Obesity Surgery (2019) 29:464–473
https://doi.org/10.1007/s11695-018-3532-1

ORIGINAL CONTRIBUTIONS

Bariatric Surgery Did Not Increase the Risk of Gallstone Disease in Obese Patients: a Comprehensive Cohort Study

Jian-Han Chen [1,2,3] · Ming-Shian Tsai [1,2,3] · Chung-Yen Chen [1,2,3] · Hui-Ming Lee [3,4] · Chi-Fu Cheng [5,6] · Yu-Ting Chiu [5,6] · Wen-Yao Yin [5,6,7] · Cheng-Hung Lee [5,6]

Published online: 11 November 2018

Abstract

Purpose The aim of this study was to evaluate the influence of bariatric surgery on gallstone disease in obese patients.

Materials and Methods This large cohort retrospective study was conducted based on the Taiwan National Health Insurance Research Database. All patients 18–55 years of age with a diagnosis code for obesity (ICD-9-CM codes 278.00–278.02 or 278.1) between 2003 and 2010 were included. Patients with a history of gallstone disease and hepatic malignancies were excluded. The patients were divided into non-surgical and bariatric surgery groups. Obesity surgery was defined by ICD-9-OP codes. We also enrolled healthy civilians as the general population. The primary end point was defined as re-hospitalization with a diagnosis of gallstone disease after the index hospitalization. All patients were followed until the end of 2013, a biliary complication occurred, or death.

Results Two thousand three hundred seventeen patients in the bariatric surgery group, 2331 patients in the non-surgical group, and 8162 patients in the general population were included. Compared to the non-surgery group (2.79%), bariatric surgery (2.89%) did not elevate the risk of subsequent biliary events (HR = 1.075, $p = 0.679$). Compared to the general population (1.15%), bariatric surgery group had a significantly higher risk (HR = 4.996, $p < 0.001$). In the bariatric surgery group, female gender (HR = 1.774, $p = 0.032$) and a restrictive procedure (HR = 1.624, $p = 0.048$) were risk factors for gallstone disease.

Conclusion The risk for gallstone disease did not increase after bariatric surgery, although the risk was still higher than the general population. The benefit of concomitant cholecystectomy during bariatric surgery should be carefully evaluated.

Keywords Bariatric surgery · Validation · NHIRD · Gallstone disease · Acute cholecystitis · Obesity

Wen-Yao Yin and Cheng-Hung Lee contributed equally to this work.

✉ Wen-Yao Yin
wenyao4748@gmail.com

✉ Cheng-Hung Lee
kawa199190@gmail.com

Jian-Han Chen
JAMIHAN1981@gmail.com

1 Bariatric and Metabolic Surgery Center, E-da hospital, Kaohsiung, Taiwan

2 Department of General Surgery, E-da hospital, Kaohsiung, Taiwan

3 School of Medicine, I-Shou University, Kaohsiung, Taiwan

4 Department of General Surgery, E-Da Cancer Hospital, Kaohsiung, Taiwan

5 Department of General Surgery, Buddhist Dalin Tzu Chi Hospital, No.2, Minsheng Rd., Dalin Township, Chiayi County 622, Taiwan

6 School of Medicine, Tzu Chi University, Hualien, Taiwan

7 Department of Surgery, College of Medicine, Tzu Chi University, Hualien, Taiwan

Introduction

Obesity is related to multiple comorbidities, including metabolic syndromes and malignancies [1], and is a reported risk factor for gallstone formation. Bariatric surgery has been shown to be a most effective and durable treatment of obesity and associated co-morbidities [2]; however, bariatric surgery leads to rapid weight loss, which is also a risk factor for gallstone formation.

The reported postoperative biliary complication rate requiring cholecystectomy is 0.9~7.5% after laparoscopic sleeve gastrectomy [3–5] and 6–50% after laparoscopic gastric bypass [6–9]. Therefore, some surgeons perform concomitant cholecystectomies for patients who undergo bariatric surgery without significantly increased operative times, length of hospital stay, and morbidity and mortality rates [7, 10, 11]. In contrast, Warschkow et al. [12] conducted a meta-analysis involving concomitant cholecystectomies and reported significantly higher complication and mortality rates than bariatric surgery alone. Moreover, Worni et al. [13] concluded that concomitant cholecystectomies have higher postoperative complications, including infections, gastrointestinal and pulmonary complications, reintervention rates, and longer hospital stays.

Thus, there is an ongoing debate regarding concomitant cholecystectomy during bariatric surgery; however, most studies have involved gallstone formation and cholecystectomy after bariatric surgery, and the difference between obese patients who do and do not undergo bariatric surgery is unknown. Moreover, selective concomitant cholecystectomies can be performed if risk factors for gallstone disease are present. Until now, with the exception of age [14], no risk factors for gallstone disease after bariatric surgery have been identified [5, 15]. Therefore, decisions regarding cholecystectomies during bariatric surgery vary, from routine prophylactic cholecystectomies [16] to cholecystectomies only in patients with biliary symptoms [17].

The aim of this study was to determine the incidence of gallstone disease after bariatric surgery and identify the influence of bariatric surgery on gallstone disease in obese patients. In addition, we attempted to identify the risk factors for gallstone disease after bariatric surgery. Using a nationwide population-based dataset, we analyzed sufficient patient data and performed comprehensive follow-up to answer these questions.

Method

This retrospective study was fully evaluated and approved by the Institutional Review Board of Buddhist Dalin Tzu Chi Hospital (approval B10502007) and was conducted in accordance with the principles of the Helsinki Declaration. For this type of study, formal consent is not required. We extracted the dataset used in this study from the Taiwan National Health Insurance Research Database (NHIRD; registered number NHIRD-103-246). The database was cross-checked, and medical charts were validated by the Taiwan Bureau of National Health Insurance. For this analysis, we extracted the data from the inpatient expenditures by admission, the registry for beneficiaries, and the Registry for Catastrophic Illness Patient Database from the NHIRD database (1996–2013).

