Full Title: Outcomes of bariatric surgery in patients with liver cirrhosis: a systematic review

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Abstract

Obesity is commonly associated with Non-Alcoholic Fatty Liver Disease and is a significant cause of chronic liver disease and cirrhosis. Some patients undergoing bariatric surgery have incidental findings of cirrhosis. Currently, there is a lack of consensus on the management of these patients and the safety and efficacy of bariatric surgery in this group. This review aims to provide an update to the previously published systematic review on the same topic. 21 studies reporting experience on patients with cirrhosis undergoing bariatric surgery were included. Sleeve gastrectomy was the most common surgery performed, followed by Roux-En-Y gastric bypass. The results show that bariatric surgery may be feasible in carefully selected patients with obesity and cirrhosis although they may have slightly higher morbidity and mortality rates.

Introduction

Obesity is strongly associated with Non-Alcoholic Fatty Liver Disease (NAFLD) and the obesity epidemic has led to NAFLD becoming the most common cause of chronic liver disease[1]. Some patients with NAFLD may progress to develop NASH and eventually liver cirrhosis which has far-reaching consequences[2]. These patients have increased perioperative risk with abdominal and non-abdominal surgery, increased risk of bleeding from the gastrointestinal tract and an increased risk of mortality from liver and renal failure[3].

Bariatric surgery has been well established as a treatment strategy for obesity – resulting in sustained weight loss, improvement in type 2 diabetes mellitus, hypertension, hyperlipidaemia, cancer mortality and overall mortality[4,5]. However, the safety and benefit of bariatric surgery in cirrhotic patients is less clear. Bariatric surgery has been shown to reverse high-grade fibrosis and cirrhosis in some obese patients pursuant to significant weight loss[2]. A recent meta-analysis has shown that bariatric surgery may be a bridge to liver transplant in patients with obesity who may have otherwise been excluded on the basis of their weight[6]. Despite these advantages, the morbidity and mortality risks of major abdominal surgery in patients with cirrhosis has to be carefully considered. Data from the United States national database shows that mortality rates for patients without cirrhosis undergoing bariatric surgery is lower than that of compensated cirrhotic patients and decompensated cirrhotic patients (0.3% vs 0.9% and 16.3%, respectively)[7].

Jan et al published a systematic review on outcomes of bariatric surgery in patients with obesity and cirrhosis in 2015[8]. A large body of literature has been published on this topic since. The aim of this review is to update the literature regarding bariatric surgery and its outcomes in patients with obesity and liver cirrhosis in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Materials and Methods

A multi database search was conducted. The patient population of interest was all patients with obesity and liver cirrhosis (e.g. all classifications, either compensated or decompensated liver cirrhosis). The intervention studied was bariatric and metabolic surgery. Outcome measures were changes in occurrence of postoperative complications, liver failure, decompensated liver failure, mortality and anthropometric variables.

A comprehensive search was undertaken using PubMed/MEDLINE, EMBASE and Cochrane Database of Systematic Reviews on papers published from the earliest date of each database until August 2020. The search was conducted using medical subject headings (MeSH) and a combination of keywords from the following two groups: (a) “liver cirrhosis”, “fatty liver”, “Non-alcoholic steatohepatitis”, and (b) “bariatric surgery”, “gastric bypass”, “sleeve gastrectomy”, “gastric band”, “biliopancreatic diversion”, “duodenal switch”, “jejuno-ileal bypass” and “obesity surgery.”

Authors SA, SP and CP individually screened and selected studies on the basis of title and abstract. After primary selection, authors reviewed the full text of the selected studies and determined suitability for inclusion, based on the established selection criteria. For further eligible studies, cross-references were screened. Disagreements were solved by discussion with each other and KM until consensus was reached.

For cumulative quantitative synthesis, we only included full-length published studies that reported experience with bariatric surgery in patients with obesity and liver cirrhosis as a primary endpoint. We excluded studies with only abstracts, review articles, clinical practice guidelines, non-human studies and non-English articles. We also excluded studies that reported on single-stage bariatric surgery and liver transplant as the outcomes would be different given the morbidity and mortality associated with liver transplant in itself. We further excluded data from surveys and national registry for quantitative analysis, as they can be unreliable for the purposes of a systematic review[8].

