OBES SURG (2012) 22:1008–1015
DOI 10.1007/s11695-012-0636-x

CLINICAL RESEARCH

The Relationship between Volume and Outcome after Bariatric Surgery: A Nationwide Study in Taiwan

Chong-Chi Chiu · Jhi-Joung Wang · Tsung-Chih Tsai · Chin-Chen Chu · Hon-Yi Shi

Published online: 28 March 2012

Abstract
Background This study purposed to explore the impact of hospital volume and surgeon volume on hospital resource utilization after bariatric surgery and to identify the predictors of length of stay (LOS) and hospital treatment cost in a nationwide population in Taiwan.

Methods This population-based cohort study retrospectively analyzed 2,674 bariatric surgery procedures performed from 1997 to 2008. Hospitals were classified as low- and high-volume hospitals if their annual number of bariatric surgeries were <35 and ≥35, respectively. Surgeons were classified as low- and high-volume surgeons if their annual number of bariatric surgeries were <15 and ≥15, respectively. Hierarchical linear regression models were used to predict LOS and hospital treatment cost.

Results The mean LOS was 7.67 days and the LOS for high-volume hospitals/surgeons was, on average, 28%/31% shorter than that for low-volume hospitals/surgeons. The mean hospital treatment cost was US$2,344.08, and the average hospital costs for high-volume hospitals/surgeons were 10%/13% lower than those for low-volume hospitals/surgeons. Advanced age, male gender, high Charlson co-morbidity index, and current treatment in a low-volume hospital, by a low-volume surgeon, and via open gastric bypass were significantly associated with long LOS and high hospital treatment cost (P<0.001).

Conclusions The data suggest that annual surgical volume is the key factor in hospital resource utilization. The results improve the understanding of medical resource allocation for this surgical procedure and can help to formulate public health policies for optimizing hospital resource utilization for related diseases.

Keywords Bariatric surgery · Volume · Lengths of stay · Hospital treatment cost

Chong-Chi Chiu and Jhi-Joung Wang are equal contributors in this work.

C.-C. Chiu
Department of Surgery, Chi Mei Medical Center,
Tainan, Taiwan

C.-C. Chiu
Taipei Medical University,
Taipei, Taiwan

C.-C. Chiu
Chia Nan University of Pharmacy and Science,
Tainan, Taiwan

J.-J. Wang · C.-C. Chu
Department of Medical Research, Chi Mei Medical Center,
Tainan, Taiwan

C.-C. Chiu · T.-C. Tsai
Department of Surgery, Chi Mei Medical Center,
Liouying, Taiwan

C.-C. Chu
Department of Anesthesiology, Chi Mei Medical Center,
Tainan, Taiwan

H.-Y. Shi (✉)
Department of Healthcare Administration
and Medical Informatics, Kaohsiung Medical University,
100, Shih-Chuan 1st Road, San Ming District,
Kaohsiung, Taiwan
e-mail: hshi@kmu.edu.tw

Introduction

The prevalence of morbid obesity has increased markedly in the past two decades and is now a significant public health concern [1]. The growing awareness of the detrimental health effects of morbid obesity has increased interest in aggressive treatments such as operative methods [2].

Bariatric surgery is widely considered the most effective treatment for morbid obesity with body mass index (BMI) ≥40 kg/m^2 and for morbid obesity with BMI ≥35 kg/m^2 with co-present symptoms of metabolic syndrome such as diabetes, hypertension, or sleep apnea [3–5]. For many surgical procedures, outcome has a well-established correlation with the volume of procedures regularly performed by the hospital or surgeon [6–8]. The correlation is usually characterized as a learning curve [6–8]. That is, outcomes of surgical procedures improve as hospitals or surgeons gain experience performing the procedures. However, despite the strong evidence of this relationship, few studies of the association have exceeded 10 years. Additionally, since most of the available data have been published in studies of US or European populations, the data may not apply in Asian countries such as Taiwan. For example, comparisons of diabetes and cardiovascular disease between eastern and western populations show that these diseases tend to develop at a younger age and at a relatively lower obesity level in Asian populations than in western populations [9, 10]. Besides, Asian has a characteristic obesity phenotype of a low BMI but with central adiposity [4]. This visceral fat area (VFA)-defined obesity is widely acknowledged that the risk for metabolic syndrome starts at a relatively normal level of BMI [11]. In other words, VFA-defined obesity is a more useful and sensitive indicator of underlying co-morbid medical conditions and predicting surgical outcomes, when compared with BMI-defined obesity. Although age is a well-recognized risk factor for bariatric surgery mortality [5], for a given BMI, Asians are at greater risk of dying from all causes than US or European populations [12].

