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Jason B. Liu
University of Chicago

Kristen A. Ban
Loyola University Chicago

Julia R. Berian
University of Chicago

Matthew M. Hutter
Harvard University

Kristopher M. Huffman
American College of Surgeons

See next page for additional authors

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Jason B Liu,[1,2] Kristen A Ban,[1,3] Julia R Berian,[1,2] Matthew M Hutter,[4] Kristopher M Huffman,[1] Yaoming Liu,[1] David B Hoyt,[1] Bruce L Hall,[1,5] Clifford Y Ko[1,6]

[1]American College of Surgeons, 633 N St Clair St, Chicago, IL, 60611, USA
[2]Department of Surgery, University of Chicago Medicine, Chicago, IL, USA
[3]Department of Surgery, Loyola University Medical Center, Maywood, IL, USA
[4]Department of Surgery, Harvard Medical School, Massachusetts General Hospital, Boston, MA, USA
[5]Department of Surgery, Washington University in St Louis, St Louis, MO, USA; Olin Business School, Washington University in St Louis, St Louis, MO, USA; BJC Healthcare, St Louis, MO, USA
[6]Department of Surgery, David Geffen School of Medicine, University of California Los Angeles, Los Angeles, CA, USA
Correspondence to: J B Liu jliu@facs.org

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ABSTRACT

OBJECTIVE

To determine whether perioperative outcomes differ between patients undergoing concurrent compared with non-concurrent bariatric operations in the USA.

DESIGN

Retrospective, propensity score matched cohort study.

SETTING

Hospitals in the US accredited by the American College of Surgeons' metabolic and bariatric surgery accreditation and quality improvement program.

PARTICIPANTS

513 167 patients undergoing bariatric operations between 1 January 2014 and 31 December 2016.

MAIN OUTCOME MEASURES

The primary outcome measure was a composite of 30 day death, morbidity, readmission, reoperation, anastomotic or staple line leak, and bleeding events. Operative duration and lengths of stay were also assessed. Operations were defined as concurrent if they overlapped by 60 or more minutes or in their entirety.

RESULTS

In this study of 513 167 operations, 739 (29.5%) surgeons at 483 (57.8%) hospitals performed 6087 (1.2%) concurrent operations. The most frequently performed concurrent bariatric operations were sleeve gastrectomy (n=3250, 53.4%) and Roux-en-Y gastric bypass (n=1601, 26.3%). Concurrent operations were more often performed at large academic medical centers with higher operative volumes and numbers of trainees and by higher volume surgeons. Compared with non-concurrent operations, concurrent operations lasted a median of 34 minutes longer (P<0.001) and resulted in 0.3 days longer average length of stay (P<0.001). Perioperative adverse events were not observed to more likely occur in concurrent compared with non-concurrent operations (7.5% *v* 7.4%; relative risk 1.02, 95% confidence interval 0.90 to 1.15; P=0.84).

CONCLUSIONS

Concurrent bariatric operations occurred infrequently, but when they did, there was no observable increased risk for adverse perioperative outcomes compared with non-concurrent operations. These results, however, do not argue against improved and more meaningful disclosure of concurrent surgery practices.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Little is known about the safety and quality of concurrent operations performed in the US

Single institution studies have suggested patient outcomes after concurrent operations are equivalent to those of non-concurrent operations

Although bariatric operations are commonly performed in the US and in high demand, no study has examined differences in outcomes between patients undergoing concurrent versus non-concurrent bariatric operations

WHAT THIS STUDY ADDS

No differences in 30 day outcomes were detected between patients who underwent concurrent versus non-concurrent bariatric surgery at US centers accredited by the metabolic and bariatric surgery accreditation and quality improvement program

Although concurrent operations result in longer operative times, progress is still made by the surgeon's designee in the surgeon's absence

Further large scale quantitative and qualitative studies addressing other surgical specialties with more granular details are needed to fully delineate the patient safety of concurrent surgery

Introduction

In the United States, the public recently became aware of the practice of concurrent and overlapping surgery, whereby one attending surgeon is responsible for the operations of two or more patients at the same time.[1] A national debate arose because of concerns about patient safety and because of the lack of public awareness surrounding the practice.[2-5]

Surgeons distinguish overlapping from concurrent operations based on the premise that certain portions of an operation are critical, requiring technical expertise and surgical judgment to achieve an optimal patient outcome, whereas other steps are more rudimentary.[6] Although consensus among surgeons could be achieved about the critical nature of certain steps, such as gastrojejunostomy during gastric bypass, the attending surgeon's judgment currently determines which portions of an operation are critical or non-critical in the US.[6 7]

Simultaneous operations are most often overlapping than concurrent—that is, the attending surgeon completes the critical portions of the first operation in one patient and moves on to a second operation in another patient; therefore, although the operations are occurring simultaneously in time, the critical portions are not. More rarely, concurrent surgery occurs when the attending surgeon is responsible for critical portions of two operations at the same time.

More than 190 000 bariatric operations are performed in the US annually and the incidence is increasing worldwide.[8-11] Patients undergoing de novo bariatric operations are extensively prepared and counseled before their operation. Additionally, they undergo standardized physiologic and psychologic preoperative evaluations to increase the likelihood of successful weight loss and maintenance and to

minimize perioperative complications.[12-14] Bariatric operations are well structured, with established maneuvers and expectations.[15] The high demand of such surgery combined with the relatively low perioperative complication rates are features that might favor their being performed concurrently or in an overlapping fashion.

Using data from the American College of Surgeons' metabolic and bariatric surgery accreditation and quality improvement program (MBSAQIP),[16 17] including more than 800 accredited centers and more than 90% of the annual bariatric procedures performed in the US, we assessed the prevalence of concurrent bariatric operations and examined associations between concurrent operations and perioperative outcomes.

