A comparison of endoscopic and non-endoscopic biliary intervention outcomes in patients with prior bariatric surgery

ABSTRACT

Background and study aims Endoscopic biliary intervention (BI) is often difficult to perform in patients with prior bariatric surgery (BRS). We sought to analyze outcomes of patients with prior BRS undergoing endoscopic and non-endoscopic BI.

Patients and methods The Nationwide Inpatient Sample (2007–2011) was reviewed to identify all adult inpatients (≥18 years) with a history of BRS undergoing BI. The clinical outcomes of interest were in-patient mortality, length of stay (LOS), and total hospital charges.

Results There were 7,343 patients with prior BRS who underwent BIs where a majority were endoscopic (4,482 vs. 2,861, \( P < 0.01 \)). The mean age was 50±30.8 years and the majority were females (80.5%). Gallstone-related disease was the most common indication for BI and managed more often with primary endoscopic management (2,146 vs. 1,132, \( P < 0.01 \)). Inpatient mortality was not significantly different between patients undergoing primary endoscopic versus non-endoscopic BI (0.2% vs. 0.7%, \( P = 0.2 \)). Patients with sepsis were significantly more likely to incur failed primary endoscopic BI (OR 2.74, 95% CI 1.15, 6.53) and were more likely to be managed with non-endoscopic BI (OR 2.13, 95% CI 1.3, 3.5). Primary non-endoscopic BI and failed endoscopic BI were both associated with longer LOS (by 1.77 days, \( P < 0.01 \) and by 2.17 days, \( P < 0.01 \), respectively) and higher hospital charges (by $11,400, \( P < 0.01 \) and by $14,200, \( P < 0.01 \), respectively).

Conclusion Primary endoscopic management may be a safe and cost-effective approach for patients with prior BRS who need BI. While primary endoscopic biliary intervention is more common, primary non-endoscopic intervention may be used more often for sepsis.

Introduction

Morbid obesity continues to rise significantly in the United States and now affects approximately 1 in 15 adults [1, 2]. Bariatric surgery (BRS) leads to sustained weight loss and improvements in morbidity and mortality [3, 4]. Morbidly obese individuals, especially those with a body mass index (BMI) ≥ 40, have been shown to have an 8-fold higher risk of gallstone formation compared with those with a lower BMI [5]. After BRS, the rapid weight loss often accelerates gallstone formation which may...
predispose to acute cholecystitis, acute pancreatitis, and ascending cholangitis [6]. Despite this risk, prophylactic concomitant cholecystectomy is not often performed due to its association with increased BRS complications and only a minority of patients developing symptomatic gallstone disease [7,8]. Patients with prior BRS often require biliary intervention including endoscopic retrograde cholangio-pancreatography (ERCP) for choledocholithiasis, recurrent pancreatitis, pancreatobiliary neoplasms, biliary obstruction, and biliary leak [9–11].

Roux-en-Y gastric bypass (RYGB) constitutes the vast majority of BRSs, accounting for approximately 60%-70% of all BRSs [12]. In patients with prior RYGB BRS that require biliary intervention, alteration of the normal foregut anatomy may make access to the native biliary tree very challenging. Conventional ERCP has a success rate of approximately 50% in patients with prior Whipple resection, with significant higher success rates (84%) when used for biliary indications [13]. Transgastric access with laparoscopic methods along with endoscopic single and double balloon enteroscopy, have been described with varying methods of success [9,14]. In patients with prior RYGB, a laparoscopic-assisted transgastric access with ERCP is recommended for assessment of the duodenum and biliary tree, and evaluation of chronic abdominal pain [15].

To our knowledge, there are no large population-based studies comparing endoscopic (laparoscopic or enteroscopy-assisted ERCP) versus non-endoscopic (percutaneous cholangiography and surgical common bile duct exploration) procedures in patients with prior BRS that require biliary intervention. Thus, our aim was to estimate the prevalence of biliary interventions in patients with prior BRS and to evaluate clinical outcomes comparing endoscopic and non-endoscopic approaches. The clinical outcomes of interest were in-patient mortality, length of stay (LOS), and total hospital charges.

Patients and methods

Data source

The Nationwide Inpatient Sample (NIS) Healthcare Cost Utilization Project (HCUP), an administrative claims database, is the largest all-payer inpatient care database in the US [16]. The NIS is a compilation of more than 8 million inpatient admissions from approximately 1000 hospitals (representing about 85% of all nonfederal hospitals). It is designed to approximate a 20% stratified probability sample of patients from all nonfederal acute-care hospitals in the US. Discharge weights are provided, which allows extraction of national level estimates from the unweighted database information [16].

The NIS-HCUP database was queried from 2007 to 2011 using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis and procedure for all adult patients (≥ 18 years) with a history of BRS undergoing biliary procedures (ERCP, percutaneous cholangiography (PTC) and surgical common bile duct exploration (CBDE). Due to the limited specificity of ICD-9-CM coding, we were unable to distinguish between laparoscopic, or enteroscopy-assisted ERCP. Therefore, these procedures were grouped into 1 category referred to as endoscopic biliary interventions. Primary endoscopic intervention is defined as the performance of any endoscopic biliary intervention as the initial procedure for treatment. Primary non-endoscopic intervention is similarly defined as the performance of either PTC or CBDE as the initial therapeutic technique. Failed endoscopic intervention was defined as the performance of a non-endoscopic biliary intervention (PTC or CBDE) within 7 days after a primary endoscopic intervention. A history of prior BRS, etiologic factors for biliary intervention and associated diagnoses, and specific types of biliary intervention were queried by using specific ICD-9-CM codes (Appendix 1).

The Ohio State University Data and Specimen Policy and Human Subjects Research Policy does not require Institutional Review Board approval for population-based public data sets. Per 45 Code of Federal Regulations (CFR 46.101), research using certain publicly available data sets does not involve “human subjects.”

Patients and outcomes

Patient-level variables included age, sex, race, median household income for patient’s zip code (quartiles), and insurance status. Race/ethnicity was categorized as White, Black, Hispanic, and others. Insurance status was categorized as Medicare, Medicaid, private insurance, and uninsured/other based on the primary payer listed on the discharge record. Comorbidities for risk adjustment were derived from Agency for Healthcare Research and Quality (AHRQ) comorbidity measures based on the methods by Elixhauser [17]. Patients were given a score of <3 or ≥3 based on the number of comorbidities. Hospital-related potential confounders were hospital location (urban vs. rural), hospital bed size (large, medium, small), and hospital teaching status (teaching vs. nonteaching). Hospital bed size was classified as small, medium, or large based on an algorithm developed by HCUP. Hospital region was classified by the US Census Bureau as Northeast, Midwest, South, or West.

Clinical outcomes of interest were inpatient mortality, LOS, and total hospital charges and we compared these in 2 groups of patients with prior BRS: (a) patients requiring primary endoscopic versus non-endoscopic biliary intervention, and (b) patients undergoing failed versus successful endoscopic biliary interventions. The LOS and total hospital charges were collectively referred to as healthcare resource utilization.

