Published in final edited form as:
J Am Coll Surg. 2014 February ; 218(2): 253–260. doi:10.1016/j.jamcollsurg.2013.10.014.

Effects of Resident Involvement on Complication Rates after Laparoscopic Gastric Bypass

Robert W Krell, MD, **Nancy JO Birkmeyer, PhD**, **Bradley N Reames, MD**, **Arthur M Carlin, MD**, **John D Birkmeyer, MD, FACS**, and **Jonathan F Finks, MD, FACS for the Michigan Bariatric Surgery Collaborative**

From the Center for Healthcare Outcomes and Policy, University of Michigan Health System, Ann Arbor (Krell, NJO Birkmeyer, Reames, JD Birkmeyer, Finks) and Henry Ford Health System, Detroit (Carlin), MI

Abstract

BACKGROUND—Although resident involvement has been shown to be safe for most procedures, the impact of residents on outcomes after complex laparoscopic procedures is not well understood. We sought to examine the impact of resident involvement on outcomes after bariatric surgery using a population-based clinical registry.

STUDY DESIGN—We analyzed 17,057 patients who underwent a primary laparoscopic gastric bypass in the 35-hospital Michigan Bariatric Surgery Collaborative from July 2006 to August 2012. Resident involvement was characterized at the surgeon level. Using hierarchical logistic regression, we examined the influence of resident involvement on 30-day complications, accounting for patient characteristics as well as hospital and surgeon case volume. To evaluate potential mediating factors for specific complications, we also adjusted for operative duration.

RESULTS—Risk-adjusted 30-day complication rates with and without residents were 13.0% and 8.5%, respectively ($p < 0.01$). Resident involvement was independently associated with wound infection (odds ratio [OR] = 2.06; 95% CI, 1.24–3.43) and venous thromboembolism (OR = 2.01; 95% CI, 1.19–3.40), but not with any other medical or surgical complications. Operative duration was longer with resident involvement (median duration with residents 129 minutes vs 88 minutes

Correspondence address: Robert W Krell, MD, Center for Healthcare Outcomes and Policy, University of Michigan Health System, 2800 Plymouth Rd, Bldg 16, Office 016-100N-13, Ann Arbor, MI 48109. rkrell@med.umich.edu.

Abstract presented at the American College of Surgeons 99th Annual Clinical Congress, Washington, DC, October 2013.

Author Contributions

Study conception and design: Krell, NJO Birkmeyer, JD Birkmeyer, Finks
Acquisition of data: Krell, NJO Birkmeyer, Reames
Analysis and interpretation of data: Krell, NJO Birkmeyer, Reames, JD Birkmeyer, Carlin, Finks
Drafting of manuscript: Krell, NJO Birkmeyer, Reames, Carlin, JD Birkmeyer, Finks
Critical revision: Krell, NJO Birkmeyer, Reames, Carlin, JD Birkmeyer, Finks

Disclosure Information: John D Birkmeyer, is Chief Scientific Officer with a financial interest in ArborMetrix, Inc., which had no role in the analysis in this article. Nancy JO Birkmeyer and John D Birkmeyer receive research funding on behalf of their institution, related to the Michigan Bariatric Surgery Collaborative, from the Agency for Healthcare Research and Quality and from Blue Cross and Blue Shield of Michigan/Blue Care Network. Dr Finks has received an honorarium fromEthicon for proctoringa laparoscopic surgery course. Dr Reames has received consulting fees from Arbormetrix Michigan Value Consortium for work on commercial software algorithm development. Dr Krell has received payment from Blue Cross and Blue Shield of Michigan for data entry unrelated to this manuscript. Dr Carlin has nothing to disclose.

without; $p < 0.01$). After adjusting for operative duration, resident involvement was still independently associated with wound infection (OR = 1.67; 95% CI, 1.01–2.76), but not venous thromboembolism (OR = 1.73; 95% CI, 0.99–3.04).

CONCLUSIONS—Resident involvement in laparoscopic gastric bypass is independently associated with wound infections and venous thromboembolism. The effect appears to be mediated in part by longer operative times. These findings highlight the importance of strategies to assess and improve resident technical proficiency outside the operating room.

In training surgical residents, teaching hospitals recognize the need to balance their educational mission with patient safety. A large and growing body of literature in this area suggests they have been successful in achieving this goal. Both single and multi-institutional studies have shown that for many open and laparoscopic procedures, resident involvement is safe, despite increased operative times and some association with specific postoperative complications.[1–10] Despite some conflicting studies, the majority of evidence suggests that resident involvement is not associated with clinically important differences in postoperative outcomes.