Data from each of the studies retrieved include gender, age, Body Mass Index (BMI), length of stay, timing of diagnosis of cirrhosis, Child Pugh status, bariatric procedure performed, weight loss at different time points, complication, liver decompensation and related mortality.

Results

The primary literature search produced 4211 results, including 209 duplicates. After screening the title and abstract, 56 studies were found to be possibly relevant and underwent a full text critical appraisal. Of these, 35 were excluded for a variety of reasons. Reasons for exclusion were - survey studies (n = 5), reviews (n = 10), duplicates (n = 5), studies assess bariatric surgery with transplantation (n = 7) and studies using large databases and/or Markov modeling studies (n = 8). Survey data from article by Brolin et al was excluded from quantitative synthesis but authors' personal data of 7 RYGB (Roux-en-Y Gastric Bypass) was included[9] . Finally, 21 studies were included in this systematic review.

Figure 1 summarizes the search results, according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[10,11]. Table 1 gives an overview of the results of the included studies. Among the 21 included studies, there were 2 case reports, 2 retrospective cohort studies and 17 case series. The number of patients included in the studies ranged from 1 to 106.

Cumulative data from studies

This review identified a total of 464 patients with cirrhosis who have undergone bariatric surgery (Table 2). 249 (53.7%) of these were females. A total of 442 bariatric surgeries were described, among these 222 underwent Sleeve Gastrectomy (SG); 186 underwent Roux-En-Y gastric bypass (RYGB), 17 had a Gastric Band (GB) and 17 underwent a Bilio-Pancreatic Diversion (BPD). Kaul et al did not report the breakdown of surgery type in their

22 patients with cirrhosis. 42 out of 381 patients (11.0%) where it was reported, had portal hypertension (Table 3). 183 (43.6%) patients had intra-operative diagnosis of cirrhosis. The overall mortality was 11 (2.4%) out of 452 patients. 3 (0.66%) of these were early mortality (occurring within 30 days post-surgery) and the rest were late mortality (1.77%).

Morbidity and mortality according to different procedures

SG was the most common procedure performed (n=222) and the results of patients undergoing SG is described in Table 4. The overall rate of complications is 16.7% and 3.83% had liver decompensation. Almost one-third of patients were from the Salman et al study who reported exclusively on SG[12].

RYGB was the second most common procedure (n=186) performed (Table 5). The rate of complications in these groups of patients is 28.6% and 3.5% risk of liver decompensation. There were 6 deaths recorded (3.22%), 2 early deaths due to hepatic failure and 4 late deaths.

BPD and GB were relatively uncommon procedures with only 17 cases recorded for each procedure. The complication rate was 18.8% and 13.3% for GB and BPD respectively. The liver decompensation risk was 5.88% and 13.3%, mortality rate 0% and 17.6% for GB and BPD respectively.

Discussion

This review updates the systematic review by Jan et al on this topic published in 2015[8]. Patients with obesity and cirrhosis pose a specific surgical challenge due to increased morbidity and mortality risk from any intervention[13,14]. The natural history of compensated cirrhosis is progression to decompensated cirrhosis with even higher risks. Therefore, bariatric surgery may be an important treatment strategy for patients with obesity and compensated cirrhosis not only to produce durable weight loss but also histologic improvement that could alter the disease trajectory[13,14].

Currently, there is limited data on the long-term impact of bariatric surgery in obese cirrhotic patients. Histologic improvements post-surgery may not necessarily translate into survival benefits. Markov modelling by Bromberger et al based-on liver disease progression by BMI data reported by Berzigotti et al suggests that RYGB has the highest impact on survival compared to GB or diet and exercise[15,16]. This study however was based on assumptions, that may not necessarily stand to closer scrutiny. A key assumption in this study was that once patients entered lower class BMI from weight loss, they were immediately exposed to lower rates of liver decompensation which may not be necessarily true. Moreover, SG which is the most common surgery performed was not included in this study.