Compared to their US counterparts, mortality risk is higher not only in Taiwan populations classified as obese but also in those classified as overweight according to the WHO definition (BMI of 25.0–29.9 kg/m^2). Specifically, in subjects with BMI at or above 25.0 kg/m^2, every unit of increase in BMI is associated with a 9% increase in relative overall mortality risk. Most importantly, compared to overweight Americans, Taiwan populations classified as overweight according to the current WHO definition (BMI=25.0–29.9 kg/m^2) have a significantly higher rate of all-cause mortality [12]. Finally, compared to Caucasians, Asians, especially Taiwanese, tend to have lower physical activity levels, which implies lower fitness levels and higher mortality rates [12].

Thus, the available literature on the volume–outcome relationship in bariatric surgery may not be generalizable to patients in Taiwan. Additionally, no longitudinal studies have compared the differences between hospital/surgeon volume and hospital resource utilization, and none have systematically compared bariatric surgery outcomes in Taiwan. This study therefore explored the impact of hospital volume and surgeon volume on hospital resource utilization after bariatric surgery and identified the predictors of length of stay (LOS) and hospital treatment cost in a nationwide population in Taiwan.

Methods

Study Design and Study Population

This study analyzed administrative claims data obtained from the Taiwan Bureau of National Health Insurance (BNHI). Because the BNHI is the sole payer in Taiwan, the BNHI data set included data for all inpatients discharged from all hospitals. According to Taiwan medical law, bariatric operations can only performed in patients aged 14 to 65 years. As noted above, the study population was comprised of adults (18 years or older) who had a principal diagnosis code for obesity (code 278.00, 278.01, 278.02, or 278.1) in the International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) and a primary procedure code for open gastric bypass (including mini gastric bypass, MGB—code 44.31 and Roux-en-Y gastric bypass, RYGB—code 44.39), laparoscopic gastric bypass (including laparoscopic mini gastric bypass, LMGB, and laparoscopic Roux-en-Y gastric bypass, LRYGB—code 44.38), open gastroplasty (including vertical banded gastroplasty, VBG—code 44.69), or laparoscopic gastroplasty (including laparoscopic vertical banded gastroplasty, LVBG—code 44.68 and laparoscopic adjustable gastric band, LAGB—code 44.95) performed between January 1, 1997 and December 31, 2008. To increase the homogeneity of the study sample, the analysis also included the diagnosis-related group for operative treatment of obesity (ICD-9-CM 288, N=267), and patients undergoing emergent procedures were excluded. The ICD-9-CM does not include a code for laparoscopic procedures converted to open procedures. The final sample therefore included 2,674 patients.

Measurement Variables

This study analyzed the following characteristics of patients who had undergone bariatric surgery: age, gender, co-morbidity, and bariatric procedures. Co-morbidity was estimated using the Charlson index [13]. Bariatric procedures were categorized as open gastric bypass, laparoscopic gastric bypass, open gastroplasty, and laparoscopic gastroplasty. The analyzed hospital characteristics were hospital volume, surgeon volume, and hospital resource utilization. Hospitals/surgeons were further sorted by their total patient volume by using the unique hospital/surgeon identifiers in this database. Hospitals/surgeons were divided into two groups based on the average number of bariatric operations they had performed within the 12-year study period. Hospitals that performed an average of <35 and ≥35 bariatric surgeries annually were classified as low- and high-volume hospitals, respectively. Surgeons who performed an average of <15 and ≥15 bariatric surgeries annually were classified as low- and high-volume surgeons, respectively. Hospital resource utilization was measured by LOS and hospital treatment cost.

Statistical Analysis

Categorical variables were tested by χ^2 analysis. Temporal trends were assessed by Cochrane–Armitage trend test. Hospital treatment cost was calculated using the fee data included in standard administrative claims for reimbursement from the Taiwan BNHI, including operating room, radiology, physical therapy, hospital room, anesthetist, pharmacy, laboratory, special materials, surgeon, and others.