Statistical analysis

Categorical variables and continuous variables were tested for statistical significance with Chi-square tests and t tests, respectively. The mean and standard deviation were calculated for all continuous outcomes and frequency counts and percentages were calculated for all categorical outcomes. Temporal trends were assessed using the Cochran-Armitage trend test. Univariate predictor variables with a P value <0.1 were included in the multivariate analysis. Multivariate linear regression models were fit for continuous outcome variables and multivariate logistic regression models were fit for each dichotomous outcome. All results in the regression model were represented by an odds ratio (OR) and 95% confidence interval (CI). All regression models were performed separately. Statistical significance
was defined by \( P < 0.05 \). These analyses were performed on weighted data from the NIS database using SAS 9.3 (SAS Institute, Cary, NC) employing appropriate survey procedures to produce national estimates.

Missing data is enlisted in Appendix 2. Race was the variable with the most missing data (9.4\%) since certain states do not document race in discharge information. Other variables had less than 1\% missing data and these were dropped from the final analysis. Imputation was not performed as data was assumed to be missing at random.

## Results

### Trends in bariatric surgery, cholecystectomy, and biliary drainage procedures

The trends in the different types of bariatric surgeries performed in the United States from 2005 to 2011 are illustrated in Appendix 3a. During this time period, the proportion of RYGBs decreased from 81.9\% (97,814 out of 119,382 total BRSs) to 58.3\% (63,178 of 108,354), while the proportion of sleeve gastrectomies and gastric band surgeries increased from 18.1\% to 41.7\%. The proportion of patients undergoing simultaneous cholecystectomies at the time of BRS decreased from 8.3\% in 2005 (9,880 of 119,382) to 3.4\% in 2011 (3,653 of 108,354), \( P < 0.001 \) (Appendix 3b). Between 2007 and 2011, there were a total of 988,015 patients discharged with a diagnostic code for history of BRS. The proportion of admissions as well as the total number of patients with prior BRS doubled from 2007 to 2011 (126,872 [0.32\%] to 250,395 [0.65\%], \( P < 0.001 \)) (Fig. 1).

For patients with a history of BRS, the proportion of primary endoscopic interventions increased (435 [61.3\%] to 1,346 [66.7\%], \( P < 0.001 \)) between 2007 and 2011 while the proportion of primary non-endoscopic interventions generally decreased (275 [38.7\%] to 672 [33.3\%], \( P < 0.001 \)) (Fig. 2).

### Patient characteristics and procedure indications

From 2007 to 2011, there were 7,343 (0.74\% of 988,015) patients with a history of BRS who underwent a biliary intervention. The majority of these patients underwent an endoscopic intervention compared to non-endoscopic interventions (2,146 [47.9\%] and 1,132 [39.6\%] respectively, \( P < 0.001 \)). Biliary intervention in BRS was more frequent in women and in large urban hospitals. Most procedures (endoscopic or non-endoscopic) were performed within 1 day of hospitalization. A majority of all endoscopic and non-endoscopic interventions were performed for gallstone-related disease (2,146 [47.9\%] and 1,132 [39.6\%] respectively). Among patients that underwent non-endoscopic interventions, more required PTC (1,692 [59\%]) compared to CBDE (1,169 [41\%]) (Appendix 4).

### Endoscopic versus non-endoscopic biliary intervention

#### Demographics and hospital variables

Univariate analysis (Table 1) revealed that patients who underwent a primary endoscopic biliary intervention were younger, with fewer comorbid conditions, and were treated at teach-
Table 1  Demographics, etiological associations, and outcomes of patients with a history of bariatric surgery undergoing endoscopic or non-endoscopic biliary intervention: Comparison of endoscopic versus non-endoscopic (PTC/CBDE) in the Nationwide Inpatient Sample from 2007 to 2011.

| Total: 7,343 | Endoscopic Intervention n=4,482 (%) | Non-endoscopic Intervention n=2,861 (%) | P value |
|--------------|------------------------------------|----------------------------------------|---------|
| Age (mean, SD) | 50.11 30.76 | 52.14 26.25 | 0.0039 |
| Gender | | | 0.0003 |
| Male | 728 16.25% | 705 24.66% | | |
| Female | 3,754 83.75% | 2,156 75.34% | | |
| Race | | | 0.1189 |
| White | 3,131 76.85% | 2,105 81.48% | | |
| Black | 402 9.86% | 252 9.76% | | |
| Hispanic | 396 9.71% | 167 6.46% | | |
| Other | 146 3.58% | 60 2.31% | | |
| Income (national quartile) | | | 0.4937 |
| 1 | 948 21.48% | 561 20.12% | | |
| 2 | 1,145 25.95% | 765 27.43% | | |
| 3 | 1,131 25.63% | 793 28.41% | | |
| 4 | 1,189 26.95% | 671 24.04% | | |
| Type of insurance | | | 0.2303 |
| Medicare | 1,129 25.19% | 833 29.11% | | |
| Medicaid | 297 6.62% | 136 4.74% | | |
| Private | 2,620 58.45% | 1,646 57.53% | | |
| Other | 436 9.74% | 247 8.63% | | |
| Hospital location | | | 0.0815 |
| Rural | 167 3.78% | 163 5.73% | | |
| Urban | 4,243 96.22% | 2,678 94.27% | | |
| Hospital teaching status | | | 0.0218 |
| Nonteaching | 1,835 41.61% | 1,396 49.14% | | |
| Teaching | 2,575 58.39% | 1,445 50.86% | | |
| Hospital size | | | 0.8159 |
| Small | 386 8.75% | 252 8.86% | | |
| Medium | 898 20.36% | 621 21.87% | | |
| Large | 3,126 70.88% | 1,968 69.28% | | |
| Hospital region | | | 0.0603 |
| Northeast | 942 21.02% | 535 18.69% | | |
| Midwest | 1,087 24.25% | 540 18.88% | | |
| South | 1,321 29.48% | 1,057 36.96% | | |
| West | 1,132 25.25% | 729 25.48% | | |
| Weekend admission | | | 0.4549 |
| No | 3,717 82.94% | 2,331 81.46% | | |
| Yes | 765 17.06% | 530 18.54% | | |
| Elixhauser comorbidity Index | | | <0.0001 |
ing hospitals compared to those requiring primary non-endoscopic interventions. Gallstone-related disease was associated with more frequent primary endoscopic management while pancreaticobiliary neoplasms and bile duct injury were associated with primary non-endoscopic management.

Presence of associated emergent conditions
Acute pancreatitis (AP), as an associated diagnosis, was more frequent in patients requiring an endoscopic approach; however, sepsis, as an associated diagnosis, was more frequent in patients undergoing non-endoscopic biliary interventions (Table 1). Multivariate analysis adjusting for demographics, hospital factors, and etiologies confirmed these findings. Sepsis was more than 2 times more likely to be associated with patients requiring non-endoscopic intervention (OR 2.13, 95% CI 1.30, 3.50, \( P = 0.003 \)). On the contrary, AP was more than 2 times more frequently associated with patients undergoing an endoscopic approach (OR = 2.44, 95% CI 0.30, 0.56, \( P < 0.001 \)).