Overall, a total of 464 patients were identified in this systematic review with 53.7% being females. 96.8% of the patients' had Child's A status and the rest Child's B, reflecting the careful selection of patients who stand to benefit most from bariatric surgery. The early mortality rate of 0.66% seen in this review compares favourably with mortality rates of up to 10% in Child's A patients undergoing major abdominal surgery. This might reflect careful selection, excellent pre-operative optimisation, meticulous surgery, and good post-operative management.

SG is the most common surgery performed in this systematic review. There are a few reasons for this phenomenon. Firstly, SG is the most common bariatric surgery performed overall and globally proportion of patients undergoing a RYGB appears to be declining[17]. There may well be other advantages of SG in this group of patients such as preserved access to stomach and ampulla in case of need for varices or biliary intervention endoscopically[13]; higher risk of hepatic decompensation with malabsorptive and gastric bypass procedures; and preservation of normal gastrointestinal continuity that does not make a future liver transplant more difficult[18]. In this review, SG had a significantly lower complication rate compared to RYGB (16.7% vs 28.6%, p = 0.02), lower mortality rate (0.45% vs 3.22%, p = 0.051) and similar rates of liver decompensation (3.83% vs 3.5%, p = 1.0). This supports the notion that SG is also probably safer than RYGB in this high-risk group. Although difficult to determine, the majority of late mortalities were probably due to the disease progression resulting in liver failure – and not a consequence of the bariatric surgery. However, this needs to be confirmed in adequately designed studies with a comparable cohort of patients not undergoing bariatric surgery.

GB and BPD have not been favoured by surgeons in this population group for some reasons. There have only been two more additional cases of each surgery reported since the Jan et al review in 2015 in contrast with an additional 181 SG and 135 RYGB reported[8]. GB has been on a steady decline trend generally in most countries due to higher complication and re-operation rates[19]. According to a meta-analysis on GB complications, band slippage rate is 4.93% and rate of band erosion 1.03%[20]. Given the high-risk nature of surgery in patients with cirrhosis, repeated intervention may not be acceptable or even feasible. It is, therefore, possible that surgeons and patients maybe opting for a more durable single stage procedure such as SG or RYGB with lower need for re-intervention in the ensuing years. Furthermore, in GB a foreign body is left in the abdomen and with risk of future ascites formation, there is a theoretical increased risk of spontaneous bacterial peritonitis. Gastric band eroding into oesophageal varices maybe a catastrophic complication. These reasons seem to dissuade both surgeons and patients from choosing GB although it may be a faster and simpler surgery.

BPD is a potent bariatric surgery with significant malabsorptive effects that result in excellent weight loss and metabolic outcomes. At the same time, the associated malabsorption increases the risk of liver decompensation in patients with cirrhosis which might lead to catastrophic consequences. Moreover, the increased surgical risk and complexity of BPD compared with RYGB and SG would further make it a less attractive option. The results of this review which shows liver decompensation rates of 13.3% (compared with 3.83% for SG) and mortality rates of 17.6% (compared with 0.45% for SG) with BPD lend support to this hypothesis.

Consistent data reporting on patients with portal hypertension who underwent bariatric surgery was lacking. Many authors did not report liver decompensation, complication and mortality outcomes separately making it difficult to draw conclusions. In a series of 13 patients with portal hypertension, Hanipah et al series reported minor complications in 3 patients [21]. None of these patients experienced liver decompensation and no mortality was reported. Given these remarkable short-term results, there might be a role for bariatric surgery in carefully selected patients with cirrhosis and portal hypertension. However, given the small numbers (n=42) and inconstant reporting in the studies included in our review, authors would like to emphasise the need for caution at this stage. More data is needed on this group of patients before any firm recommendations can be made. Additionally, it would seem prudent for all patients with cirrhosis being considered for bariatric surgery to have a prior esophagogastroduodenoscopy to rule out oesophageal varices which will affect the risk profile and counselling of the patient for surgery. This is an important consideration especially because routine preoperative upper endoscopy is not mandatory in all bariatric centres[22].

There are several limitations to this review. Firstly, the level of evidence among the studies included is low – mostly case series. There is, therefore, a significant potential for publication bias. It is possible that experiences with worse (or better) outcomes have not been published. An ideal study would randomise patients with cirrhosis to surgery or best medical management and examine the cohorts over medium to long-term. However, such a study would be difficult without a global effort given the relatively low numbers of these patients.

