 % with DM, 51.4 % with HTN, and 73.6 % with DYS up to 1 year postoperatively [23]. Bariatric surgery has also been shown to reduce the prevalence of metabolic syndrome from 87 to 29 % compared to medical management, which can only achieve a minor reduction from 85 to 75 % [14]. The dramatic improvement in obesity-related comorbidities is the primary driving force behind the decrease in disease-related mortality experienced by patients who undergo bariatric surgery.

Mortality After Bariatric Surgery

The case for mortality benefit following bariatric surgery has been historically based on the hypothesis that significant improvement in obesity-related comorbidities would translate into reduced end-organ injury and, ultimately, improved health and increased survival. Despite widespread acceptance, the premise that weight loss and associated comorbidity improvements following bariatric surgery would decrease long-term mortality (5 or more years after surgery) in obese individuals had, until recently, been subjected to surprisingly little specific scientific evaluation. Long-term mortality can be viewed within the context of specific procedures, namely, adjustable gastric banding (AGB), vertical sleeve gastrectomy (VSG), biliopancreatic diversion (BPD) with or without duodenal switch (DS), and RYGB, or in terms of the effects of bariatric surgery overall.

Adjustable Gastric Banding

AGB is a safe and effective weight loss operation with very low perioperative mortality [24]. While the long-term outcomes of AGB can be confounded by a number of variables, several of these issues deserve specific mention. First, there are a variety of bands made by a number of manufacturers. Second, the technology of AGB has changed, such that current bands are technologically quite different than previous generations. Third, the technical aspects of AGB placement have evolved over the years, most notably illustrated by the change from perigastric to pars flaccida technique and more deliberate diagnosis and treatment of concurrent hiatal hernia [25, 26]. Finally, the weight loss success and health improvement following AGB is highly dependent on postoperative management [27]. Although these limitations increase the heterogeneity of study conditions in this literature, there is strong evidence that AGB is safe and can lead to a survival benefit in morbidly obese patients. The Australian experience of O'Brien et al. has contributed significantly to the current literature regarding AGB. In an early report contrasting 996 AGB patients to 2,119 obese individuals, AGB reduced mortality risk by 72 % (10.6–0.4 %) at 4 years [28]. A recent update to this experience revealed that the survival benefit with AGB continued to 10 years [29]. The authors affirmed the safety of AGB by reporting 0 % perioperative mortality among 3,227 cases. This chapter also provided longer follow-up on the original cohort of 996 AGB patients and reported the same 0.4 % mortality at 10 years with 98 % follow-up for deaths. The four deaths in 10 years occurred from cancer ($n=2$), suicide ($n=1$), and CVD ($n=1$) [29].

Similar low mortality rates following AGB have been reported. At 5 years post-surgery, a significantly lower mortality rate was identified in AGB patients (0.97 %) than matched nonoperative controls (4.38 %) [30]. At the same 5-year follow-up interval, another group identified a mortality risk of 0 % among surgical patients and 2.5 % among matched controls [31]. The same study also reported a noncontrolled mortality rate of 0 % in 1,791 AGB patients up to 12 years after surgery [31]. Additional data without control groups revealed long-term mortality at a mean of 7 years post-AGB to range from 0.2 to 2 % [32, 33].

Even studies which report a high reoperation rate corroborate the low long-term mortality risk associated with AGB. At 13 years of follow-up (54.3 % of eligible patients), a significant proportion of patients (59.8 %) required reoperation following AGB while the mortality was only 3.7 %. Furthermore, the three deaths were not directly related to health risks of obesity or operative factors (melanoma, lung cancer, and suicide) [34]. As a consensus statistic, a review of seven studies, with adequate long-term follow-up after AGB, revealed only one death in 6,177 patients (mortality of 0.02 %) over 10 years [29].

Vertical Sleeve Gastrectomy

VSG has only recently gained significant traction as a primary bariatric procedure. The original case for VSG was made as the first stage of two-stage RYGB in high-risk bariatric patients [35]. In the relatively short period since the original reports, data have been amassed to support the safety and efficacy of VSG. However, there are currently no long-term case-controlled mortality data on VSG.

