ORIGINAL ARTICLE

Simultaneous liver transplant and sleeve gastrectomy not associated with worse index admission outcomes compared to liver transplant alone – a retrospective cohort study

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SUMMARY

Sleeve gastrectomy (SG) at the time of liver transplant (LT) has been argued to decrease resource utilization. However, larger studies examining outcomes are lacking. We aim to determine the outcomes of simultaneous SG and LT compared to LT alone. This is a retrospective cohort study using the 2011–2017 National Inpatient Sample (NIS). The primary outcome was the odds of inpatient mortality in patients undergoing simultaneous SG and LT compared with LT alone. Secondary outcomes included inpatient morbidity, resource utilization, hospital length of stay (LOS), and inflation-adjusted total hospital costs and charges. A total of 45 361 patients underwent LT in the study period, 49 underwent simultaneous SG. Patients undergoing simultaneous LT and SG had lower crude mortality (0.0%) compared to LT alone (2.97%; $P = 0.52$). There were no statistically significant differences in morbidity, resource utilization, and hospital costs and charges. Patients undergoing simultaneous LT and SG did not have significantly different mortality rates, morbidity, resource utilization, or LOS during the index admission when compared to LT alone. SG may be feasible at the time of LT in very carefully selected patients. Studies should focus in determining which patients are the optimal candidates to undergo simultaneous LT and SG.

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Introduction

Severe obesity is a significant public health concern with high prevalence, estimated to be at least 35% [1]. If the predicted obesity trend in the United States continues 51.1% of adults will be obese by 2030, the total healthcare costs attributable to obesity will account for 16–18% of total US healthcare costs by 2030 [2].

Lifestyle modifications are the primary modalities for the treatment of obesity; however, strategies are needed to avoid weight regain and to prevent relapse into prior sedentary behaviors and poor dietary habits. Unfortunately, lifestyle intervention is often inadequate for sustained and meaningful weight loss. It has been demonstrated that bariatric surgery is more effective in achieving weight loss than medical therapy alone [3].

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Guidelines suggest that bariatric surgery referral is appropriate for adults with a body mass index (BMI) ≥40 kg/m^2 or BMI ≥35 kg/m^2 with two obesity-related comorbid conditions [4]. Bariatric surgery has been associated with lower all-cause mortality at 5 and 10 years following surgery, suggesting that there is a beneficial effect of bariatric surgery [5]. In addition, weight loss associated with bariatric surgery has been shown to improve glycemic control, hypertriglyceridemia, and hypertension [3,6,7].

Obesity presents unique challenges in patients undergoing liver transplantation (LT) given it has been shown to increase perioperative and long-term complications post-LT [8–10]. A BMI of >40 kg/m^2 has also been associated with elevated rates of mortality after LT [11].

Currently, there are no guidelines on the use of bariatric surgery in patients with cirrhosis or a consensus as to which bariatric surgery modality is best. In patients with advanced liver disease, the decision to undergo bariatric surgery requires appropriate selection, determination of the optimal surgical procedure, and a patient-centered discussion of the risks and benefits. Several small studies have suggested that simultaneous bariatric surgery and LT lead durable weight loss, fewer metabolic complications at follow-up compared to medical weight loss interventions, and is a safe procedure [12].

In this study, we used the National Inpatient Sample (NIS) database to examine the outcomes of patients undergoing simultaneous sleeve gastrectomy (SG) and LT to LT alone during the index admission.