Methods

Data source and study population

This propensity score matched cohort study utilized registry data from the American College of Surgeons' MBSAQIP from 1 January 2014 to 31 December 2016.

The program was created in 2012 when the American College of Surgeons' Bariatric Surgery Center Network merged with the American Society for metabolic and bariatric surgery centers of excellence program.[16 17] The MBSAQIP accredits hospitals in the US and Canada that have undergone an independent, voluntary, and rigorous peer evaluation in accordance with nationally recognized metabolic and bariatric surgical standards to ensure ongoing commitment to high quality care.[16-19] In addition to meeting structural requirements, surgeons at accredited centers must have formal didactic training in bariatric surgery, which includes completion of an accredited bariatric surgery fellowship, documentation of previous experience in bariatric surgery, or both, and be credentialed following nationally recognized guidelines.[17 20] The data registry is used to provide accredited hospitals on a semiannual basis with their risk adjusted surgical outcomes for continuous quality improvement. All bariatric and metabolic operations (eg, adjustable gastric band, Roux-en-Y gastric bypass, sleeve gastrectomy) and procedures for complications directly related to these operations performed at accredited hospitals (see supplemental file for more details) are accrued.[16-19 21 22] Supplemental table 1 depicts the characteristics of MBSAQIP accredited hospitals compared with non-MBSAQIP accredited hospitals.

Registry data collection processes of the MBSAQIP are similar to those of the American College of Surgeons' national surgical quality improvement program (NSQIP).[17 23-25] Briefly, dedicated and trained metabolic and bariatric surgical clinical reviewers abstract patient characteristics, operative details, and outcomes from the medical record using standardized definitions within 30 days of the index operation irrespective of patient discharge status. They also have discussions with treating physicians and contact patients directly when information is needed. These processes are regularly audited to ensure data validity and integrity.[26] The expectation is that each audited site will have a disagreement rate of 5% or less over all variables evaluated to ensure data accuracy and validity. Centers that do not pass auditing can result in additional metabolic and bariatric surgery clinical reviewer training, exclusion from performance measurement reports, or loss of accreditation. The US Centers for Medicare and Medicaid Services (CMS) has certified the MBSAQIP data registry as a qualified clinical data registry.[27] Thus, in addition to the registry undergoing internal data validation processes, it is also externally audited for regulatory purposes.

In the registry, operations performed in the US are linked to the attending surgeon using National Provider Identifier numbers. Because no surgeon grouping variable was available for operations performed in Canada, we necessarily excluded them (n=3750).

We obtained hospital characteristics from the American Hospital Association annual survey data.[28]

Definition of concurrence

Operative start and end times are routinely collected in the registry, defined as the time the incision is made and the time when all procedure related activities are completed (eg, incision closed). Operations were defined a priori as concurrent if a surgeon performed two or more operations with at least 60 minutes of overlap (see supplemental figure 1). Additionally, any operation less than 60 minutes had to overlap completely with another to be considered concurrent. Because there are generally no accepted criteria for defining operations as concurrent nor is there consensus on which portions of an operation are critical, 60 minutes was chosen conservatively on the basis of clinical experience and because this longer period is more likely to encompass critical portions of an operation. This 60 minute definition may not be applicable to other types of procedures with more laborious approaches. Concurrence can also occur with lesser overlap. However, this 60 minute definition is more likely to err by not identifying a concurrence, not by falsely identifying a concurrence.

We recorded surgeons and hospitals as concurrent if they had one or more instances of concurrence over the study period.

The data do not distinguish operations involving multidisciplinary surgical teams (ie, multiple surgeons performing multiple procedures under the same anesthetic) because one National Provider Identifier number is assigned for each operation. Generally, the assigned number reflects the surgeon primarily responsible for the patient's care.[16] By using a time proxy for concurrence, misclassification might occur when multiple surgical teams are involved and prolong the operation. To at least partially control for this, we scanned the data for procedures performed that would be out of the scope of practice for the primary attending bariatric surgeon and excluded patients who had inferior vena cava filter placement (n=142), urogynecologic procedures (n=539), and abdominoplasties (n=41) under the same anesthetic.

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Perioperative outcomes

Because perioperative morbidity and mortality are infrequent events for patients undergoing bariatric operations,[13 14] the primary outcome measure was a composite of the following outcomes, all within 30 days: death, morbidity, unplanned admission to an intensive care unit, anastomotic or staple line leak, bleeding, or any reoperations, interventions (eg, endoscopy), or readmissions directly related to the index operation (as recorded in any available medical records, or reported by physician, patient, family, or other care provider). Morbidity was deemed to have occurred if any one of the following complications took place within 30 days: surgical site infection, wound disruption, pneumonia, unplanned intubation, vein thrombosis or pulmonary embolism requiring therapy, mechanical ventilation for more than 48 hours, acute renal failure, urinary tract infection, cerebral vascular accident or stroke, coma for more than 24 hours, peripheral nerve injury, myocardial infarction or cardiac arrest requiring cardiopulmonary resuscitation, transfusion, sepsis, or septic shock. Each component of the primary outcome composite measure comprised the secondary outcomes. Supplemental table 2 provides more details of the outcomes. We also studied operative times and hospital lengths of stay.