Existing studies which evaluate long-term outcomes following VSG are largely retrospective. The largest study compared 811 VSG patients to 786 RYGB patients for complications and mortality at 1, 2, and 3 years [36]. Although patients who underwent VSG had a relatively low mean BMI (37.9 ± 4.6 kg/m^2), VSG was associated with low operative time (76.6 ± 28 min), short hospital stay (2.8 ± 0.8 days), and low complication rates (early = 2.9 % and late = 3.3 %) [36]. Specifically, leaks occurred in only 0.5 % of cases and only one patient had to be converted to RYGB for stenosis. VSG patients were also able to achieve sustained excess weight loss of 86.8 % ± 27.1 % at 3 years and had significant improvement in metabolic biochemical parameters. This profile of safety and efficacy of LVSG resulted in 0 % mortality during adequate postoperative follow-up at 1 (81.8 %), 2 (74.7 %), and 3 (71.7 %) years [36]. A much smaller study followed only 20 patients who underwent LVSG but was able to achieve 100 % follow-up at 3 years with 0 % mortality [37]. The low power of this study clearly compromises its generalizability to the general population of bariatric surgery patients [37].

The excellent mortality results for VSG have also been shown in high-risk patients. In a recent study, VSG was designed as a first-stage therapy in class V obese patients (mean BMI = 66 kg/m^2) [38]. Although the original intention was to proceed with second-stage conversion to RYGB, 75 patients (60 %) were able to achieve 48 % excess weight loss with VSG as a single procedure [38]. With 93 % follow-up at a mean of 6 years postoperatively, this study also demonstrated 0 % mortality [38].

Biliopancreatic Diversion

No case-controlled studies of long-term mortality following BPD with or without DS have been performed. In a case series of 74 patients undergoing BPD, with excellent follow-up of 93.7 % between 4 and 8 years postoperatively, data were collected for weight loss, changes in comorbidities, nutritional deficiencies, morbidity, and mortality [39]. This study demonstrated 0 % perioperative deaths and 1.35 % long-term mortality. The single death during the study period was unrelated to bariatric surgery and occurred as a consequence of breast cancer [39].

A large series of 1,423 patients evaluated the outcomes of BPD-DS in terms of change in body mass, improvement in medical conditions, nutritional issues, complications, and mortality [40]. BPD-DS was performed via the open technique early in the study and subsequently switched to laparoscopy. The authors were able to achieve follow-up on 93 % of patients at a mean of 7.3 years and reported specific causes of mortality. The patient population, which had a mean age of 40.1 ± 10.5 years and mean BMI of 51.5 ± 9.9 kg/m^2, experienced a mortality rate of 8 % [40]. However, the authors only attributed 20 % of the deaths to surgery (malnourishment, delayed operative death, reoperation, intestinal obstruction, and gastrointestinal hemorrhage). Long-term mortality unrelated to surgery resulted from cancer, trauma, suicide, pulmonary insufficiency, pulmonary embolus, and sudden death [40].

Several other non-case-controlled studies have examined the mortality after BPD-DS at several years follow-up. The largest study had a group of 1,300 BPD-DS patients that were followed from 1 to 15 years and reported mortality of

0.57 % [41]. A similarly low mortality rate of 0.74 % was identified in 540 patients, half of whom underwent BPD while the other half underwent BPD-DS, followed for a mean of 7.4 years [42]. Large surgical experiences seem to corroborate these low mortality rates. A study of 1,000 patients with BPD-DS reported mortality of 0.2 % with a 90 % follow-up at a mean of 2 years [43]. Another multicenter report of 874 patients found a mortality rate of 0.8 % at a mean follow-up of 11.9 years [44]. Smaller series have reported higher rates of mortality, such as 3.9 % in 51 patients who underwent BPD-DS with 92 % follow-up for 5 years [45]. Although somewhat larger with 190 patients, another investigation reported 2.8 % mortality at 3.7 years with 93.7 % follow-up [46].