Mortality and health care resource utilization
The overall in-hospital mortality rate for patients with prior BRS undergoing biliary intervention was 0.41% (30 of 7,343 patients). Inpatient mortality was not significantly different between patients undergoing primary endoscopic versus primary non-endoscopic procedures (0.22% vs. 0.69%, \( P = 0.2 \) (Table 1). However, non-endoscopic interventions were associated

| Table 1 (Continuation) |
|------------------------|
| Total: 7,343           |
| Endoscopic Intervention n = 4,482 (%) | Non-endoscopic Intervention n = 2,861 (%) | \( P \) value |
| • < 3 | 2,860 | 63.82% | 1,508 | 52.71% |
| • ≥ 3 | 1,622 | 36.18% | 1,353 | 47.29% |

Etiology
- Gallstone related: 2,146 (47.88%) vs. 1,132 (39.57%), \( P = 0.0023 \)
- Pancreaticobiliary neoplasm: 81 (1.80%) vs. 197 (6.89%), \( P < 0.0001 \)
- Disease of bile duct: 223 (4.97%) vs. 96 (3.4%), \( P = 0.1383 \)
- Bile leak, bile duct injury, biliary peritonitis: 253 (5.63%) vs. 309 (10.81%), \( P = 0.0008 \)
- Bile duct obstruction and jaundice NOS: 262 (5.84%) vs. 186 (6.51%), \( P = 0.6299 \)
- Stent-related (changes, others): 134 (2.99%) vs. 53 (1.86%), \( P = 0.1597 \)
- Chronic pancreatitis: 54 (1.21%) vs. a, \( P = 0.00% \)
- Sphincter of Oddi dysfunction: 22 (0.50%) vs. a, \( P = 0.11% \)
- Abdominal pain: 41 (0.92%) vs. a, \( P = 0.00% \)

Time to PTC/CBDE or ERCP
- \(< 0 to 1 day\): 2,294 (51.19%) vs. 1,571 (54.90%)
- 2 – 4 days: 1,593 (35.53%) vs. 890 (31.11%)
- 5 – 10 days: 595 (13.27%) vs. 400 (13.99%)

Cholecystectomy: 1,697 (37.86%) vs. 1,135 (39.66%)

Associated diagnoses (DX1-DX25)
- Sepsis: 184 (4.10%) vs. 303 (10.58%), \( P < 0.0001 \)
- Acute pancreatitis: 1,146 (25.57%) vs. 360 (12.57%), \( P < 0.0001 \)
- Cholangitis: 532 (11.87%) vs. 387 (13.54%), \( P = 0.3403 \)

Outcome
- Death: a, 0.22% vs. 20, 0.69%, \( P = 0.2181 \)
- Length of stay ≥ 7 days: 1,215 (27.12%) vs. 1,352 (47.25%), \( P < 0.0001 \)
- Length of stay (mean, SD): 5.31, 9.46 vs. 7.40, 11.69, \( P < 0.0001 \)
- Total charges (mean, SD): 50,664, 92,279 vs. 64,349, 125,999, \( P < 0.0001 \)

\( \text{a) The cell’s value is not displayed. As per data agreements with AHRQ, researchers cannot report any statistics where the number of observations in any given cell of analyzed data is} \leq 10. \)

\( \text{CBDE, common bile duct exploration; ERCP, endoscopy retrograde cholangiopancreatography; PTC, percutaneous transhepatic cholangiography} \)
with a longer length of hospital stay and greater total hospital charges. More specifically, patients with a primary non-endoscopic intervention stayed 1.77 (95% CI 1.32, 2.21, \(P < 0.001\)) days longer and were charged $11,453 (95% CI 5,811, 17,095, \(P < 0.001\)) more than those with a primary endoscopic intervention (\(\text{Table 2}\)). Notably, patients who underwent any biliary intervention within 1 day of hospitalization accounted for significantly lower health care resource utilization (\(\text{Table 2}\)).

### Successful versus failed endoscopic interventions

#### Demographics and hospital variables

A total of 4,482 patients with history of BRS underwent primary endoscopic interventions. Procedure success and failure rates were 88.3% (n=3,956) and 11.7% (n=526) respectively, \(P<0.001\). Univariate analysis (\(\text{Table 3}\)) revealed that patients who had successful procedures were younger compared to patients who underwent failed procedures. Multivariate linear regression model for healthcare utilization in patients with a history of bariatric surgery undergoing biliary intervention, Nationwide Inpatient Sample, 2007 – 2011.

\(\text{Table 2}\) Multivariate linear regression model for healthcare utilization in patients with a history of bariatric surgery undergoing biliary intervention, Nationwide Inpatient Sample, 2007 – 2011.

| Length of stay | Total charges |
|----------------|---------------|
|                | Days 95% CI  | \(P\) value | $ 95% CI  | \(P\) value |
| Primary procedure |                |             |       |             |
| - ERCP Reference | <0.0001       | Reference   |           | <0.0001     |
| - CBDE/PTC 1.77 (1.32, 2.21) | 11,453 (5,811, 17,095) | \(P < 0.001\) |
| Age 0.01 (-0.01, 0.02) | 0.423 | -78 (-225, 69) | 0.3001 |
| Gender Male Reference | 0.7499 | Reference   |           | 0.0316     |
| - Female -0.09 (-0.61, 0.44) | -6,460 (-12,351, 569) | \(P < 0.001\) |
| Hospital location Rural Reference | 0.0854 | Reference   |           | <0.0001     |
| - Urban 0.64 (-0.09, 1.37) | 19,625 (12,775, 26,475) | \(P < 0.001\) |
| Hospital teaching status Nonteaching Reference | 0.9229 | Reference   |           | 0.7444     |
| - Teaching 0.03 (-0.54, 0.59) | -1,177 (-8,254, 5,901) | \(P < 0.001\) |
| Hospital region Northeast Reference | 0.9181 | Reference   |           | 0.0001     |
| - West -0.16 (-0.92, 0.59) | 14,764 (3,652, 25,876) | \(P < 0.001\) |
| - South 0.04 (-0.56, 0.64) | -2,088 (-11,703, 7,526) | \(P < 0.001\) |
| - Midwest 0.09 (-0.54, 0.72) | -6,548 (-16,804, 3,708) | \(P < 0.001\) |
| Elixhauser comorbidity Index <3 Reference | <0.0001 | Reference   |           | <0.0001     |
| - \(\geq 3\) 1.27 (0.79, 1.75) | 10,826 (5,559, 16,092) | \(P < 0.001\) |
| Gallstone related -0.79 (-1.21, -0.37) | 0.0002 | -3,651 (-8,654, 1,351) | 0.1525 |
| Pancreaticobiliary neoplasm 1.55 (-0.09, 3.19) | 0.0639 | 3,699 (-9,976, 17,373) | 0.5959 |
| Bile leak, bile duct injury, biliary peritonitis 0.79 (-0.37, 1.94) | 0.1806 | 5,833 (-6,525, 18,191) | 0.3547 |
| Chronic pancreatitis -1.35 (-1.89, -0.80) | <0.0001 | -18,484 (-38,533, 1,565) | 0.0707 |
| Time to PTC/CBDE or ERCP <0 to 1 day Reference | <0.0001 | Reference   |           | <0.0001     |
| - 2 – 4 days 1.72 (1.27, 2.16) | 12,004 (7,454, 16,553) | \(P < 0.001\) |
| - 5 – 10 days 6.29 (5.45, 7.14) | 43,740 (33,291, 54,189) | \(P < 0.001\) |

CBDE, common bile duct exploration; ERCP, endoscopy retrograde cholangiopancreatography; PTC, percutaneous transhepatic cholangiography;
those who had a failed procedure. Failed procedures were associated with more frequent cholecystectomies compared to successful procedures (47.1% and 36.6% respectively, \( P=0.04 \)).