Two regression models, an ordinary linear regression model and a hierarchical linear regression model, were fit to these data. The hierarchical linear regression model was used to compare LOS and hospital treatment cost observed in the reference group with those observed at different hospital volumes and surgeon volumes after adjusting for age, gender, Charlson co-morbidity index (CCI), and bariatric procedures. Hierarchical linear regression method was used to prevent hospital clustering effects (i.e., effects resulting from policies, procedures, or physician compensation mechanisms unique to each hospital) on the analysis of care quality and costs. The intra-class coefficients of LOS and hospital treatment cost based on two variance components were 0.24 and 0.38, respectively, and hospital-level random effects were considered later. Hospital treatment costs at different hospital levels were adjusted for differences in BNHI reimbursements, the largest of which were generally received by medical centers and the smallest of which were generally received by local hospitals. Additionally, to reflect changes in real dollar value, all dollar values at the end of each year were adjusted to year 2008 values for the Taiwan currency. Hospital treatment cost was then converted from Taiwan dollars to US dollars at an exchange rate of 30.5:1, which was the average exchange rate during 1997–2008.

Statistical analyses were conducted using SPSS version 15.0 (SPSS Inc., Chicago, IL, USA) and Stata Statistical Package, version 9.0 (Stata Corp, College Station, TX, USA). All tests were two-sided, and P values less than 0.05 were considered statistically significant.

Results

Table 1 shows the characteristics of the patients and hospitals analyzed in this study. Table 2 lists the differences between low- and high-volume hospitals in terms of patient characteristics and hospital characteristics. The mean LOS and hospital treatment cost were significantly lower for high-volume hospitals than for low-volume hospitals (P<0.001). Otherwise, there was no statistical difference in patients' gender, age, and CCI between groups. Additionally, patients who received bariatric surgery by high-volume surgeons were more likely to get lower LOS and hospital treatment cost than those by low-volume surgeons (P<0.001) (Table 3).

Table 1 Patient characteristics and hospital characteristics of the study sample (N=2,674)

Variables	N (%)
Age (years)[*])[a]	32.21±9.60
Gender	
Male	856 (32.01%)
Female	1,818 (67.99%)
Charlson co-morbidity index score[*a]	2.88±1.39
1	603 (22.55%)
2	501 (18.74%)
3	644 (24.08%)
4	467 (17.46%)
≧5	459 (17.17%)
Bariatric procedures	
Open gastric bypass	392 (14.66%)
Laparoscopic gastric bypass	834 (31.19%)
Open vertical banded gastroplasty	1,042 (38.97%)
Laparoscopic vertical banded gastroplasty	406 (15.18%)
Length of stay (days)[*])[a]	7.67±6.09
Hospital treatment costs (dollars)[*])[a]	2,344.08±2,143.04

[*a] Values are the mean ± standard deviation.

After adjusting for patient characteristics and hospital characteristics, the hierarchical linear regression model revealed that the LOS for high-volume hospitals was significantly shorter (by 3.71 days) than that for low-volume hospitals (P< 0.001). However, since the mean LOS was 7.67 days, the LOS for high-volume hospitals was, on average, 48% shorter than that for low-volume hospitals after adjusting for patient characteristics and hospital characteristics (Table 4). Moreover, the LOS for high-volume surgeons was also significantly shorter (by 4.23 days) than that for low-volume surgeons (P<0.001), and the average LOS for high-volume surgeons were 55% lower than those for low-volume surgeons after adjusting for patient characteristics and hospital characteristics. Additionally, LOS was significantly associated with age, gender, CCI, and bariatric procedures (P<0.001).

The hierarchical linear regression model also showed that, compared to low-volume hospitals, mean hospital treatment cost was significantly lower in high-volume hospitals (US $308.93 lower; P<0.001). For all hospitals, the mean hospitalization cost

Table 2 The comparison of patient characteristics and hospital characteristics of 2,674 bariatric surgery patients according to hospital volume in Taiwan from 1997 to 2008

Characteristics	Low volume (<35 cases/ year)	High volume (≧35 cases/ year)	*P* value
Total number of hospitals	262	14	
Total number of bariatric surgeries	1,770	904	
Number of bariatric surgeries performed per hospital[*a]	6.76±8.43	64.57±42.20	<0.001
Patient characteristics			
Male/female	584/1,186	289/615	0.867
Age, years[*a]	31.49±14.23	30.92±14.84	0.827
Charlson co-morbidity index score[*a]	2.82±1.64	2.93±2.04	0.506
Hospital characteristics			
Lengths of stay, days[*a]	7.51±5.19	6.74±5.82	<0.001
Hospital treatment cost, dollars[*a]	2,399.64±2,117.57	2,141.67±2,021.74	<0.001