Secondly, the diagnosis of cirrhosis was made using a variety of methods in the included studies. The modalities for diagnosis include liver biopsy, intraoperative identification of nodular liver, imaging studies and transient elastography. Some authors regard liver biopsy as the gold-standard for diagnosis for cirrhosis while others consider intra-operative diagnosis as the standard[13,23,24]. Visual identification is considered to be more sensitive than histology, which may lead to a number of patients with cirrhosis being 'missed'[24]. Thirdly, not all authors reported on validated measures of liver disease severity such as MELD (Model for End-Stage Liver Disease) and CPS (Child Pugh Score) making comparisons across studies and procedures difficult.

Newer endoscopic modalities to treating obesity and metabolic syndrome such as endoscopic gastroplasty are gaining traction. Long-term data regarding endoscopic gastroplasty is only now emerging. Future research could focus on metabolic outcomes and safety profile of these endoscopic procedures in patients with cirrhosis.

We believe surgeons should have a clear discussion of pros and cons of bariatric surgery with these patients and highlight the lack of robust data. It might be useful to have a preoperative discussion with every patient regarding the options available if a cirrhotic looking liver is encountered at laparoscopy. The options might include doing nothing, simply obtaining a liver biopsy without any bariatric procedure, proceeding with the planned procedure, or choosing an alternative option (with or without a simultaneous liver biopsy).

Comparing with the previous systematic review on the same topic several observations can be made. Firstly, the current review has almost twice the number of studies and more than 3 times the number of patients as the previous one. This might reflect the increasing numbers of bariatric surgery being performed worldwide as well as the increasing safety profile of these operations in high risk patients. It is also noted that SG is the most common surgery performed in this review compared to the RYGB in the 2015 review, consistent with overall global trends. Early mortality rates continue to remain low (0.66 % vs 1.6%) re-affirming the safety profile of bariatric surgery in these group of patients. There were substantially more patients with portal hypertension in this series (42 vs 7) suggesting increased acceptance of surgery in this high-risk group, although firm conclusions cannot yet be reached.

Conclusion:

Morbidity and mortality in patients with cirrhosis undergoing bariatric surgery appears to be higher in both short and long-term compared to patients with no cirrhosis. Patients should be appropriately counselled for these risks prior to surgery. SG appears to be the safest bariatric procedure in this cohort until better quality data emerges. Data on outcomes of bariatric surgery in patients with portal hypertension and Childs' B cirrhosis is limited. Surgeons should have an advanced discussion with the patients and have a strategy to hand for dealing with incidental intraoperative diagnosis of cirrhosis.

All authors have no conflicts of interest to declare.

