Improving Outcomes of Bariatric Surgery in Patients With Cirrhosis in the United States: A Nationwide Assessment

Vijay S. Are, MD[1,2], Shannon M. Knapp, PhD[3], Ambar Banerjee, MD[4], Hani Shamseddeen, MD[1,2], Marwan Ghabril, MD[1,2], Eric Orman, MD[1,2], Kavish R. Patidar, DO[1,2], Naga Chalasani, MD[1,2] and Archita P. Desai, MD[1,2]

INTRODUCTION: **With increasing burden of obesity and liver disease in the United States, a better understanding of bariatric surgery in context of cirrhosis is needed. We described trends of hospital-based outcomes of bariatric surgery among cirrhotics and determined effect of volume status and type of surgery on these outcomes.**

METHODS: **In this population-based study, admissions for bariatric surgery were extracted from the National Inpatient Sample using *International Classification of Diseases, 9th and 10th Revision, Clinical Modification* codes from 2004 to 2016 and grouped by cirrhosis status, type of bariatric surgery, and center volume. In-hospital mortality, complications, and their trends were compared between these groups using weighted counts, odds ratios [ORs], and logistic regression.**

RESULTS: **Among 1,679,828 admissions for bariatric surgery, 9,802 (0.58%) had cirrhosis. Cirrhosis admissions were more likely to be in white men, had higher Elixhauser Index, and higher in-hospital complications rates including death (1.81% *vs* 0.17%), acute kidney injury (4.5% *vs* 1.2%), bleeding (2.9% *vs* 1.1%), and operative complications (2% *vs* 0.6%) ($P < 0.001$ for all) compared to those without cirrhosis. Overtime, restrictive surgeries have grown in number (12%–71%) and complications rates have trended down in both groups. Cirrhotics undergoing bariatric surgery at low-volume centers (<50 procedures per year) and nonrestrictive surgery had a higher inpatient mortality rate (adjusted OR 4.50, 95% confidence interval 3.14–6.45, adjusted OR 4.00, 95% confidence interval 2.68–5.97, respectively).**

DISCUSSION: **Contemporary data indicate that among admissions for bariatric surgery, there is a shift to restrictive-type surgeries with an improvement in-hospital complications and mortality. However, patients with cirrhosis especially those at low-volume centers have significantly higher risk of worse outcomes (see Visual abstract, Supplementary Digital Content, http://links.lww.com/AJG/B648).**

SUPPLEMENTARY MATERIAL accompanies this paper at http://links.lww.com/AJG/B646; http://links.lww.com/AJG/B647; http://links.lww.com/AJG/B648

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INTRODUCTION

Currently, more than 1 in every 3 persons are obese in the United States (1). Mirroring this trend, there has been an increase in prevalence of nonalcoholic steatohepatitis (NASH) and NASH-associated cirrhosis (2,3). In the United States, NASH-related cirrhosis is now the second leading cause for liver transplantation and is projected to become the leading cause over the next decade (4). In addition to a causative role in NASH-related cirrhosis, obesity negatively influences the course of cirrhosis irrespective of its etiology (5). Obese compensated cirrhotics are at 3 times risk of decompensation, and thus reduced survival, compared with their counterparts with normal weight (5). Finally, obesity has been linked to poor post-transplant outcomes including higher perioperative complications (6) and disease recurrence in 30%–60% nonalcoholic fatty liver disease (NAFLD) patients following liver transplantation at 1- and 5-year follow-up (7). Unfortunately, the prevalence of obesity among patients with cirrhosis presenting for liver transplantation has doubled since 1990s and has reached to more than 30% (8,9). Taken together, these data suggest that addressing obesity has become essential to clinical care of those with cirrhosis.

Sustained weight loss is a key pillar to obesity management; however, achieving this goal remains difficult for many individuals. Both in the general population and those with NASH, bariatric surgery has been proven to be more effective than medical therapy or other nonsurgical treatments for weight loss (10–12). Histological improvement has been shown after