[*a]Values are the mean ± standard deviation

was US $2,344.08. The average hospital treatment cost for high-volume hospitals was 13% lower than that for low-volume hospitals after adjusting for patient characteristics and hospital characteristics. Furthermore, mean hospital treatment cost for procedures performed by high-volume surgeons was significantly lower than that for procedures performed by low-volume surgeons (US $400.32 lower; $P<0.001$). Average hospital treatment cost for high-volume surgeons was 17% lower than that for low-volume surgeons after adjusting for patient characteristics and hospital characteristics. Finally, hospital treatment cost was significantly lower ($P<0.001$) in females than in males and was also significantly associated with age, CCI, and bariatric procedures ($P<0.001$).

Discussion

A major development in bariatric surgery in the past decade is the widespread use of minimally invasive techniques. Within this time frame, the number of laparoscopic gastric bypass operations performed annually in the USA has risen dramatically [14]. In fact, in the USA, the annual number of surgical treatments for morbid obesity is growing faster than that of any other surgical procedure [15]. An estimated 121,055 weight loss procedures were performed in the USA in 2008 [16]. In Taiwan, the number of bariatric procedures performed annually to treat morbid obesity has also increased substantially in recent years. For example, of the estimated 3,226 bariatric procedures performed throughout the Asia-Pacific region in 2004, approximately 2,100 (65%) were performed in Taiwan alone [4]. Thus, the database analyzed in this study is representative of bariatric procedures performed throughout the entire Asia-Pacific region. Additionally, the database analyzed in this study included all procedures performed from 1997 to 2008, which is the longest period of analysis of all studies of bariatric surgery procedures in the current literature.

During the last decade, laparoscopy has revolutionized the practice of bariatric surgery [17]. For example, use of LRYGB is now common despite its technical difficulty and its association with intra-operative and post-operative complications [14, 18]. Although morbidity and mortality associated

Table 3 The comparison of patient characteristics and hospital characteristics of 2,674 bariatric surgery patients according to surgeon volume in Taiwan from 1997 to 2008

Characteristics	Low volume (<15 cases/ year)	High volume (≧15 cases/ year)	*P* value
Total number of surgeons	392	43	
Total number of bariatric surgeries	1,767	907	
Number of bariatric surgeries performed per surgeon[*a]	4.51±3.89	21.09±17.23	<0.001
Patient characteristics			
Male/female	562/1,205	295/612	0.785
Age, years[*a]	32.20±17.84	31.88±17.09	0.968
Charlson co-morbidity index score[*a]	2.94±1.83	2.83±1.94	0.925
Hospital characteristics			
Lengths of stay, days[*a]	7.76±6.24	7.18±5.67	<0.001
Hospital treatment cost, dollars[*a]	2,398.34±2,201.22	2,096.81±2,011.94	<0.001

[*a]Values are the mean ± standard deviation

Table 4 Hierarchical linear regression model of the relationship between effective predictors and length of stay (days) and hospital treatment cost (dollars) (N=2,674)

Variables	Length of stay			Hospital treatment cost		
	Parameter estimate	Standard error	*P* value	Parameter estimate	Standard error	*P* value
(constant)	4.48	0.20	<0.001	2,418.46	111.97	<0.001
Age	0.12	0.03	<0.001	3.47	0.84	<0.001
Gender[#a]						
Female	-−1.11	-−0.05	<0.001	-−8.59	-−2.10	<0.001
Charlson co-morbidities index	1.18	0.23	<0.001	72.41	11.24	<0.001
Hospital volume[#a]						
High	-−3.71	-−0.67	<0.001	-−308.93	-−49.09	<0.001
Surgeon volume[#a]						
High	-−4.23	-−0.72	<0.001	-−400.32	-−77.64	<0.001
Bariatric procedures[#a]						
Laparoscopic gastric bypass	-−0.59	-−0.14	<0.001	-−46.57	-−8.24	<0.001
Open vertical banded gastroplasty	-−0.52	-−0.13	<0.001	-−38.40	-−7.46	<0.001
Laparoscopic vertical banded gastroplasty	-−1.34	-−0.40	<0.001	-−39.72	-−6.53	<0.001
Residual variance	24.18			89,245,621.57		
Random effect associated with hospital	1.67			346,818.91		

[#a] References: male, low hospital volume, low surgeon volume, open gastric bypass

with LRYGB clearly decrease as operator experience increases, the learning curve for LRYBG is very steep even for experienced laparoscopic surgeons. For example, laparoscopic surgeons rarely achieve a lower than average morbidity and mortality rate until they acquire experience performing 75 to 100 LRYGB procedures [14, 19]. The extreme complexity of the procedure explains why laparoscopic gastric bypass is usually performed via LMGB in Taiwan.