Roux-en-Y Gastric Bypass

RYGB enjoys a robust body of literature that has examined the outcomes of this procedure over five decades. Numerous studies have elucidated the efficacy of RYGB in achieving and maintaining meaningful weight loss. Additionally, the beneficial effects of RYGB on obesity-related medical conditions have become well established. Mortality following RYGB has been primarily studied from the perspective of surgical safety and has focused heavily on early postoperative results. Thus, sufficiently powered randomized controlled data that address long-term mortality and are specific to RYGB are virtually nonexistent. Furthermore, studies with case-matched controls involve primarily open RYGB, while one case series with exclusively laparoscopic RYGB comments on long-term mortality.

One of the earlier studies followed 154 patients who underwent RYGB and found a mortality rate of 9 % up to 9 years postoperatively. This represented a significant improvement when compared with the control group of 78 morbidly obese patients who did not have surgery and exhibited a mortality rate of 28 % up to 6.2 years of follow-up [47]. An identical mortality rate of 9 % was reported by another study of 233 patients who underwent RYGB and were followed for 10 years postoperatively [48]. This investigation benchmarked surgery patients against a large group of 11,132 morbidly obese individuals in the general population followed for the same 10-year interval and determined a significant reduction in long-term mortality as compared to the approximately 12 % mortality rate observed in the control group [48]. Similar results have been identified by noncomparative descriptive data, illustrated by a report of 8 % all-cause mortality among 1,025 RYGB patients followed for 2–12 years [49].

More recent data corroborate the significant reduction in long-term mortality (40 %) for morbidly obese individuals who undergo RYGB [50]. These data are based on a large experience with RYGB in 7,925 patients operated during an 18-year experience. Surgical patients and an identical number of control patients (matched for age, gender, and BMI) were evaluated over 7 years. While the reduction in mortality following RYGB was significantly lower, mortality in both groups was lower than other studies (2.7 % in the surgery group vs. 4.1 % in the control group) [50]. Another recent report identified a 5-year mortality of 1.8 % following LRYGB [51].

These overall mortality data are most notable in that the reduced rates for surgical patients also inherently contain all mortality-associated surgery and related complications. When specifically investigated, mortality within the first year following surgery was essentially identical between RYGB patients (0.53 %) and matched obese individuals (0.52 %), underscoring the safety of current bariatric surgical practice [50]. In this vein, the transition from open RYGB to laparoscopic RYGB has fundamentally changed the safety profile of this operation. In a review of nine studies which reported a mortality rate of 0.8 % at 10 years among 2,684 RYGB patient, all deaths occurred during the open bypass era [29].

The positive impact of RYGB on mortality is most prominent in patients with significant comorbidities related to obesity. Death attributable to CVD is reduced by 56 % in patients who undergo RYGB [50]. Similarly, mortality related to DM decreases by 92 %, and mortality related to cancer diminishes by 60 % [50]. Men also seem to derive a greater mortality benefit than women (56 % reduction vs. 32 % reduction) [50]. It is hypothesized that this difference may be due to a higher prevalence of medical conditions responsive to RYGB, such as CVD, in morbidly obese male patients. However, the rate of death from accidents and suicide has been reported to be 58 % higher in RYGB patients [50].