**Presence of associated emergent conditions**

Acute pancreatitis was an associated diagnosis found more frequently in patients with successful endoscopic interventions while sepsis was an associated diagnosis more frequent in failed interventions (\( \text{Table 3} \)). Specifically, sepsis was more than 2.7 times more likely to be associated with failed endoscopic interventions (OR 2.74, 95% CI 1.15, 6.53, \( P=0.02 \)) compared to successful interventions.

**Mortality and health care resource utilization**

There was no documented death for patients with failed endoscopic interventions and all 10 deaths in the endoscopic intervention group occurred in patients with successful procedures. Failed endoscopic interventions accounted for greater healthcare resource utilization (longer LOS and greater total charges). Specifically, failed endoscopic interventions necessitated 2.17 (95% CI 1.79, 3.33, \( P<0.001 \)) additional days of stay and $14,214 (95% CI 3,749, 24,679, \( P=0.008 \)) more than successful interventions. Patients who underwent either successful or failed endoscopic intervention within 1 day of hospitalization accounted for significantly lower health care resource utilization, \( P<0.001 \).

**Discussion**

In this population-based study analysis of all biliary interventions in hospitalized patients with prior BRS from 2007 to 2011, we have demonstrated that gallstone disease is the most common indication for biliary intervention. To our knowledge, this is the most comprehensive population-based study comparing outcomes of endoscopic versus non-endoscopic interventions in patients with biliary disease and a prior history of BRS. For all patients with BRS needing biliary interventions, a majority underwent endoscopic (ERCP or enteroscopy-assisted or laparoscopic-assisted ERCP) guided procedure. Patients with sepsis were significantly more likely to incur failed primary endoscopic BI and were more likely to be managed with non-endoscopic BI. Although there was no difference in inpatient mortality comparing different types of biliary intervention, primary non-endoscopic interventions were associated with increased healthcare resource utilization. Failed endoscopic interventions did not result in greater inpatient mortality but did account for increased healthcare resource utilization.

Our study highlights recent trends in BRS including a steady decrease in RYGBs with a concomitant increase in sleeve gastrectomies; which is consistent with prior studies [18]. Multiple studies have illustrated the increase in prevalence of gallstones with rapid weight loss following BRS, although to varying degrees [5, 19]. Even though the total number of patients with a history of BRS doubled during the study period, the proportion of patients undergoing simultaneous cholecystectomies at the time of BRS decreased by approximately 60%. Another study analyzing NIS trends during BRS illustrated that the proportion of patients undergoing concomitant cholecystectomy decreased from 26.3% in 2001 to 3.7% in 2008 [8]. Concomitant cholecystectomy during gastric bypass surgery is no longer routine practice because operative time, postoperative hospital stay, and postoperative morbidity and mortality are higher with prophylactic cholecystectomy [20]. Several studies have indicated its use only in cases of symptomatic gallbladder disease, particularly cholelithiasis [21].

Among patients who required biliary intervention, the majority underwent primary endoscopic intervention compared to non-endoscopic intervention. The endoscopic intervention failure rate was 12%. However, the database does not differentiate between the 3 major types of bariatric surgeries and endoscopic biliary intervention is more difficult in patients with RYGB anatomy. Furthermore, prior studies have demonstrated that 60% to 70% of all BRS patients had RYGB; thus, we can project that the failure rate of endoscopic biliary intervention in patients with RYGB anatomy would be 17% to 20% [18]. This failure rate is comparable to prior literature. With the steady decrease in RYGBs along with an increase in sleeve gastrectomies, the success rate of endoscopic biliary interventions may rise in the future, as the latter procedure, in theory, allows for easier access to the papilla compared to the former. In long limb surgical bypass patients with suspected pancreatobiliary diseases, ERCP was successful in 63% of patients, and specifically in 88% when the papilla was reached [22]. Common reasons for ERCP failure include afferent limb entered but papilla not reached, cannulation failure, afferent limb angulation, and jejunojejunostomy not identified [22]. Thus, a safe and effective alternative to these modalities in RYGB patients is laparoscopic transgastric endoscopy [23, 24]. Laparoscopic-assisted ERCP has been shown to be superior than balloon enteroscopy assisted ERCP with a 100% rate of papilla identification, cannulation rate, and therapeutic success [25]. However, this procedure should be preferred in patients with Roux biliopancreatic limb (from ligament of Treitz to jejunoojejunal anastomosis) of 150 cm or longer while those with a limb length less than 150 cm should be offered deep enteroscopy-assisted ERCP first [25].

In this study, overall mortality with either endoscopic or non-endoscopic biliary intervention was 0.41% and there was no difference in mortality between the 2 groups. Notably, primary non-endoscopic and failed endoscopic interventions accounted for increased healthcare resource utilization. A cohort study utilizing administrative data demonstrated that in all patients presenting with biliary emergencies, failed ERCP and open cholecystectomy were associated with increased mortality and increased healthcare resource utilization [26]. Another retrospective analysis showed that failed ERCP prolongs hospital stays and increases costs of hospitalization [27]. The sickest patients in our study (those with sepsis) required primary or secondary non-endoscopic intervention and hence contributed to increased healthcare resource utilization. Failed ERCP may be a marker for sepsis resulting from delayed biliary decompression leading to increased need for hospital-based interventions. This association was demonstrated in this study where patients with sepsis were managed with non-endoscopic

Kamboj Amrit K et al. A comparison of... Endoscopy International Open 2018; 06: E11–E28
**Table 3** Demographics, etiological associations, and outcomes of patients with a history of bariatric surgery undergoing endoscopic intervention: Comparison of endoscopic intervention success in the Nationwide Inpatient database from 2007 to 2011.