Advanced age is a well-recognized risk factor for bariatric surgery mortality because it has a strong and positive association with high number of co-morbidities. For example, Raftopoulos et al. studied 4,685 patients who had received gastric bypass surgery (age range, 16–74 years; mean age, 42 years; median age, 42 years) [5]. The study population included 3,076 (80%) patients who were 50 years or younger (mean age, 38 years) and 609 patients who were older than 50 years (mean age, 55 years). The rate of adverse outcomes was significantly ($P<0.05$) higher in patients older than 50 years (23%) than in those aged 50 years or younger (16%). Adverse outcome rates were also significantly ($P<0.05$) higher in older patients than in those with no co-morbidity [5]. In contrast, the estimated mean age in the current study (32.21 years) was about 10 years younger than that in Raftopoulos et al. [5]. However, since age-related differences in adverse outcome rates were still noted in our series, older patients in Asian regions who are recommended for bariatric surgery should be counseled regarding their higher than normal perioperative risk.

Analysis of gender differences in LOS and hospital treatment cost incurred by the bariatric surgery patients in this study also indicated that females tended to have shorter LOS and lower hospital treatment cost than males did. Raftopoulos et al. concluded that mortality was unrelated to pre-existing medical conditions in males, but not in females [5]. Several studies have also reported that male gender is a major risk factor for complications such as anastomotic leaks [20, 21]. Another study of 1,067 RYGB patients by Livingston et al. showed that adverse outcomes were more common in males than in females (13.1% vs.6%, respectively) [22]. We propose two possible explanations for this phenomenon. First, males who undergo bariatric surgery may have higher morbidity and mortality because of their larger body size and their tendency to accumulate fat in the abdominal compartment (central obesity), both of which increase the technical difficulty of the procedure [5]. Second, the diseases tend to be more severe in males than in females at the time of surgery because males tend to delay surgery [23].

Morbidly obese patients undergoing bariatric surgery are typically burdened by a host of obesity-related co-morbidities that increase their risk of surgical complications [24]. Our statistical data also agree that resource utilization in terms of LOS and treatment cost tends to increase with Charlson co-morbidity index.

The learning curve for a task can be defined as the amount of repetition needed to learn the task. It consists of an initial steep phase in which proficiency in performing the procedure and success in treating the complication increase rapidly [25]. Although both the European Association of

Endoscopic Surgeons [26] and the Society of American Gastrointestinal Endoscopic Surgeons [27] have both published training recommendations, these do not specify numerical requirements for any particular procedure [25]. During the last decade, laparoscopy has revolutionized the practice of bariatric surgery [17]. Although a systematic literature review shows no agreement on the number of operations needed to achieve proficiency in laparoscopic surgery [25], Schauer et al. [28] and Oliak et al. [29] proposed that the learning curve for LRYGB, even for experienced laparoscopic surgeons, is 76 to 100 surgeries [19]. Conversely, Mohamed et al. validated the concept that advanced surgical training can eliminate the learning curve often associated with complex minimally invasive procedures, specifically LRYGB [14]. The current study found that treatments performed at high-volume centers and by high-volume surgeons required significantly fewer medical resources compared to low-volume hospitals and surgeons, which was consistent with most studies in the literature [6–8].

Actually, the cooperation of a surgical team improves similarly to the learning curve of an individual surgeon. For example, this study showed that both LOS and hospital treatment cost were significantly lower in patients treated in high-volume hospitals than in those treated in low-volume hospitals. Moreover, a study of 5,365 bariatric patients by Ballantyne et al. also documented a lower mortality rate in bariatric operations performed in high-volume centers than in those performed in low-volume centers [30]. Similarly, Saunders et al. showed that 30-day [31] and 1-year readmission rates were lower in patients who had received bariatric surgery in high-volume hospitals than in those treated in low-volume hospitals [32]. However, the mean LOS in our study was longer than that reported in comparable populations elsewhere [33, 34]. Possible explanations for the longer LOS observed in the Taiwan population analyzed in this study include the comparatively lower cost of hospitalization, the difference in habitual use of medical resources, and different economic characteristics. A recent study of socio-economic stratification of obesity and metabolic syndrome showed that both conditions correlated positively with affluence in Asian regions, which was opposite to the correlation observed in Western populations, in which obesity correlates negatively with socio-economic status [4].