Inclusion Criteria

In Taiwan, patients must meet several criteria in order for the National Health Insurance (NHI) to pay for bariatric surgery. Specifically, the following criteria must be met: (1) between 18 and 55 years of age, (2) attempted conservative methods to lose weight for at least 6 months, (3) BMI > 35 kg/m^2 with comorbidities or > 40 kg/m^2, and (4) no psychiatric disease. Thus, we included all patients 18–55 years of age with the diagnosis code for overweight or obesity (ICD-9 codes 278.00–278.02 or 278.1) [18, 19] on admission between 2003 and 2010. The patients were separated into two groups (bariatric surgery and non-surgical groups).

We defined bariatric surgery based on ICD-9 codes, as follows: malabsorptive procedures (high gastric bypass, ICD-9-CM OP44.31; laparoscopic gastroenterostomy, ICD-9-CM OP44.38; and other gastroenterostomy without gastrectomy, ICD-9-CM OP44.39) and restrictive procedures (laparoscopic sleeve gastrectomy, ICD-9-CM OP43.82; open and other partial gastrectomy, ICD-9-CM OP43.89; laparoscopic gastroplasty, ICD-9-CM OP44.68; other repair of stomach, ICD-9-CM OP44.69; laparoscopic gastric restrictive procedure, ICD-9-CM OP44.95; and other operations on the stomach, ICD-9-CM OP44.99) [20, 21].

Exclusion Criteria

Patients were also excluded for the following reasons: (1) < 18 or > 55 years of age, (2) had a history of cholelithiasis or choledocholithiasis, (3) a history of cholecystectomy (before or concomitant with the index date), (4) a history of hepatobiliary cancer (ICD-9-CM code 155, 156), (5) died during admission or within 30 days of the index admission [22], or (6) undetermined gender.

Patients who did not meet these criteria were given the option to self-pay for bariatric surgery. In the non-surgical group, we excluded patients admitted to the surgical ward to prevent this event. In the bariatric surgery group, we also excluded patients with a primary diagnosis other than obesity to exclude those patients who underwent surgery for other reasons.

Covariates

Several comorbidities, including diabetes (ICD-9 diagnostic code, 250.x), hypertension (ICD-9 diagnostic code, 401.x–405.x) [23], hyperlipidemia (ICD-9 diagnostic code, 272.x), and gout (ICD-9 diagnostic code, 274.x). These patients were matched 1:1 based on age, gender, and comorbidities by propensity score matching.

Validation

Although several validation studies have confirmed the reliability of this database [24–27], the validity of bariatric procedure codes in the NHI database has not been well-documented. We applied the inclusion criteria for bariatric surgery as detailed in the "Inclusion Criteria" section to patients who underwent bariatric surgery covered by the NHI program at Buddhist Dalin Tzu Chi Hospital (a 1000-bed regional hospital in Taiwan) from July 2001 to February 2016. Two general surgeons (Drs. Cheng-Hung Lee and Chi-Fu Cheng) independently reviewed the clinical data, medical records, and operative notes from all patients. Disagreements were resolved by discussion until consensus was reached. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of bariatric surgery procedure codes were determined.

General Population

We randomly selected 100,000 adult patients (≧ 18 years of age) from the Registry for Beneficiaries in 2002. Patients > 55 years of age with unknown gender, obesity, a history of hepatobiliary malignancies, and a history of admissions before 2003 were excluded. The included patients were matched 1:4 based on age and gender with patients in the surgical group by propensity score matching. Figure 1 shows the study algorithm.

End Point

The primary end point was the development of biliary complications. Development of gallstone disease after bariatric surgery was defined as rehospitalization with a diagnosis of cholelithiasis (ICD-9-CM codes 574.x, 575.0, 575.1, and 575.6) after the index hospitalization. Patients with cholecystitis (ICD-9-CM codes 574.0, 574.1, 574.3, 574.4, 574.6, 574.7, 574.8, 575.0, and 575.1) and choledocholithiasis ((ICD-9-CM codes 574.30-1, 574.40-1, 574.50-1, 574.60-1, 574.70-1, 574.80-1, and 574.90-1) were also identified. All patients were followed until 31 December 2013, gallstone disease developed, or withdrawn from the database because of death.

Statistical Analysis

We used SPSS software (IBM, Chicago, IL, USA) for the descriptive statistics and contingency tables for data analysis.