| Total: 4,482 | Successful endoscopic intervention | Failed endoscopic intervention | P value |
|--------------|-----------------------------------|-------------------------------|---------|
|              | n = 3,956 (%)                     | n = 526 (%)                   |         |
| Age (mean, SD) | 49.68 ± 13.69                     | 53.35 ± 14.91                | 0.0132  |
| Gender        |                                   |                               |         |
| Male          | 650 (16.42%)                      | 79 (14.97%)                  | 0.6979  |
| Female        | 3,306 (83.58%)                    | 447 (85.03%)                 |         |
| Race          |                                   |                               |         |
| White         | 2,744 (76.14%)                    | 387 (82.26%)                 | 0.0901  |
| Black         | 351 (9.75%)                       | 50 (10.70%)                  |         |
| Hispanic      | 368 (10.21%)                      | 28 (5.89%)                   |         |
| Other         | 140 (3.89%)                       | a (1.15%)                    |         |
| Income (national quartile) |                 |                               | 0.2689  |
| 1             | 823 (21.11%)                      | 125 (24.20%)                 |         |
| 2             | 984 (25.26%)                      | 161 (31.12%)                 |         |
| 3             | 1,006 (25.81%)                    | 125 (24.29%)                 |         |
| 4             | 1,084 (27.82%)                    | 105 (20.39%)                 |         |
| Type of insurance |                               |                               | 0.5429  |
| Medicare      | 967 (24.43%)                      | 162 (30.85%)                 |         |
| Medicaid      | 262 (6.61%)                       | 35 (6.71%)                   |         |
| Private       | 2,342 (59.22%)                    | 277 (52.71%)                 |         |
| Other         | 385 (9.74%)                       | 51 (9.74%)                   |         |
| Hospital location |                             |                               | 0.7970  |
| Rural         | 149 (3.84%)                       | 18 (3.36%)                   |         |
| Urban         | 3,740 (96.16%)                    | 503 (96.64%)                 |         |
| Hospital teaching status |                     |                               | 0.7989  |
| Nonteaching   | 1,624 (41.76%)                    | 211 (40.44%)                 |         |
| Teaching      | 2,265 (58.24%)                    | 310 (59.56%)                 |         |
| Hospital size |                                   |                               | 0.0486  |
| Small         | 354 (9.10%)                       | 32 (6.16%)                   |         |
| Medium        | 829 (21.31%)                      | 69 (13.25%)                  |         |
| Large         | 2,706 (69.59%)                    | 420 (80.59%)                 |         |
| Hospital region |                               |                               | 0.6458  |
| Northeast     | 851 (21.52%)                      | 91 (17.28%)                  |         |
| Midwest       | 969 (24.49%)                      | 118 (22.45%)                 |         |
| South         | 1,153 (29.14%)                    | 168 (32.00%)                 |         |
| West          | 983 (24.85%)                      | 149 (28.27%)                 |         |
| Weekend admission |                             |                               | 0.1778  |
| No            | 3,261 (82.43%)                    | 457 (86.81%)                 |         |
| Yes           | 695 (17.57%)                      | 69 (13.19%)                  |         |
interventions and more likely to incur failed ERCP. However, difficulties in timing an endoscopic intervention appropriately may explain why patients with sepsis were more often managed with non-endoscopic interventions. A statistically significant mortality difference may have not been seen due to the relatively low death rate and improvements in the management of sepsis [28, 29].

Early biliary intervention in patients with a history of BRS is critical when clinically indicated as patients who underwent biliary intervention within 1 day of hospitalization accounted for significantly lower health care resource utilization. The literature on the timing of endoscopic intervention after hospital admission in patients with BRS remains limited; however, early ERCP has been described in the non-bariatric population. A prospective multicenter study analyzing early ERCP (within 72 hours) versus conservative treatment for acute non-obstructive biliary pancreatitis found that early ERCP was not beneficial in these patients [30]. Other systematic reviews have also found that early ERCP does not effect mortality and complications in patients with acute gallstone pancreatitis compared to conser-

Table 3 (Continuation)

| Etiology                                                                 | Successful endoscopic intervention n = 3,956 (%) | Failed endoscopic intervention n = 526 (%) | P value |
|--------------------------------------------------------------------------|-------------------------------------------------|------------------------------------------|---------|
| Elixhauser comorbidity index                                              |                                                 |                                          | 0.2182  |
| ▪ < 3                                                                   | 2,553                                           | 64.53%                                   |         |
| ▪ ≥ 3                                                                   | 1,403                                           | 35.47%                                   |         |
| ETIOLOGY                                                                 |                                                 |                                          |         |
| Gallstone related                                                        | 1,863                                           | 47.11%                                   | 0.2901  |
| Pancreaticobiliary neoplasm                                              | 76                                              | 1.93%                                    | 0.2917  |
| Disease of bile duct                                                     | 207                                             | 5.23%                                    | 0.2783  |
| Bile leak, bile duct injury, biliary peritonitis                         | 202                                             | 5.11%                                    | 0.1312  |
| Bile duct obstruction and jaundice NOS                                   | 218                                             | 5.52%                                    | 0.3393  |
| Stent related (changes, others)                                          | 125                                             | 3.16%                                    | 0.2898  |
| Chronic pancreatitis                                                     | 54                                              | 1.38%                                    |         |
| Sphincter of Oddi dysfunction                                             | 22                                              | 0.56%                                    |         |
| Abdominal pain                                                           | 36                                              | 0.91%                                    | 0.9534  |
| Time to ERCP                                                             |                                                 |                                          | 0.4979  |
| ▪ < 0 to 1 day                                                           | 2,029                                           | 51.29%                                   |         |
| ▪ 2 – 4 days                                                             | 1,419                                           | 35.88%                                   |         |
| ▪ 5 – 10 days                                                            | 507                                             | 12.83%                                   |         |
| Cholecystectomy                                                          | 1,449                                           | 36.63%                                   | 0.0401  |
| Associated diagnoses (DX1-DX25)                                          |                                                 |                                          |         |
| Sepsis                                                                   | 130                                             | 3.27%                                    | 0.0286  |
| Acute pancreatitis                                                       | 1,047                                           | 26.47%                                   | 0.0429  |
| Cholangitis                                                              | 444                                             | 11.23%                                   | 0.1715  |
| Outcome                                                                  |                                                 |                                          |         |
| Death                                                                    | a                                               | 0.25%                                    |         |
| Length of stay ≥ 7 days                                                  | 964                                             | 24.37%                                   |         |
| Length of stay (mean, SD)                                                | 5.03                                            | 4.03                                      |         |
| Total charges (mean, SD)                                                 | 48,981                                          | 41,197                                    |         |

a) The cell’s value is not displayed. As per data agreements with AHRQ, researchers cannot report any statistics where the number of observations in any given cell of analyzed data is ≤ 10.

ERCP, endoscopy retrograde cholangiopancreatography
tive treatment [31,32]. However, in patients with co-existing cholangitis and biliary obstruction, early ERCP significantly reduced mortality and complications [31].

Given changing trends in prevalence of different types of BRS during the study period, we performed a univariate and multivariate sensitivity analysis of the study time period. Specifically, we dichotomized the study period into 2007–2008 and 2009–2011. Prior studies have demonstrated that gallstone-related problems are typically seen within 1 to 2 years of bariatric surgery [33]. In one study, the mean follow-up time to cholecystectomy for symptomatic gallstone disease after BRS was 21.5 months [33]. Accordingly, we dichotomized the years into these 2 categories as our trend analysis demonstrated that the decrease in RYGB and increase in sleeve gastrectomies was after 2008. Endoscopic biliary intervention was significantly more frequent in the later time period, 2009–2011 (62.9%), compared to 2007–2008 (55.7%) (P=0.05). However, we found that there were higher total charges (by $6,378, P=0.03) in 2009–2011 (not adjusted for inflation) and no differences in the length of stay (by 0.07 days, P=0.77) (Appendix 5). Moreover, there were no differences between successful and failed interventions during the 2 time periods. While successful endoscopic interventions were more frequent in 2009–2011 (89.2%) compared to 2007–2008 (85.1%), this difference was not statistically significant (P=0.13), and this did not impact health care utilization (Appendix 6).

