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Familiarity of the Surgeon-Anesthesiologist Dyad and Major Morbidity After High-Risk Elective Surgery

Julie Hallet, MD, MSc; Angela Jerath, MD, MSc; Pablo Perez d'Empaire, MD; François Carrier, MD, MSc; Alexis F. Turgeon, MD, MSc; Daniel I. McIsaac, MD, MPH; Chris Idestrup, MD, MSc; Gianni Lorello, MD, MSc; Alana Flexman, MD; Biniam Kidane, MD, MSc; Wing C. Chan, MPH; Anna Gombay, BA, Hons; Natalie Coburn, MD, MPH; Antoine Eskander, MD, ScM; Rinku Sutradhar, PhD

IMPORTANCE The surgeon-anesthesiologist teamwork is a core component of performance in the operating room, which can influence patient outcomes.

OBJECTIVE To examine the association between surgeon-anesthesiologist dyad familiarity (as dyad volume, the number of procedures done together) with 90-day postoperative major morbidity for high-risk elective surgery.

DESIGN, SETTING, AND PARTICIPANTS This population-based retrospective cohort study used administrative health care data from Ontario, Canada. Participants included high-risk elective operations (cardiac, low- and high- risk gastrointestinal [GI], genitourinary, gynecology oncology, neurosurgery, orthopedic, spine, vascular, and head and neck) from 2009 through 2019. Data were analyzed from January 2009 to March 2020.

EXPOSURE Dyad familiarity, as the annual volume of procedures done by the surgeon-anesthesiologist dyad in 4 years prior to index surgery.

MAIN OUTCOMES AND MEASURES 90-day major morbidity (any Clavien-Dindo grade 3 to 5). The association between exposure and outcome was examined using multivariable logistic regression, stratified by type of procedure.

RESULTS Among 711 006 index procedures, the median dyad volume and rate of 90-day major morbidity varied by type of procedure. There was higher median volume and dyad consistency for cardiac, orthopedic, and lung surgery. For other procedures, the median dyad volume was low (3 or less procedures per dyad per year). An independent association was observed between dyad volume and 90-day major morbidity for high-risk GI surgery (odds ratio [OR], 0.92; 95% CI, 0.88-0.96), low-risk GI surgery (OR, 0.96; 95% CI, 0.95-0.98), gynecology oncology surgery (OR, 0.97; 95% CI, 0.94-0.99), and spine surgery (OR, 0.97; 95% CI, 0.96-0.99), after adjusting for hospital setting, hospital, surgeon and anesthesiologist volume, and patient age, sex, and comorbidity burden. The adjusted associations were not significant for other types of procedures.

CONCLUSIONS AND RELEVANCE In this study, increasing familiarity of the surgeon-anesthesiologist dyad was associated with improved postoperative outcomes for patients undergoing low- and high-risk GI surgery, gynecology oncology surgery, and spine surgery. For each additional time that a unique surgeon-anesthesiologist dyad worked together, the odds of 90-day major morbidity decreased by 4% for low-risk GI surgery, 8% for high-risk GI surgery, 3% for gynecology oncology surgery, and 3% for spine surgery. Additional research is needed to determine the most effective care structures that harness the benefits of surgeon-anesthesiologist familiarity to potentially improve patient outcomes.

Invited Commentary
Multimedia
Supplemental content

Author Affiliations: Author affiliations are listed at the end of this article.

Corresponding Author: Julie H. Hallet, MD, MSc, Sunnybrook Health Sciences Centre, 2075 Bayview Ave, Toronto, ON M4N 3M5, Canada (julie.hallet@sunnybrook.ca).

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The operating room is a fast-paced and complex environment where team dynamics have the potential to influence patient outcomes.[1-7] Among the many interactions that take place, the relationship between the surgeon and anesthesiologist is a core component of functioning.[1,2,8,9] Recently, our team reported how familiarity between surgeon-anesthesiologist dyads is associated with postoperative outcomes after hepatopancreatobiliary and esophageal operations. We observed that greater familiarity between a surgeon and anesthesiologist—measured by the number of times they had worked together—was associated with a reduction in the odds of major morbidity within 90 days of surgery.[9] These findings suggest that organizing perioperative care in a way that promotes more frequent collaboration between specific surgeon-anesthesiologist pairs could improve outcomes for patients undergoing these procedures. However, it remains unclear whether these results apply to other high-risk operations.

Effective teamwork is recognized as a key determinant of success in various high-pressure environments, including aviation, sports, and prehospital emergency care, where team performance improves when team members frequently work together.[10-12] This improvement is often attributed to enhanced coordination, shared mental models, and a better understanding of how to respond to challenges under pressure, together.[13-18] Although these principles could logically extend to the operating room, data in this domain are limited.[7,9,19-24] Given that postoperative morbidity is a significant factor in long-term disability, health care costs, and patient recovery, understanding how surgeon-anesthesiologist familiarity impacts patient outcomes in broader contexts is essential.[25-28] Perioperative team organization, including the scheduling of specific surgeon-anesthesiologist dyads, represents a modifiable factor that could be leveraged to improve patient outcomes.

We conducted a population-based retrospective cohort study to examine the association between the familiarity of the surgeon-anesthesiologist dyad (defined as the dyad's clinical volume) and postoperative outcomes after high-risk elective surgery.