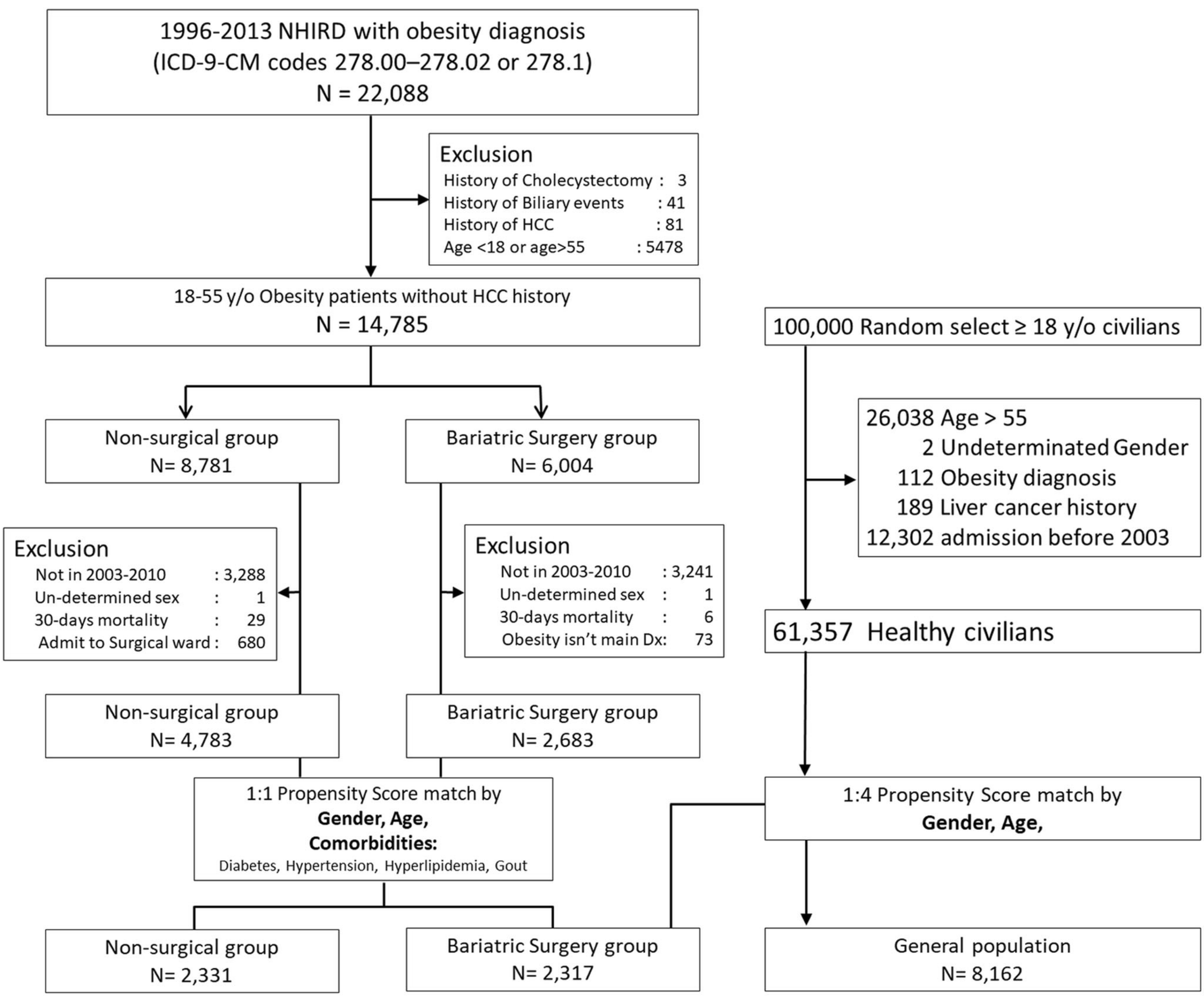

Fig. 1 Study algorithm

Differences among age groups, gender, and comorbidities are listed in the contingency table and compared using a chi-square test. We used Kaplan–Meier (KM) analysis to identify the percentage of patients who did not have a biliary complication during the follow-up period. The risk of developing gallstone disease among different covariates was evaluated using a backward stepwise Cox proportional hazards model. Variables with p values < 0.2 were entered into a Cox regression for multivariable analysis. A p value ≤ 0.05 was considered significant.

Results

We identified 22,088 patients who were diagnosed with obesity from 1996 to 2013. After applying the exclusion criteria and a 1:1 propensity score match with gender, age, and comorbidities, there were 2331 patients in the non-surgical group and 2317 patients in the bariatric surgery group. The study algorithm is presented in Fig. 1.

Gallstone Disease: Difference Between Obese Patients in the Bariatric Surgery and Non-surgical Groups

Table 1 demonstrates the clinical characteristics of the obese patients in the non-surgical and bariatric surgery groups. There was no significant difference between the two groups with respect to age ($p = 0.053$), gender ($p = 0.635$), diabetes ($p = 0.679$), hypertension ($p = 0.082$), hyperlipidemia ($p = 0.088$), and gout ($p = 0.158$).

The overall median duration of follow-up was 71.40 months. By the end of the study, 67 patients (2.89%) developed gallstone disease in the bariatric surgery group. The median time to gallstone disease was 33.89 ± 24.32 months; 33% (22/67) developed gallstone disease within 2 years and 82% (55/67) developed gallstone disease within 5 years. Among the patients with gallstone disease, 5 (7.58%) had choledocholithiasis and 36 (53.73%) had cholecystitis.

Sixty-five patients (2.79%) had gallstone disease in the non-surgical group. The median time to develop gallstone disease was 37.01 ± 26.02 months; 7 (8.33%) had choledocholithiasis and 29 (44.62%) had cholecystitis.

No significant difference in the prevalence of gallstone disease existed between the two groups ($p = 0.860$). Figure 2 demonstrates the results of Kaplan–Meier analysis. There was no difference between the non-surgical and bariatric surgery groups ($p = 0.678$).

We used COX regression to evaluate the hazard ratios (HRs) of gallstone disease as a function of age, gender, comorbidities, and effect of bariatric surgery. Univariate analysis demonstrated that patients in the bariatric surgery group had a similar risk for gallstone disease (HR = 1.075, 95% CI 0.764–1.512, $p = 0.679$) as the non-surgical group. No other independent risk factors for gallstone disease were identified during COX regression analysis (Table 2).

Gallstone Disease: Difference Between the Bariatric Surgery Group and the General Population

After a 1:4 propensity score match by age and gender with the bariatric surgery group, we selected 8162 patients as the general population via the criteria specified in the "Method" section. Table 3 demonstrates the clinical characteristics of the patients. There was no significant difference between age ($p = 0.483$) and gender ($p = 0.417$).