[1]Division of Gastroenterology and Hepatology, Department of Medicine, Indiana University School of Medicine, Indianapolis, Indiana, USA; [2]Indiana Center for Liver Research, Indiana University School of Medicine, Indianapolis, Indiana, USA; [3]University of Arizona Health Sciences and Bio5 Institute, Tucson, Arizona, USA; [4]Department of Surgery, Indiana University School of Medicine, Indianapolis, Indiana, USA. **Correspondence:** Archita P. Desai, MD. E-mail: desaiar@iu.edu.
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biliopancreatic diversion surgery in obese cirrhotics, and it was proposed that bariatric surgery has additional metabolic benefits independent of weight loss (13). Despite these benefits of bariatric surgery in cirrhotics, it is established that perioperative mortality is higher in cirrhotic patients compared with noncirrhotic counterparts (14). Most existing studies looking at outcomes of bariatric surgery in cirrhotics have small number of subjects and/or were limited to a single tertiary center (15–17) or used data from the previous 2 decades (18). Bariatric surgical procedures have evolved since then, and many of the older procedures are no longer favored (19). Taken together, outcomes in cirrhotics undergoing bariatric surgery are not well-defined, making risk-benefit analysis of bariatric procedures in cirrhotic patients challenging.

Therefore, this study aims to describe hospital-based outcomes of bariatric surgery among individuals with cirrhosis in the modern era, identify the role of surgical volume on outcomes, and determine trends of these outcomes among patients with cirrhosis undergoing bariatric surgery in a nationwide sample.

METHODS

Study design

Data were obtained from Healthcare Cost and Utilization Project (HCUP)—National Inpatient Sample (NIS) database between 2004 and 2016 which is sponsored by the Agency for Healthcare Research and Quality. It is the largest all-payer inpatient database in the United States and collects data from a discharge sample of US hospitals from 46 states and the District of Columbia, covers 97% of the US population, estimating more than 35 million hospitalizations nationally (20). For all years, each hospitalization is deidentified and carries demographic and hospital characteristics as well as up to 30 procedure and diagnosis *International Classification of Diseases* (*ICD*) codes. Further details on the NIS design are available through HCUP (21).

Inclusion and exclusion criteria

We included all hospitalizations with codes for bariatric surgery with concurrent diagnosis of obesity and excluded admissions with diagnosis code for gastrointestinal cancers to enhance specificity (18,22). Admissions were included in the cirrhosis cohort if they contained at least 1 diagnosis code indicating cirrhosis. Diagnoses were extracted through *ICD 9th or 10th revision* diagnosis and procedure codes. Previous literature as well as www.ICD9Data.com and www.ICD10Data.com, which crosswalk between *ICD-9* and *ICD-10*, was used to identify diagnoses codes (see Supplementary Table 1, Supplementary Digital Content 2, http://links.lww.com/AJG/B647) (23).

Variables of interest

Bariatric procedures were grouped into restrictive and mixed based on mechanism of weight loss. The restrictive group included vertical banded gastroplasty, adjustable gastric banding, and sleeve gastrectomy (SG), whereas the mixed group included Roux-en-Y gastric bypass (RYGB) and biliopancreatic diversion with duodenal switch (see Supplementary Table 1, Supplementary Digital Content 2, http://links.lww.com/AJG/B647). Hospitals were divided into low volume *vs* high volume (<50 *vs* ≥ 50 bariatric procedures per year) (18,24) Using *ICD* diagnosis codes and HCUP-NIS comorbidity software, we identified etiology of liver disease, relevant comorbidities, and modified Elixhauser Comorbidity Index (liver disease excluded) (see Supplementary Table 1, Supplementary Digital Content 2, http://links.lww.com/AJG/B647) (25,26). Decompensated cirrhosis was defined as presence of diagnosis codes, indicating either ascites, variceal hemorrhage, and hepatic encephalopathy (see Supplementary Table 1, Supplementary Digital Content 2, http://links.lww.com/AJG/B647).

Outcomes

Our primary objective was to determine trends and inpatient outcomes in patients with cirrhosis undergoing bariatric surgery in a nationwide sample. Along with mortality, we studied the frequency of sepsis, acute kidney injury, pneumonia, urinary tract infections (UTIs), other infections (cellulitis, abscess, wound infections, and spontaneous bacterial peritonitis), bleeding, operative complication rates (anastomotic leaks, accidental cuts, punctures or perforations during surgery, disruptions of internal operation wound, foreign bodies accidentally left during procedure, and exploration or incision of hematoma), the cost per admission (adjusted to 2016 dollars), and length of stay (LOS) (see Supplementary Table 1, Supplementary Digital Content 2, http://links.lww.com/AJG/B647).