Key Points

Question Is familiarity of the surgeon-anesthesiologist dyad associated with 90-day major morbidity after high-risk elective surgery?

Findings In this study, increasing familiarity of the surgeon-anesthesiologist dyad was associated with improved postoperative outcomes for low- and high-risk gastrointestinal (GI), gynecology oncology, and spine surgery. For each additional time that a unique surgeon-anesthesiologist dyad worked together, the odds of 90-day major morbidity decreased by 4% for low-risk GI surgery, 8% for high-risk GI surgery, 3% for gynecology oncology surgery, and 3% for spine surgery.

Meaning These results demonstrate that increasing the familiarity of surgeon-anesthesiologist dyads represents an opportunity to improve patient outcomes for GI, gynecology oncology, and spine surgery.

Methods

Study Design

We conducted a population-based retrospective cohort study using administrative health care data in Ontario, Canada, housed at ICES (formerly known as the Institute of Clinical Evaluative Sciences). ICES is a prescribed entity under Ontario's Personal Health Information Protection Act (PHIPA). Projects that use data collected by ICES under section 45 of PHIPA, and use no other data, are exempt from research ethics board review. The use of the data in this project is authorized under section 45 and approved by ICES' Privacy and Legal Office. Reporting followed the Reporting of Studies Conducted Using Observational Routinely-Collected Health Data (RECORD) extension of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines statement.[29]

Data Sources

Datasets were linked using unique encoded identifiers and analyzed at ICES. All datasets used are detailed in eTable 1 in Supplement 1. The Ontario Cancer Registry is a provincial database comprised of all patients with a cancer diagnosis.[30,31] Additional data were obtained from the Registered Persons Database, the Canadian Institute of Health Information Discharge Abstract Database, the National Ambulatory Care Reporting System, the cancer Activity Level Reporting, the Ontario Health Insurance Plan Claims Database, and the ICES Physicians Database.[32]

Study Population

Ontario's 14.5 million residents receive health services through a universal public single-payer health system.[33] All patients 18 years or older who underwent high-risk elective surgical procedures (eTable 2 in Supplement 1) with a postoperative inpatient stay over 24 hours from January 2009 to December 2019 were identified. Those procedures were chosen because they are commonly performed, associated with higher morbidity risk, and more sensitive to differences in the experience of the surgeon-anesthesiologist dyad. All procedures were performed at public institutions covered under the Canada Health Act. We excluded patients with an invalid identification number, a duplicate surgery record (primary record could not be identified reliably), if the primary anesthesiologist or surgeon could not be identified, or if the surgery occurred at a hospital performing fewer than 50 procedures over the entire study period. If a patient had more than 1 procedure of interest performed, unique procedures more than 90 days apart were included.

Exposure

To assess the familiarity between health care professionals, we captured the dyad's volume: the annual volume of cases done by a unique surgeon-anesthesiologist dyad prior to index surgery, as previously reported by our group.[34,35] The dyad volume was defined as the average annual number of procedures of interest (within the same group of procedures, such as cardiac or genitourinary) done by that same dyad in the 4

Table 1. Characteristics of Included Patients Stratified by Type of Procedure

Characteristic	Surgery type, No. (%)				
	Cardiac (n = 14 328)	High-risk GI (n = 13 728)	Low-risk GI (n = 84 709)	Genitourinary (n = 51 584)	Gynecologic oncologic (n = 16 629)
Age, y, median (IQR)	74 (65-82)	64 (56-72)	66 (55-75)	64 (57-69)	62 (55-70)
Sex					
Female	5439 (38.0)	5894 (42.9)	40 422 (47.7)	9438 (18.3)	16 629 (100)
Male	8889 (62.0)	7834 (57.1)	44 287 (52.3)	42 146 (81.7)	NA
High comorbidity burden					
Elixhauser index ≥4	2865 (20.0)	3349 (24.4)	11 156 (13.2)	6125 (11.9)	823 (4.9)
pFI >0.21	3629 (25.3)	1535 (11.2)	7377 (8.7)	2517 (4.9)	755 (4.5)
Rural residence	1515 (10.6)	1320 (9.6)	9409 (11.1)	5293 (10.3)	1623 (9.8)
Material deprivation, quintiles					
1 (Least deprived)	3287 (22.9)	2937 (21.4)	16 724 (19.7)	11 712 (22.7)	3305 (19.9)
2	3051 (21.3)	2730 (19.9)	17 255 (20.4)	10 976 (21.3)	3370 (20.3)
3	2748 (19.2)	2681 (19.5)	17 007 (20.1)	10 352 (20.1)	3307 (19.9)
4	2662 (18.6)	2702 (19.7)	16 923 (20.0)	9597 (18.6)	3365 (20.2)
5 (Most deprived)	2472 (17.3)	2594 (18.9)	16 198 (19.1)	8597 (16.7)	3190 (19.2)
Hospital annual volume, procedures, y, median (IQR)	1267 (1058-1560)	157 (88-219)	281 (166-443)	113 (61-198)	367 (250-493)
Hospital setting					
Community	2405 (16.8)	3901 (28.4)	56 023 (66.1)	26 815 (52.0)	7590 (45.6)
Teaching	11 923 (83.2)	9827 (71.6)	28 686 (33.9)	24 769 (48.0)	9039 (54.4)

Abbreviations: GI, gastrointestinal; NA, not applicable; pFI, preoperative frailty index.

years prior to index surgery. This approach accounts for dynamic changes of the surgeon and anesthesiologist volumes over time.[36,37] The 4-year window ensured that longitudinal familiarity was taken into account; this number of procedures was annualized to create the final dyad annual volume reported as number of procedures per dyad per year. The dyad volume focused on procedures of interest acknowledging that separate groups of surgeons, and sometimes anesthesiologists, perform each group of procedure.