Adjustment covariates

We analyzed patient, operative, surgeon, and hospital characteristics. Patient characteristics included age (continuous), preoperative hematocrit (continuous), sex, race (African American, white, other), Hispanic ethnicity, American Society of Anesthesiologists physical status classification (1-2, 3, 4-5), body mass index classification (<35, 35-39, 40-49, 50-59, 60-69, ≥70 kg/m^2), gastresophageal reflux disease, history of myocardial infarction, history of percutaneous coronary intervention or percutaneous transluminal coronary angioplasty, history of cardiac surgery, hyperlipidemia requiring therapy, hypertension requiring therapy, venous stasis disease, chronic kidney disease or renal failure requiring dialysis, systemic anticoagulation, diabetes requiring therapy, smoking status, obstructive sleep apnea, chronic steroid use, need for mobility device, history of deep vein thrombosis or pulmonary embolism requiring therapy, history of foregut surgery, dependent functional status, chronic obstructive pulmonary disease, and oxygen dependence. Operative characteristics included whether the operation was performed as an emergency and the surgery type (biliopancreatic diversion with duodenal switch, adjustable gastric banding, gastric bypass, conversion from one bariatric surgery type to another, revision of a previous bariatric surgery, sleeve gastrectomy, other; see supplemental table 3 for more details). We also examined the surgeon's first assistant (no assistant, physician assistant or nurse practitioner, junior resident, senior resident, fellow, or other attending surgeon) for the operation.

Annual hospital and surgeon bariatric case volumes were calculated over the study period. We stratified the hospitals by case volume into three groups (<25, 25-49, and ≥50 operations/year) based on MBSAQIP accreditation definitions,[17] and, in a separate analysis, into fourths, such that an equal number of hospitals were in each group by hospital case volume. Surgeons were stratified by case volume into fourths, such that an equal number of surgeons were in each group.

Additional hospital characteristics obtained from the American Hospital Association annual survey data[28] included total number of: hospital beds, physicians and dentists employed, medical and dental residents employed, and staff employed. The teaching status of the hospital was also included: residency program approved by the Accreditation Council for Graduate Medical Education, medical school affiliated with the American Medical Association, or member of the Council of Teaching Hospitals of the Association of American Medical Colleges.

Statistical analyses

SAS v9.4 (SAS Institute; Cary, NC) was used for statistical analyses. We compared cohorts using Student's t test, Wilcoxon's rank sum test, or Pearson's χ^2 test for association, where appropriate. The Cochran-Armitage test was used to assess trends of hospital and surgeon volumes with frequency of concurrence.

Analyses of outcomes were performed on 1:1 propensity score matched cohorts (concurrent versus non-concurrent operations) generated using a "greedy" algorithm with a 0.2 caliper width based on the logit of the propensity score and with exact matches on surgery type.[29-31] Propensity scores were calculated from logistic regression predicting the probability of undergoing a concurrent compared with non-concurrent bariatric surgery conditional on all measured patient, hospital, and surgeon adjustment covariates, as described above. To evaluate balance we calculated and plotted standardized differences; values within 0.1 either way indicated excellent balance (table 1; supplemental figure 2).[29-31]

Outcomes were then assessed from the propensity score matched cohorts. Where appropriate we used McNemar's test or Wilcoxon's signed ranked test to account for the dependence of matched pairs.[29-32] We considered two sided P values less than 0.05 to be significant. No adjustments for multiple testing were made, but we used Bonferroni adjustment to interpret significance levels of the secondary outcomes, as they were components of the primary outcome composite.

Sensitivity analyses

We conducted several sensitivity analyses. First, we calculated the Rosenbaum sensitivity parameter to estimate the degree to which the effect of concurrence on the primary outcome was robust to unmeasured confounders.[31 32] The parameter is interpreted as if there was an unmeasured confounder that increased the odds of exposure by x per cent, then accounting for this unmeasured confounder would nullify the observed treatment effect. That is, we estimated how much hidden bias can be present before the

Table 1 | Characteristics of patients undergoing concurrent and non-concurrent operations. Values are numbers (percentages) unless stated otherwise