At the end of the study, 94 patients (1.15%) developed gallstone disease in the general population. The bariatric surgery group had a significantly higher rate of biliary events (67 patients [2.89%,] $p < 0.001$) than the general population. Based on multivariate analysis, patients in the bariatric surgery group had

Table 1 Clinical characteristics of non-surgical and bariatric surgery groups

	Non-surgical group		Bariatric surgery group		p
	$N = 2331$		$N = 2317$		
Age, mean (SD), year	33.32	(8.87)	32.83	(8.55)	0.053
Gender					0.635
Female	1321	56.67%	1330	57.40%	
Male	1010	43.33%	987	42.60%	
Comorbidities					
Diabetes	157	6.74%	149	6.43%	0.679
Hypertension	258	11.07%	220	9.50%	0.082
Hyperlipidemia	136	5.83%	109	4.70%	0.088
Gout	84	3.60%	66	2.85%	0.158
Gallstone disease	65	2.79%	67	2.89%	0.860
With choledocholithiasis	7	8.33%	5	7.58%	0.558
With cholecystitis	29	44.62%	36	53.73%	0.303

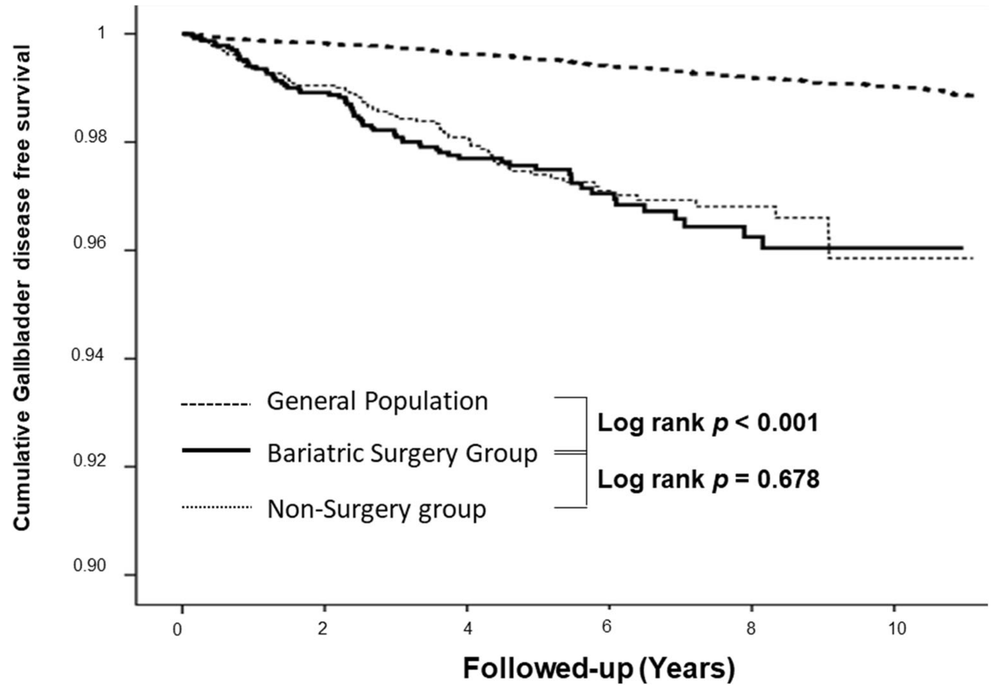

Fig. 2 Kaplan–Meier analysis of gallstone disease

a significantly higher risk of gallstone disease (HR = 4.996, 95% CI 3.553–7.026, $p < 0.001$) than the general population.

Risk Factors of Gallstone Disease in Obese Patients Undergoing Bariatric Surgery

We applied COX regression to 2317 patients in the bariatric surgery group to identify the risk factors for following biliary events (Table 4). Univariate analysis demonstrated that only female patients had a significantly increased risk for gallstone disease (HR = 1.706, 95% CI 1.011–2.880, $p = 0.045$). Based on multivariate analysis, restrictive procedures were associated with a significantly higher risk for gallstone disease (HR = 1.624, 95% CI 1.005–2.626, $p = 0.048$) than malabsorptive procedures. Female gender (HR 1.774, 95% CI 1.049–2.998, $p = 0.032$) was identified as another risk factor for gallstone disease.

Validation of Bariatric Surgical Codes

Between July 2001 and February 2016, 59 patients underwent bariatric surgery that was covered by National Health Insurance. Among the 59 patients, 54 underwent restrictive procedures and 5 underwent malabsorptive procedures. The sensitivity, specificity, PPV, and NPV of bariatric surgery procedure codes are listed in Table 5. The sensitivity of bariatric surgery codes was 98.3% with a PPV 100%. The restrictive procedure codes had a 98.15% sensitivity and a 98.15% PPV. The sensitivity and PPV of malabsorptive procedure codes were 80% and 100%, respectively.

Table 2 Risk for gallstone disease in obese patients

	Univariant analysis		
	HR	95% CI	*p*
Age	1.013	(0.994–1.032)	0.189
Gender			
Female	1		
Male	0.779	(0.546–1.110)	0.167
Bariatric surgery	1.075	(0.764–1.512)	0.679
Comorbidities			
Diabetes	0.973	(0.476–1.990)	0.941
Hypertension	1.163	(0.679–1.990)	0.583
Hyperlipidemia	0.867	(0.382–1.965)	0.732
Gout	1.477	(0.651–3.350)	0.351

Discussion

Based on this study, we describe several points about gallstone disease after bariatric surgery. First, the prevalence of gallstone disease in patients who underwent bariatric surgery was similar to obese patients who did not undergo bariatric surgery (2.79% in the non-surgery group vs. 2.89% in the bariatric surgery group, $p = 0.860$). Moreover, the risk for gallstone disease (HR = 1.075, 95% CI 0.764–1.512, $p = 0.679$) did not increase after bariatric surgery with a median follow-up duration of 71.4 months. Second, compared to the general population, patients who underwent bariatric surgery had a higher risk of gallstone disease. Third, after bariatric surgery, female patients (HR 1.774, $p = 0.032$) and patients who

Table 3 Clinical characteristics of the general population and bariatric surgery groups

	General population		Bariatric surgery group		p
	$N = 8162$		$N = 2317$		
Age, mean (SD), year	33.08	(10.20)	32.83	(8.55)	0.483
Gender					0.417
Female	4762	58.34%	1330	57.40%	
Male	3400	41.66%	987	42.60%	
Gallstone disease	94	1.15%	67	2.89%	< 0.001*
With cholecystitis	58	61.70%	36	53.73%	0.334

*$p < 0.05$

underwent restrictive procedure (HR = 1.624, $p = 0.048$) were at higher risk for gallstone disease.