Outcome

The primary outcome was 90-day major morbidity (eTable 3 in Supplement 1). Major morbidity was defined as any Clavien-Dindo grade 3 to 5 postoperative complications, which includes mortality as a grade 5 complication.[38] The 90-day window was chosen as it provides a better representation of the morbidity burden of surgery.[39-41] Patients were followed-up until date of death, date of last clinical contact with the health care system, or end of study date on March 31, 2020, allowing for the opportunity of 90 days follow-up for all patients.

Covariates

Patient, physician, and hospital characteristics were captured. Clinical and demographic characteristics were measured at the time of surgery. Patient age, sex, and rural residence, defined according to the Rurality Index of Ontario, were captured.[42] Socioeconomic status was assessed with material deprivation quintile, a multidimensional ecologic measure assessing socioeconomic status that incorporates socioeconomic factors, such as education and income.[43] The patient's comorbidity burden was measured using the Elixhauser comorbidity index with the number of comorbidities (excluding cancer and metastases diagnoses) summed as a continuous variable, as well as dichotomized using a cutoff of 4 or higher for high burden.[44] We created groups of specialty-based procedures based on the surgical specialty and morbidity risk profile: cardiac, high-risk gastrointestinal (GI) (esophageal, hepatobiliary, and pancreatic), low-risk GI (gastric, enteric, colorectal), genitourinary, gynecology oncology, neurosurgery, orthopedic, spine, vascular, thoracic, and head and neck (eTable 2 in Supplement 1). We also captured surgeon, anesthesiologist, and hospital annual volume of procedures of interest (computed as for dyad volume), as well as hospital setting (academic vs community).

Statistical Analysis

Because distinct groups of physicians perform the different types of procedures and because there was variability in the risk of the included procedures, all analyses were stratified by procedure group. Descriptive statistics were calculated for each group; categorical variables were reported as frequencies with proportions and continuous variables as median with IQR.

We first explored the linear and nonlinear associations between dyad volume (primary exposure) and the outcome. Logistic regression was implemented to examine the outcome, where dyad volume was incorporated and assessed in numerous ways: as a continuous linear variable, as a continuous polynomial variable (with a quadratic term, and with a quadratic and cubic term), and as a continuous spline.[45] Log-likelihood values and assessment of figures plotting the estimated outcome probability against dyad volume were used to determine the final functional form of dyad volume. We also examined the spline-based fitted curve to identify any inflection point that may determine a clinically meaningful dichotomization of dyad volume.[46]

Table 2. Characteristics of Included Patients Stratified by Type of Procedure

Characteristic	Surgery type, No. (%)					
	Head and neck (n = 3253)	Neuro (n = 13 140)	Orthopedic (n = 414 313)	Spine (n = 49 738)	Lung (n = 25 803)	Vascular (n = 23 781)
Age, y, median (IQR)	64 (56-73)	57 (47-66)	68 (61-75)	61 (50-70)	67 (58-73)	69 (62-76)
Sex						
Female	1128 (34.7)	7430 (56.5)	245 907 (59.4)	23 391 (47.0)	13 405 (52.0)	6816 (28.7)
Male	2125 (65.3)	5710 (43.5)	168 406 (40.6)	26 347 (53.0)	12 398 (48.0)	16 965 (71.3)
High comorbidity burden						
Elixhauser index ≥4	687 (21.1)	2227 (16.9)	28 024 (6.8)	2996 (6.0)	4547 (17.6)	3789 (15.9)
pFI >0.21	295 (9.1)	782 (6.0)	11 721 (2.8)	1522 (3.1)	2316 (9.0)	4663 (19.6)
Rural residence	305 (9.4)	1264 (9.6)	51 750 (12.5)	6673 (13.4)	3496 (13.5)	3304 (13.9)
Material deprivation, quintiles						
1 (Least deprived)	592 (18.2)	2886 (22.0)	89 439 (21.6)	9794 (19.7)	4851 (18.8)	3654 (15.4)
2	614 (18.9)	2677 (20.4)	87 256 (21.1)	10 036 (20.2)	4975 (19.3)	4135 (17.4)
3	625 (19.2)	2476 (18.8)	83 663 (20.2)	9769 (19.6)	5224 (20.2)	4759 (20.0)
4	651 (20.0)	2592 (19.7)	79 985 (19.3)	10 005 (20.1)	5320 (20.6)	5181 (21.8)
5 (Most deprived)	750 (23.1)	2413 (18.4)	70 799 (17.1)	9695 (19.5)	5239 (20.3)	5834 (24.5)
Hospital annual volume, procedures, y, median (IQR)	70 (40-148)	250 (109-338)	727 (443-1094)	557 (312-774)	210 (112-288)	177 (94-256)
Hospital setting						
Community	126 (3.9)	1977 (15.0)	282 727 (68.2)	18 245 (36.7)	13 697 (53.1)	12 598 (53.0)
Teaching	3127 (96.1)	11 163 (85.0)	131 586 (31.8)	31 493 (63.3)	12 106 (46.9)	11 183 (47.0)

Abbreviations: GI, gastrointestinal; pFI, preoperative frailty index.