Statistical analysis

Using odds ratios (ORs) with 95% confidence intervals (CIs), we compared the cirrhosis and noncirrhotic groups both overall and stratified by high- *vs* low-volume centers and by type of bariatric surgery (restrictive *vs* mixed) as well as comparing decompensated and compensated cirrhotic groups. All the analyses incorporated sampling weights provided by HCUP (21). For binary variables such as in-hospital mortality, the trend in probability over time was modeled using logistic regression. For cost, we chose to trend the median cost over time using quantile regression due to skewed data. Because LOS is integer valued with primarily small numbers, we initially modeled the mean LOS using Poisson regression; however, we observed over dispersion relative to the Poisson, so over dispersed Poisson regression was used. For all analyses, we included effects of time and cirrhosis as well as the time-cirrhosis interaction effect. Because of the large time span covered, we did not assume a constant (linear) trend over time, but, instead, explored up to fifth-order polynomial effects over time for all models. For each outcome, the final model was selected through a combination of visual inspection of model-fit (comparing the observed to model-predicted values) and either Akaike Information Criteria (see Supplementary Table 2, Supplementary Digital Content 2, http://links.lww.com/AJG/B647) or examination of the statistical significance of higher-order terms.

RESULTS

Study cohort

From 2004 to 2016, there were an estimated 1,679,828 admissions for bariatric surgery, of which 9,802 (0.58%) were coded for cirrhosis. The annual number of admissions for bariatric surgery with cirrhosis generally increased over time, ranging from a low of 355 in 2007 to a high of 1,070 in 2016 (Figure 1). Type of surgery (restrictive *vs* mixed) was not different among both groups with 43% of noncirrhotics *vs* 43% of cirrhotics receiving restrictive procedures ($P < 0.0001$, Table 1). Over the study period, there was a change in the type of bariatric surgery that is preferred in

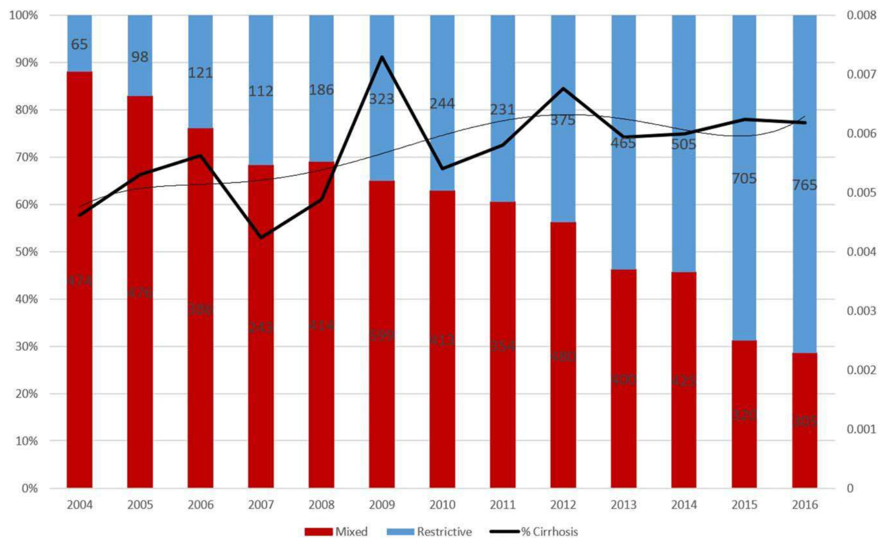

Figure 1. Bar graph depicts proportion of bariatric surgeries by type (restrictive *vs* mixed), and line graph with smoothed trend line shows percent of bariatric surgeries performed in cirrhotics. Number within the bar represents the annual weighted number of procedures performed in cirrhotics by category. A minority of admissions had codes for both procedure categories (2%) and were excluded while categorizing bariatric procedures.

both the groups. Mixed procedures were common in early period with an uptrend in proportion of restrictive procedures over the study period. By 2016, three-fourths of all procedures were restrictive (Figure 1). The mean cost of admission was substantially lower among admissions without cirrhosis compared to those with cirrhosis ($14,325 ± $30,994 *vs* $18,665 ± $45,008 for each, $P < 0.0001$), and the mean LOS was significantly higher in cirrhotics (noncirrhotics, 2.5 ± 8.7 days *vs* cirrhotics, 3.4 ± 10.5 days, $P < 0.0001$ (Table 1).