Whether resident involvement is safe with complex videoscopic surgery, however, is less certain. There is emerging evidence that outcomes after these procedures are more closely linked to operative technique than patient risk factors or postoperative management.[11,12] Complex videoscopic operations entail a higher degree of technical difficulty and steeper learning curve for trainees, and attending physicians have reduced ability to compensate for the technical skills of their assistants during laparoscopic procedures when compared with open procedures because of the the limited space and availability of working ports.[13,14]

In this context, we performed a population-based study to evaluate the impact of resident involvement on 30-day postoperative outcomes with laparoscopic gastric bypass, a complex procedure with multiple steps that requires a high level of technical skill.

METHODS

Data source and study population

We analyzed data from the 35-hospital Michigan Bariat-ric Surgery Collaborative (MBSC) clinical registry, which includes information from >95% of patients undergoing bariatric surgery in the state. Specifics of data collection have been detailed elsewhere.[15] In brief, trained data abstractors conduct chart reviews and collect preoperative demographic data, medical comorbidities, perioperative and intraoperative process details, as well as 30-day postoperative outcomes. Nurses from the coordinating center of the MBSC audit each hospital annually to ensure data accuracy. In this study, we included all adult patients undergoing primary (nonrevision) laparoscopic gastric bypass between June 2006 and August 2012. The Institutional Review Boards of all participating sites have approved patient data collection for the purposes of MBSC participation and analysis.

Outcomes

We examined 30-day complications as the primary result. Complications are defined by their documentation in the record as well as evidence of specific treatment for the complication. Recorded complications include wound infections (treated with antibiotics, opening the wound or reoperation); anastomotic complications (anastomotic leak or perforation, gastroje-junal ulcer/stricture, stenosis requiring endoscopic dilation or obstruction requiring reoperation); bowel obstruction requiring reoperation; bleeding (requiring blood transfusion, splenectomy, or reoperation), cardiac complications (myocardial infarction or cardiac arrest), pulmonary complications (pneumonia, unplanned reintubation, prolonged mechanical ventilation, or tracheostomy); renal complications (renal failure requiring dialysis); venous thromboembolism ([VTE]) [deep vein thrombosis or pulmonary embolism]; hospital-acquired infections (urinary tract infection or *Clostridium difficile* colitis); and presence of postoperative shock. Other 30-day outcomes recorded include reoperation, emergency department visits, and readmissions.

Independent variables

Patient characteristics recorded in the clinical registry include age, sex, primary insurer, height and weight (at time of initial surgical consultation and final preoperative clinic visit), mobility limitations, smoking status, and comorbid conditions. Comorbid conditions are defined by their documentation in the medical record along with evidence of treatment for that condition. Recorded comorbidities include cardiac (coronary artery disease, earlier cardiac procedure, congestive heart failure, arrhythmia), hypertension, hyperlipidemia, peripheral vascular disease, pulmonary (asthma, obstructive sleep apnea or home oxygen requirement), current or previous smoking status, renal (pre-existing renal insufficiency or dialysis), liver disorders (fatty liver disease or cirrhosis), gastroesophageal reflux or peptic ulcer disease, diabetes and whether it requires pharmacologic treatment, previously or currently documented gallstones, history of venous thromboembolism, current or previous psychiatric disorders (depression, anxiety, bipolar disorder, substance abuse, or eating disorder), musculoskeletal disease, and earlier upper abdominal wall hernia repair. Operative data include duration (minutes from incision to skin closure), pre- and postoperative venous thromboembolism prophylaxis type and specific chemoprophylactic agents, and other concurrent procedures performed (cholecystectomy, hiatal or abdominal wall hernia repair). Using a previously published VTE risk calculator, we assigned each patient a dichotomous variable representing receipt of appropriate risk-based VTE prophylaxis.[16] Patients were deemed to have received adequate VTE prophylaxis if they received both preoperative and postoperative low-molecular-weight heparin. Those in the medium- and high-risk categories also required post-discharge low-molecular-weight heparin (at prophylactic or therapeutic dose, respectively) for at least at least 2 weeks.