These affirmative data certainly seem to point to a distinct survival advantage as a response to RYGB in morbidly obese patients. However, a number of potential confounding issues exist. Most prominent among these is the lack of data on comorbidity severity among RYGB patients or among the control groups of obese individuals. Similarly, there are no indications as to whether or not surgical patients may have received more aggressive treatment of comorbidities. Additionally, patients who undergo surgery may be more predisposed to seeking and adhering to medical care. Finally, the demonstrable increase in deaths not related to disease among RYGB patients has not been fully evaluated. While it is unclear whether such factors would appreciably impact the survival benefit observed following RYGB, they certainly warrant consideration and further study. Variability in mortality reduction has been reported in high-risk patients undergoing RYGB. Advanced age, high BMI, and male gender have been identified as risk factors for poor surgical outcomes, including complications and perioperative mortality [52, 53]. High-risk patients who undergo RYGB experience a 36 % reduction in mortality over 7 years [54]. After adjustment for covariates, this benefit drops to 20 % but remains statistically significant. However, the mortality improvement loses statistical significance when compared to a matched cohort (17 %) and when corrected for follow-up interval (6 %) [54]. It should be noted that within these data lie a relatively high perioperative mortality rate of 1.5 %. This accounts for 86.6 % of deaths at 1 year, 59 % of deaths at 2 years, and 19.4 % of deaths at 6 years. Furthermore, while the hazard ratios may not have been significant, RYGB patients exhibited decreased mortality rates at 1 year (1.5 % vs. 2.2 %), 2 years (2.2 % vs. 4.6 %), and 6 years (6.8 % vs. 15.2 %) when compared to unmatched obese patients [54]. Although early survival was not statistically different when benchmarked against matched obese individuals at 1 and 2 years, a significant reduction was identified at 6 years (6.7 % vs. 12.8 %) [54]. Thus, the interpretation of survival benefit following RYGB in high-risk patients must include three critical variables: optimization of physiologic status to reduce higher than average perioperative mortality risk, potential quality of life gains associated with weight loss, and comorbidity improvement and evidence that a significant survival advantage may not be realized until a long postoperative interval.

As further illustration, 908 patients underwent RYGB and were followed for a mean of 4.4 years [55]. When contrasted to a control group of 112 obese individuals followed for a mean of 3.6 years, surgical patients exhibited significantly reduced overall mortality rate of 2.9 % as compared with 14.3 % in the control group. These investigators reported that the mortality curves diverged more greatly with increasing length of follow-up [55].

Another notable obstacle to determining long-term mortality following RYGB (and bariatric surgery in general) is the inconsistent and often low rate of long-term patient follow-up. Few studies can document excellent patient follow-up at many years postoperatively. Furthermore, many studies of bariatric surgical outcomes do not specifically address the adequacy of patient follow-up. When patient follow-up has been reported, it has frequently been quite low in the long term as exemplified by a study which found an overall mortality rate of 3.3 % but only had follow-up of 33 % at 2 years and 26 % at 10 years [56].

Overall Effect of Bariatric Surgery on Mortality

It is undeniable that bariatric operations have varying mechanisms of achieving weight loss and effects on obesity-related comorbidities. Yet, bariatric surgery has been repeatedly shown to improve overall health in morbidly obese patients regardless of the specific operation [57, 58]. Within this context, the generalized effects of bariatric surgery on overall and disease-specific mortality have been evaluated. In a large series of RYGB and vertical banded gastroplasty (VBG) with case-matched controls, the reported mortality was 0.68 % for the surgical cohort compared to 6.17 % for the control group at 5 years [57].

Perhaps the most robust data set regarding bariatric surgery comes from the Swedish Obese Subjects (SOS) study. The SOS has addressed mortality in a long-term prospective case-controlled fashion. In a report that contrasted 2,010 patients who underwent bariatric surgery (RYGB 13 %, VBG 68 %, and AGB 19 %) to 2,037 patients who received conventional treatment for obesity and related comorbidities, the overall mortality was 5.0 % in the surgery group and 6.3 % in the control group [58]. The corresponding 24 % reduction in mortality was observed at a mean follow-up of 10.9 years [58].

In addition to its breadth, the SOS data collection was also specific and detailed. The patients in both groups were well-matched for anthropomorphic and demographic characteristics. All patients were evaluated at regular intervals, up to 15 years, indexed to the timing of operation of patients in the surgery group. Evaluation consisted of anthropomorphic, physiologic, comorbidity, and biochemical assessments. The investigators were able to achieve excellent follow-up at 2, 10, and 15 years of 94, 84, and 66 % for the surgical arm and 83, 75, and 87 % for the control group [58].

Although the 90-day mortality following bariatric surgery was low (0.25 %), it was higher than mortality in the control group (0.10 %) [58]. However, surgical patients gained survival benefit as the duration of follow-up increased. In terms of cause-specific mortality, surgical patients had less death due to CVD (2.14 % vs. 2.6 %) and noncardiovascular causes (2.88 % vs. 3.7 %) [58]. Cancer-related mortality dropped from 2.36 % in control patients to 1.44 % in surgical patients [58]. The greatest predictor of overall mortality was history of myocardial infarction or stroke, which corresponded to mortality risk of 19.6 % in the surgical group and 24.5 % in the control group [58]. Other factors shown to increase risk of death among all patients included advanced age, smoking, increased plasma triglycerides, and increased blood glucose. Body mass also affected mortality in that more severely obese patients (BMI $\geq$ 40 kg/m^2) realized a greater reduction in mortality (30 %) in response to bariatric surgery than patients with BMI below 40 kg/m^2 (20 %) [58].