Cohort specific characteristics

Table 1 describes individual and hospital characteristics of those with and without cirrhosis. There were higher proportions of men in the cirrhotic group *vs* noncirrhotic group (30% *vs* 21%, $P < 0.0001$). Both groups differed in race with greater proportion of whites (72% *vs* 61%) and lower proportion of Hispanics (9.9% *vs* 9.8%) and blacks (13.3% *vs* 4.6%) in cirrhotics compared with noncirrhotics. Compared to admissions without cirrhosis, those with cirrhosis were more likely to have hypertension (68% *vs* 54%, $P < 0.0001$), dyslipidemia (27% *vs* 23%, $P < 0.0001$), diabetes (66% *vs* 31%, $P < 0.0001$), coronary artery disease (7% *vs* 3%, $P < 0.0001$), chronic pulmonary disease (4% *vs* 2%, $P < 0.0001$), chronic kidney disease (6% *vs* 2%, $P < 0.0001$), and smoking (20% *vs* 16%, $P < 0.0001$). Greater proportion of admissions with cirrhosis had bariatric surgery at a liver transplant center (31% *vs* 24%, $P < 0.0001$) and a teaching hospital (63% *vs* 59%, $P < 0.0001$) compared to those without cirrhosis.

In-hospital complications

Table 2 describes rates of in-hospital complications in both groups. ORs were adjusted for age, sex, and modified Elixhauser Comorbidity Index. Those with cirrhosis had higher odds for all complications analyzed except sepsis and pneumonia. These include higher odds of operative complications (adjusted OR [AOR] 1.92, 95% CI 1.66–2.21), UTIs (AOR 1.47, 95% CI 1.26–1.70), other infections (AOR 1.31, 95% CI 1.18–1.46), and acute kidney injury (AOR 1.49, 95% CI 1.34–1.66). The overall inpatient mortality rate was 0.17% for noncirrhotics. Importantly, cirrhotic patients had considerably higher in-hospital mortality (1.8%, AOR 4.36, 95% CI 3.72–5.12). When divided by hospitalizations coded for decompensated cirrhosis *vs* not, those with decompensation had higher odds of in-hospital mortality compared with those compensated cirrhosis (0.8% *vs* 22.1%, AOR 11.76, 95% CI 8.31–16.66), operative complications (AOR 6.18, 95% CI 4.28–8.93), bleeding (AOR 4.79, 95% CI 3.40–6.74), sepsis (AOR 11.73, 95% CI 8.26–16.65), UTI (AOR 3.13, 95% CI 2.05–4.76), pneumonia (AOR 6.35, 95% CI 3.90–10.34), other infections (AOR 5.02, 95% CI 3.75–6.72), and acute kidney injury (AOR 3.67, 95% CI 2.80–4.82) (Table 2).

Impact of center volume and type of surgery on outcomes

Table 3 describes adjusted odds of complications by volume status of the center and cirrhosis. Compared with high-volume centers, the odds of most complications were higher at low-volume centers in both cirrhotic and noncirrhotics. For example, the odds for AKI in cirrhotics undergoing bariatric surgery were 3 times higher in those at low-volume centers *vs* high-volume centers (AOR 2.76, 95% CI 2.09–3.65). In addition to complications, inpatient mortality was significantly higher at low-volume centers (AOR 4.50, 95% CI 3.14–6.45). This was true for noncirrhotics as well. Among cirrhotics, mean cost per admission and the mean LOS were higher at low-volume centers compared with high-volume centers ($30,059 ± $66,022 *vs* $17,936 ± $42,819, $P < 0.0001$ and 7.1 ± 15.4 days *vs* 3.2 ± 10.0 days, $P < 0.0001$, respectively).

Type of surgery also impacted outcomes in both noncirrhotics and cirrhotics (see Supplementary Table 3, Supplementary Digital Content 2, http://links.lww.com/AJG/B647). Mixed-type surgery was associated with higher odds of all complications analyzed in noncirrhosis admissions. In cirrhosis admissions, mixed-type bariatric procedures were associated with higher odds of in-hospital death (AOR 4.00, 95% CI 2.68–5.97), bleeding (AOR 1.81, 95% CI 1.39–2.37), sepsis (AOR 2.69, 95% CI 1.87–3.87), UTI (AOR 2.29, 95% CI 1.64–3.20), and acute kidney injury (AOR 1.83, 95% CI 1.48–2.26).