In the summer of 2012, as part of MBSC's efforts to better understand provider outcomes variation, participating surgeons were asked to complete an email survey indicating how frequently they operated with residents for bariatric cases (never, <80%, and >80%). The 80% cutoff was chosen to help respondents differentiate between "sometimes" and "very often/always." A separate survey documented each surgeon's preferred method for performing the gastrojejunal anastomosis (circular stapler, linear stapler, or hand-sewn). For

outcomes analysis, we collapsed resident involvement to a dichotomous variable (never or yes), as relatively few (n = 10 [15%]) surgeons responded “always.” We merged survey data with the MBSC clinical registry to assign each patient a level of resident involvement. Finally, we categorized surgeon and hospital case volume using cutoffs empirically derived from the distribution of patients in the dataset. We categorized surgeon case volume into equal terciles (ie, equal numbers of surgeons based on their annual case volume) and hospital case volume as a dichotomous variable (>200 or <200 cases per year) for use in our analyses.

Statistical analysis

We compared baseline patient characteristics and operative details across levels of resident involvement using *t*-tests or Kruskal-Wallis tests for normally and non-normally distributed continuous data and Pearson chi-square tests for categorical variables. Using serious complications as the dependent variable, we then selected preoperative patient characteristics with p values <0.25 in univariate analysis for use in a forward stepwise logistic regression model. Variables with $p < 0.05$ were kept in the model and used along with male sex, total comorbidity number, surgeon annual case volume, and hospital annual case volume to develop a predictive score for serious complications.

We then entered the patient’s summary risk score into hierarchical logistic regression models with each specific medical or surgical complication as the dependent variable. These models included resident involvement as a dichotomous covariate as well as surgeon-level random effects to account for patient clustering.

Given the known association between operative duration and risk for VTE and wound infection, we developed additional regression models to examine those outcomes. We created a categorical variable representing operative duration longer than 2 hours (yes/no). We then repeated the hierarchical model, including the patient summary risk score and the operative duration variable. We then compared risk- and operative duration-adjusted wound infection and VTE rates by resident involvement.

We performed all statistical analyses using STATA release 12 (StataCorp).

RESULTS

During the study period, 17,981 patients underwent primary laparoscopic gastric bypass by 71 surgeons. Sixty-one surgeons (86%) completed the surveys, accounting for 17,057 patients (95%). Table 1 demonstrates baseline patient characteristics, surgeon and hospital case volume, and operative details by resident involvement. There were statistically significant but clinically insignificant differences between the 2 groups for most variables. However, patients in the resident involvement group were more likely to have private insurance (69% vs 66%; $p < 0.01$), mobility limitations (8% vs 5%; $p < 0.01$), lung disease (29% vs 27%; $p < 0.01$), and cardiovascular disease (60% vs 54%; $p < 0.01$). Surgeons operating with residents were more likely to have lower annual case volumes (30% vs 18%; $p < 0.01$) and use the circular stapler approach (69% vs 55%; $p < 0.01$). Finally, cases with residents were less likely to have adequate VTE prophylaxis (38% vs 67%; $p < 0.01$). Cases

with resident involvement were longer than those without residents (median duration with residents 129 minutes vs 88 minutes without; $p < 0.01$).

Significant patient predictors for severe complications on multivariable analysis were preoperative renal insufficiency, earlier upper abdominal wall hernia repair, earlier VTE, age older than 50 years, mobility limitations, pulmonary disease, psychological disease, and noninsulin-dependent diabetes. These risk factors were used along with male sex, cardiovascular disease, smoking status, total comorbidity number, surgeon case volume, and hospital case volume for all risk-adjustment models. Model c-statistics ranged from 0.61 to 0.86 and Hosmer-Lemeshow chi-square values ranged from 1.71 to 15.4. All Hosmer-Lemeshow chi-square p values were >0.05.

Table 2 and Figures 1 and 2 show the results of the risk-adjusted analysis. Resident involvement was independently associated with increased overall complication rates (13.0% vs 8.5% without residents; $p < 0.01$) and overall surgical complications (10.9% vs 6.9%; $p = 0.02$, Table 2). Although resident involvement was associated with higher overall complication rates (Fig. 1), this difference was statistically significant for only 2 complications after adjusting for patient characteristics and surgeon/hospital case volumes. Among surgical complications, residents retained an independent effect on superficial or deep wound infection (4.5% vs 2.3%; $p = 0.01$). Risk-adjusted anastomotic leak rates, bowel obstruction, abdominal abscess, bleeding, and reoperation rates were not significantly different between groups (Fig. 2A). Among medical complications, residents retained a statistically significant effect on VTE (0.6% vs 0.2%; $p = 0.01$). Rates of cardiac, respiratory, and renal complications, as well as hospital acquired infections, were not affected by resident involvement (Fig. 2B).