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Figure 1: PRISMA flowchart

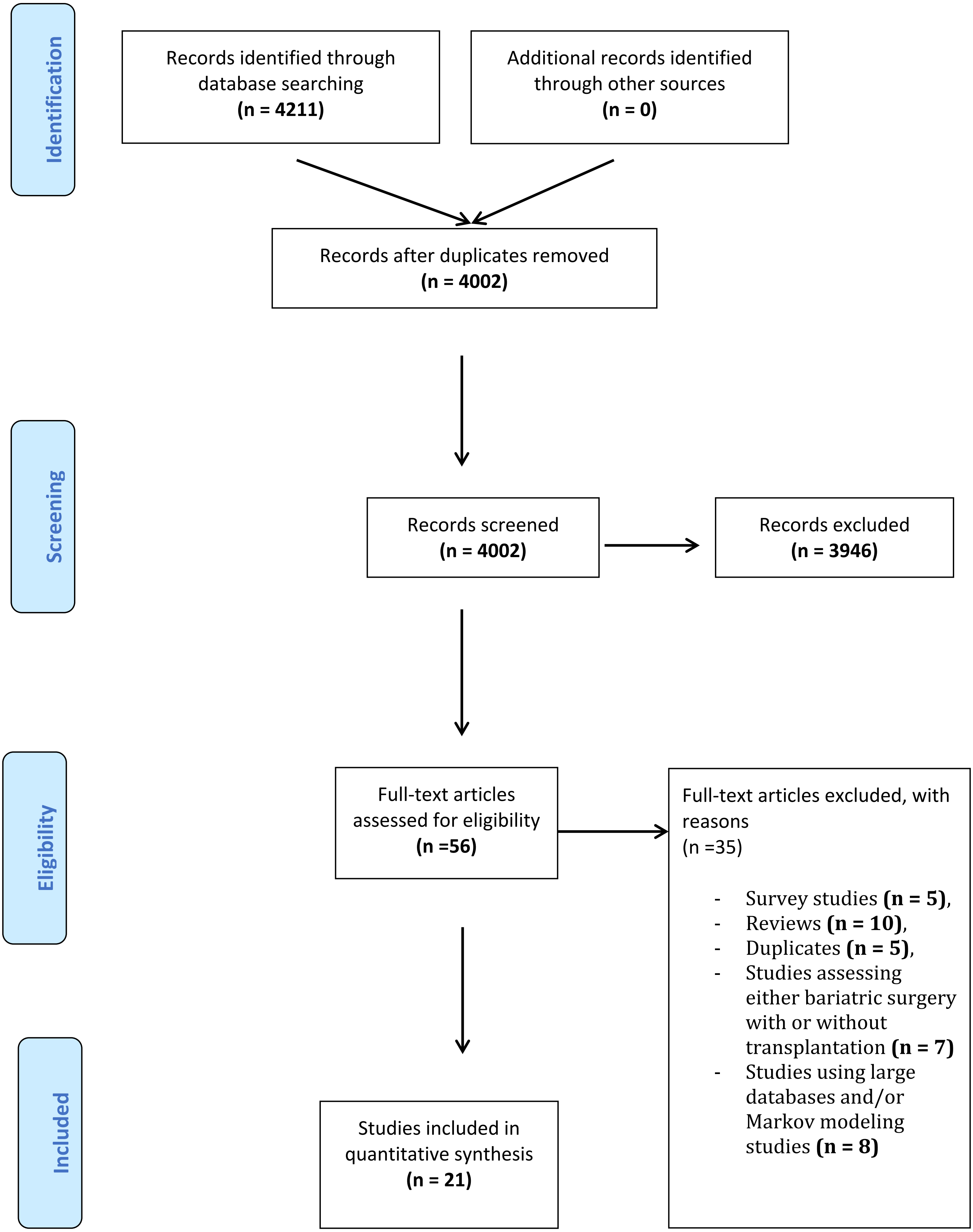

Table 1: Included studies describing experience with bariatric surgery in patients with cirrhosis of the liver as a primary endpoint

Study Characteristics	Diagnosis of Cirrhosis	Child Pugh/ MELD/ PH status	Procedures	Weight Loss	Complications	Liver Decompensation	Related Mortality (Early ≤ 30 days, Late > 30 days)
Brolin et al, 1998[9] Case series n = 7, F:M = 4:3 Mean Age= 45.5 years Mean BMI= 62.1	Intraoperative	Not reported	RYGB =7	NA	2	1	1 Early death due to fulminant Hepatic Failure 2 Late deaths (one congestive cardiac failure and one fulminant hepatic failure)
Dallal et al, 2004[23] Retrospective cohort n = 30, F:M = 20:10 Mean Age =50 years Mean BMI =52.6 kg/m2	Diagnosed intraoperatively in 27 patients	A =30, PH = 0	RYGB =27 SG = 3	Mean EWL of 62 % at 1 year	9 (1 leak, 4 acute tubular necrosis, 2 prolonged intubation, 1 ileus, 2 blood transfusion)	0	0
Kral et al, 2004[2] Case series n = 14, F:M = 10:4 Mean Age = 40 years Mean BMI = 54 kg/m^2	Intraoperative	Not reported	BPD = 14	NA	2	2	1 Early death (due to PE). 2 Late death (4 years due to hepatic failure)
Sarr et al, 2006[25] Case report n = 1, F Age 22 years BMI 73 kg/m^2	Intraoperative	Not reported	BPD/DS	90 kg weight loss at 12 months	0	0	0
Takata et al 2008[26] Case series n= 6, F:M = 4:2	Preoperative	A =4, B=2 PH not reported	SG = 6	At 9 months follow up an	2 (1 bleeding followed by ascites, 1 encephalopathy)	2 (1 early ascites, 1	0