Methods

Study design and data source

This is a population-based analysis of the NIS, the largest publically available inpatient, all-payer database in the United States. This dataset is maintained by the Healthcare Cost and Utilization Project (HCUP), which is an entity ultimately overseen by the US Department of Health and Human Services. Each year of data contains more than 7 million hospital stays, which are a 20% stratified sample of over 4000 nonfederal acute care hospitals of more than 40 states of the United States, and after applying discharge weights provided by the HCUP is the representative of 95% of hospital discharges nationwide. The dataset includes the principal diagnosis, defined as the primary discharge diagnosis, and up to 39 other secondary diagnoses. The dataset also includes codes for up to 25 procedures performed during the hospital stay. It also allows determining the length of hospital stay, and total hospitalization charges, and the desired outcome measures such as calculations of inpatient disease prevalence. All analyzed data were extracted from the database for the year 2011–2017 to design this retrospective cohort study which were the latest datasets available at the time of analysis. Since multiple years of data were used, costs and charges were adjusted for inflation using the Consumer Price Index to reflect 2017 $USD equivalents.

Study population

All patients in the NIS dataset for 2011–2017 with an International Classification of Diseases, Ninth and Tenth Revisions, Clinical Modification (ICD-9/10 CM) procedural codes for sleeve gastrectomy (SG) were identified. Obesity was identified if the patient had corresponding ICD codes corresponding to a BMI of at least 30 mg/kg^2 or if the disease modifier variable for obesity (i.e., specific to NIS) was present. All patients with a BMI less than 30 kg/m^2, as well as patients undergoing LT after having undergone any type of bariatric surgery (BS) during the same admission, were excluded. The cohort was stratified into two groups depending on whether they had undergone simultaneous SG at the time of LT or not.

Variable definition

The general patient baseline characteristics that were examined included demographics such as age, gender, ethnicity, median income in zip code, insurance type, and Charlson Comorbidity Index. Baseline characteristics pertaining to the hospital itself included hospital region, teaching status, number of hospital beds, and hospital location. The HCUP divides the United States into four geographical locations into census regions. We abstracted each patient's vital status at the conclusion of hospital stay, total days of hospitalization, and total hospitalization charges from the database. Hospital costs were calculated by multiplying total hospitalization charges and the hospital-specific cost-to-charge ratios provided by the HCUP. To account for patient comorbidities, the Deyo adaptation of the Charlson Comorbidity Index was used, which is a validated tool for large database analysis [13].

Aims

The primary outcome was the odds of inpatient mortality in patients undergoing simultaneous SG at the time of LT compared to patients who underwent LT alone.

Secondary outcomes included inpatient morbidity, resource utilization, hospital length of stay (LOS), and inflation-adjusted total hospital costs and charges.

Statistical analysis

Discharge-level weights published by the HCUP were used to estimate the number of simultaneous LT and SG and LT alone. Proportions and means were evaluated with Fisher's exact test and Student's *t*-test, respectively. To assess associations between simultaneous LT and SG and the various outcomes of interest, multivariate regression analyses were used to adjust for age, gender, ethnicity, insurance status, Charlson Comorbidity Index, median income in patient's zip code, weekend admission, hospital region, location, size, and teaching status. All statistical analyses were conducted using STATA, version 14 (StataCorp LP, College Station, TX, USA).

Results

A total of 45 361 patients underwent LT in the study period, of which 17 761 (39.15%) met the inclusion criteria. A total of 49 underwent simultaneous SG. The mean patient age was 48.9 years in patients who underwent simultaneous LT and SG compared to 51.7 years in patients who underwent LT alone ($P < 0.01$), while 40.7% and 35.8% were female ($P = 0.75$), respectively. Baseline characteristics are presented in Table 1. Patients who underwent simultaneous LT and SG tended to proportionately be composed of less Caucasian, but higher African American and Hispanic ethnicity.

For the primary outcome, a total of 526 (2.97%) of patients undergoing LT alone died during index admission, while no patients undergoing simultaneous LT and SG died during the index admission ($P = 0.52$) as shown in Table 2. Since there was no mortality in the cohort of patients with simultaneous LT and SG, additional multivariate adjusted analysis comparing simultaneous LT and SG with LT alone was not possible.