Table 3 demonstrates the changes in odds ratios for resident involvement on VTE and wound infection after accounting for prolonged operative duration (defined as longer than 2 hours). Adjusting for prolonged operative duration attenuated, but did not eliminate, the resident effect on wound infection rates (adjusted OR = 1.67; 95% CI, 1.01–2.76). However, the resident effect on risk-adjusted VTE rates was no longer statistically significant (adjusted OR = 1.73; 95% CI, 0.99–3.04).

In a sensitivity analysis, we excluded cases in which there were additional procedures performed (eg, hiatal hernia repair, cholecystectomy). Median operative duration in the group with resident involvement remained longer (128 minutes [interquartile range 104–159 minutes] vs 86 minutes [interquartile range 68–110 minutes]; $p < 0.01$). After adjusting for patient, surgeon, hospital caseload, and prolonged operative duration as mentioned, resident involvement remained associated with wound infection (adjusted OR = 1.71; 95% CI, 1.03–2.85), but not VTE (adjusted OR = 1.42; 95% CI, 0.78–2.61).

DISCUSSION

In this population-based study of morbidly obese patients undergoing laparoscopic gastric bypass in Michigan, we found that cases involving residents were longer than those without and that resident involvement was independently associated with an increased risk for

wound infections and VTE after controlling for patient comorbidity differences and surgeon/hospital case volume. With regard to VTE, much of the resident effect appears to be mediated through prolonged operative times. However, operative duration did not fully account for the resident effect on wound infection rates.

Our results add to a growing body of literature demonstrating higher risk-adjusted complication rates with resident involvement in complex laparoscopic procedures. Although many studies of open operations have shown that resident participation does not have an appreciable influence on patient outcomes after accounting for higher patient illness severity in teaching hospitals,[2–4,7,9,10] those examining complex laparoscopic procedures have demonstrated increased complication rates with resident involvement.[13,17–20] Recent investigations of the Nationwide Inpatient Sample and the American College of Surgeons NSQIP registry showed higher risk-adjusted wound infection, deep vein thrombosis, and septic complication rates with resident or fellow involvement in bariatric procedures, even after accounting for patient illness severity.[17,21] Unlike those studies, we did not observe an increase in septic complications after risk adjustment, which can relate to the broader definition of septic complications used in those databases as compared with the more granular bariatric-surgery–specific outcomes recorded in the MBSC registry. Our results echo the higher risk-adjusted VTE and wound infection rates with resident involvement seen in those studies. Those results are concerning, given that VTE is a leading cause of mortality for bariatric patients.[22]

Not surprisingly, median operative duration was nearly 50% longer when residents were involved. Although there were more additional procedures performed in the residents group, excluding those cases did not change our findings with regard to the resident effect on operating time or risk-adjusted outcomes. Increased operative duration was an important driver of the increased VTE and wound infections rates seen with resident involvement. Other investigators have shown that increased operative duration is an independent risk factor for wound infections with many procedures, and contributes to VTE risk with bariatric surgery.[16,23,24] Although adjusting for operative duration attenuated the resident effect on VTE, we also found that patients were far less likely to receive adequate VTE prophylaxis when residents were involved, which might help explain why patients with resident involvement had higher risk-adjusted VTE rates. The reasons for the discrepancy in adequate VTE prophylaxis are unclear and warrant additional investigation. It is possible they might reflect disruptions in or unfamiliarity with care protocols associated with frequent changes of resident personnel at teaching hospitals.

Longer operative durations did not fully explain the resident effect on wound-infection risk, suggesting that there are other mechanisms at play. One potential explanation is differences in anastomotic technique among surgeons who operate with residents and those who do not. We found that surgeons who operate with residents were more likely to use the circular stapler to create the gastrojejunal anastomosis. The circular stapler technique has previously been associated with significantly higher rates of wound infection than linear stapler or hand-sewn techniques.[11] Also, differences in technical skill (eg, gentle tissue manipulation, accuracy, and efficiency) between trainees and attending surgeons likely play a role in the increased risk for wound infection.

There are important limitations with this study. We characterized resident involvement at the surgeon rather than patient level. We can, therefore, only conclude that surgeons who operate with residents tend to have higher wound infection and VTE rates than those who do not. As the survey only assessed the overall frequency of resident participation for each surgeon, we were unable to determine at the patient level which level of trainee was involved (PGY1–5, Fellow, etc) and what proportion of the procedure he or she performed. These factors likely vary by surgeon and even by individual case within the same surgeon's practice. Although these data might have helped to better define the mechanisms through which resident involvement influences patient outcomes for complex laparoscopic procedures, it was beyond the scope of this study to obtain this information at the patient level. Another limitation involves our finding of higher VTE rates associated with resident involvement. Although increased operative duration and possibly differences in thromboprophylaxis likely contributed to this effect, it is also possible that hospitals with residents are more vigilant in diagnosing these complications and higher VTE rates with resident involvement might reflect a lower threshold for VTE screening at teaching hospitals. With regard to wound infection, we lacked granular data on antibiotic administration and wound closure techniques, which might have provided more insight into mechanisms for the higher wound infection rates seen with resident involvement. Finally, an important limitation to this study is that MBSC hospitals are participants in a unique quality improvement collaborative, some for many years; as such these results might not be fully generalizable.