Taken together, AGB and RYGB are quite effective at reducing mortality associated with obesity. A recent meta-analysis identified eight case-controlled clinical trials that compared 44,022 bariatric surgery (RYGB or AGB) patients to a control cohort of 29,970 obese individuals to an average follow-up of 7 years [59]. The type of operation (RYGB or AGB) did not statistically affect global mortality or all-cause mortality. Surgical patients exhibited reduced global mortality (50 %), cardiovascular mortality (42 %), and all-cause mortality (30 %) [59]. RYGB more significantly reduced CVD mortality than AGB (52 % vs. 29 %), presumably related to its metabolic effects on DM [59]. In terms of absolute rates, overall mortality was 2.84 % in the surgical group and 9.73 % in the control group [59].

TABLE 1. Mortality following restrictive procedures

Study	*N*	Mortality (%)	Follow-up (years)	Procedure
Busetto et al. (2004)				
Surgery	821	0.97	5	AGB
Control	821	4.4	5	
Peeters et al. (2007)				
Surgery	996	0.4	4	AGB
Control	2,119	10.6	4	
Miller et al. (2007)				
Surgery	554	0.2	7.6	AGB
Control	N/A			
Favretti et al. (2007)				
Surgery	821	0	5	AGB
Control	821	2.5	5	
Stroh et al. (2011)				
Surgery	200	2	7.8	AGB
Control	N/A			
Himpens, et al. (2011)				
Surgery	82	3.7	13	AGB
Control	N/A			
Boza et al. (2012)				
Surgery	811	0	3	VSG
Control	N/A			
Sarela et al. (2012)				
Surgery	20	0	3	VSG
Control	N/A			
Eid et al. (2012)				
Surgery	75	0	6	VSG
Control	N/A			

AGB adjustable gastric band, *VSG* vertical sleeve gastrectomy

TABLE 2. Mortality following biliopancreatic diversion

Study	*N*	Mortality (%)	Follow-up (years)	Procedure
Guedea et al. (2004)	74	1.4	4–8	BPD
Hess et al. (2005)	1,300	0.6	1–15	BPD-DS
Marceau et al. (2007)	1,423	8	7.3	BPD-DS
Crea et al. (2011)	540	0.7	7.4	BPD/BPD-DS
Biertho et al. (2011)	1,000	0.2	2	BPD-DS
Topart et al. (2011)	51	3.9	5	BPD-DS
Pata et al. (2012)	874	0.8	11.9	BPD-DS
Dorman et al. (2012)	190	2.8	3.7	BPD-DS

BPD biliopancreatic diversion, *DS* duodenal switch

TABLE 3. Mortality following Roux-en-Y gastric bypass

Study	*N*	Mortality (%)	Follow-up (years)
McDonald et al. (1997)			
Surgery	154	9	9
Control	78	28	6.2
Sugerman et al. (2003)			
Surgery	1,025	8	2–12
Control	N/A		
Flum et al. (2004)			
Surgery	233	9	10
Control	1,131	16	15
Sowemimo et al. (2006)			
Surgery	908	2.9	4.4
Control	112	14.3	3.6
Adams et al. (2007)			
Surgery	7,925	2.7	7
Control	7,925	4.1	7
Maciejewski et al. (2011)			
Surgery	847	6.8	6
Control	847	15.2	6
Suter et al. (2011)			
Surgery	379	1.8	5
Control	N/A		
Higa et al. (2011)			
Surgery	242	3.3	10
Control	N/A		

Summary

Obese individuals often suffer from associated comorbidities. Left untreated, these medical consequences of obesity can cause end-organ injury and resultant mortality. Bariatric surgery is the best current means of achieving and maintaining significant weight loss [18, 19]. Surgery also effectively treats many of the medical conditions associated with obesity as a consequence of weight loss and by weight-loss-independent mechanisms. Thus, bariatric surgery is hypothesized to significantly reduce mortality, in large part, by improving comorbidities of obesity. The mortality benefit derived from the various bariatric operations is likely related to the comorbidity severity of the individual patients as well as the metabolic effects of each procedure.