Mean Age = 52 years Mean BMI = 49 kg/m2				EWL of 33% was achieved.		encephalo pathy)	
Shimizu et al, 2013[24] Case series n = 23, F:M = 14:9 Mean Age: 51.5 years Mean BMI: 48.2 kg/m2 Mean Hospital Stay = 4.3 days	12 diagnosed preoperatively and 11 diagnosed intraoperatively	A =22, B=1, 2 patients had TIPS	RYGB= 14 SG = 8 GB= 1	67.4% EWL at 12 months and 67.7% at 37 months	8	0	0
Rebibo et al, 2014[27] Case-matched study n=13, F:M = 7:6 Median Age = 52 years Median BMI= 46.3 kg/m2	Intraoperative	A =13, Median MELD score = 7, PH = 0	SG =13	Median BMI was 33.3 kg/m^2 at 6 months and 30.8 kg/m^2. Median EWL was 61.9 % at 6 months and 73.4% at 12 months.	2 (1 conversion to open for bleeding, 1 postoperative haematoma)	1 (late ascites)	0
Woodford et al, 2015[28] Case series n = 14, F:M = 10:4 Mean Age = 52.5 years Mean BMI = 38.9	Intraoperative	All patients either Child-Pugh A or B	GB=14	61.3 % EWL at 12 months and 39.55% EWL at 5 years for 7 patients followed up to 5 years	2 (1 mild surgical site infection, 1 mal positioned band requiring reoperation)	0	0
Lin et al, 2013[29] Case series n = 20 Mean age = 57 years Mean BMI = 48.3	Preoperative	Mean MELD = 11	SG = 20	Mean % EWL 26, 50 and 66 a 3, 12 and 24 months respectively	5 (2 - superficial wound infection, 1 – transient renal insufficiency, 1 – bleeding managed conservatively, 1 – leak)	1 (transient encephalo pathy)	1 Late death (4 years after staple line leak)
Pestana et al, 2015[30] Case series n = 14, F:M = 10:4	Preoperative	A=14, PH = 4	SG = 11 RYGB = 3	Mean weight decreased from 125 kg to 102 kg	0	1 (late encephalo pathy at 2	0

Mean Age = 55.5 years				at 6 months, 94 kg at 1 year, and 93 kg at 2 years		years attributed to TIPS and use of sedative medications in a patient with no PH prior to surgery)	
Wolter et al, 2017[31] Case series n = 12 Gender, mean age, BMI not reported separately for cirrhotic cohort	Intraoperative	NA	SG = 11 RYGB = 1	Weight loss not reported separately in cirrhotic group	4 (1 – staple line bleeding, 1 – intra-abdominal abscess, 1 – extraluminal bleeding, 1 dysrhythmias)	0	Not reported separately in cirrhotic group
Hanipah et al, 2018[21] Case series n = 13, F:M = 8:5 Median age = 54 years Median BMI = 48	Preoperative and intraoperative	Median MELD Score = 9, PH = 13	SG = 10 RYGB = 3	Mean weight decreased from 137 kg to 109 kg and 97.1 kg at 1 and 2 year post surgery respectively	3 early (1 wound infection requiring debridement, 1 – intra-abdominal hematoma, 1 – subcutaneous hematoma)	0	0
García-Sesma et al, 2018[32] Case series n = 8, F:M = 6:2 Mean age = 53.6 years Mean BMI = 46.3	Preoperative	A = 6, B = 2, PH = 2	SG = 8	Mean % EWL 42.9, 62.2 and 76.3 at 3, 6 and 12 months respectively	0	0	0
Moulla et al, 2018[33] Case series n = 9	Preoperative and intraoperative	A = 2, B = 1 (among those known preoperatively)	RYGB = 6 SG = 3	NA	No bleeding complications	0	0
Minambres et al, 2019[34] Case series	Preoperative and intraoperative	A = 40, B = 1, Mean MELD	SG = 28 RYGB = 11	% TWL was 26.33 at 12	7 (1 – leak, 1 – hemoperitoneum, 1 –	2 (early ascites)	0