Table 1. Baseline characteristics of the cohort, cirrhosis *vs* no cirrhosis

Variable	Noncirrhotics (N = 1,670,025)	Cirrhotics (N = 9,802)	*P* Value
Demographics			
Age[a]	45 ± 26	53 ± 22	<0.0001
Male sex[b] (%)	21	30	<0.0001
Race (%)			<0.0001
White	61	72	
Hispanic ethnicity[c]	9.9	9.8	
Blacks[c]	13.3	4.6	
Others[c]	4.1	3.4	
Zip code–based income quartile (%)			
Quartile 1	22	22.2	
Quartile 2	25.1	25.9	0.840
Quartile 3	26.4	26.1	0.300
Quartile 4	24.2	23.9	0.460
Insurance type (%)			
Medicaid	9.9	9.2	
Medicare	13.3	29.2	<0.0001
Private	68.1	54.4	<0.0001
Other	8.4	6.1	0.200
Etiology (%)			
NASH	9.6	86.1	
Hepatitis C	0.3	9.0	
Alcohol	0.0	3.6	
Other	0.4	6.1	
Comorbid conditions			
Elixhauser Index[a]	2 ± 3	3 ± 3	<0.0001
Hypertension (%)	54	68	<0.0001
Diabetes (%)	31	66	<0.0001
Dyslipidemia (%)	23	27	<0.0001
Coronary artery disease (%)	3	7	<0.0001
COPD (%)	2	4	<0.0001
CKD (%)	2	6	<0.0001
Sleep apnea (%)	28	35	<0.0001
Smoking (%)	16	20	<0.0001
Hospital and procedure type			
High-volume center (%)	96	94	<0.0001
Teaching hospital (%)	59	63	<0.0001
Liver transplant center[d] (%)	24	31	<0.0001
Urban hospital (%)	97	97	0.020
Restrictive procedure (%)	45	46	<0.0001
Cost[a]	14,325 ± 30,994	18,665 ± 45,008	<0.0001
Length of stay[a]	2.5 ± 8.7	3.4 ± 10.5	<0.0001

CKD, chronic kidney disease; COPD, chronic pulmonary disease; NASH, nonalcoholic steatohepatitis.
[a]Mean ± SD.
[b]*vs* female.
[c]*vs* white race.
[d]A liver transplant center was defined as a hospital that performed at least 1 liver transplant during the year of admission (18).

Trends

Trends of complications and outcomes of interest were examined from 2004 to 2016 in those with and without cirrhosis (Figure 2a–c and see Supplementary Figure 1A–C, Supplementary Digital Content 1, http://links.lww.com/AJG/B646). Over the study period, the inpatient mortality rate decreased for both groups. In cirrhotics, there was an initial uptrend in the inpatient mortality rate which peaked around 2011–2012 and then trended downward. Despite this downtrend, inpatient mortality remained higher among admissions with cirrhosis compared to those without cirrhosis across all years (Figure 2a).

Rates of sepsis in cirrhotics initially rose with a peak in 2013 followed by a trend downward to approach that of noncirrhotics by 2016 (Figure 2b). The frequency of AKI also initially trended up in both the groups (Figure 2c); however, the increase was more prominent in the cirrhotic group. As with other complications, rates of AKI also peaked around 2011–2012 and then started to trend down. Across all years, the cirrhotic group persistently had higher frequency of AKI compared with noncirrhotics. Over time, the rate of bleeding complications among cirrhotics was undulating up to 2013, and then, there was a decline (see Supplementary Figure 1A, Supplementary Digital Content 1, http://links.lww.com/AJG/B646).

Over the study period, mean LOS decreased with time in cirrhotics but remained higher than in noncirrhotics (see Supplementary Figure 1B, Supplementary Digital Content 1, http://links.lww.com/AJG/B646). Median cost did not follow a clear linear trend, but, overall, a downward trend was observed (see Supplementary Figure 1C, Supplementary Digital Content 1, http://links.lww.com/AJG/B646). Nevertheless, hospitalization costs were persistently higher in cirrhotics compared with noncirrhotics across all years.

DISCUSSION

In this large, nationwide sample of admissions for bariatric surgery spanning 2004–2016, more cirrhotics are getting bariatric surgery over time, although these patients remain a small proportion of those undergoing bariatric surgery. We also describe important demographic differences between those who are cirrhotic and noncirrhotic. This is the first study to report trends of complications and outcomes in a nationwide sample of cirrhotics undergoing bariatric surgery and is novel in its use of *ICD-10* codes. We