As with all administrative databases, coding errors represent a potential limitation of the present study. In the absence of a national bariatric surgery registry, NIS represents a great data source for different types of BRS given its sophisticated sampling design and large number of observations. However, the code for prior-BRS (v45.86) is a v-code, which unfortunately does not detail the various types of bariatric surgeries. However, based on prior studies, we can project that 60% to 70% of all BRS patients had RYGB anatomy [18]. Moreover, the ICD-9 code for BRS has been utilized in other studies in the literature [12, 34]. In addition to the potential for miscoding, some unique features of the NIS database should be recognized. First, this study was unable to differentiate between endoscopic and laparoscopic-guided ERCP due to a lack of specificity in the ICD-9 codes. Second, the presence of an ICD-9 code for gallstones only proves an association but doesn’t convey causality. Third, this database is unable to differentiate distinctive patients, and therefore patients with recurrent biliary interventions could be represented multiple times. The influence of this on the current results is uncertain but expected to be of small magnitude con-

| Table 4 Multivariate linear regression model for healthcare utilization in patients with a history of bariatric surgery undergoing endoscopic biliary intervention, Nationwide Inpatient Sample, 2007–2011. |
|---------------------------------|-----------------|-----------------|
| Length of stay | Total charges |
| Days | 95% CI | P value | $ | 95% CI | P value |
| Endoscopic intervention | <0.0001 | 0.0078 |
| Successful | Reference | Reference |
| Failed | 2.17 | (1.18, 3.16) | 14,214 | (3,749, 24,679) |
| Age | 0.01 | (–0.01, 0.03) | 149 | (–11, 309) |
| Race | 0.7441 | 0.0834 |
| White | Reference | Reference |
| Black | –0.02 | (–0.75, 0.72) | 4,450 | (–5,146, 14,046) |
| Hispanic | –0.28 | (–0.93, 0.37) | 8,751 | (1,822, 15,680) |
| Other | 0.37 | (–0.92, 1.65) | –1,142 | (–14,208, 11,924) |
| Hospital size | 0.163 | 0.4041 |
| Small | Reference | Reference |
| Medium | 0.14 | (–0.46, 0.74) | 4,017 | (–8,061, 16,096) |
| Large | 0.49 | (–0.06, 1.05) | 6,322 | (–3,111, 15,756) |
| Chronic pancreatitis | –0.18 | (–0.86, 0.50) | 0.611 | (–13,961, 3,950) |
| Time to ERCP | <0.0001 | <0.0001 |
| <0 to 1 day | Reference | Reference |
| 2–4 days | 1.87 | (1.42, 2.33) | 14,835 | (9,635, 20,034) |
| 5–10 days | 7.16 | (6.11, 8.22) | 39,107 | (28,564, 49,649) |

ERCP, endoscopy retrograde cholangiopancreatography
sidering the statistically large sample size. Lastly, the NIS database cannot account for unobserved characteristics that may influence an intervention, complication, or outcome, so inferring "causality" from observed associations is not valid.

Conclusion

In conclusion, rates of obesity and prevalence of BRS for morbidly obese patients are increasing. In the vast majority of patients with BRS, concurrent prophylactic cholecystectomy is not performed. As a result, the most common indication for biliary intervention in this population is gallbladder-related disease. While primary endoscopic biliary intervention is more common, primary non-endoscopic intervention may be used more often for sepsis. Future research on improving success rates of endoscopic biliary intervention is prudent to reduce healthcare resource utilization.

Competing interests

None

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### Appendix 1  ICD-9-CM codes used for data extraction and analysis from the Nationwide Inpatient Sample (2007 – 2011).

| Diagnosis | ICD-9-CM codes used | Variable location |
|-----------|---------------------|-------------------|
| Acute pancreatitis | 577.0 | DX1 |
| History of bariatric surgery | V45.86 | DX2-DX25 |
| Morbid obesity | 278.01, V85.4, V85.41, V85.42, V85.43, V85.44 | DX2-DX25 |
| Cholelithiasis or choledocholithiasis (gallstone related) | 574, 574.00, 574.01, 574.10, 574.11, 574.20, 574.21, 574.30, 574.40, 574.41, 574.50, 574.51, 574.60, 574.61, 574.70, 574.71, 574.80, 574.81, 574.90, 574.91 | DX2-DX25 |
| Cholangitis | 576.1 | DX2-DX25 |
| Other diseases and obstruction OF BILE DUCT Adhesions of bile duct [any] | 576.2, 576.8, 782.4, 576.9 | DX2-DX25 |
| Adrophy of bile duct [any] | 576.2, 576.8, 782.4, 576.9 | DX2-DX25 |
| Cyst of bile duct [any] | 576.2, 576.8, 782.4, 576.9 | DX2-DX25 |
| Hypertrophy of bile duct [any] | 576.2, 576.8, 782.4, 576.9 | DX2-DX25 |
| Stasis of bile duct [any] | 576.2, 576.8, 782.4, 576.9 | DX2-DX25 |
| Ulcer of bile duct [any] | 576.2, 576.8, 782.4, 576.9 | DX2-DX25 |
| Bile duct obstruction and jaundice NOS 5762 (bile duct obstruction), 5769 (disease of the bile duct), 7824 (biliary atresia) | 156.2, 157, 157.0, 157.1, 157.2, 157.3, 157.8, 157.9 | DX2-DX25 |
| Pancreatic neoplasm | 291.0, 291.1, 291.2, 291.3, 291.4, 291.5, 291.81, 291.82, 291.89, 291.9, 303.00, 303.01, 303.02, 303.03, 303.09, 303.91, 303.92, 303.93, 305.00, 305.01, 305.02, 305.03 | DX2-DX25. |
| Alcohol related | 291.0, 291.1, 291.2, 291.3, 291.4, 291.5, 291.81, 291.82, 291.89, 291.9, 303.00, 303.01, 303.02, 303.03, 303.09, 303.91, 303.92, 303.93, 305.00, 305.01, 305.02, 305.03, 760.71, 980.0, 357.5, 425.5, 535.30, 535.31, 571.0, 571.1, 571.2, 571.3 | DX2-DX25. |
| History of chronic pancreatitis | 577.1 | DX2-DX25 |

### TREATMENT

| Description | ICD-9-CM codes used | Location |
|-------------|---------------------|----------|
| Cholecystectomy | 51.21, 51.22, 51.23, 51.24 | PR1-PR15 |
| Any ERCP | 51.83, 51.84, 51.85, 51.86, 51.87, 51.88 – 51.88, 51.10, 51.11, 51.14, 52.13, 52.93, 52.94, 52.98, 97.05 | PR1-PR15 |
| Percutaneous biliary procedures | 51.01, 51.96, 51.98 | PR1-PR15 |
| Open biliary procedures (common bile duct exploration) | 51.02, 51.03, 51.04, 51.32, 51.36, 51.37, 51.39, 51.41, 51.43, 51.51, 51.59, 51.63, 51.64, 51.69, 51.71, 51.79 | PR1-PR15 |
| Respiratory intubation and mechanical ventilation | 93.90, 96.01, 96.02, 96.03, 96.04, 96.05, 96.70, 96.71, 96.72 | PR1 to PR15 |
| Alcohol detoxification/rehabilitation | 94.61, 94.62, 94.63, 94.64, 94.65, 94.66, 94.67, 94.68, 94.69 | PR1-PR15 |