Characteristics	Concurrent operations (n=6087)	Matched non-concurrent operations (n=6087)	Standardized difference*	All non-concurrent operations (n=507 080)	P value†
Mean (SD) age (years)	45.9 (11.9)	45.7 (12.0)	0.02	45.7 (12.0)	0.20
Mean (SD) hematocrit (%)	40.4 (3.7)	40.5 (3.7)	−0.02	40.6 (3.7)	<0.001
Female	4793 (78.7)	4783 (78.6)	0.004	404 959 (79.9)	0.03
Race:					
African American	1340 (22.0)	1338 (21.9)		84 768 (16.7)	
White	4034 (66.3)	4051 (66.6)	0.008	382 103 (75.4)	<0.001
Other	713 (11.7)	698 (11.5)		40 209 (7.9)	
Hispanic ethnicity	664 (10.9)	683 (11.2)	−0.01	58 548 (11.5)	0.12
ASA class:					
1-2	1628 (26.7)	1653 (27.2)		129 955 (25.6)	
3	4232 (69.5)	4211 (69.2)	0.01	358 883 (70.8)	0.10
4-5	227 (3.7)	223 (3.7)		18 242 (3.6)	
Body mass index:					
<35	405 (6.7)	402 (6.6)		39 869 (7.9)	
35-39	1286 (21.1)	1280 (21.0)		114 170 (22.5)	
40-49	2967 (48.7)	2977 (48.9)	0.02	243 836 (48.1)	<0.001
50-59	1042 (17.1)	1051 (17.3)		82 890 (16.3)	
60-69	273 (4.5)	254 (4.2)		19 235 (3.8)	
≥70	114 (1.9)	123 (2.0)		7080 (1.4)	
Gastroesophageal reflux disease	2003 (32.9)	2087 (34.3)	−0.03	162 301 (32.0)	0.14
History of myocardial infarction	83 (1.4)	78 (1.3)	0.007	6847 (1.4)	0.93
History of PCI/PTCA	119 (2.0)	108 (1.8)	0.01	11 010 (2.2)	0.27
Previous cardiac surgery	85 (1.4)	105 (1.7)	−0.03	6060 (1.2)	0.15
Hyperlipidemia	1446 (23.8)	1454 (23.9)	−0.003	122 136 (24.1)	0.56
Hypertension	2823 (46.4)	2801 (46.0)	0.007	241 895 (47.7)	0.04
Venous stasis	84 (1.4)	83 (1.4)	0.001	5409 (1.1)	0.02
Dialysis	23 (0.4)	25 (0.4)	−0.005	1355 (0.3)	0.10
Chronic kidney disease	36 (0.6)	29 (0.5)	0.02	3151 (0.6)	0.77
Systemic anticoagulation	142 (2.3)	132 (2.2)	0.01	12 200 (2.4)	0.71
Diabetes	1603 (26.3)	1612 (26.5)	−0.003	125 708 (24.8)	0.006
Smoker	431 (7.1)	444 (7.3)	−0.008	44 193 (8.7)	<0.001
Sleep apnea	2266 (37.2)	2250 (37.0)	0.005	174 076 (34.3)	<0.001
Chronic steroids	97 (1.6)	99 (1.6)	−0.003	8104 (1.6)	0.98
Mobility device	132 (2.2)	148 (2.4)	−0.02	9784 (1.9)	0.18
History of deep vein thrombosis	134 (2.2)	137 (2.3)	−0.003	8108 (1.6)	<0.001
Previous surgery	972 (16.0)	970 (15.9)	0.001	78 919 (15.6)	0.39
Dependent functional status	60 (1.0)	64 (1.1)	0.007	3760 (0.7)	0.03
COPD	99 (1.6)	100 (1.6)	−0.001	8813 (1.7)	0.51
Oxygen dependent	44 (0.7)	39 (0.6)	0.01	3629 (0.7)	0.95
History of pulmonary embolism	73 (1.2)	83 (1.4)	−0.01	5795 (1.1)	0.68
Emergency	47 (0.8)	69 (1.1)	−0.04	5847 (1.2)	0.006
Operation:					
BPDDS	20 (0.3)	20 (0.3)		2956 (0.6)	
Band	92 (1.5)	92 (1.5)		14 556 (2.9)	
Bypass	1601 (26.3)	1601 (26.3)		120 244 (23.7)	
Conversion	201 (3.3)	201 (3.3)	0	14 633 (2.9)	<0.001
Other	122 (2.0)	122 (2.0)		10 420 (2.1)	
Revision	801 (13.2)	801 (13.2)		66 374 (13.1)	
Sleeve	3250 (53.4)	3250 (53.4)		277 897 (54.8)	
First assistant:					
None	250 (4.1)	245 (4.0)		28 151 (5.6)	
Physician assistant or nurse practitioner	1221 (20.1)	1229 (20.2)		81 300 (16.0)	
Junior resident (PGY 1-3)	1338 (22.0)	1505 (24.7)	0.08	43 361 (8.6)	<0.001
Senior resident (PGY ≥4)	764 (12.6)	726 (11.9)		81 451 (16.1)	
Fellow	1490 (24.5)	1489 (24.5)		191 195 (37.7)	
Surgeon	1024 (16.8)	893 (14.7)		81 622 (16.1)	
Hospital characteristics:					
Median (interquartile range) No of hospital bed	441 (264-789)	456 (262-711)	0.04	366 (218-454)	<0.001
Median (interquartile range) total No of physicians and dentists, FTE	40 (1-262)	63 (3-252)	0.07	14 (0-86)	<0.001
Median (interquartile range) total No of medical and dental residents, FTE‡	73 (0-674)	72 (0-289)	0.04	9 (0-108)	<0.001
Median (interquartile range) total No of staff, FTE§	3148 (1349-7344)	3531 (1444-7188)	0.06	2148 (1211-3866)	<0.001

(*Continued*)

Table 1 | (Continued)

Characteristics	Concurrent operations (n=6087)	Matched non-concurrent operations (n=6087)	Standardized difference*	All non-concurrent operations (n=507 080)	P value†
Annual bariatric volume by MBSAQIP criteria:					
<25	0 (0.0)	5 (0.1)	0.04	651 (0.1)	<0.001
25-49	38 (0.6)	36 (0.6)		5075 (1.0)	
≥50	6049 (99.4)	6046 (99.3)		501 354 (98.9)	
Annual bariatric volume fourths:					
<85	198 (3.3)	192 (3.2)	0.02	23 390 (4.6)	<0.001
85-168	499 (8.2)	531 (8.7)		71 519 (14.1)	
169-289	1322 (21.7)	1296 (21.3)		133 140 (26.3)	
≥291	4068 (66.8)	4068 (66.8)		279 031 (55.0)	
ACGME approved residency program	4940 (81.2)	4990 (82.0)	−0.02	377 030 (74.4)	<0.001
Medical school affiliation reported to AMA	4981 (81.8)	4875 (80.1)	0.04	333 269 (65.7)	<0.001
Member of COTH	2826 (46.4)	2927 (48.1)	−0.03	117 835 (23.2)	<0.001
Surgeon characteristics:					
Annual bariatric volume fourths:					
<8	4 (0.1)	9 (0.2)	0.05	2052 (0.4)	<0.001
8-44	226 (3.7)	255 (4.2)		40 257 (7.9)	
45-108	1038 (17.1)	1099 (18.1)		122 434 (24.1)	
≥109	4918 (79.2)	4724 (77.6)		342 337 (67.5)	