Table 2. In-hospital complications, cirrhosis *vs* no cirrhosis

Type of complication	Noncirrhotics (N = 1,670,025)	All cirrhotics (N = 9,802)	Adjusted odds ratio[a,b] (95% CI)	Compensated cirrhotics (N = 9,356)	Decompensated cirrhotics (N = 446)	Adjusted odds ratio[a,c] (95% CI)
In-hospital death (%)	0.2	1.8	4.36 (3.72–5.12)	0.8	22.1	11.76 (8.31–16.66)
Operative complications[d] (%)	0.6	2.0	1.92 (1.66–2.21)	1.4	14.1	6.18 (4.28–8.93)
Bleeding (%)	1.1	2.9	2.10 (1.87–2.37)	2.4	12.1	4.79 (3.40–6.74)
Sepsis (%)	0.6	1.8	1.12 (0.96–1.32)	0.9	19.8	11.73 (8.26–16.65)
Urinary tract infection (%)	0.7	1.9	1.47 (1.26–1.70)	1.6	n < 10	[e]
Pneumonia (%)	0.5	1.0	0.91 (0.75–1.12)	0.7	n < 10	[e]
Other infections (%)	1.6	3.8	1.31 (1.18–1.46)	3.0	19.9	5.02 (3.75–6.72)
Acute kidney injury (%)	1.2	4.5	1.49 (1.34–1.66)	3.5	25.4	3.67 (2.80–4.82)

CI, confidence interval; HCUP, Healthcare Cost and Utilization Project.
[a]Adjusted for age, sex, and modified Elixhauser Index.
[b]Noncirrhotics vs all cirrhotics.
[c]Decompensated cirrhotics vs compensated cirrhotics.
[d]Anastomotic leak, accidental cut, puncture or perforation during surgery, disruption of internal wound, foreign body accidentally left during procedure, and exploration or incision of hematoma.
[e]Cannot report due to n < 10 as per HCUP guidelines https://www.hcup-us.ahrq.gov/db/publishing.jsp.

found that more restrictive procedures are being performed in cirrhotics. In parallel, hospitalization costs, in-hospital morbidity, and mortality are decreasing. Importantly, in cirrhotics, bariatric surgeries at low-volume centers have substantially inferior outcomes.

First, we show that those with cirrhosis who are admitted for bariatric surgery are more likely to be men compared with noncirrhotics. This is contrary to existing literature, which points to underutilization of bariatric surgery in men (27). Given that cirrhotics are more likely to be men, we would postulate the increased burden of cirrhosis might be the driver for higher rates of bariatric surgery in men. In fact, men were more likely to pursue bariatric surgery in the face of comorbidities, hereby supporting our hypothesis (27).

Second, the prevalence of Hispanics in both the groups was lower than expected in comparison with the US population, which is 18.3% (28). Our findings are in line with existing data, which points to a lower rate of weight loss surgeries among Hispanics compared with whites (29,30). It is known that Hispanics have the highest prevalence of NAFLD (31) and metabolic comorbidities, putting them at unique risk of NASH (32). By 2060, the Hispanic population is estimated to comprise 28% of the total US population (33). With changing demographics in the United States coupled with Hispanics having the highest prevalence of NAFLD, ethnic disparities in provision of bariatric surgery for cirrhotic patients need to be explored and future efforts are needed to improve the underutilization of bariatric procedures (22).

Importantly, our study helps to better define the risk of perioperative complications which plays an essential role in decision making before surgery. In our analysis, cirrhosis admissions had higher rates of complications and in-hospital mortality. Specifically, the adjusted odds of dying were 4.3 times higher in cirrhotics compared with noncirrhotics. This was in agreement with existing data (18,34). Furthermore, in those hospitalizations with complication of cirrhosis (ascites, variceal hemorrhage, or hepatic encephalopathy), the odds of in-hospital complications are even higher with a nearly 12-fold increase in mortality. Looking at measures of healthcare costs, admissions with cirrhosis during initial years (2004–2006) had higher costs with longer LOS. Notably, the rates of all complications including mortality as well as cost and LOS have trended down since 2012–2013. These trends are consistent with existing literature (22) and may be due to improving surgical expertise and shift in type of bariatric surgery to restrictive procedures and better patient selection.

Studies have shown improved outcomes for bariatric procedures performed at high-volume centers (35,36). Consistent with this, we observed that the odds of in-hospital complications and mortality were lower in high- *vs* low-volume centers. In fact, the inpatient mortality rate for cirrhotics at high-volume centers in our data is approximately equal to that after a laparoscopic cholecystectomy (37) and lower than that for hernia repair (38). Numerous reasons are quoted for better outcomes at high-volume centers including experience of surgeon, patient selection, and improved processes of care (36). Our data suggest that annual volume of bariatric surgeries at a center is crucial to consider when referring individuals with cirrhosis for bariatric surgery.