Informed by the relationships explored above, we described the association between dyad volume and the primary outcome using the exposure as a continuous variable with both linear and quadratic terms (per increment of 1 procedure per dyad per year). We then implemented multivariable logistic regression models to adjust for potential confounders. Collinearity was assessed, defined as variance inflation factor of 2.5 or higher.[47] To build a parsimonious model, a directed acyclic graph was built to illustrate the interconnected associations between the exposure, outcomes, and measured covariates (eFigure 1 in Supplement 1).[48,49,51] The following covariates were adjusted for in each model: patient age, sex (except for gynecology oncology), and comorbidity burden, hospital annual volume, surgeon and anesthesiologist annual volumes, hospital setting, and year of surgery. We examined the correlation coefficient within models; this was near 0 and, thus, we did not further account for clustering in the models. We also presented changes in adjusted odds ratio (OR) for each subsequential increment in dyad volume (1 vs 0; 2 vs 1; 3 vs 2; 4 vs 5; and so forth).

We conducted a sensitivity analysis to examine the association between dyad volume and 30-day major morbidity. Results from the regression models were reported as ORs with 95% CI.

We looked at missing data for key variables. There were no missing data on the exposure or outcomes used for the analysis. For covariates, data were missing in 0.2% for rural residence and 0.8% for material deprivation. These were not included in multivariable models and, therefore, complete case analyses were conducted.

Statistical tests were 2-sided and *P* value less than .05 considered statistically significant. All analyses were conducted using SAS Enterprise Guide version 7.1 (SAS Institute).

Results

A total of 711 006 index procedures were included (eFigure 2 in Supplement 1). Of those, 102 972 patients had 2 procedures (17.9%) and 15 266 had 3 or more procedures (2.7%), most of which were for orthopedic surgery. The characteristics of index procedures are detailed in **Table 1** and **Table 2**. The index procedures were performed at 95 unique hospitals.

The number of unique surgeon-anesthesiologist dyads caring for patients varied depending on the type of procedures (**Table 3**). The ratio of procedures to number of unique dyads was highest for cardiac, orthopedic, and lung surgery, indicating higher dyad volumes and dyad consistency for those types of procedures. The distribution of dyad volume varied depending on the type of procedure (eFigure 3 in Supplement 1); most distributions were right skewed. The median dyad volume was 3 or less procedures per dyad per year for most types of procedures, except for cardiac surgery (median of 9 procedures per dyad per year) and orthopedic surgery (median of 8 procedures per dyad per year) that presented higher medians, despite persistent right-skewness (Table 3).

The occurrence of 90-day major morbidity also varied depending on the type of procedure: 9343 for cardiac surgery (65.2%), 5505 for high-risk GI surgery (40.1%), 20 450 for low-risk GI surgery (24.1%), 7779 for genitourinary surgery (15.1%),

Table 3. Characteristics of Surgeon-Anesthesiologist Dyads, Stratified by Type of Procedure

Characteristic	Surgery type										
	Cardiac (n = 14 328)	High-hrisk GI (n = 13 728)	Low-risk GI (n = 84 709)	Genito-urinary (n = 51 584)	Gyneco-logic oncologic (n = 16 629)	Head and neck (n = 3253)	Neuro (n = 13 140)	Ortho-pedic (n = 414 313)	Spine (n = 49 738)	Lung (n = 25 803)	Vascular (n = 23 781)
Surgeon-anesthesiologist dyad volume, procedures/dyad/y, median (IQR)	9 (5-19)	1 (0-2)	1 (1-3)	2 (1-3)	2 (1-3)	1 (0-2)	1 (0-2)	8 (4-13)	3 (1-5)	3 (1-4)	2 (1-4)
No. of unique surgeon-anesthesiologist dyads	1147	3256	15 415	7447	6965	1125	3200	12 893	5406	2277	3287
Procedure dyads ratio	12.5	4.2	5.5	6.9	2.4	2.9	4.1	32.1	9.2	11.3	7.2

Abbreviation: GI, gastrointestinal.

1924 for gynecologic oncologic surgery (11.6%), 1284 for head and neck surgery (39.5%), 4690 for neurosurgery (35.7%), 31 504 for orthopedic surgery (7.6%), 4732 for spine surgery (9.7%), 6071 for lung surgery (23.5%), and 8794 for vascular surgery (37.0%). The unadjusted and adjusted ORs for the association between dyad volume and 90-day major morbidity are depicted in **Figure 1** and detailed in eTable 4 in Supplement 1. There was evidence of a linear association between dyad volume and 90-day major morbidity for all types of procedures , except for lung surgery. Nonlinear association were also identified when adding a quadratic term for high-risk GI surgery, low-risk GI surgery, and genitourinary surgery (eFigure 4 in Supplement 1). Restricted cubic splines did not consistently identify meaningful inflection points.