In this study, the patients who underwent laparoscopic gastric bypass had shorter LOS and lower hospital costs compared to those treated by open approach. The major differences between the two procedures are the method of access, method of exposure, and extent of operative trauma. Typically, an upper midline incision is made in open procedure whereas five small access incisions are made in laparoscopic approach. Open procedure requires retractors to expose the abdominal wall and mechanical retractors to retract the abdominal viscera. In laparoscopic procedure, however, the pneumoperitoneum is used to create a working space to expose the abdominal wall, and the abdominal viscera are displaced by gravity. Nguyen et al. showed that, compared to open approach, laparoscopic gastric bypass causes less operative trauma because it requires a smaller surgical incision and it does not require mechanical retraction of the abdominal wall [17, 35]. Physiologically, laparoscopic approach is also superior to open gastric bypass because it produces a lower systemic stress response [17]. Recent randomized studies have convincingly demonstrated the advantages of laparoscopic approach compared to open gastric bypass for surgically treating morbid obesity, including less postoperative pain, shorter hospital stay, improved pulmonary function, faster recovery of perioperative function, and lower rate of incisional hernia [36].

Gastroplasty, a purely restrictive method, is the safest procedure [37]. In comparison, gastric bypass, a combined malabsorptive and restrictive procedure, is technically more demanding but is now considered the “gold standard” procedure in terms of outcomes such as weight loss and comorbidity [37]. As noted above, LMGB is the most common laparoscopic gastric bypass procedure in Taiwan whereas LRYBG is the most common in the USA. Therefore, the longer operative time and hospital stay observed in laparoscopic gastric bypass compared to laparoscopic gastroplasty was not unexpected. Additionally, the procedural complexity of laparoscopic gastric bypass is relatively higher. For example, division of the stomach requires two anastomoses in LRYBG but only one in LMGB. In laparoscopic gastroplasty, however, LVBG only requires sufficient space for mesh placement and gastric partition by stapling, and LAGB only requires sufficient space for a tunnel used to deploy the retrogastric band. The timing of oral intake is faster in gastroplasty, which results in a comparatively shorter hospital stay. The type and severity of both early and late complications also differed between the two groups. Complications requiring reoperations tended to occur early in the LRYGB group but later in the LAGB group. Of the complications that arose early after surgery and required reoperation, those that occurred shortly after LRYGB were usually related to a flawed performance of the initial operation whereas those that occurred shortly after LAGB were usually related to defects in the device. However, a study of 106 patients with extreme morbid obesity by Bowne et al. found that LRYGB and LABG did not significantly differ in the number of early complications [38].

This study has several limitations that are inherent in any large database analysis. Firstly, the clinical picture obtained by analyzing claims data is not as precise as that obtained by analyzing prospective clinical trial data due to possible errors in the coding of primary diagnoses and surgical modalities. For example, although this study found that

LMGB is performed more frequently than LRYGB in Taiwan, the database used in this study did not enable further differentiation between LMGB and LRYGB because laparoscopic gastric bypass procedures are not assigned different ICD-9 codes. Similarly, LAGB (code 44.95) could not be differentiated from LVBG (code 44.68) in surgeries performed before introduction of the ICD-9 procedural codes (i.e., before 2004). Although LAGB is currently the only purely restrictive procedure performed in Taiwan, all patients who receive LAGB are routinely mis-registered with code 44.68 instead of code 44.95. Moreover, despite the different ICD-9 codes for open gastric bypass (MGB—code 44.31 and RYGB—code 44.39), frequent mis-registration of the codes in the early stage of database establishment precludes an accurate calculation of the number of open gastric bypass surgeries performed. Secondly, complications associated with bariatric procedures could not be exactly analyzed in our database, which limits the validity of the data. For example, intra-operative complications include cardiac arrhythmia and intra-abdominal hemorrhage whereas post-operative complications include pneumonia, cardiac arrhythmia, bowel obstruction, urinary tract infection, gastrointestinal tract or intra-abdominal hemorrhage, anastomotic leakage, wound infection, deep venous thrombosis, or pulmonary embolism. Complications other than infection and urinary tract infection are considered major complications. However, none of these details could be derived from the database analyzed in this study. Finally, the analysis did not examine outcome data such as patient-reported quality of life and indirect costs incurred after discharge.