Cholecystitis is a common disease worldwide. The incidence of gallbladder stones in the general population based on ultrasonography ranges from 2 to 15% [28], and it has been reported that 6–25% of individuals with asymptomatic gallbladder stones in the healthy population will develop symptoms with time [29]. A previous study demonstrated that female gender, patients > 40 years of age, obesity, and a rapid change in body weight are risk factors for gallstones [30]. Obese individuals were reported not only to have an elevated risk of cholelithiasis, up to eightfold higher than the general population [28, 31], but also gallstone disease, including cholecystitis, choledocholithiasis, obstructive jaundice, and biliary pancreatitis [32]. When a patient develops biliary colic, cholecystitis, or other biliary events, such as obstructive cholangitis or biliary pancreatitis, the recurrence risk for biliary events is as high as 30% [33]. Thus, it is recommended that patients who develop biliary events due to gallstones undergo cholecystectomy to prevent a recurrence.

Obese patients are at higher risk for gallstone formation. Patients who undergo bariatric surgery are also at high risk for gallstone formation due to a rapid reduction in weight. The incidence of gallstone formation ranges from 6 to 7% following gastric band procedures [34, 35], 10% following laparoscopic sleeve gastrectomy [36], and 13.4–71% after Roux-en-Y gastric bypass [31, 37–41]. Gallstone formation is increased compared with the risk of cholelithiasis in the general population, which is 10–20% [42]. It may relate to the postoperative diet change. After bariatric surgery, most patients should be taught to change their diet to a low-calorie and low-fat diet. It may alternate the hepatic cholesterol synthesis, bile secretion, and even alternate the contraction of the gallbladder to enhance the gallstone formation [43]. Moreover, it is reported that the level of cholecystokinin decreased after metabolic surgery, such as gastric bypass. It may induce incomplete gallbladder contraction, bile stasis, and gallstone formations [44].

Moreover, the reported prevalence of postoperative gallstone disease requiring cholecystectomy was 3.4–16% [8, 9, 14, 42, 45], which is slightly higher than the general

Table 4 Risk for gallstone disease in the bariatric surgery group

	Univariable analysis			Multivariable analysis		
	HR	95% CI	p	HR	95% CI	p
Age	1.002	(0.974–1.030)	0.909*			
Gender						
Male	1			1		
Female	1.706	(1.011–2.880)	0.045*	1.774	(1.049–2.998)	0.032*
Bariatric surgery						
Mal-absorptive	1			1		
Restrictive	1.557	(0.964–2.514)	0.070*	1.624	(1.005–2.626)	0.048*
Comorbidities						
Diabetes	0.726	(0.228–2.310)	0.587*			
Hypertension	0.629	(0.229–1.728)	0.368*			
Hyperlipidemia	0.314	(0.044–2.262)	0.250*			
Gout	1.593	(0.500–5.071)	0.431*			

*$p < 0.05$

Table 5 The sensitivity, specificity, positive predict value (PPV), and negative predict value (NPV) of bariatric procedure codes

		Dalin Hospital database		Inclusion criteria			
	Inclusion Criteria	Recorded	Non-recorded	PPV (95% CI)	NPV (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)
All bariatric surgery	Identified	58	0	100%	0	98.31% (90.91–99.96)	N.A.
	Non-identified	1	0				
Restrictive procedure	Identified	53	1	98.15% (90.18–99.67)	80.00% (35.34–96.70)	98.15% (90.11–99.95)	80.00% (28.36–99.49)
	Non-identified	1	4				
Mal-absorptive procedure	Identified	4	0	100%	98.18%(90.34–99.68)	80.00%(28.36–99.49)	100%(93.40–100)
	Non-identified	1	54				

population (1–5%) [46]. The highest incidence of gallstone disease is within the first 12 months to 2.5 years following the procedure [8, 31, 45]. The incidence of biliary complication has been reported to be 0.9~13% after laparoscopic sleeve gastrectomy [3–5, 47, 48] and 6–50% after laparoscopic gastric bypass [6–9]. These differences reflect differences in the management of gallbladder disease. Some surgeons are in favor of combining laparoscopic cholecystectomy with the primary bariatric procedure, while other surgeons oppose doing so [16, 38, 49–51] because of the higher morbidity [13]. Grover et al. [28] reported that an intraoperative cholangiogram was routinely performed on patients undergoing Roux-en-Y gastric bypass. Few groups recommend ursodeoxycholic acid after bariatric surgery for 6–12 months, while there are other groups that think consider ursodeoxycholic acid [39, 52]. Post-bariatric laparoscopic cholecystectomy has been advised for patients with symptomatic disease by few groups [17, 53].

To date, there are a limited number of journals that address whether or not bariatric surgery increases the risk for gallstone disease. If bariatric surgery increases the risk for gallstone disease, a concomitant cholecystectomy may be justified. Although several studies have reported that concomitant cholecystectomy is safe [7, 10, 11], concomitant cholecystectomy has several challenges, including a high intra-abdominal pressure [54] and different trocar sites than conventional laparoscopic cholecystectomy. Moreover, obesity has been reported to be a risk factor for conversion and bile duct injuries [55, 56]. These challenges may give rise to significantly higher complication and mortality rates in patients undergoing concomitant cholecystectomy than bariatric surgery alone [12, 13]. Therefore, Yardimci et al. [5] suggested observation after bariatric surgery, even for patients with asymptomatic gallstones.