Our results have implications for resident training with complex laparoscopic procedures. The mechanisms underlying increased VTE and wound-infection risk with resident involvement need to be better understood so those risks can be minimized, especially given the ongoing need to train surgical residents to perform complex laparoscopic operations. We have identified 2 potential targets for improvement—VTE prophylaxis practices and operative efficiency—that might help inform efforts to reduce complication risk. System-level approaches (eg, checklists or preprinted order sets) could improve consistency in following accepted guidelines for VTE and surgical site infection prophylaxis regardless of trainee involvement. Improving resident operative efficiency is a more difficult goal, given the learning curve for complex laparoscopic procedures, such as gastric bypass, but this might be achievable with increased use of simulation-based training and more strictly defined operative goals. Although current simulator-based training programs have been shown to increase resident operative efficiency, they are not universally used, and few are specific to the technical requirements of bariatric surgery.[25–27] Another possible approach is establishing time goals for resident involvement for critical steps of the operation and using structured "takeovers" by the attending surgeon if the resident cannot meet those goals. This approach would permit learning in the operating room and protect the patient from excessive operative durations caused by resident inefficiency.

CONCLUSIONS

As surgical education continues to evolve, training safe operators and ensuring patient safety will require consideration of these issues from both residents and attending surgeons.

Acknowledgments

Dr Krell was supported by National Institutes of Health grant 5T32CA009672-22.

The authors wish to thank Dr Mousumi Banerjee for her assistance with statistical analysis.

References

1. Advani V, Ahad S, Gonczy C, et al. Does resident involvement effect surgical times and complication rates during laparoscopic appendectomy for uncomplicated appendicitis? An analysis of 16,849 cases from the ACS-NSQIP. Am J Surg. 2012; 203:347–351. discussion 351–352. [PubMed: 22364902]
2. Graat LJ, Bosma E, Roukema JA, Heisterkamp J. Appendectomy by residents is safe and not associated with a higher incidence of complications: a retrospective cohort study. Ann Surg. 2012; 255:715–719. [PubMed: 22367440]
3. Itani KM, DePalma RG, Schifftner T, et al. Surgical resident supervision in the operating room and outcomes of care in Veterans Affairs hospitals. Am J Surg. 2005; 190:725–731. [PubMed: 16226948]
4. Kiran RP, Ali UA, Coffey JC, et al. Impact of resident participation in surgical operations on postoperative outcomes: National Surgical Quality Improvement Program. Ann Surg. 2012; 256:469–475. [PubMed: 22842127]
5. Khuri SF, Najjar SF, Daley J, et al. Comparison of surgical outcomes between teaching and nonteaching hospitals in the Department of Veterans Affairs. Ann Surg. 2001; 234:370–382. discussion 382–383. [PubMed: 11524590]
6. Patel SP, Gauger PG, Brown DL, et al. Resident participation does not affect surgical outcomes, despite introduction of new techniques. J Am Coll Surg. 2010; 211:540–545. [PubMed: 20801695]
7. Raval MV, Wang X, Cohen ME, et al. The influence of resident involvement on surgical outcomes. J Am Coll Surg. 2011; 212:889–898. [PubMed: 21398151]
8. Robinson RP. The impact of resident teaching on total hip arthroplasty. Clin Orthop Relat Res. 2007; 465:196–201. [PubMed: 18090473]
9. Tseng WH, Jin L, Canter RJ, et al. Surgical resident involvement is safe for common elective general surgery procedures. J Am Coll Surg. 2011; 213:19–26. discussion 26–28. [PubMed: 21493108]
10. Yaghoubian A, de Virgilio C, Lee SL. Appendicitis outcomes are better at resident teaching institutions: a multi-institutional analysis. Am J Surg. 2010; 200:810–813. discussion 813. [PubMed: 21146025]
11. Finks JF, Carlin A, Share D, et al. Effect of surgical techniques on clinical outcomes after laparoscopic gastric bypass—results from the Michigan Bariatric Surgery Collaborative. Surg Obes Relat Dis. 2011; 7:284–289. [PubMed: 21126927]
12. Suter M, Donadini A, Calmes JM, Romy S. Improved surgical technique for laparoscopic Roux-en-Y gastric bypass reduces complications at the gastrojejunostomy. Obes Surg. 2010; 20:841–845. [PubMed: 20443151]
13. Hsu GP, Morton JM, Jin L, et al. Laparoscopic Roux-en-Y gastric bypass: differences in outcome between attendings and assistants of different training backgrounds. Obes Surg. 2005; 15:1104–1110. [PubMed: 16197780]
14. Schauer P, Ikramuddin S, Hamad G, Gourash W. The learning curve for laparoscopic Roux-en-Y gastric bypass is 100 cases. Surg Endosc. 2003; 17:212–215. [PubMed: 12457218]
15. Birkmeyer NJ, Dimick JB, Share D, et al. Hospital complication rates with bariatric surgery in Michigan. JAMA. 2010; 304:435–442. [PubMed: 20664044]
16. Finks JF, English WJ, Carlin AM, et al. Predicting risk for venous thromboembolism with bariatric surgery: results from the michigan bariatric surgery collaborative. Ann Surg. 2012; 255:1100–1104. [PubMed: 22566018]