ASA=American Society of Anesthesiologists; PCI=percutaneous coronary intervention; PTCA=percutaneous transluminal coronary angioplasty; COPD=chronic obstructive pulmonary disease; BPDDS=biliopancreatic diversion with duodenal diversion; PGY=postgraduate year; FTE=full time equivalent; MBSAQIP=American College of Surgeons' metabolic and bariatric surgery accreditation and quality improvement program; ACGME=Accreditation Council for Graduate Medical Education; AMA=American Medical Association; COTH=Council of Teaching Hospitals of the Association of American Medical Colleges.
*Standardized difference for concurrent versus matched non-concurrent cohorts. Values within 0.1either way indicate excellent balance.[29-32]
†P values represent comparisons between concurrent compared with all non-concurrent cohorts.
‡Includes medical and dental residents, interns, and other trainees in all medical specialties available per hospital.
§Includes all staff types per hospital excluding medical and dental residents, interns, and other trainees.

study results would change. Second, to detect any association of concurrence with the primary outcome while accounting for unmeasured surgeon and hospital characteristics we fit a three level (patients nested in surgeons, nested in hospitals) hierarchical logistic regression model.[24] For this sensitivity analysis, we considered a surgeon operating at two different hospitals to be two different surgeons as the hospitals may have different characteristics. Third, to increase homogeneity we repeated our analyses on the subgroup of operations excluding those that were performed as an emergency. This subgroup analysis did not change our results and thus are not discussed further. Last, we repeated our analyses using two additional post hoc definitions of concurrence: at least 30 and 90 minutes of overlap.

Patient involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study. No patients were asked to advise on interpretation or writing up of results. There are no plans to disseminate the results of the research to study participants or the relevant patient community.

Results

Prevalence of concurrent bariatric operations

In total, 2501 surgeons performed 513 167 operations at 835 hospitals over three years. Within the concurrent surgery cohort, 6087 (1.2%) operations were performed by 739 (29.5%) surgeons at 483 (57.8%) hospitals. Concurrent operations were performed by a median of 4 (interquartile range 2-10) hospital and 4 (2-6) surgeons. Patients who underwent concurrent operations had similar comorbidity profiles to those who did not; patients who underwent concurrent operations were less often white (table 1). The most commonly performed concurrent bariatric operation was sleeve gastrectomy (n=3250, 53.4%) followed by Roux-en-Y gastric bypass (n=1601, 26.3%; table 1). The most commonly combined concurrent operations were sleeve gastrectomy and sleeve gastrectomy, comprising 1315 pairs, followed by sleeve gastrectomy and Roux-en-Y gastric bypass, comprising 725 pairs.

Concurrent operations more often had a physician assistant, nurse practitioner, or junior resident recorded as the surgeon's first assistant compared with all non-concurrent operations (table 1). Conversely, senior residents or fellows were less often recorded as participating in concurrent operations. For instance, a fellow was the first assistant in 24.5% of concurrent operations compared with 37.7% of non-concurrent operations (P<0.001).

When concurrent operations occurred, they were more often performed at high volume hospitals and by high volume surgeons (table 1). Hospitals with one or more instance of concurrent operations were more often large academic medical centers with more trainees compared with hospitals without any concurrent operations (table 2).

Operative times

The duration of operations was significantly longer for concurrent (versus non-concurrent) bariatric operations overall (median 120 *v* 86 minutes, P<0.001), and for each procedure individually except for biliopancreatic diversion with duodenal switch (of which there were relatively few procedures; table 3).

Table 2 | Characteristics of hospitals and surgeons with one or more instance of concurrent operations. Values are numbers (percentages) unless stated otherwise

Characteristics	Concurrent operations (n=483)	Non-concurrent operations (n=352)	P value
Hospital characteristics			
Median (interquartile range) No of hospital beds	352 (214-536)	279 (175.5-424.5)	<0.001
Median (interquartile range) total No of physicians and dentists, FTE	12 (0-71)	13.5 (0-57.5)	0.57
Median (interquartile range) total medical and dental residents, FTE*	14 (0-114)	0 (0-27.5)	<0.001
Median (interquartile range) total No of staff, FTE†	2039 (1107-3823)	1689 (979-2764)	<0.001
Annual bariatric volume by MBSAQIP criteria:			
<25	0 (0.0)	38 (10.8)	<0.001
25-49	13 (3.7)	47 (13.4)	
≥50	470 (97.3)	267 (75.8)	
Annual bariatric volume fourths:			
<85	50 (10.4)	158 (44.9)	<0.001
85-168	103 (21.3)	107 (30.4)	
-289	145 (30.0)	63 (17.9)	
≥291	185 (38.3)	24 (6.8)	
ACGME approved residency program	355 (73.5)	215 (61.1)	<0.001
Medical school affiliation reported to AMA	328 (67.9)	183 (52.0)	<0.001
Member of COTH	128 (26.5)	41 (11.7)	<0.001
Surgeon characteristics	**(n=739)**	**(n=1762)**	
Annual bariatric volume fourths:			
<8	2 (0.3)	615 (34.9)	<0.001
8-44	79 (10.7)	562 (31.9)	
45-108	240 (32.5)	378 (21.5)	
≥109	418 (56.5)	207 (11.7)	

FTE=full time equivalent; ACGME=Accreditation Council for Graduate Medical Education; AMA=American Medical Association; COTH=of Teaching Hospitals of the Association of American Medical Colleges.
Hospitals and surgeons were considered to participate in concurrent operations if they were involved in at least one instance of concurrent surgery by our definition.
*Includes medical and dental residents, interns, and other trainees in all medical specialties available for each hospital.
†Includes all staff types per hospital excluding medical and dental residents, interns, and other trainees.
The propensity score matched cohorts (concurrent versus matched non-concurrent operations) had similar baseline characteristics, as all standardized differences were within 0.1 either way (table 1).