n = 41, F:M = 19:22 Mean age = 53.8 years Mean BMI = 45		score = 7.2, PH = 11	BPD = 2	months and 21.16 at 5 years	bleeding from anastomosis, 1 - wound infection, 1 – portal thrombosis, 2 – ascites)		
Younus et al, 2019[3] Retrospective cohort n = 23, F:M = 12:14 Mean age = 52 years Mean BMI = 46	Intraoperative	A = 25, B = 1, Median MELD score = 7, PH = 0	SG = 7 GB = 1 RYGB = 15	NA	3 (Clavien-Dindo class ≥ III, 1 – hematemesis, 1 – respiratory failure, 1 – bleeding from port site, hypoventilation). 10 overall morbidity.	0	0
Frey et al, 2020[35] Case report n = 1, M = 1 Age = 60 BMI 38.9	Preoperative	A = 1, PH = 1	RYGB = 1	% EWL 41.3 at 1 year	0	0	0
Quezada et al, 2020[36] Case-Control study n = 16, F:M = 11:5 Mean age = 50 Mean BMI = 39.3	Preoperative	A = 16, Mean MELD score = 7.38, PH = 3	SG = 5 RYGB = 11	Mean % TWL 22.7, 27.4 and 28% at 6, 12 and 24 months respectively	2 (Clavien-Dindo Class ≥ III). 5 overall morbidity.	0	0
Kaul et al, 2020[13] Case series n = 22, F:M = 8:14 Mean age = 41.4 years Mean BMI = 48.8	Preoperative and intraoperative	A = 22, PH = 1	Not reported separately in cohort group	Mean weight decreased from 129.5 kg to 88.8 kg	1 transient liver decompensation in PH patient who had SG managed conservatively, 1 flank ecchymosis	1	1 late death at 6 months due to liver failure
Salman et al, 2020[12] Prospective Case series n = 71, F;M = 33:38 Mean age = 44.4 years Mean BMI = 44.1	Preoperative	A = 71, PH = 0	SG = 71	Mean weight loss after 30 months = 26.9 kg/21.7%	11 overall morbidity, 4 post-operative bleeding, 2 leak, 1 ascites, 1 mild hepatic encephalopathy, 1 chest infection needing intubation, 1 wound	2 (1 ascites, 1 mild hepatic encephalo pathy)	0

					infection, 1 dehydration		
Vuppalanchi et al, 2020 [37] Case-controlled study N = 106, F:M = 72:34 Mean age = 53 Mean BMI = 48	Preoperative and intraoperative	A = 102, B = 4, Portal hypertension preoperatively in 5 patients	RYGB = 87 SG = 18 GB = 1	Mean % TWL 17.2, 23.9 and 29.1 at 3, 6 and 12 months respectively	Intraoperative complication – 3.8% vs 1.6% in control, 90 day postoperative complications 13% vs 12.3% in control	3 ascites, 4 HE, 1 ascites and HE, 1 HE leading to multi-organ failure	1 early death due to HE, 2 late deaths, one due to multi-organ failure and another to ascites

BMI – Body Mass Index, EWL – excess weight loss, F – Female, GB – gastric band, H – hepatic encephalopathy, M – Male, PH – Portal Hypertension, RYGB – Roux-en-Y gastric bypass, SG – Sleeve Gastrectomy, TIPS - Transjugular intrahepatic portosystemic shunt, TWL – Total weight loss

Table 2: **Cumulative Quantitative Data from Studies Describing Bariatric Surgery in Cirrhotic patients**

Characteristic	**Numbers**
Number	467
Female	249/426 (58.5 %)
Procedures	RYGB: 186, SG: 222, GB: 17, BPD: 17
Child-Pugh Classification	A =368/380 (96.8 %), B= 12/380 (3.2 %)
Portal Hypertension Present	42/381 (11.0%)
Complications	88 (18.8 %)
Liver Decompensation	22 (4.7 %)
Early Mortality	3 (0.66 %)
Late Mortality	8 (1.76 %)

Table 3: **Outcomes of bariatric surgery among patients with portal hypertension**