Given the presence of a nonlinear association but lack of meaningful inflection points, the dyad volume was treated as continuous variable with a linear and quadratic term. Unadjusted and adjusted ORs for each type of procedure are presented in Figure 1; eTable 4 in Supplement 1. The association of each increment of 1 procedure per year with 90-day major morbidity was assessed. Unadjusted ORs were statistically significant for high-risk GI surgery, low-risk GI surgery, and genitourinary surgery, but not for other procedures. After adjusting for hospital setting, hospital, surgeon and anesthesiologist volume, and patient age, sex, and comorbidity burden, an independent association was observed between dyad volume and 90-day major morbidity for high-risk GI surgery (OR, 0.92; 95% CI, 0.88-0.96), low-risk GI surgery (OR, 0.96; 95% CI, 0.95-0.98), gynecologic oncologic surgery (OR, 0.97; 95% CI, 0.94-0.99), and spine surgery (OR, 0.97; 95% CI, 0.96-0.99). The adjusted associations were not significant for other types of procedures. The detailed multivariable models are presented in eTable 5 in Supplement 1.

Using the quadratic term, the changes in adjusted OR for each subsequential increment in dyad volume were observed (for example, 1 vs 0; 2 vs 1; 3 vs 2; 4 vs 5), which are presented in **Figure 2** and eFigure 4 in the Supplement. For procedures with an independent association between dyad volume and 90-day major morbidity, the ORs reduction was more pronounced immediately as the dyad volume started to increase (high-risk GI and low-risk GI surgery) or remained stable (gynecologic oncologic, and spine surgery).

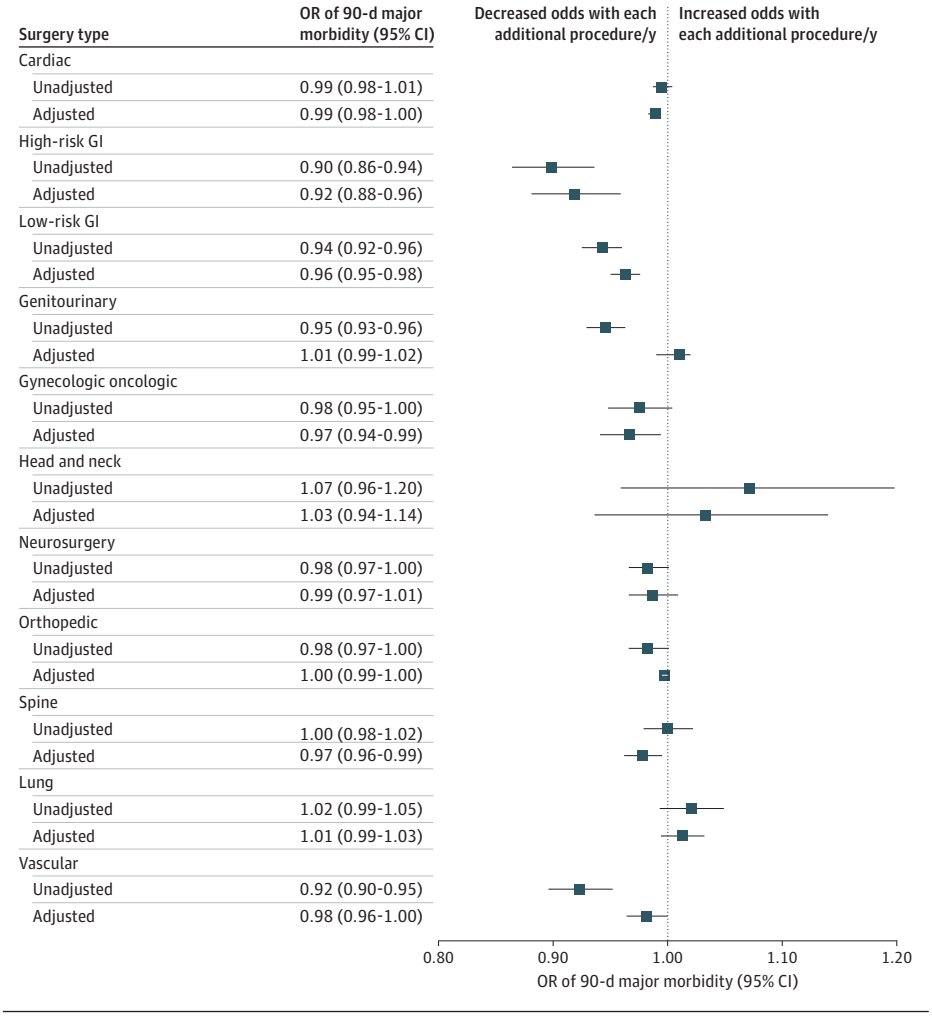
The associations between dyad volume and outcome persisted when examining 30-day major morbidity (eTable 6 in the Supplement). There was an independent adjusted association between dyad volume and 30-day major morbidity for high-risk GI surgery (OR, 0.90; 95% CI, 0.86-0.94) and low-risk GI surgery (OR, 0.96; 95% CI, 0.94-0.97). The direction of the association also persisted for gynecology oncologic surgery (OR, 0.99; 95% CI, 0.95-1.02) and spine surgery (OR, 0.99; 95% CI, 0.97-1.01).