Interpreting operative durations alone may not be most appropriate. The conceptual model in this work defines cases as concurrent when the actual operating overlaps by 60 minutes or more, or entirely. As a rough conceptual approximation, during the overlap time the attending surgeon is assumed to be in one or the other of those two concurrent cases. Thus, for two concurrent cases, the attending surgeon would be absent from either case for half of the overlapping time—ie, for 60 minutes of overlap, on average, the attending surgeon would be absent from either case for 30 minutes. Two situations can therefore occur when the attending surgeon is absent: either the attending surgeon's designees make progress, such that the operation is not halted, or the designees are unable to make progress, the operation is stalled, and the operation can only resume when the attending surgeon returns. In the first situation, the overall operative duration is not prolonged because progress is made in both operating rooms. However, in the second situation, the overall operative duration is prolonged because the attending surgeon's presence is required to make progress. For the two most common operations (gastric bypass and sleeve gastrectomy), progress was likely made in the absence of the attending surgeon because the difference in time between concurrent and non-concurrent operations is less than the one half predicted (table 3).

Table 3 | Comparison of differences in operative duration between concurrent and non-concurrent bariatric operations versus overlap time by operation type

Operation type	Median (interquartile range) operative duration (mins)				Median (interquartile range) overlap time (mins): concurrent operations (n=6087)
	Concurrent operations (n=6087)	Matched non-concurrent operations (n=6087)	P value*	Difference†	
All (n=6087)	120 (76-166)	86 (59-120)	<0.001	34	79 (61-110)
BPDDS (n=20)	190 (117.5-232.5)	128 (112.5-195)	0.25	62	83 (56.5-167)
Band (n=92)	60.5 (60-100)	49 (33.5-67)	<0.001	11.5	60 (55-74)
Bypass (n=1601)	145 (104-195)	120 (91-155)	<0.001	25	94 (70-129)
Conversion (n=201)	140 (111-194)	111 (85-156)	<0.001	29	94 (70-121)
Other (n=122)	127.5 (76-218)	65.5 (33-122)	<0.001	62	74 (60-104)
Revision (n=801)	129 (85-215)	81 (47-131)	<0.001	48	79 (60-118)
Sleeve (n=3250)	102 (65-139)	73 (54-101)	<0.001	29	74 (60-98)

BPDDS=biliopancreatic diversion with duodenal switch.
*Wilcoxon signed rank test.
†Difference=median operative duration of concurrent operations−median operative duration of matched non-concurrent operations. These are not differences between matched pairs.

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Table 4 | Lengths of stay by cohort and operation type

	Concurrent operations (n=6087)		Matched non-concurrent operations (n=6087)			All non-concurrent operations (n=507 080)		
Operation type	Mean (SD)	Median (interquartile range)	Mean (SD)	Median (interquartile range)	P value	Mean (SD)	Median (interquartile range)	P value
All	2.1 (2.9)	2 (1-2)	1.8 (2.4)	2 (1-2)	<0.001	1.8 (2.3)	2 (1-2)	<0.001
BPDDS	2.7 (1.3)	2 (2-4)	2.8 (1.8)	2 (2-3)	0.99	2.7 (3.0)	2 (2-3)	0.42
Band	0.8 (0.7)	1 (0-1)	0.6 (2.2)	0 (0-1)	<0.001	0.4 (1.6)	0 (0-1)	<0.001
Bypass	2.2 (2.1)	2 (1-2)	2.1 (2.2)	2 (1-2)	<0.001	2.1 (2.2)	2 (1-2)	0.002
Conversion	2.4 (5.7)	2 (1-2)	1.9 (1.6)	2 (1-2)	0.71	1.9 (2.8)	2 (1-2)	0.33
Other	2.3 (3.8)	2 (1-3)	1.3 (1.4)	1 (0-2)	0.002	1.8 (3.7)	1 (0-2)	0.004
Revision	2.6 (5.2)	2 (1-3)	1.8 (3.6)	1 (0-2)	<0.001	1.9 (3.9)	1 (0-2)	<0.001
Sleeve	1.9 (2.1)	2 (1-2)	1.7 (2.1)	2 (1-2)	<0.001	1.7 (1.7)	2 (1-2)	<0.001

BPDDS=biliopancreatic diversion with duodenal switch.
See table 1 for number of operations in each category.

Length of stay

Patients undergoing concurrent surgery also had a statistically significantly longer length of stay overall, although differences were small; when procedures were evaluated individually, this was true for gastric banding, sleeve gastrectomy, revision and conversion procedures, and others, representing more than 70% of cases (table 4). For instance, the mean length of stay for concurrent sleeve gastrectomies was 1.9 (SD 2.1) days compared with 1.7 (2.1) days for matched non-concurrent ones (P<0.001).

Perioperative outcomes

No significant differences were detected between propensity score matched groups in the frequency of the primary outcome (7.5% in the concurrent group and 7.4% in the matched non-concurrent group; P=0.84; relative risk 1.02, 95% confidence interval 0.90 to 1.15). None of the secondary outcomes reached statistical significance (table 5).