For secondary outcomes, there were no significant differences in morbidity, as measured by shock, intensive care unit (ICU) needs, acute kidney injury (AKI), multi-organ failure, or resource utilization in patients with simultaneous LT and SG compared to LT alone (Table 2). Additional adjusted costs, charges, and LOS were not statistically significantly different in patients with simultaneous SG and LT compared to LT alone.

Discussion

The current study utilized the Nationwide Inpatient Sample (NIS) database to investigate the inpatient morbidity, mortality, resource utilization, hospital LOS, and costs associated with simultaneous SG and LT compared to LT alone during the index admission.

The results suggest there is less mortality in simultaneous LT and SG compared to LT alone although it did not reach statistical significance. Moreover, this study does not suggest a difference in inpatient morbidity between simultaneous SG and LT compared to LT alone. The results of the study are in agreement with prior studies. Work by Heimbach *et al.* [14] compared obese patients who underwent simultaneous SG and LT compared to patients who underwent LT alone and found no difference in postoperative deaths between groups. They found that despite a slightly increased mean operative time in the simultaneous group, there were no intraoperative complications. However, there were two postoperative complications associated with SG—a leak from the gastric staple line and excess weight loss [14]. Overall, patients in the simultaneous SG and LT group had a lower mean BMI at last follow-up and a lower incidence of diabetes compared to the LT group alone, despite the fact that those who underwent LT alone had a lower mean BMI at the time of transplant compared to those who underwent simultaneous SG and LT [14]. The Mayo Clinic group published their long-term outcomes following simultaneous SG and LT in a subsequent paper, with all patients having at least 3 years of follow-up post-transplant [15]. Patients who underwent simultaneous SG and LT experienced a greater percentage of total body weight loss and a lower prevalence of metabolic syndrome components, hypertension, insulin resistance, and hepatic steatosis, compared to LT alone [15]. Patients who underwent simultaneous SG and LT also required a lower number of medications for the treatment of hypertension and dyslipidemia [15]. However, these studies are limited due to their small sample size.

The results of this study also suggest that there are no differences in shock, ICU needs, AKI, or multi-organ failure between the two groups. There are no differences in adjusted costs, charges, or hospital LOS. This is the first study to compare cost and LOS in patients who undergo simultaneous SG and LT compared to LT alone during the index admission. Despite that there were no statistically significant differences between the

Table 1. Baseline characteristics of patients with simultaneous liver transplant and sleeve gastrectomy and liver transplant alone before conducting propensity score matching.

Variable	Liver transplant alone (*N* = 17 712)	Simultaneous liver transplant and sleeve gastrectomy (*N* = 49)	*P*-value
Mean age	51.7	48.9	<0.01
Female gender	35.8%	40.7%	0.74
Race			
Caucasian	66.9%	31.3%	<0.01
African American	9.8%	20.7%	
Hispanic	13.6%	20.7%	
Other	10.2%	20.7%	
Median income in zip code			
$1–$37 999	25.9%	40.0%	0.46
$38K–47 999	26.3%	0.0%	
$48K–63 999	26.4%	20.0%	
>$64 000	21.4%	40.0%	
Charlson comorbidity index			
0	5.7%	0.0%	0.83
1	4.1%	0.0%	
2	3.1%	0.0%	
3 or more	87.1%	100.0%	
Hospital region			
Northeast	17.6%	11.7%	0.16
Midwest	22.9%	49.9%	
South	41.8%	12.8%	
West	17.7%	25.6%	
Urban location	99.5%	100.0%	0.96
Weekend admission	23.5%	25.6%	0.89
Teaching hospital	99.4%	100.0%	0.89
Bed size			
Small	3.8%	0.0%	0.01
Medium	14.0%	50.06%	
Large	82.2%	50.0%	

two cohorts in terms of comorbidity burden, as measured by the Charlson Comorbidity Index, we speculate that patients undergoing simultaneous LT and SG must have been very carefully selected. The results of this study suggest the fact that simultaneous LT and SG may be relatively safe and technically feasible in the well-experienced centers with carefully selected cases. However, the risk of complications related to SG should be taken into consideration [14,15], such as leakage from the gastric staple line, reflux, or excessive weight loss.