Discussion

In this population-based study, we observed an association between care by a more familiar surgeon-anesthesiologist dyad and lower 90-day major morbidity for GI surgery, gynecology oncology surgery, and spine surgery. For each additional procedure performed by the same surgeon-anesthesiologist dyad, there was an associated reduction in the odds of 90-day major morbidity by 4% for low-risk GI surgery, 8% for high-risk GI surgery, 3% for gynecology oncology surgery, and 3% for spine surgery, after adjusting for potential confounders. This association did not show any clear dyad volume threshold point where the relationship changed. These findings indicate that for each additional procedure performed by a specific surgeon-anesthesiologist dyad, there is a corresponding decrease in the likelihood of experiencing 90-day major morbidity. Each procedure done together matters.

Existing literature on team dynamics in the operating room has focused on different components of the team and relied on single-center designs. Higher familiarity of the surgeon and surgical trainee has been associated with more efficient procedures, with reduced clamp time in vascular surgery, and shorter operative time in orthopedic surgery.[22,23] Familiarity between the surgeon and scrub nurse has been associated with smoother workflows and fewer disruptions in neurosurgery.[7] Patient outcomes were not assessed in those studies. A single-center study[20] in vascular surgery also examined familiarity of the entire operating room team, using a complex familiarity score across all team members, and observed that higher levels of familiarity were associated with reduced operative time, shorter length of stay, and fewer complications. The cur-

Figure 1. Unadjusted and Adjusted Associations Between Surgeon-Anesthesiologist Dyad Volume and 90-Day Postoperative Major Morbidity, Stratified by Type of Procedure



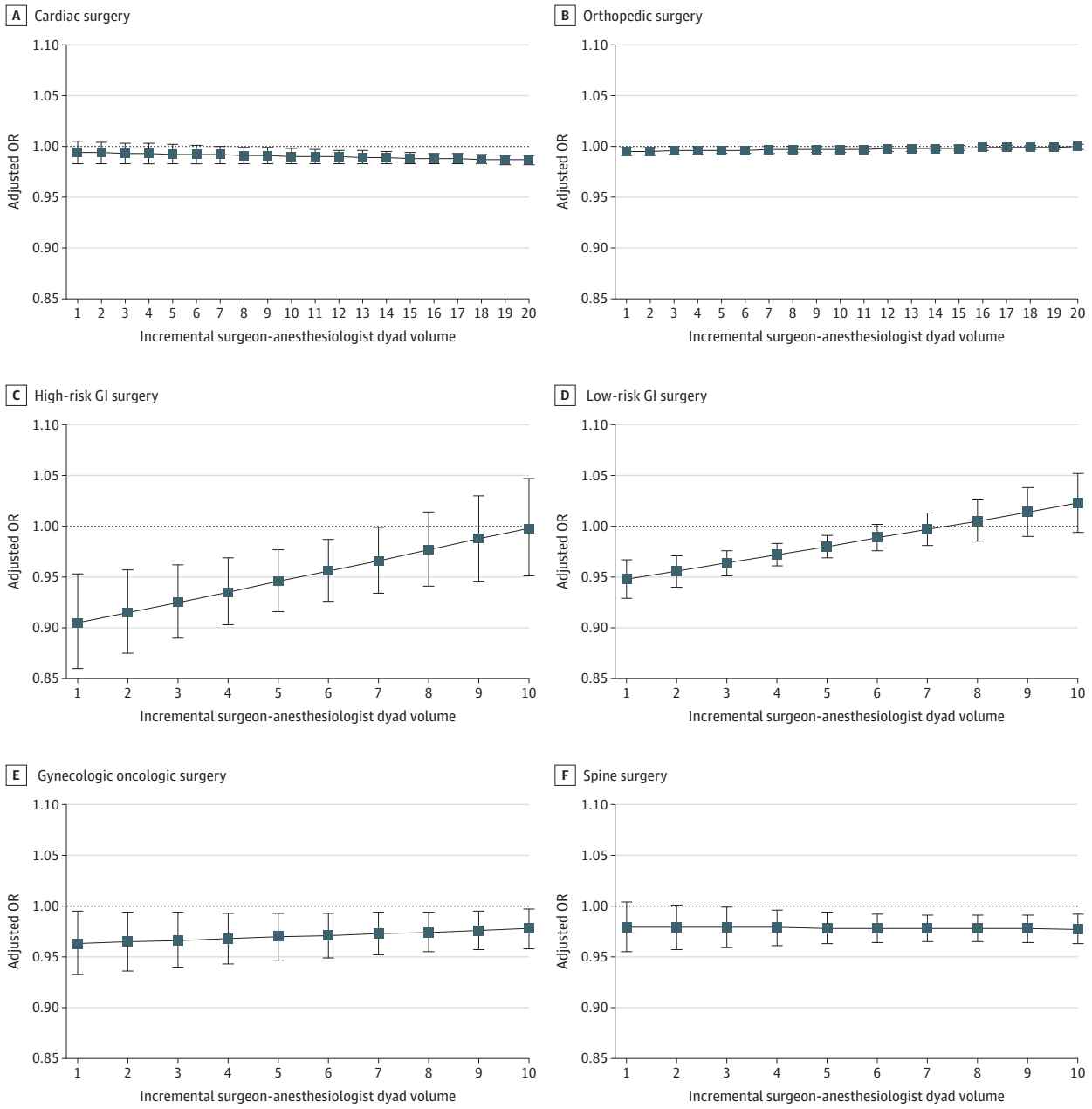
Odds ratios (ORs) (unadjusted, and adjusted for patient age, sex, and comorbidity burden, hospital annual volume, surgeon and anesthesiologist annual volumes, hospital setting, and year of surgery) are presented with 95% CIs. ORs represent the change in odds of 90-day postoperative major morbidity for each increment of 1 procedure per dyad per year An OR below 1 indicates reduced odds of 90-day postoperative major morbidity. The dotted line represents the null value of the OR. Complete models for adjusted ORs are available in eTable 5 in Supplement 1. GI indicates gastrointestinal.