Sensitivity analyses

Regarding the robustness of our findings to unmeasured confounding, our results for the primary outcome would change if in addition to the measured confounders an unmeasured confounder increased the odds of undergoing concurrent surgery by 16% or larger compared with non-concurrent surgery. On hierarchical regression modeling, the adjusted odds ratio for the primary outcome comparing concurrent with non-concurrent bariatric operations was 0.97 (95% confidence interval 0.83 to 1.13). No statistically significant association of concurrence with perioperative outcomes was detected when we used 30 minute (see

Table 5 | Perioperative outcomes in propensity score matched cohorts. Values are numbers (percentages) unless stated otherwise

Outcomes	Concurrent operations (n=6087)	Matched non-concurrent operations (n=6087)	Relative risk (95% CI)	P value*
Primary outcome†	456 (7.5)	449 (7.4)	1.02 (0.90 to 1.15)	0.84
Secondary outcomes:				
Death	5 (0.1)	9 (0.2)	0.56 (0.19 to 1.66)	0.42
Morbidity‡	202 (3.3)	184 (3.0)	1.10 (0.90 to 1.34)	0.38
Unplanned ICU admission	66 (1.1)	65 (1.1)	1.02 (0.72 to 1.43)	1.00
Anastomotic leak	24 (0.4)	22 (0.4)	1.09 (0.61 to 1.94)	0.88
Bleeding	64 (1.1)	72 (1.2)	0.89 (0.64 to 1.24)	0.55
Reoperation	82 (1.4)	82 (1.4)	1.00 (0.74 to 1.36)	1.00
Intervention	88 (1.5)	69 (1.1)	1.27 (0.93 to 1.74)	0.15
Readmission	247 (4.1)	268 (4.4)	0.92 (0.78 to 1.09)	0.37
Surgical site infection	84 (1.4)	75 (1.2)	1.12 (0.82 to 1.53)	0.52
Wound disruption	7 (0.1)	3 (0.1)	2.33 (0.60 to 9.02)	0.34
Prolonged ventilation	18 (0.3)	11 (0.2)	1.63 (0.77 to 3.46)	0.26
Pneumonia	22 (0.4)	11 (0.2)	2.00 (0.97 to 4.12)	0.08
Renal failure	11 (0.2)	10 (0.2)	1.10 (0.47 to 2.59)	1.00
Urinary tract infection	24 (0.4)	30 (0.5)	0.80 (0.47 to 1.37)	0.50
Stroke or CVA	2 (0.03)	0 (0.0)	–	–
Unplanned intubation	21 (0.3)	11 (0.2)	1.91 (0.92 to 3.96)	0.11
Peripheral nerve injury	2 (0.03)	1 (0.02)	2.00 (0.18 to 22.05)	1.00
Myocardial infarction or CPR	5 (0.1)	3 (0.1)	1.67 (0.40 to 6.97)	0.73
Transfusion	57 (0.9)	53 (0.9)	1.08 (0.74 to 1.56)	0.77
Sepsis	33 (0.5)	19 (0.3)	1.74 (0.99 to 3.05)	0.07
Vein thrombosis	21 (0.3)	25 (0.4)	0.84 (0.47 to 1.50)	0.66

ICU=intensive care unit; UTI=urinary tract infection; CVA=cerebral vascular accident; CPR=cardiopulmonary resuscitation.
*For secondary outcomes, P values less than 0.002 are considered significant after Bonferroni adjustment as all secondary outcomes are components of the primary outcome.
†Composite of 30 day death, morbidity, readmission, reoperation, anastomotic or staple line leak, and bleeding events.
‡Morbidity occurred if any one of the following outcomes occurred: surgical site infection, wound disruption, prolonged ventilation, pneumonia, renal failure, urinary tract infection, stroke or CVA, unplanned intubation, peripheral nerve injury, myocardial infarction or CPR, transfusion, sepsis, or vein thrombosis.

supplemental table 4) or 90 minute (see supplemental table 5) post hoc definitions of concurrence.

Discussion

Using data from a large US registry of metabolic and bariatric operations, we detected no statistically significant differences in the risk for adverse perioperative clinical outcomes for patients who underwent concurrent bariatric operations compared with a propensity score matched cohort who did not. Our results suggested that concurrent operations carry an increased risk of no greater than 15% for the primary outcome, although this was not statistically significant. Concurrent bariatric operations occurred infrequently and were generally performed by high volume surgeons at large, high volume academic medical centers. Compared with non-concurrent cases, concurrent operations were associated with longer operative times and longer lengths of stay, although the latter differences were small.

There are several plausible explanations for our finding of no significant increase in adverse perioperative outcomes associated with concurrent surgery. Judicious application of concurrent surgery, as supported by the low concurrence rate observed, might help to maintain safety. Good surgeon judgment is likely also required to determine which operations are suitable for concurrence, potentially involving consideration of the operation type (ie, straightforward versus technically demanding), availability of back-up assistance (ie, another available surgeon should help be needed), patients' expected perioperative risk, and faith in the assistant's operative abilities (eg, trainee involvement). Previous commentaries suggest that surgeons are less likely to schedule concurrent operations in high risk patients with comorbidities or in technically difficult cases.[4 33] In the current study, however, the concurrent cohort had similar frequencies of some comorbidities as the non-concurrent cohort, suggesting that perhaps there is less patient selection bias when surgeons decide to perform these types of operations concurrently. Additional studies are needed to understand why surgeons operate concurrently.

Regulatory factors may have also blunted our ability to detect any differences. MBSAQIP accredited hospitals undergo a rigorous accreditation process, ensuring each center meets standards of quality for bariatric surgery.[17] MBSAQIP accredited hospitals also tend to be large academic, high volume hospitals (see supplemental table 1) and thus might have more experienced perioperative professionals (eg, anesthesiologists, perioperative nurses) supporting these operations.[34] These features may have blunted any adverse effects of concurrent surgery, and limit the generalizability of our results to non-MBSAQIP accredited hospitals. Additionally, the US Centers for Medicare and Medicaid Services require that, for appropriate reimbursement, teaching surgeons must attest in the operative record that they were present for and performed all critical portions of the operation, and that they or another qualified surgeon were immediately available at all times in case of unforeseen circumstances.[7] Although "critical portions" or "immediately available" are not precisely defined, these regulations might also control risky practices.