The restrictive procedures (AGB and VSG) exert their comorbidity effects primarily as a function of weight loss, and their mortality reduction data are summarized in Table 1. The long-term mortality for AGB ranged from 0 to 3.7 % with a range of mean follow-up of 5–13 years, while the respective controls had mortality of 2.5–10.6 % [28–34]. VSG also demonstrated a low long-term mortality at mean follow-up of 3–6 years, although the data were much less established, not case controlled, and relatively shorter term [36–38]. As observed in the SOS, VBG is associated with 10-year mortality of 5 % compared to 6.3 % in the control group [58].

The procedures that include intestinal bypass (BPD and RYGB) have metabolic effects that act synergistically with weight loss to improve medical comorbidities. The mortality reduction data for these operations are summarized in Tables 2 and Table 3. BPD with or without DS has a reported a mortality of 0.2–8 % at mean follow-up of 2–12 years (Table 2) [36–43]. RYBG had the most data available. The long-term mortality ranged from 1.8 to 9 % at a mean follow-up of 4.4–10 years compared to a control mortality rate of 4.1–28 % during a similar follow-up period (Table 3) [29, 46–51, 54].

Studies that reviewed aggregated mortality of bariatric surgery across multiple procedures are summarized in Table 4. The overall long-term mortality rate for bariatric surgery ranged from 0.68 to 5 % and was significantly lower

TABLE 4. Mortality In mixed studies

Study	*N*	Mortality (%)	Follow-up (years)	Procedure (%)
Christou et al. (2004)				
Surgery	1,035	0.68	5	RYGB (81.3)
Control	5,746	6.17	5	VBG (18.7)
Sjostrom et al. (2007)				
Surgery	2,010	5.00	10.9	AGB (19)
Control	2,037	6.30	10.9	VBG (68)
				RYGB (13)

RYGB Roux-en-Y gastric bypass, *VBG* vertical banded gastroplasty, *AGB* adjustable gastric band

than control mortality of 6.17–6.3 % at 5–11 years after surgery [57, 58].

Accurate determination of long-term mortality following bariatric surgery can be hindered by several limitations that pervade the current body of literature. First, most of the studies are not case controlled, while randomized trials are even rarer. Many outcome reports do not specifically address long-term mortality as an outcome variable. Also, long-term follow-up is frequently poor in studies of bariatric surgery, such that it is difficult to interpret outcomes in light of diminishing sample sizes. Another inherent issue is the lack of homogeneity of study control groups, which most commonly consist of patients from clinical programs or individuals from the general population. Control groups of patients in clinical programs tend to more closely resemble the comorbidity profiles of surgical patients when contrasted to control groups from the general population. Despite these limitations, the current state of knowledge in bariatric surgery seems to clearly support a reduction in obesity-related mortality in response to bariatric surgery.

Review Questions and Answers

1. According to the World Health Organization, what chronic condition is now a major cause of mortality in the majority of countries?

A. Malnutrition
B. Tuberculosis
C. Obesity
D. Pesticides

Answer: C

2. Which of the following causes of mortality is MOST reduced by Roux-en-Y gastric bypass?

A. Diabetes
B. Cancer
C. Cardiovascular
D. All-cause mortality

Answer: A

3. What is the proposed mechanism by which bariatric surgery reduces long-term mortality?

A. Weight loss
B. Improvement in comorbidities
C. Decrease in cancer incidence
D. Multifactorial
E. All of the above

Answer: E

4. Which of the following is the greatest predictor of overall mortality following bariatric surgery?

A. Previous surgery
B. History of myocardial infarction
C. BMI > 50 kg/m^2
D. Type II diabetes mellitus

Answer: B

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