Study	Number of patients	Complications	Liver decompensation	Related Mortality
Shimizu et al[24]	2	Not reported separately	Not reported separately	Not reported separately
Pestana et al[30]	4	0	0	0
Hanipah et al[21]	13	3 early (1 wound infection requiring debridement, 1 – intra-abdominal hematoma, 1 – subcutaneous hematoma)	0	0
García-Sesma et al[32]	2	0	0	0
Minambres et al [34]	11	Not reported separately	Not reported separately	0l
Frey et al[35]	1	0	0	0
Quezada et al[36]	3	Not reported separately	0	0
Kaul et al[13]	1	1 Liver decompensation managed conservatively	1	0
Vupppalanchi et al	5	Not reported separately	Not reported separately	Not reported separately

Table 4: **Results of patients with Cirrhosis undergoing sleeve gastrectomy**

Study	Number of patients	Complications	Liver decompensation	Related Mortality
Dallal et al[23]	3	0	0	0
Takata et al [26]	6	2 (1 - bleeding followed by ascites, 1 - encephalopathy)	2 (1 Early ascites, 1 encephalopathy)	0
Shimizu et al[24]	8	3 (1 – staple line leak, 1 – stricture, 1 – pneumonia)	0	0
Rebibo et al [27]	13	2 (1 - conversion to open for bleeding, 1 - postoperative haematoma)	1 (late ascites)	0
Lin et al [29]	20	5 (2 - superficial wound infection, 1 – transient renal insufficiency, 1 – bleeding managed conservatively, 1 – leak)	1 (transient encephalopathy)	1 Late death (4 years after staple line leak)

Pestana et al [30]	11	0	No separate breakdown available	0
Wolter et al [31]	11	No separate breakdown available		
Hanipah et al [21]	10	No separate breakdown available	0	0
García-Sesma et al [32]	8	0	0	0
Moulla et al [33]	3	0	0	0
Minambres et al[34]	28	No separate breakdown available	No separate breakdown available	0
Younus et al[3]	7	2	0	0
Quezada et al[36]	5	No separate breakdown available	0	0
Salman et al[12]	71	11 overall morbidity, 4 post-operative bleeding, 2 leaks, 1 ascites, 1 mild hepatic encephalopathy, 1 chest infection needing intubation, 1 wound infection, 1 dehydration	2 (1 ascites, 1 mild hepatic encephalopathy)	0
Vuppalanchi et al[37]	18	No separate breakdown available	1 (hepatic encephalopathy)	0
Total	222	25/150 (16.7%)	7/183 (3.83%)	1/222 (0.45%)

Table 5: **Results of patients with Cirrhosis undergoing Roux-En-Y Gastric Bypass**

Study	**Number of patients**	**Complications**	**Liver decompensation**	**Related Mortality**
Brolin et al [9]	7	2 (ascitic fluid leak through wound, marginal ulcer)	1 (Ascites)	3(1 Early death due to fulminant Hepatic Failure, 2 Late deaths -one congestive cardiac failure and one fulminant hepatic failure)
Dallal et al [23]	27	9 (1 leak, 4 acute tubular necrosis, 2 prolonged intubation, 1 ileus, 2 blood transfusion)	0	0

Shimizu et al [24]	14	4 (1 – anastomotic leak, 2 – stricture, 1 – infected hematoma)	0	0
Pestana et al[30]	3	0	No separate breakdown available	0
Wolter et al[31]	1	No separate breakdown available		
Hanipah et al[21]	3	No separate breakdown available	0	0
Moulla et al[33]	6	0	0	0
Minambres et al[34]	11	No separate breakdown available	No separate breakdown available	0
Younus et al[3]	15	7	0	0
Frey et al[35]	1	0	0	0
Quezada et al[36]	11	No separate breakdown available	0	0
Vuppalanchi et al[37]	87	No separate breakdown available	5 (3 ascites, 1 ascites and hepatic encephalopathy, 1 multi-organ failure)	3 (1 early death due to hepatic encephalopathy, 2 late deaths, one due to multi-organ failure and another to ascites)
Total	186	22/73 (28.6%)	6/172 (3.50%)	6/186 (3.22%)