Our analysis demonstrated that the prevalence and risk for gallstone disease between obese patients who did and did not undergo bariatric surgery were similar (2.79% in the non-surgery group vs. 2.89% in the bariatric surgery group, $p = 0.860$; HR = 1.075, $p = 0.679$). Furthermore, patients who underwent bariatric surgery were at higher risk for gallstone disease than the general population, which demonstrated that the risk for gallstone disease increases when patients are obese. Bariatric surgery did not change the risk for gallstone disease in obese patients. Thus, patients with gallbladder disease who undergo bariatric surgery should be treated similar to the general population.

Risk factors predicting the development of gallstone disease after bariatric surgery is very important in decision-making for concomitant cholecystectomy; however, most reported risk factors exist postoperatively. Morais et al. [15] could not identify any predictors of developing symptomatic gallbladder disease after bariatric surgery. Li et al. [57] reported that a > 25% loss of original body weight is the only predictive factor for gallstone formation. Some studies have reported that patients with normal preoperative hepatobiliary ultrasound findings who develop gallbladder stones during the weight loss process are more likely to be symptomatic [15, 58, 59]. Only one study has indicated that advanced age (> 50 years) is an independent predictive factor for gallstone formation [14]. Based on our analysis, we identified two risk factors (female gender [HR = 1.774, $p = 0.032$] and patients who underwent a restrictive procedure [HR = 1.624, $p = 0.048$]) were at higher risk for gallstone disease.

Based on our analysis, patients who underwent a restrictive procedure were at higher risk for gallstone disease than patients who underwent a malabsorptive procedure. This finding differs from a previous report. Specifically, Tsirline et al. [60] reported that laparoscopic Roux-en-Y bypass had a threefold increase in the incidence of cholecystectomy compared to laparoscopic sleeve gastrectomy (10.6% vs. 3.5%). In contrast, Moon et al. [41] reported that the frequency of symptomatic gallstones was not significantly different (6.1% vs. 5.7%) between the two surgical procedures; however, even patients who underwent restrictive bariatric surgery were at higher risk for gallstone disease, especially choledocholithiasis and obstructive cholangitis. Such patients can be easily treated via an endoscopic procedure because restrictive surgery maintains the normal anatomy of the gastrointestinal tract.

Limitations

There were limitations to our study. First, the database we used was secondary and administrative in nature; thus, there is a risk of miscoding. Some details, including patient body weight, initial BMI, change in BMI, the details of each operation (operative time, blood loss, conversion status, length of bypassed intestine during bypass surgery, bougie size, or the length of the residual antrum following sleeve gastrectomy), and other details were not recorded in the database, and therefore, could not be obtained. Also, the database included only five procedure codes and five diagnostic codes; thus, some details of admission may have been lost. Most ICD-9 codes during admission were assigned by professional coders based on the records collected during admission because these codes are directly related to payments from NHI. We used relatively reliable data, such as age, gender, date of admission, discharge condition, and death to make the results more reliable. Second, patient selection bias was possible. Obese patients who were admitted may have had a relatively poor general health status compared to those patients not admitted or admitted for bariatric surgery. This finding may have influenced the incidence of gallstone disease. Third, we only used inpatient expenditures by admissions to detect gallstone disease. Thus, we could not identify those patients who have gallstone disease without admission via this database; however, NHIRD covers almost all medical providers and citizens in Taiwan and records all medical behaviors in the country. Thus, we detected any gallstone disease or death when a patient was admitted to a hospital in Taiwan. We estimated that a long duration of follow-up (median, 71 months) could identify most gallstone disease after bariatric surgery in Taiwan. Although the absolute number of gallstone disease may have been higher than suggested in the data presented herein, coupled with the use of data regarding admissions, we presented estimates that reflect the rate of clinically significant gallstone disease.

Conclusion

Our analysis demonstrated that bariatric surgery does not change the risk for gallstone disease in obese patients. Although patients who underwent bariatric surgery are still at a higher risk for gallstone disease than the general population, the prevalence and risk for gallstone disease was similar between the non-surgical and bariatric surgery groups after a median follow-up of 71.4 months. Other than female gender and restrictive procedures, there were no other risk factors for developing gallstone disease after bariatric surgery. Taken together, we recommend a more careful evaluation of the benefit of concomitant cholecystectomy during bariatric surgery.

Acknowledgments This study is based in part on data from National Health Insurance Research Database (NHIRD), provided by the National Health Insurance Administration, Ministry of Health and Welfare and managed by the National Health Research Institutes (registered number NHIRD-103-246). The data utilized in this study cannot be made available in the manuscript, the supplemental files, or in a public repository due to the "Personal Information Protection Act" executed by Taiwan's government, starting from 2012. Requests for data can be sent as a formal proposal to the NHIRD (http://nhird.nhri.org.tw) or by email to nhird@nhri.org.tw.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

1. Schauer DP, Feigelson HS, Koebnick C, Caan B, Weinmann S, Leonard AC, et al. Bariatric surgery and the risk of Cancer in a large multisite cohort. Ann Surg 2017.
2. Schauer PR, Kashyap SR, Wolski K, et al. Bariatric surgery versus intensive medical therapy in obese patients with diabetes. N Engl J Med. 2012;366(17):1567–76.
3. Dakour Aridi H, Sultanem S, Abtar H, et al. Management of gallbladder disease after sleeve gastrectomy in a selected Lebanese population. Surg Obes Relat Dis. 2016;12(7):1300–4.
4. Hasan MY, Lomanto D, Loh LL, et al. Gallstone disease after laparoscopic sleeve gastrectomy in an Asian population-what proportion of gallstones actually becomes symptomatic? Obes Surg. 2017;27(9):2419–23.