### OUTCOME

| Description | ICD-9-CM codes used | Location |
|-------------|---------------------|----------|
| Acute respiratory failure | 518.0, 518.81, 518.82, 518.84 | DX2-DX25 |
| Acute kidney injury | 584.5, 584.6, 584.7, 584.8, 584.9, 586 | DX2-DX25 |
| Pancreatectomy | 52.01, 52.09, 52.22, 52.51, 52.52, 52.59, 52.6, 52.7, 52.95, 52.96, 52.99 | DX2-DX25 |
| Roux-en-Y (open and laparoscopic) | 4438, 4439, 4431 | PR1 |
| Laparoscopic gastric band | 4495 | PR1 |
| Sleeve gastrectomy | 4389, 4468, 4382 | PR1 |
| Cholecystectomy | 5121, 5122, 5123, 5124 | PR2-PR15 |
Appendix 2  Summary of missing data for demographic and hospital characteristics in the present analysis of Nationwide Inpatient Sample from 2007 – 2011 for 7,343 patients with a history of BRS requiring biliary intervention.

| Total: 7,343 | Percent missing |
|--------------|-----------------|
| Gender       | 0%              |
| Race         | 9.36%           |
| Income       | 1.87%           |
| Type of insurance | 0%          |
| Hospital location | 1.20%     |
| Teaching status | 1.20%     |
| Hospital size | 1.20%           |
| Hospital region | 0%         |
| Admission day | 0%              |

Appendix 3  Trends in the Type of Bariatric Surgery (a) and Frequency of Concomitant Cholecystectomies (b) in the Nationwide Inpatient Sample from 2005 – 2011.
Appendix 4  Demographics, etiological associations, and outcomes of patients with a history of bariatric surgery undergoing endoscopic or non-endoscopic biliary intervention: Comparison of endoscopic versus PTC versus CBDE.

| Total: 7,343 | Endoscopic n=4,482 (%) | PTC n=1,692 (%) | CBDE n=1,169 (%) |
|--------------|------------------------|-----------------|-----------------|
| Age (mean, SD)| 50.11 30.76            | 51.54 27.26     | 53.01 24.62     |
| Gender       |                        |                 |                 |
| ▪ Male       | 728 16.25 %            | 394 23.30 %     | 311 26.62 %     |
| ▪ Female     | 3,754 83.75 %          | 1,298 76.70 %   | 858 73.38 %     |
| Race         |                        |                 |                 |
| ▪ White      | 3,131 76.85 %          | 1,225 81.46 %   | 880 81.50 %     |
| ▪ Black      | 402 9.86 %             | 147 9.78 %      | 105 9.72 %      |
| ▪ Hispanic   | 396 9.71 %             | 102 6.80 %      | 65 5.98 %       |
| ▪ Other      | 146 3.58 %             | 29 1.96 %       | 30 2.80 %       |
| Income (national quartile) |              |                 |                 |
| ▪ 1          | 948 21.48 %            | 362 22.00 %     | 199 17.41 %     |
| ▪ 2          | 1,145 25.95 %          | 480 29.16 %     | 285 24.94 %     |
| ▪ 3          | 1,131 25.63 %          | 440 26.73 %     | 353 30.83 %     |
| ▪ 4          | 1,189 26.95 %          | 364 22.11 %     | 307 26.82 %     |
| Type of insurance |                    |                 |                 |
| ▪ Medicare   | 1,129 25.19 %          | 497 29.39 %     | 336 28.70 %     |
| ▪ Medicaid   | 297 6.62 %             | 80 4.74 %       | 55 4.74 %       |
| ▪ Private    | 2,620 58.45 %          | 974 57.56 %     | 672 57.49 %     |
| ▪ Other      | 436 9.74 %             | 141 8.31 %      | 106 9.07 %      |
| Hospital location |                |                 |                 |
| ▪ Rural      | 167 3.78 %             | 136 8.15 %      | 27 2.27 %       |
| ▪ Urban      | 4,243 96.22 %          | 1,536 91.85 %   | 1,143 97.73 %   |
| Hospital teaching status |          |                 |                 |
| ▪ Nonteaching| 1,835 41.61 %          | 902 53.93 %     | 495 42.30 %     |
| ▪ Teaching   | 2,575 58.39 %          | 770 46.07 %     | 675 57.70 %     |
| Hospital size |                    |                 |                 |
| ▪ Small      | 386 8.75 %             | 169 10.12 %     | 82 7.05 %       |
| ▪ Medium     | 898 20.36 %            | 385 23.03 %     | 236 20.21 %     |
| ▪ Large      | 3,126 70.88 %          | 1,118 66.85 %   | 851 72.74 %     |
| Hospital region |                  |                 |                 |
| ▪ Northeast  | 942 21.02 %            | 313 18.48 %     | 222 18.98 %     |
| ▪ Midwest    | 1,087 24.25 %          | 324 19.14 %     | 216 18.50 %     |
| ▪ South      | 1,321 29.48 %          | 644 38.05 %     | 414 35.38 %     |
| ▪ West       | 1,132 25.25 %          | 412 24.33 %     | 317 27.14 %     |
| Weekend admission |               |                 |                 |
| ▪ No         | 3,717 82.94 %          | 1,400 82.74 %   | 931 79.61 %     |
| ▪ Yes        | 765 17.06 %            | 292 17.26 %     | 238 20.39 %     |
| Total: 7,343 | Endoscopic n=4,482 (%) | PTC n=1,692 (%) | CBDE n=1,169 (%) |
|-----------------|------------------------|-----------------|-----------------|
| **Elkhauser comorbidity Index** | | | |
| < 3 | 2,860 | 63.82 % | 994 | 58.75 % | 514 | 43.96 % |
| ≥ 3 | 1,622 | 36.18 % | 698 | 41.25 % | 655 | 56.04 % |
| **ETIOLOGY** | | | |
| Gallstone related | 2,146 | 47.88 % | 854 | 50.45 % | 279 | 23.82 % |
| Pancreaticobiliary Neoplasm | 81 | 1.80 % | 72 | 4.28 % | 125 | 10.67 % |
| Disease of bile duct | 223 | 4.97 % | 40 | 2.38 % | 55 | 4.74 % |
| Bile leak, bile duct injury, biliary peritonitis | 253 | 5.63 % | 152 | 9.01 % | 157 | 13.42 % |
| Bile duct obstruction and jaundice NOS | 262 | 5.84 % | 94 | 5.54 % | 93 | 7.92 % |
| Stent related (changes, others) | 134 | 2.99 % | 21 | 1.26 % | 32 | 2.74 % |
| Chronic Pancreatitits | 54 | 1.21 % | a | 0.00 % | a | 0.00 % |
| Sphincter of Oddi dysfunction | 22 | 0.50 % | a | 0.19 % | a | 0.00 % |
| Abdominal pain | 41 | 0.92 % | a | 0.00 % | a | 0.00 % |
| **Time to PTC/CBDE or ERCP** | | | |
| < 0 to 1 day | 2,294 | 51.19 % | 1,672 | 98.81 % | 1,165 | 99.60 % |
| 2 – 4 days | 1,593 | 35.53 % | a | 0.60 % | a | 0.40 % |
| 5 – 10 days | 595 | 13.27 % | a | 0.59 % | a | 0.00 % |
| **Cholecystectomy** | 1,697 | 37.86 % | 1,018 | 60.19 % | 116 | 9.95 % |
| **ASSOCIATED DIAGNOSES** | (DX1-DX25) | | | | |
| Sepsis | 184 | 4.10 % | 132 | 7.80 % | 171 | 14.60 % |
| Acute Pancreatitits | 1,146 | 25.57 % | 198 | 11.70 % | 162 | 13.84 % |
| Cholangitis | 532 | 11.87 % | 210 | 12.40 % | 178 | 15.19 % |
| **OUTCOME** | | | |
| Death | a | 0.22 % | a | 0.30 % | 15 | 1.26 % |
| Length of stay ≥ 7 days | 1,215 | 27.12 % | 783 | 46.27 % | 569 | 48.66 % |
| Length of stay | 5.31 | 9.46 % | 7.11 | 9.89 | 7.83 | 13.89 |
| Total charges | 50,664 | 92,279 | 66,873 | 137,658 | 60,624 | 106,082 |