17. Bhayani NH, Gupta A, Kurian AA, et al. Does fellow participation in laparoscopic Roux-en-Y gastric bypass affect perioperative outcomes? Surg Endosc. 2012; 26:3442–3448. [PubMed: 22648124]
18. Davis SS Jr, Husain FA, Lin E, et al. Resident participation in index laparoscopic general surgical cases: impact of the learning environment on surgical outcomes. J Am Coll Surg. 2013; 216:96–104. [PubMed: 22999330]
19. Fanous M, Carlin A. Surgical resident participation in laparoscopic Roux-en-Y bypass: is it safe? Surgery. 2012; 152:21–25. [PubMed: 22503322]
20. Rovito PF, Kreitz K, Harrison TD, et al. Laparoscopic Roux-en-Y gastric bypass and the role of the surgical resident. Am J Surg. 2005; 189:33–37. [PubMed: 15701487]
21. Kohn GP, Galanko JA, Overby DW, Farrell TM. 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; 210:909–918. [PubMed: 20510799]
22. Birkmeyer NJ, Finks JF, Carlin AM, et al. Comparative effectiveness of unfractionated and low-molecular-weight heparin for prevention of venous thromboembolism following bariatric surgery. Arch Surg. 2012; 147:994–998. [PubMed: 23165612]
23. Chan MM, Hamza N, Ammori BJ. Duration of surgery independently influences risk of venous thromboembolism after laparoscopic bariatric surgery. Surg Obes Relat Dis. 2013; 9:88–93. [PubMed: 22055389]
24. Procter LD, Davenport DL, Bernard AC, Zwischenberger JB. General surgical operative duration is associated with increased risk-adjusted infectious complication rates and length of hospital stay. J Am Coll Surg. 2010; 210:60–65. [PubMed: 20123333]
25. Scott DJ, Dunnington GL. The new ACS/APDS skills curriculum: moving the learning curve out of the operating room. J Gastrointest Surg. 2008; 12:213–221. [PubMed: 17926105]
26. Zendejas B, Cook DA, Bingener J, et al. Simulation-based mastery learning improves patient outcomes in laparoscopic inguinal hernia repair: a randomized controlled trial. Ann Surg. 2011; 254:502–509. discussion 509–511. [PubMed: 21865947]
27. Zevin B, Aggarwal R, Grantcharov TP. Simulation-based training and learning curves in laparoscopic Roux-en-Y gastric bypass. Br J Surg. 2012; 99:887–895. [PubMed: 22511220]

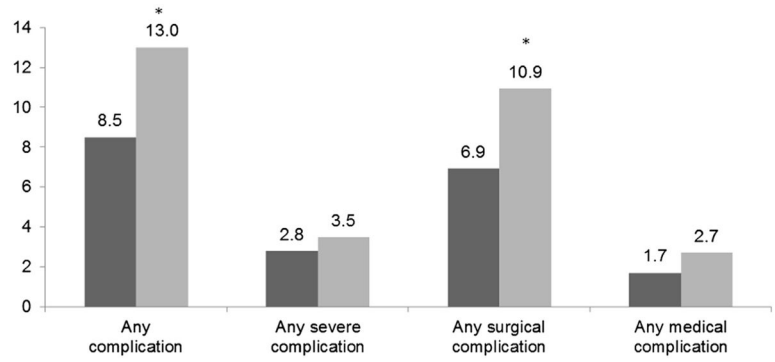

Figure 1.