Although this study has several strengths, the weaknesses of the current study must be acknowledged. The NIS is a stratified probability sample of inpatient databases including data on approximately 20.0% of discharged from US community hospitals, which may be prone to mis-coding bias and lacks granularity. Since the standard data unit of the NIS is the hospital discharge, tracking individual patients or readmissions is not possible. Given the nature of the NIS, data on medication use or laboratory values are not available, essentially preventing calculation of MELD score or determine the severity of cirrhosis. The BMI is abstracted from the dataset is a suboptimal surrogate for nutritional or clinical condition in patients with end-stage liver disease given the volume-overload state. Additionally, the NIS does not allow the capture of data inherent to specific transplant centers or donor characteristics. Naturally, it would be of much interest to determine long-term outcomes in this subset of patients, such as cardiovascular disease or diabetes. However, this was not within the scope of this project, as we aimed to determine outcomes only during the index admission. Other more specific immediate postoperative complications inherent to bariatric surgery are not captured by the dataset. In addition, the

Table 2. Crude mortality and adjusted odds ratio and additional adjusted means in patients undergoing simultaneous sleeve gastrectomy at the time of liver transplant compared to patients undergoing liver transplant alone.

Crude	LT alone (n = 17 712)	LT + SG (n = 49)	P-value
Mortality (%)	2.97	0.0	0.52
Variable	**Adjusted OR**	**95% CI**	**P-value**
Mortality	NA	NA	NA
Shock	1.91	0.23–16.13	0.55
ICU	0.84	0.09–7.98	0.88
AKI	2.56	0.28–23.08	0.40
Multi-organ failure	1.89	0.21–16.95	0.57
Variable	**Adjusted mean**	**95% CI**	**P-value**
Additional adjusted costs	−$58 417	−149 190 to 32 356	0.21
Additional adjusted charges	−$202 414	−33 1136 to 73 695	0.13
Additional adjusted LOS (days)	−4.0	−10.9 to 2.9	0.26

AKI, acute kidney injury; CI, confidence interval; ICU, intensive care unit; LOS, length of stay; LT, liver transplant; NA, not applicable; OR, odds ratio; SG, sleeve gastrectomy.

purpose of administrative databases, such as the NIS, is to gather data for billing purposes; therefore, the data can be limited by erroneous coding.

In conclusion, our study showed that simultaneous SG and LT are not associated with increased mortality, morbidity, costs, or hospital length of stay compared to LT alone during index admission. Despite that association between variables does not necessarily imply causation, these results suggest that simultaneous SG and LT may represent a surgically safe option for patients who are unable to achieve an appropriate BMI to be eligible for transplantation with lifestyle modifications alone. In patients with advanced liver disease, the decision to undergo bariatric surgery requires a very careful selection and a thorough patient-centered discussion of the risks and benefits. The current study provides meaningful results which can help to reduce knowledge gaps in the field, supporting that SG may be feasible at the time of LT in very carefully selected patients. Further work is needed in this field, including prospective studies with larger sample sizes, as well as studies with longer follow-up time to detect the impact of these interventions on long-term survival and associated conditions.

Authorship

Dr. KW: involved in study concept and design, acquisition of data, analysis and interpretation of data, and drafting of the manuscript. Dr. SP: involved in study concept. Dr. ESA: involved in acquisition of the data, interpretation of data, and drafting the manuscript. Drs. KPC and CBT: involved in study concept and design, and critical revision of the manuscript. Dr. CCT: involved in study concept and design, critical revision of the manuscript, and study supervision. Dr. PTK: involved in study concept and design, acquisition of data, analysis, and interpretation of data, drafting of the manuscript, critical revision of the manuscript, and study supervision. All authors had access to the data and a role in writing the manuscript.

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Conflict of interest

The authors have declared no conflicts of interest.

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