a) The cell’s value is not displayed. As per data agreements with AHRQ, researchers cannot report any statistics where the number of observations in any given cell of analyzed data is ≤ 10.
**Appendix 5** Multivariate linear regression model for healthcare utilization in patients with a history of bariatric surgery undergoing biliary intervention with the addition of time period as a variable, Nationwide Inpatient Sample, 2007 – 2011.

|                              | Length of stay       | Total charges       |
|------------------------------|----------------------|---------------------|
|                              | Days | 95% CI | P-value | $ | 95% CI | P-value |
| Primary procedure            |      |        |         |   |        |         |
| ERCP                         | Reference |        | <0.0001 |   | Reference | <0.0001 |
| CBDE/PTC                     | 1.77 | (1.32, 2.22) | 11,885 | (6,462, 17,308) |
| Age                          | 0.01 | (−0.01, 0.02) | 0.4191 | −78 | (−224, 67) | 0.2912 |
| Gender                       |      |        |         |   |        |         |
| Male                         | Reference |        | 0.7549 |   | Reference | 0.0409 |
| Female                       | −0.08 | (−0.60, 0.43) | −6,034 | (−11,818, −251) |
| Hospital location            |      |        |         |   |        |         |
| Rural                        | Reference |        | 0.0365 |   | Reference | <0.0001 |
| Urban                        | 0.64 | (0.04, 1.23) | 19,313 | (13,710, 24,917) |
| Hospital teaching status     |      |        |         |   |        |         |
| Nonteaching                  | Reference |        | 0.9254 |   | Reference | 0.6763 |
| Teaching                     | 0.03 | (−0.51, 0.56) | −1,409 | (−8,035, 5,217) |
| Hospital region              |      |        |         |   |        |         |
| Northeast                    | Reference |        | 0.8802 |   | Reference | <0.0001 |
| West                         | −0.17 | (−0.86, 0.53) | 14,640 | (4,446, 24,834) |
| South                        | 0.04 | (−0.59, 0.67) | −2,360 | (−11,336, 6,615) |
| Midwest                      | 0.09 | (−0.55, 0.73) | −7,003 | (−16,173, 2,167) |
| Elixhauser comorbidity Index |      |        | <0.0001 |   | <0.0001 |         |
| < 3                          | Reference |        |         |   | Reference |         |
| ≥ 3                          | 1.27 | (0.79, 1.75) | 10,306 | (5,330, 15,282) |
| Gallstone related            | −0.79 | (−1.22, −0.36) | 0.0004 | −3,731 | (−8,624, 1,162) | 0.1348 |
| Pancreaticobiliary neoplasm  | 1.55 | (0.03, 3.08) | 0.0459 | 4,032 | (−7,632, 15,697) | 0.4974 |
| Bile leak, bile duct injury, biliary peritonitis | 0.79 | (−0.38, 1.96) | 0.1867 | 5,770 | (−6,532, 18,072) | 0.3572 |
| Chronic pancreatitis         | −1.34 | (−2.29, −0.38) | 0.0064 | −17,281 | (−35,898, 1,336) | 0.0688 |
| Time to PTC/CBDE or ERCP     |      |        | <0.0001 |   | <0.0001 |         |
| < 0 to 1 day                 | Reference |        |         |   | Reference |         |
| 2 – 4 days                   | 1.72 | (1.29, 2.15) | 12,112 | (7,779, 16,445) |
| 5 – 10 days                  | 6.29 | (5.49, 7.09) | 43,714 | (33,387, 54,040) |
| Time period                  |      |        |         |   |        |         |
| 2007 – 2008                  | Reference |        | 0.7669 |   | 0.0227 |         |
| 2009 – 2011                  | 0.07 | (−0.37, 0.50) | 6,378 | (893, 11,863) |
### Appendix 6

Multivariate linear regression model for healthcare utilization in patients with a history of bariatric surgery undergoing endoscopic biliary intervention with the addition of time period as a variable, Nationwide Inpatient Sample, 2007 – 2011.

|                      | Length of stay | Total charges |
|----------------------|----------------|---------------|
|                      | Days  | 95% CI      | P-value | $    | 95% CI      | P-value |
| Endoscopic intervention |      |             | <0.0001 |      |             |         |
| • Successful         | Reference |             |         |      |             |         |
| • Failed             | 2.18  | (1.16, 3.19) | 0.0078  |      |             |         |
| Age                  | 0.01  | (–0.01, 0.03) | 0.2081 | 145  | (–21, 311)  | 0.0858  |
| Race                 | 0.7097 |             |         |      |             |         |
| • White              | Reference |             |         |      | Reference |         |
| • Black              | –0.01 | (–0.75, 0.73) | 0.1255 | 4,778 | (–4,873, 14,430) | |
| • Hispanic           | –0.30 | (–0.96, 0.36) | 0.0858 | 8,178 | (1,249, 15,107) | 
| • Other              | 0.37  | (–0.91, 1.66) |         | –860 | (–14,039, 12,319) | 
| Hospital size        | 0.1669 |             |         |      |             |         |
| • Small              | Reference |             |         |      | Reference |         |
| • Medium             | 0.12  | (–0.49, 0.73) | 0.3426 | 3,299 | (–7,999, 14,597) | 
| • Large              | 0.49  | (–0.07, 1.05) |         | 6,217 | (–2,439, 14,873) | 
| Chronic pancreatitis | –0.14 | (–0.80, 0.52) |         | 0.6731 | (–12,795, 8,950) | 0.2479 |
| Time to ERCP         | 0.4483 |             | <0.0001 |      | <0.0001 |         |
| • <0 to 1 day        | Reference |             |         |      | Reference |         |
| • 2 – 4 days         | 1.87  | (1.41, 2.33) |         | 14,894 | (9,663, 20,124) | 
| • 5 – 10 days        | 7.16  | (6.09, 8.22) |         | 38,859 | (28,422, 49,296) | 
| Time period          | 0.0596 |             |         |      |             |         |
| • 2007 – 2008        | Reference |             |         |      |             |         |
| • 2009 – 2011        | 0.18  | (–0.29, 0.65) |         | 5,950 | (–242, 12,142) |