5. Yardimci S, Coskun M, Demircioglu S, et al. Is concomitant cholecystectomy necessary for asymptomatic cholelithiasis during laparoscopic sleeve gastrectomy? Obes Surg. 2018;28(2):469–73.
6. Karadeniz M, Gorgun M, Kara C. The evaluation of gallstone formation in patients undergoing Roux-en-Y gastric bypass due to morbid obesity. Ulus Cerrahi Derg. 2014;30(2):76–9.
7. Nougou A, Suter M. Almost routine prophylactic cholecystectomy during laparoscopic gastric bypass is safe. Obes Surg. 2008;18(5):535–9.
8. Villegas L, Schneider B, Provost D, et al. Is routine cholecystectomy required during laparoscopic gastric bypass? Obes Surg. 2004;14(2):206–11.
9. Pineda O, Maydon HG, Amado M, et al. A prospective study of the conservative management of asymptomatic preoperative and postoperative gallbladder disease in bariatric surgery. Obes Surg. 2017;27(1):148–53.
10. Amstutz S, Michel JM, Kopp S, et al. Potential benefits of prophylactic cholecystectomy in patients undergoing bariatric bypass surgery. Obes Surg. 2015;25(11):2054–60.
11. Weiss AC, Inui T, Parina R, et al. Concomitant cholecystectomy should be routinely performed with laparoscopic Roux-en-Y gastric bypass. Surg Endosc. 2015;29(11):3106–11.
12. Warschkow R, Tarantino I, Ukegjini K, et al. Concomitant cholecystectomy during laparoscopic Roux-en-Y gastric bypass in obese patients is not justified: a meta-analysis. Obes Surg. 2013;23(3):397–407.
13. Worni M, Guller U, Shah A, et al. Cholecystectomy concomitant with laparoscopic gastric bypass: a trend analysis of the nationwide inpatient sample from 2001 to 2008. Obes Surg. 2012;22(2):220–9.
14. Chang J, Corcelles R, Boules M, et al. Predictive factors of biliary complications after bariatric surgery. Surg Obes Relat Dis. 2016;12(9):1706–10.
15. Morais M, Faria G, Preto J, et al. Gallstones and bariatric surgery: to treat or not to treat? World J Surg. 2016;40(12):2904–10.
16. Mechanick JI, Youdim A, Jones DB, et al. Clinical practice guidelines for the perioperative nutritional, metabolic, and nonsurgical support of the bariatric surgery patient–2013 update: cosponsored by American Association of Clinical Endocrinologists, the Obesity Society, and American Society for Metabolic & bariatric surgery. Obesity (Silver Spring). 2013;21(Suppl 1):S1–27.
17. Quesada BM, Kohan G, Roff HE, et al. Management of gallstones and gallbladder disease in patients undergoing gastric bypass. World J Gastroenterol. 2010;16(17):2075–9.
18. Chiu CC, Wang JJ, Tsai TC, et al. The relationship between volume and outcome after bariatric surgery: a nationwide study in Taiwan. Obes Surg. 2012;22(7):1008–15.
19. Huang CC, Huang YT, Chiu CC. A population-based analysis of use and outcomes of laparoscopic bariatric surgery across socioeconomic groups in Taiwan. Int J Equity Health. 2015;14:127.
20. Chien W-C, Chung C-H, Lin F-H, et al. Is weight control surgery associated with increased risk of newly onset psychiatric disorders? A population-based, matched cohort study in Taiwan. J Med Sci. 2017;37(4):137–49.
21. Lu CW, Chang YK, Chang HH, et al. Fracture risk after bariatric surgery: a 12-year nationwide cohort study. Medicine (Baltimore). 2015;94(48):e2087.
22. Liang TJ, Liu SI, Chen YC, et al. Analysis of gallstone disease after gastric cancer surgery. Gastric Cancer. 2017;20(5):895–903.
23. Li SC, Lee CH, Hung CL, et al. Surgical resection of metachronous hepatic metastases from gastric cancer improves long-term survival: a population-based study. PLoS One. 2017;12(7):e0182255.
24. Cheng CL, Lee CH, Chen PS, et al. Validation of acute myocardial infarction cases in the national health insurance research database in Taiwan. J Epidemiol. 2014;24(6):500–7.
25. Cheng CL, Chien HC, Lee CH, et al. Validity of in-hospital mortality data among patients with acute myocardial infarction or stroke in National Health Insurance Research Database in Taiwan. Int J Cardiol. 2015;201:96–101.
26. Hsieh CY, Chen CH, Li CY, et al. Validating the diagnosis of acute ischemic stroke in a National Health Insurance claims database. J Formos Med Assoc. 2015;114(3):254–9.
27. Yang H, Chen YH, Hsieh TF, et al. Prediction of mortality in incident hemodialysis patients: a validation and comparison of CHADS2, CHA2DS2, and CCI scores. PLoS One. 2016;11(5):e0154627.
28. Grover BT, Kothari SN. Biliary issues in the bariatric population. Surg Clin North Am. 2014;94(2):413–25.
29. Behari A, Kapoor VK. Asymptomatic gallstones (AsGS) - to treat or not to? Indian J Surg. 2012;74(1):4–12.
30. Desbeaux A, Hec F, Andrieux S, et al. Risk of biliary complications in bariatric surgery. J Visc Surg. 2010;147(4):e217–20.
31. Iglezias Brandao de Oliveira C, Adami Chaim E, da Silva BB. Impact of rapid weight reduction on risk of cholelithiasis after bariatric surgery. Obes Surg. 2003;13(4):625–8.
32. Torgerson JS, Lindroos AK, Naslund I, et al. Gallstones, gallbladder disease, and pancreatitis: cross-sectional and 2-year data from the Swedish obese subjects (SOS) and SOS reference studies. Am J Gastroenterol. 2003;98(5):1032–41.
33. de Mestral C, Rotstein OD, Laupacis A, et al. A population-based analysis of the clinical course of 10,304 patients with acute cholecystitis, discharged without cholecystectomy. J Trauma Acute Care Surg. 2013;74(1):26–30. discussion
34. O'Brien PE, Dixon JB. A rational approach to cholelithiasis in bariatric surgery: its application to the laparoscopically placed adjustable gastric band. Arch Surg. 2003;138(8):908–12.
35. Deitel M, Petrov I. Incidence of symptomatic gallstones after bariatric operations. Surg Gynecol Obstet. 1987;164(6):549–52.
36. Mishra T, Lakshmi KK, Peddi KK. Prevalence of cholelithiasis and choledocholithiasis in morbidly obese south Indian patients and the further development of biliary calculus disease after sleeve gastrectomy, gastric bypass and mini gastric bypass. Obes Surg. 2016;26(10):2411–7.
37. Nagem R, Lazaro-da-Silva A. Cholecystolithiasis after gastric bypass: a clinical, biochemical, and ultrasonographic 3-year follow-up study. Obes Surg. 2012;22(10):1594–9.
38. Caruana JA, McCabe MN, Smith AD, et al. Incidence of symptomatic gallstones after gastric bypass: is prophylactic treatment really necessary? Surg Obes Relat Dis. 2005;1(6):564–7. discussion 7-8
39. Sugerman HJ, Brewer WH, Shiffman ML, et al. A multicenter, placebo-controlled, randomized, double-blind, prospective trial of prophylactic ursodiol for the prevention of gallstone formation following gastric-bypass-induced rapid weight loss. Am J Surg. 1995;169(1):91–6. discussion 6–7
40. Shiffman ML, Sugerman HJ, Kellum JH, et al. Gallstones in patients with morbid obesity. Relationship to body weight, weight loss and gallbladder bile cholesterol solubility. Int J Obes Relat Metab Disord. 1993;17(3):153–8.
41. Moon RC, Teixeira AF, DuCoin C, et al. Comparison of cholecystectomy cases after Roux-en-Y gastric bypass, sleeve gastrectomy, and gastric banding. Surg Obes Relat Dis. 2014;10(1):64–8.
42. Shiffman ML, Sugerman HJ, Kellum JM, et al. Changes in gallbladder bile composition following gallstone formation and weight reduction. Gastroenterology. 1992;103(1):214–21.
43. Adams LB, Chang C, Pope J, et al. Randomized, prospective comparison of ursodeoxycholic acid for the prevention of gallstones after sleeve gastrectomy. Obes Surg. 2016;26(5):990–4.
44. Shiffman ML, Shamburek RD, Schwartz CC, et al. Gallbladder mucin, arachidonic acid, and bile lipids in patients who develop gallstones during weight reduction. Gastroenterology. 1993;105(4):1200–8.