Beyond surgical center volume, we hypothesize that improved outcomes in cirrhotics are seen due to shift toward more restrictive surgeries. Since 2013, rates of RYGB are declining along with a steep increase in SG rates (22) which is now the most preferred procedure (39). Laparoscopic SG is associated with lesser postoperative bleeding compared with laparoscopic RYGB (40). Our data extend these findings in all-comers undergoing bariatric surgery to those with cirrhosis. First, the shift to restrictive procedures in cirrhotics temporarily coincide with lower in-hospital complications rates. Second, we show mixed-type bariatric procedures were associated with higher odds for in-hospital death, bleeding complications, sepsis, UTI, and acute kidney injury in cirrhotic admissions. Nonetheless, future studies are needed to confirm our hypothesis because better outcomes could also be due to other factors such as improved

Table 3. Complications and outcomes by volume status of the center

Complications/outcome	No cirrhosis				Cirrhosis			
	Low volume (N = 73,820)	High volume (N = 1,593,813)	Unadjusted or (95% CI)	Adjusted OR[a] (95% CI)	Low volume (N = 570)	High volume (N = 9,227)	Unadjusted or (95% CI)	Adjusted OR[a] (95% CI)
In-hospital death (%)	1.07	0.13	8.18 (7.53–8.88)	5.65 (5.19–6.16)	7.89	1.44	5.87 (4.14–8.33)	4.50 (3.14–6.45)
Operative complications (%)	2.03	0.57	3.61 (3.42–3.82)	3.35 (3.17–3.54)	3.40	1.92	1.80 (1.12–2.90)	1.77 (1.10–2.87)
Bleeding (%)	1.58	1.04	1.52 (1.43–1.61)	1.46 (1.38–1.55)	2.55	2.89	0.88 (0.51–1.50)	0.82 (0.48–1.40)
Sepsis (%)	3.68	0.46	8.18 (7.82–8.55)	6.71 (6.41–7.02)	9.55	1.28	8.17 (5.85–11.40)	6.86 (4.87–9.66)
Pneumonia (%)	2.31	0.46	5.12 (4.85–5.40)	4.62 (4.37–4.87)	5.26	0.74	7.49 (4.83–11.61)	7.14 (4.57–11.15)
Urinary tract infection (%)	2.50	0.61	4.16 (3.95–4.37)	3.76 (3.58–3.96)	7.08	1.53	4.91 (3.42–7.05)	4.91 (3.40–7.10)
Other infections (%)	5.92	1.37	4.53 (4.38–4.69)	4.13 (4.00–4.27)	14.88	3.11	5.45 (4.21–7.06)	5.49 (4.21–7.15)
Acute kidney injury (%)	4.73	1.02	4.83 (4.652–5.01)	3.84 (3.69–3.99)	12.01	4.02	3.26 (2.48–4.26)	2.76 (2.09–3.65)
Length of stay[b] (d)	4.6 ± 18.0	2.4 ± 7.9	<0.0001[c]	—	7.1 ± 15.4	3.2 ± 10.0	<0.0001[c]	—
Cost per admission (2016$)[b]	20,320 ± 56,143	14,046 ± 29,155	<0.0001[c]	—	30,059 ± 66,022	17,936 ± 42,819	<0.0001[c]	—

CI, confidence interval; OR, odds ratio.
[a]Adjusted for age and sex.
[b]Mean ± SD.
[c]*P* value.

patient selection, refined anesthetic and surgical techniques, and better training of personnel involved in perioperative care (41).

In addition to decreasing complications rates, we also noted lower costs associated with bariatric surgery in cirrhotics over time. Despite this, costs remained higher in cirrhotics than noncirrhotics. It is possible that the downtrend in cost is associated increasing use of SG which is much cheaper compared with RYGB; however, this association would need to be explored further in future studies (22). In addition, the persistent difference between cirrhotics and noncirrhotics could be explained by increased frequency of complications and complexity of care in the cirrhosis cohort. Although costs are higher in cirrhotics, it is important to note that the cost of 1 bariatric surgery hospitalization is comparable with the cost of 1 hospital admission for decompensation in cirrhotics (42). Our data are in line with a recent report of cost effectiveness of bariatric surgery in NASH cirrhosis (43).

Finally, our data support underutilization of bariatric surgery despite improving outcomes of bariatric surgery. Specifically, the estimated number of bariatric surgery admissions with cirrhosis over a 12-year period was 9,802 (weighted number). Considering that up to 6% of US population could be affected with NASH (3,44), more bariatric surgeries would be expected among cirrhotics. Campos et al. recently reported underutilization of bariatric procedures in the United States (22). Our data support this conclusion may apply to obese cirrhotics as well. Future studies should explore the reasons for underutilization, and measures to improve eligibility for bariatric procedures in cirrhotics should be instituted.