rent study brings novel information by focusing specifically on the surgeon-anesthesiologist dyad, using a simple pragmatic measure of familiarity that is actionable and can be monitored in practice, and analyzing multicenter data representing an entire health system. The results outline differences in the relationships between dyad volume and postoperative outcomes depending on the type of procedure.

Team familiarity in the operating room may improve patient outcomes through enhanced teamwork and trust.[19] Nontechnical skills are recognized as essential for maintaining the flow of procedures and ensuring positive outcomes in the operating room, and are facilitated within stable and familiar teams.[50-53] Familiarity created transactive memory systems, whereby close relationships lead to a shared understanding of each other's tasks, goals, resources, and environment.[54-57] This results in increased cooperation, cohesiveness, trust, support, and assistance, all of which are correlated with improved perceptions of work effectiveness and satisfaction.[21] More familiar teams are more likely to adhere to best practices and care processes, respond effectively to unexpected events, and offer (and accept) support when needed.[54-57] These dynamics may further be impacted by the sociodemographics of anesthesiologists and surgeons within unique dyads; exploring how the association between dyad familiarity may be modified by the dyad sociodemographics fell beyond the scope of the current study but would be a worthy area for future investigations.

The associations between surgeon-anesthesiologist dyad volume and 90-day major morbidity differed across procedures. This may point to different structures of care and different baseline risks and management. First, no significant association was observed for procedures where the median dyad volume was high (cardiac, lung, and orthopedic surgery). Structures of care for these procedures are unique within our system, with higher dyad volume and familiarity overall. Cardiac surgery is only performed by a small group of specialized anesthesiologists in designated centers, lung surgery is regionalized with requirements for specific anesthesiology training for designated centers of excellence, and most elective orthopedic surgery is performed in specialized centers dedicated to hip and knee surgery where smaller anesthesiology teams work. Second, for procedures like genitourinary surgery, neu-

Figure 2. Association Between Surgeon-Anesthesiologist Dyad Volume and 90-Day Postoperative Major Morbidity by Dyad Volume



Odds ratios (ORs) (adjusted for patient age, sex, and comorbidity burden, hospital annual volume, surgeon and anesthesiologist annual volumes, hospital setting, and year of surgery) with 95% CIs error bars presented for the association between surgeon-anesthesiologist dyad volume and 90-day postoperative major morbidity. The OR was determined for each increment of dyad volume. An OR below 1 indicates a reduction in the risk of 90-day postoperative major morbidity. The dotted line represents the null value of the OR. Each x-axis value represents a comparison between that value and the increment below, ie, 1 vs 0, 2 vs 1, 3 vs 2, and so on. Data for other types of procedures can be found in eFigure 3 in Supplement 1. GI indicates gastrointestinal.

rosurgery, or vascular surgery, it is possible that either the dyad volumes in the cohort were too small and skewed toward low numbers with little spread to be able to detect a difference. The number of events was high in those groups and confidence intervals narrow, such that we do not believe the lack of significance was related to lack of statistical power. For those procedures (genitourinary, neurosurgery, vascular), we cannot definitely conclude that no relationship exists between surgeon-anesthesiologist dyad familiarity and patient outcomes. For procedures for which high dyad volume had been achieved and no association was observed (cardiac, orthopedic, lung), we can conclude that when high dyad familiarity (or dyad volume) already exists, no association was observed with further increases in dyad volume.