Conclusion

The data suggest that annual surgical volume is the key factor in hospital resource utilization. This study suggests that LOS may explain the lower costs incurred at high-volume hospitals and by high-volume surgeons in comparison with low-volume hospitals and surgeons. Therefore, to increase healthcare quality and decrease costs, payers may consider using high-volume hospitals/surgeons preferentially for performing complex surgical procedures or consider providing expert consultation to low-volume surgeons. Additionally, the results also can improve the understanding of medical resource allocation for this surgical procedure and can help to formulate public health policies for optimizing hospital resource utilization for related diseases. Careful management of these factors can enhance efficiency in allocating scarce hospital resources.

Conflicts of interest Drs. Chiu, Wang, Tsai, Chu, and Shi have no conflict of interest with any institution or product that is mentioned in the manuscript.

References

1. Orci L, Chilcott M, Huber O. Short versus long Roux-limb length in Roux-en-Y gastric bypass surgery for the treatment of morbid and super obesity: a systematic review of the literature. Obes Surg. 2011;21(6):797–804.
2. Fierabracci P, Pinchera A, Martinelli S, et al. Prevalence of endocrine diseases in morbidly obese patients scheduled for bariatric surgery: beyond diabetes. Obes Surg. 2011;21(1):54–60.
3. Busetto L, Sbraccia P, Frittitta L, et al. The growing role of bariatric surgery in the management of type 2 diabetes: evidences and open questions. Obes Surg. 2011;21(9):1451–7.
4. Chowbey P. Laparoscopic bariatric surgery in Asia. Asia J Endosc Surg. 2008;1:21–6.
5. Raftopoulos Y, Gatti GG, Luketich JD, et al. Advanced age and sex as predictors of adverse outcomes following gastric bypass surgery. JSLS. 2005;9:272–6.
6. Padwal R, Klarenbach S, Wiebe N. Bariatric surgery: a systematic review of the clinical and economic evidence. J Gen Intern Med. 2011;26:1183–94.
7. Campos GM, Rabl C, Roll GR, et al. Better weight loss, resolution of diabetes, and quality of life for laparoscopic gastric bypass vs banding: results of a 2-cohort pair-matched study. Arch Surg. 2011;146(2):149–55.
8. Kohn GP, Galanko JA, Overby DW, et al. High case volumes and surgical fellowships are associated with improved outcomes for bariatric surgery patients: a justification of current credentialing initiatives for practice and training. J Am Coll Surg. 2010;210(6):909–18.
9. Huang CK, Shabbir A, Lo CH, et al. Laparoscopic Roux-en-Y gastric bypass for the treatment of type II diabetes mellitus in Chinese patients with body mass index of 25–35. Obes Surg. 2011;21(9):1344–9.
10. Tai CM, Lee YC, Tu HP, et al. The relationship between visceral adiposity and the risk of erosive esophagitis in severely obese Chinese patients. Obesity. 2010;18(11):2165–9.
11. Lakdawala M, Bhasker A. Asian Consensus Meeting on Metabolic Surgery (ACMOMS). Report: Asian Consensus Meeting on Metabolic Surgery. Recommendations for the use of Bariatric and Gastrointestinal Metabolic Surgery for Treatment of Obesity and Type II Diabetes Mellitus in the Asian Population: August 9th and 10th, 2008, Trivandrum, India. Obes Surg. 2010;20:929–36.
12. Wen CP, Cheng TYD, Tsai SP, et al. Are Asians at greater mortality risks for being overweight than Caucasians? Redefining obesity for Asians. Public Health Nutr. 2008;12:497–506.
13. D'Hoore W, Sicotte C, Tilquin C. Risk adjustment in outcome assessment: the Charlson comorbidity index. Methods Inf Med. 1993;32:382–7.
14. Ali MR, Tichansky DS, Kothari SN, et al. Validation that a 1-year fellowship in minimally invasive and bariatric surgery can eliminate the learning curve for laparoscopic gastric bypass. Surg Endosc. 2010;24:138–44.
15. Livingston EH. Procedure incidence and in-hospital complication rates of bariatric surgery in the United States. Am J Surg. 2004;188:105–10.
16. Puzziferri N, Nakonezny PA, Livingston EH, et al. Variations of weight loss following gastric bypass and gastric band. Ann Surg. 2008;248:233–42.
17. Nguyen NT, Hinojosa M, Fayad C, et al. Use and outcomes of laparoscopic versus open gastric bypass at academic medical centers. J Am Coll Surg. 2007;205:248–55.
18. Gould JC, Garren MJ, Starling JR. Lessons learned from the first 100 cases in a new minimally invasive bariatric surgery program. Obes Surg. 2004;14:618–25.
19. Mohr CJ, Nadzam GS, Curet MJ. Totally robotic Roux-en-Y gastric bypass. Arch Surg. 2005;140:779–86.