We do acknowledge limitations with our study. The number of in-hospital deaths among cirrhotics was low overall, preventing detailed analysis to identify factors independently associated with poor outcomes. Owing to the retrospective nature of the data, we can only comment on associations. In addition, although we could not apply validated measures of liver disease severity such as model for end-stage liver disease or Child-Pugh scores, it is unlikely that those with decompensated liver disease would undergo elective bariatric surgery. Use of an administrative data set can also lead to undercoding of conditions associated with obesity such as hypertension and diabetes in those with cirrhosis (25,42). Despite this limitation, our NIS analysis captured up to 30 diagnostic and procedure codes, ensuring that the most important diagnoses and procedures are cataloged.

Our study has important notable strengths. By using nationwide data, our conclusions are supported by a large sample size and more generalizable to the entire US population (20). In addition, this is the first study to capture longitudinal trends of postsurgical complications at national level over a 12-year period among cirrhotics undergoing bariatric procedures. Therefore, compared with previous studies on this topic, our findings are more relevant in the era of modern bariatric surgery. Our data also provide unique insight into the importance of center volume in influencing outcomes. Finally, this is also the first study to use *ICD-10* codes to study the cohort with cirrhosis undergoing bariatric surgery.

In conclusion, as bariatric procedures evolved, restrictive procedures are being preferred and in-hospital complications, mortality rates, median cost, and LOS are trending down overtime among admissions for bariatric surgery in those with cirrhosis. Despite these gains, the complication rates experienced by cirrhotics undergoing bariatric surgery at low-volume centers remain significant. Future studies which aim to further refine center characteristics and surgical practices leading to the best

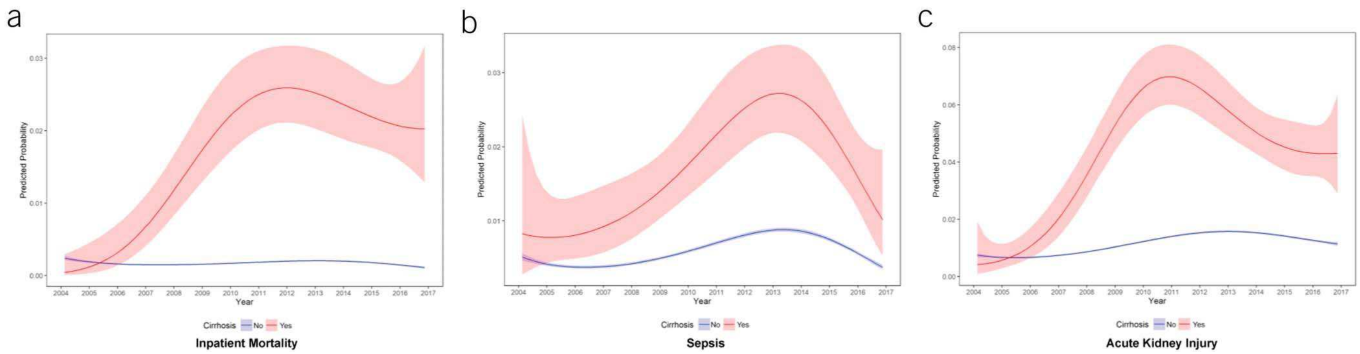

Figure 2. Regression analyses showing predicted trends of outcomes after bariatric surgery in hospitalized cirrhotics and noncirrhotics. Colored bands show 95% confidence interval. (**a**) Inpatient mortality. (**b**) Sepsis. (**c**) Acute kidney injury.

outcomes are needed to combat the growing burden of obesity and liver disease in the United States.

CONFLICTS OF INTEREST

Guarantor of the article: Archita P. Desai, MD.

Specific author contributions: V.S.A. and A.P.D.: study concept and design. V.S.A., S.M.K., A.B., and A.P.D.: data analysis. V.S.A. and A.P.D.: manuscript preparation. All authors: critical manuscript review.

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Study Highlights

WHAT IS KNOWN

- ✓ Obesity-related liver disease is surging in the United States with limited therapeutic options.
- ✓ Bariatric surgery is effective, but trends in utilization and outcomes in cirrhotics are unknown.

WHAT IS NEW HERE

- ✓ Overtime, bariatric surgeries are increasing in cirrhotics and restrictive procedures are performed more commonly.
- ✓ In-hospital complications, mortality after bariatric procedures are at an all-time low in cirrhotics.
- ✓ Center-specific procedure volume significantly influences outcomes for cirrhotics in the era of modern bariatric surgery.

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