The results regarding low- and high-risk GI surgery, gynecology oncology surgery, and spine surgery can inform team models and care organization for high-risk elective surgery that leverage surgeon-anesthesiologist familiarity to optimize postoperative patient outcomes. Dedicated or specialized anesthesiology teams could contribute to increasing dyad volume. However, one may foresee unintended consequences, such as reducing the volume of other operations for anesthesiologists in specialized teams, resulting in challenges maintaining expertise for general practice necessary to cover all operating room activities. Novel models of care fostering increased surgeon-anesthesiologist dyad familiarity need to take this into account. It is also important to note that familiarity cannot be replicated through protocols and processes of care. Both familiarity and optimized processes of care are needed.[21,54-61]

Limitations

This study has limitations that ought to be considered when interpreting the results. First, the routinely collected health administrative data used were not collected specifically to address the research question. This introduces risk of misclassification for some variables and limits the availability of details on factors that may have impacted the dyad volume-outcome association, such as organizational culture or institutional protocols. Additionally, unmeasured confounding cannot be avoided. Second, we focused on the relationship between surgeon-anesthesiologist dyads, which did not capture the contributions of other key team members, such as nurses, trainees, or anesthesiology assistants. While familiarity among those team members certainly also matters, the importance of dyadic relationships within teams is well described.[58] Third, we limited our analysis to high-risk and elective operations, as these types of procedures are more sensitive to detecting differences based on team characteristics, and there is more opportunity to intervene on team schedules in elective settings than in emergency operations. We recognize that there was heterogeneity in procedure risk across the procedures included in the study, which is one of the reason the analyses were stratified by type of procedures. We also acknowledge that team expertise and familiarity also likely matter in the emergency setting; this would require separate studies to ascertain. Lastly, our findings are based on the dyad volumes existing within our cohort, and it is possible that in other systems with different baseline volumes or distribution of volumes, the magnitude of the observed effect estimates could differ. However, we believe that the direction of the association would remain consistent across different contexts.

Conclusions

In this study, increasing the familiarity of the surgeon-anesthesiologist dyad was associated with improved postoperative outcomes for patients undergoing low and high-risk GI surgery, gynecology oncology surgery, and spine surgery. For each additional time that a unique surgeon-anesthesiologist dyad worked together, the odds of 90-day major morbidity decreased by 4% for low-risk GI surgery, 8% for high-risk GI surgery, 3% for gynecology oncology surgery, and 3% for spine surgery. Increasing the familiarity of surgeon-anesthesiologist dyads, or the number of procedures they do together, represents an opportunity to improve patient outcomes for GI, gynecology oncology, and spine surgery. Additional research is needed to determine the most effective care structures that harness the benefits of surgeon-anesthesiologist familiarity to improve patient outcomes.

ARTICLE INFORMATION

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Author Affiliations: Department of Surgery, University of Toronto, Toronto, Ontario, Canada (Hallet, Coburn); Division of Surgical Oncology, Odette Cancer Centre, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada (Hallet, Coburn, Eskander); Clinical Evaluative Sciences, Sunnybrook Research Institute, Toronto, Ontario, Canada (Jerath, Gombay, Coburn, Eskander); ICES, Toronto, Ontario, Canada (Jerath, Chan, Coburn, Eskander, Sutradhar); Department of Anesthesiology, Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada (Jerath, d'Empaire, Idestrup); Department of Anesthesiology and Pain Medicine, University of Toronto, Toronto, Ontario, Canada (Jerath, d'Empaire, Idestrup, Lorello); Carrefour de l'innovation et santé des populations, Centre de recherche du CHUM, and Department of Anesthesiology and Division of Critical Care, Centre Hospitalier de l'Université de Montréal, Montréal, Québec, Canada (Carrier); Department of Anesthesiology and Pain Medicine, Université de Montréal, Montréal, Québec, Canada (Carrier); Department of Anesthesiology and Critical Care Medicine, Division of Critical Care Medicine, Université Laval, Québec City, Québec, Canada (Turgeon); CHU de Québec–Université Laval Research Centre, Population Health and Optimal Health Practices Research Unit, Trauma–Emergency–Critical Care Medicine, Université Laval, Québec City, Québec, Canada (Turgeon); Departments of Anesthesiology & Pain Medicine, University of Ottawa and The Ottawa Hospital, Ottawa, Ontario, Canada (McIsaac); Department of Anesthesiology and The Wilson Centre, University Health Network, Toronto Western Hospital, Toronto, Ontario, Canada (Lorello); Women's College Research Institute, Women's College Hospital, Toronto, Ontario, Canada (Lorello); Department of Anesthesiology, Pharmacology and Therapeutics, University of British Columbia, Vancouver, British Columbia, Canada (Flexman); Section of Thoracic Surgery, Departments of Surgery and of Community Health Sciences, University of Manitoba, Winnipeg, Manitoba, Canada (Kidane); Department of Otolaryngology–Head & Neck Surgery, University of Toronto, Toronto, Ontario, Canada (Eskander); Division of Biostatistics, Dalla Lana School of Public Health, University of Toronto, Ontario, Canada (Sutradhar); Department of Anesthesiology, St Paul's Hospital/Providence Health Care, Vancouver, British Columbia, Canada (Flexman).

Author Contributions: Ms Chan had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Hallet, Perez d'Empaire, Turgeon, McIsaac, Idestrup, Lorello, Flexman, Coburn, Eskander, Sutradhar.
Acquisition, analysis, or interpretation of data: Hallet, Jerath, Carrier, Turgeon, Lorello, Flexman, Kidane, Chan, Gombay, Eskander, Sutradhar.
Drafting of the manuscript: Hallet, Perez d'Empaire, McIsaac, Sutradhar.
Critical review of the manuscript for important intellectual content: All authors.
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Supervision: Hallet, McIsaac, Kidane, Coburn, Sutradhar.

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