20. Nguyen NT, Rivers R, Wolfe BM. Factors associated with operative outcomes in laparoscopic gastric bypass. J Am Coll Surg. 2003;197:548–55.
21. Gentileschi P, Kini S, Catarci M, et al. Evidence-based medicine: open and laparoscopic bariatric surgery. Surg Endosc. 2002;16:736–44.
22. Livingston EH, Huerta S, Arthur D, et al. Male gender is a predictor of morbidity and age a predictor of mortality for patients undergoing gastric bypass surgery. Ann Surg. 2002;236:576–82.
23. Tiwari MM, Goede MR, Reynoso JF, et al. Differences in outcomes of laparoscopic gastric bypass. Surg Obes Relat Dis. 2011;7:277–82.
24. Cawley J, Sweeney MJ, Kurian M, et al. Predicting complications after bariatric surgery using obesity-related co-morbidities. Obes Surg. 2007;17(11):1451–6.
25. Dagash H, Chowdhury M, Pierro A. When can I be proficient in laparoscopic surgery? A systematic review of the evidence. J Pediatr Surg. 2003;38:720–4.
26. Guidelines EAES. training and assessment of competence. Surg Endosc. 1994;8:721–2.
27. Society of American Gastrointestinal Endoscopic Surgeons. Granting of privileges for laparoscopic general surgery. Am J Surg. 1991;161:324–5.
28. Schauer P, Ikramuddin S, Hamad G, et al. The learning curve for laparoscopic Roux-en-Y gastric bypass is 100 cases. Surg Endosc. 2003;17:212–5.
29. Oliak D, Ballantyne GH, Weber P, et al. Laparoscopic Roux-en-Y gastric bypass: defining the learning curve. Surg Endosc. 2003;17:405–8.
30. Ballantyne GH, Belsley S, Stephens D, et al. Bariatric surgery: low mortality at a high-volume center. Obes Surg. 2008;18:660–7.
31. Saunders JK, Ballantyne GH, Belsley S, et al. 30-day readmission rates at a high volume bariatric surgery center: laparoscopic adjustable gastric banding, laparoscopic gastric bypass, and vertical banded gastroplasty-Roux-en-Y gastric bypass. Obes Surg. 2007;17:1171–7.
32. Saunders J, Ballantyne GH, Belsley S, et al. One-year readmission rates at a high volume bariatric surgery center: laparoscopic adjustable gastric banding, laparoscopic gastric bypass, and vertical banded gastroplasty-Roux-en-Y gastric bypass. Obes Surg. 2008;18:1233–40.
33. Kelles SM, Barreto SM, Guerra HL. Mortality and hospital stay after bariatric surgery in 2,167 patients: influence of the surgeon expertise. Obes Surg. 2009;19:1228–35.
34. Thomas H, Agrawal S. Systematic review of same-day laparoscopic adjustable gastric band surgery. Obes Surg. 2011;21:805–10.
35. Nguyen NT, Lee SL, Anderson JT, et al. Evaluation of intra-abdominal pressure after laparoscopic and open gastric bypass. Obes Surg. 2001;11:40–5.
36. Sekhar N, Torquati A, Youssef Y, et al. A comparison of 399 open and 568 laparoscopic gastric bypasses performed during a 4-year period. Surg Endosc. 2007;21:665–8.
37. Holéczy P, Novák P, Králová A. 30% complications with adjustable gastric banding: what did we do wrong? Obes Surg. 2001;11:748–51.
38. Bowne WB, Julliard K, Castro AE, et al. Laparoscopic gastric bypass is superior to adjustable gastric band in super morbidly obese patients: a prospective, comparative analysis. Arch Surg. 2006;141:683–9.