Whereas no significant differences were detected between concurrent and non-concurrent surgery groups in the major perioperative outcomes examined, there was an association of concurrent operations with longer operative duration and hospital length of stay. Previous studies have reported an association of poorer outcomes with longer operative times, mediated in general by prolonged anesthetic times and partially by resident involvement.[35 36] However, for more than 80% of concurrently performed bariatric operations, it does not appear the operation was halted in the attending surgeon's absence, implying that during the attending surgeon's absence the operative team and surgeon's designee (eg, trainee) were able to accomplish operative steps that would otherwise be performed by the attending surgeon. Regarding length of stay, concurrent bariatric operations resulted in an average of 0.3 days, or 7.2 hours longer stay compared with non-concurrent operations. The consequence of this difference in length of stay needs further delineation.

The decision to perform concurrent surgery might involve substantial faith in the skills and competency of the individual being delegated operative responsibilities.[33] As such, one might expect that trainees in later stages of their training (eg, senior residents, fellows) would more frequently be involved in concurrent operations because attending surgeons would be more likely to entrust these advanced trainees with independent operative responsibilities. Interestingly, we found that concurrent operations more frequently had physician extenders (eg, physician assistants, nurse practitioners) or junior residents as first assistants. It is conceivable that senior residents and fellows who are imminently approaching independent practice require more attention and active teaching from the attending surgeon, and therefore the responsible teaching surgeon less frequently performs concurrent surgery when operating with senior residents or fellows. Admittedly, more studies examining the interplay between concurrent surgery, surgical education, and patient safety are warranted.

Potential benefits of concurrent operations include increased operating room efficiency and increased patient access to surgical specialists.[4 6] It is conceivable that the tendency of higher volume surgeons to operate concurrently may allow greater access to these specialists, but the low prevalence of concurrent procedures overall suggests this is unlikely to substantively affect access, particularly for bariatric operations. We do not have information on the reasons operations were performed concurrently.

Comparison with other studies

Our findings are similar to the few single institution studies conducted in response to a call for more evidence.[5] Using administrative data, Hyder et al[37] were unable to detect an increased risk of mortality

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in patients who underwent overlapping operations at a high volume academic referral center in the US. Guan et al[38] and Zygourakis et al[39-41] examined the outcomes of overlapping neurosurgical and spine operations performed at their respective academic referral centers in the US and detected no increased risk to patient safety. Adverse outcomes were also not detected to be increased in the ambulatory orthopedic setting nor was there an improvement in operating room efficiency.[42] No increased risk to patient safety was observed in these studies and others[43 44] despite heterogeneity in the definition used: definitions of any overlap,[37 38] ≥1 second,[40] ≥1 minute,[39 41] ≥10 minutes,[44] ≥30 minutes,[43] and ≥45 minutes[44] have been used. Because what defines operations as overlapping or concurrent is largely discretionary based on the attending surgeon's determination of what portions of the operation are critical, the effect of these types of operations on patient safety is difficult to study.[2] Our study utilized 60 minutes, as a shorter period may include less critical portions (eg, wound closure), and the overlap of critical portions becomes increasingly likely with longer periods.

Limitations of this study

Several limitations of our study should be noted. First, we studied only bariatric operations; it is possible that concurrence may be more prevalent in other types of operations and might adversely affect outcomes in some settings. Second, these data come only from MBSAQIP accredited hospitals, which are more commonly large teaching hospitals with training programs. These hospitals and teams could be more adept at limiting a potential negative impact of concurrence, and thus generalization to other hospitals and specialties may be limited. Third, given the observational design of our study, unmeasured confounding might be present. Fourth, we used time as a proxy for concurrence, as others have done, because the critical portions of bariatric operations are not identifiable and the steps of operations are not tracked in any US registry of which we are aware. Although imprecise, our use of a substantial time overlap to identify concurrence would be expected to increase the likelihood of finding an association of concurrence with adverse events. We examined overlaps of 30 and 90 minutes and found no difference in results. Last, we could not directly account for the presence of multiple surgeons operating on a patient under the same anesthetic, and thus we had to exclude these cases, albeit few.

Conclusions and implications

Concurrent bariatric operations occurred infrequently at MBSAQIP accredited centers in the US in the period studied. When they did, operative times and length of stay were longer, but no statistically significant increase in perioperative adverse clinical outcomes compared with non-concurrent operations were detected in these data. Future studies are needed to understand whether other metrics of quality are affected (eg, patient experience, rare safety events such as retained foreign objects), the reasons for operating concurrently, and the effect of concurrent surgery on healthcare access (eg, waiting times) and utilization (eg, operating room efficiency, costs). Work is also needed to understand the role concurrent surgery plays in surgical training. Whatever reasons there are for its practice in bariatric surgery, widespread bans may have unforeseeable consequences unless more thoughtful studies are conducted.

Our results do not imply that proper disclosure should be withheld from patients, or that concurrent surgery can be practiced without further monitoring. Limitations of registry data such as these suggest that patient safety must be continually assessed locally at each hospital. Hospitals, which have access to more granular internal data, must continually study their local patient outcomes to evaluate patient safety. As long as patient safety remains preserved, the conversation regarding concurrent surgery is one of proper and sufficient patient disclosure. Indeed, patients consider the disclosure of its practice much more important than its existence because concurrent surgery can be acceptable in specific circumstances.[45] Further study is needed in outcomes of concurrence, including for other types of operations. Much work remains to be done in this realm.

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Ethical approval: This study was reviewed by the Chesapeake institutional review board and deemed non-human subjects research as it analyzed pre-existing, deidentified data.

Data sharing: Hospitals accredited by the metabolic and bariatric surgery accreditation and quality improvement program have access to the Participant Use Data File, a de-identified secondary dataset intended for research purposes, which can be requested here: www.facs.org/quality-programs/mbsaqip/participant-use. Otherwise, no additional data are available.

Transparency: The lead author (JBL) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies are disclosed.

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Supplemental material: additional information