Risk-adjusted 30-day complication rates by resident involvement. Dark gray bar, no residents; light gray bar, resident involvement. *$p < 0.05$ compared with risk-adjusted complication rate without resident involvement. Variables included in risk-adjustment model: renal insufficiency, non-insulin–requiring diabetes, earlier venous thromboembolism, mobility limitations, age older than 50 years, pulmonary disease, male sex, psychological disease, earlier upper abdominal wall hernia repair, body mass index quintile, current smoking status, cardiovascular disease, presence of >4 comorbidities as a dichotomous variable, surgeon procedure volume tercile, and hospital procedure volume (<200 or >200 cases/y).

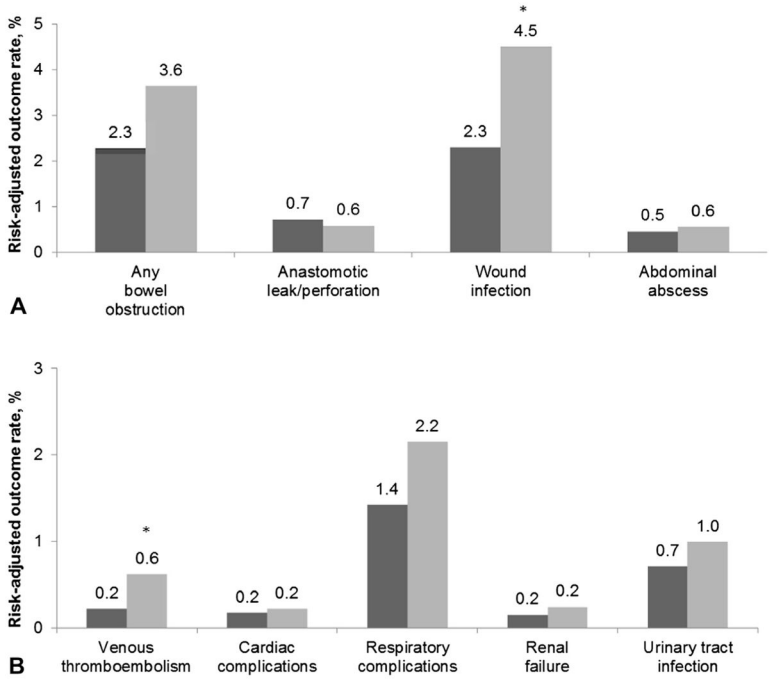

Figure 2.

Risk-adjusted surgical and medical complication rates by resident involvement. (A) Surgical complications; (B) medical complications. Dark gray bar, no residents; light gray bar, resident involvement. *$p < 0.05$ compared with risk-adjusted complication rate without resident involvement. Variables included in risk-adjustment model: renal insufficiency, non-insulin–requiring diabetes, earlier venous thromboembolism, mobility limitations, age older than 50 years, pulmonary disease, male sex, psychological disease, earlier upper abdominal wall hernia repair, body mass index quintile, current smoking status, cardiovascular disease, presence of >4 comorbidities as a dichotomous variable, surgeon procedure volume tercile, and hospital procedure volume (<200 or >200 cases/y).

Table 1

Baseline Characteristics of Patients Undergoing Primary Laparoscopic Gastric Bypass in the Michigan Bariatric Surgery Collaborative, June 2006–August 2012