45. Portenier DD, Grant JP, Blackwood HS, et al. Expectant management of the asymptomatic gallbladder at Roux-en-Y gastric bypass. Surg Obes Relat Dis. 2007;3(4):476–9.
46. Liddle RA, Goldstein RB, Saxton J. Gallstone formation during weight-reduction dieting. Arch Intern Med. 1989;149(8):1750–3.
47. Sioka E, Zacharoulis D, Zachari E, et al. Complicated gallstones after laparoscopic sleeve gastrectomy. J Obes. 2014;2014:468203.
48. Raziel A, Sakran N, Szold A, et al. Concomitant cholecystectomy during laparoscopic sleeve gastrectomy. Surg Endosc. 2015;29(9):2789–93.
49. Taylor J, Leitman IM, Horowitz M. Is routine cholecystectomy necessary at the time of Roux-en-Y gastric bypass? Obes Surg. 2006;16(6):759–61.
50. Fobi M, Lee H, Igwe D, et al. Prophylactic cholecystectomy with gastric bypass operation: incidence of gallbladder disease. Obes Surg. 2002;12(3):350–3.
51. Mason EE, Renquist KE. Gallbladder management in obesity surgery. Obes Surg. 2002;12(2):222–9.
52. Wudel Jr LJ, Wright JK, Debelak JP, et al. Prevention of gallstone formation in morbidly obese patients undergoing rapid weight loss: results of a randomized controlled pilot study. J Surg Res. 2002;102(1):50–6.
53. Patel JA, Patel NA, Piper GL, et al. Perioperative management of cholelithiasis in patients presenting for laparoscopic Roux-en-Y gastric bypass: have we reached a consensus? Am Surg. 2009;75(6):470–6. discussion 6
54. Lambert DM, Marceau S, Forse RA. Intra-abdominal pressure in the morbidly obese. Obes Surg. 2005;15(9):1225–32.
55. Pavlidis TE, Marakis GN, Ballas K, et al. Risk factors influencing conversion of laparoscopic to open cholecystectomy. J Laparoendosc Adv Surg Tech A. 2007;17(4):414–8.
56. Aziz H, Pandit V, Joseph B, et al. Age and obesity are independent predictors of bile duct injuries in patients undergoing laparoscopic cholecystectomy. World J Surg. 2015;39(7):1804–8.
57. Li VK, Pulido N, Fajnwaks P, et al. Predictors of gallstone formation after bariatric surgery: a multivariate analysis of risk factors comparing gastric bypass, gastric banding, and sleeve gastrectomy. Surg Endosc. 2009;23(7):1640–4.
58. Conley A, Tarboush M, Manatsathit W, et al. Do gallstones found before sleeve gastrectomy behave the same as those formed after surgery due to weight loss? Am J Surg. 2016;212(5):931–4.
59. Johna S. Gallstones and bariatric surgery: to treat or not to treat? World J Surg. 2016;40(12):2911–2.
60. Tsirline VB, Keilani ZM, El Djouzi S, et al. How frequently and when do patients undergo cholecystectomy after bariatric surgery? Surg Obes Relat Dis. 2014;10(2):313–21.