	No resident involvement (n = 9,456)	Resident involvement (n = 7,601)	p Value
Age, y, mean (SD)	45.4 (11.3)	46.3 (11.3)	<0.01
Preoperative BMI, mean, (SD)	47.4 (7.8)	47.8 (8.0)	<0.01
Male	20.6 (0.4)	21.1 (0.5)	0.44
Private insurance	66.4 (0.5)	69.1 (0.5)	<0.01
Current smoker	2.7 (0.2)	4.8 (0.2)	<0.01
Mobility limitations	4.9 (0.2)	7.9 (0.3)	<0.01
Lung disease	26.5 (0.5)	29.1 (0.5)	<0.01
Cardiovascular disease	53.5 (0.5)	60.4 (0.6)	<0.01
Hypertension	51.8 (0.5)	58.4 (0.6)	<0.01
Hyperlipidemia	51.7 (0.5)	55.2 (0.6)	<0.01
Gastroesophageal reflux	47.9 (0.5)	52.6 (0.6)	<0.01
Peptic ulcer disease	2.7 (0.2)	4.5 (0.2)	<0.01
Urinary incontinence	21.9 (0.4)	26.5 (0.5)	<0.01
Non-insulin–dependent diabetes	30.6 (0.5)	32.8 (0.5)	<0.01
Insulin-dependent diabetes	11.0 (0.3)	12.3 (0.4)	0.01
Liver disorder	3.5 (0.2)	5.5 (0.3)	<0.01
Prior venous thromboembolism	3.7 (0.2)	4.8 (0.2)	<0.01
Sleep apnea	45.8 (0.5)	47.7 (0.6)	0.02
Musculoskeletal disorder	82.6 (0.4)	77.4 (0.5)	<0.01
Surgeon annual case volume, cases/y			<0.01
1–100	18.4 (0.4)	30.1 (0.5)	
100–200	29.8 (0.5)	45.6 (0.6)	
>200	51.8 (0.5)	24.4 (0.5)	
Hospital annual case volume, >200 cases/y	64.8 (0.5)	57.1 (0.6)	<0.01
Operative data			
Operative time, min, median (IQR)	88 (69–112)	129 (104–160)	<0.01
Additional procedures	6.3 (0.2)	11.0 (0.4)	<0.01
Circular stapler anastomotic technique	55.4 (0.5)	69.3 (0.5)	<0.01
Adequate VTE prophylaxis	66.6 (0.5)	38.0 (0.6)	<0.01

Data are presented as proportion (SE) unless stated otherwise.

BMI, body mass index (calculated as kg/m^2); IQR, interquartile range; VTE, venous thromboembolism.

Table 2

30-Day Risk-Adjusted Postoperative Complication Rates by Resident Involvement

	Risk-adjusted outcomes rates		
Outcomes	**No residents**	**Residents**	**Adjusted odds ratio for resident involvement (95% CI)**
Any complication, %	8.5	13.0	1.44 (1.12–1.85)
Any severe complication, %	2.8	3.5	1.05 (0.82–1.35)
Any surgical complication, %	6.9	10.9	1.41 (1.07–1.87)
Any medical complication, %	1.7	2.7	1.32 (0.94–1.87)
Surgical complications, %			
Any bowel obstruction	2.3	3.6	1.42 (0.97–2.08)
Anastomotic leak/perforation	0.7	0.6	0.72 (0.43–1.19)
Wound infection	2.3	4.5	2.06 (1.24–3.43)
Abdominal abscess	0.5	0.6	1.01 (0.53–1.92)
Bleeding requiring transfusion	2.4	3.1	1.00 (0.73–1.36)
Reoperation	2.1	2.3	0.97 (0.71–1.32)
Medical complications, %			
Venous thromboembolism	0.2	0.6	2.01 (1.19–3.40)
Cardiac complications	0.2	0.2	1.13 (0.49–2.63)
Respiratory complications	1.4	2.2	1.21 (0.81–1.82)
Renal failure	0.2	0.2	1.39 (0.69–2.81)
Urinary tract infection	0.7	1.0	1.10 (0.64–1.90)

Variables included in risk-adjustment model: renal insufficiency, non-insulin–requiring diabetes, earlier venous thromboembolism, mobility limitations, age older than 50 years, pulmonary disease, male sex, psychological disease, and earlier upper abdominal wall hernia repair, body mass index quintile, current smoking status, cardiovascular disease, presence of >4 comorbidities as a dichotomous variable, surgeon case volume tercile, and hospital case volume (<200 or >200 cases/year).

Table 3

Odds Ratios for Resident Involvement Associated with Wound Infection and Venous Thromboembolism, Adjusted for Prolonged Operative Duration and Anastomotic Technique or Adequate Venous Thromboembolism Prophylaxis

	Odds ratio for resident involvement (95% CI)		
Outcomes	**Unadjusted**	**Adjusted for patient variables,* surgeon and hospital case volumes**	**Further adjusted for operative duration >2 hours**
Wound infection	2.33 (1.33–4.10)	2.06 (1.24–3.43)	1.67 (1.01–2.76)
Venous thromboembolism	2.65 (1.26–5.58)	2.01 (1.19–3.40)	1.73 (0.99–3.04)

*Patient variables included renal insufficiency, non-insulin–requiring diabetes, earlier venous thromboembolism, mobility limitations, age older than 50 years, pulmonary disease, male sex, psychological disease, earlier upper abdominal wall hernia repair, body mass index quintile, current smoking status, cardiovascular disease, and presence of >4 comorbidities as a dichotomous variable.