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Association Between Handover of Anesthesia Care and Adverse Postoperative Outcomes Among Patients Undergoing Major Surgery

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IMPORTANCE Handing over the care of a patient from one anesthesiologist to another occurs during some surgeries and might increase the risk of adverse outcomes.

OBJECTIVE To assess whether complete handover of intraoperative anesthesia care is associated with higher likelihood of mortality or major complications compared with no handover of care.

DESIGN, SETTING, AND PARTICIPANTS A retrospective population-based cohort study (April 1, 2009-March 31, 2015 set in the Canadian province of Ontario) of adult patients aged 18 years and older undergoing major surgeries expected to last at least 2 hours and requiring a hospital stay of at least 1 night.

EXPOSURE Complete intraoperative handover of anesthesia care from one physician anesthesiologist to another compared with no handover of anesthesia care.

MAIN OUTCOMES AND MEASURES The primary outcome was a composite of all-cause death, hospital readmission, or major postoperative complications, all within 30 postoperative days. Secondary outcomes were the individual components of the primary outcome. Inverse probability of exposure weighting based on the propensity score was used to estimate adjusted exposure effects.

RESULTS Of the 313 066 patients in the cohort, 56% were women; the mean (SD) age was 60 (16) years; 49% of surgeries were performed in academic centers; 72% of surgeries were elective; and the median duration of surgery was 182 minutes (interquartile [IQR] range, 124-255). A total of 5941 (1.9%) patients underwent surgery with complete handover of anesthesia care. The percentage of patients undergoing surgery with a handover of anesthesiology care progressively increased each year of the study, reaching 2.9% in 2015. In the unweighted sample, the primary outcome occurred in 44% of the complete handover group compared with 29% of the no handover group. After adjustment, complete handovers were statistically significantly associated with an increased risk of the primary outcome (adjusted risk difference [aRD], 6.8% [95% CI, 4.5% to 9.1%]; $P < .001$), all-cause death (aRD, 1.2% [95% CI, 0.5% to 2%]; $P = .002$), and major complications (aRD, 5.8% [95% CI, 3.6% to 7.9%]; $P < .001$), but not with hospital readmission within 30 days of surgery (aRD, 1.2% [95% CI, −0.3% to 2.7%]; $P = .11$).

CONCLUSIONS AND RELEVANCE Among adults undergoing major surgery, complete handover of intraoperative anesthesia care compared with no handover was associated with a higher risk of adverse postoperative outcomes. These findings may support limiting complete anesthesia handovers.

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Supplemental content

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Handovers of anesthesia care from one anesthesiologist to another can occur intraoperatively due to personal or professional commitments, illness, or fatigue. Handovers can be temporary (initial clinician hands over care to another clinician for a break and then returns) or complete (initial clinician hands over care completely to another clinician and is no longer available).

During handovers, the outgoing clinician must communicate important facts about the patient and the surgery to the incoming clinician while continuing to provide patient care. This is a potentially vulnerable time for the patient because all information required for safe anesthesia care must be transferred between clinicians in a busy environment with many distractions. If crucial details are omitted, the patient may be at increased risk of adverse events. Alternatively, a sufficiently rested clinician taking over for a fatigued clinician may improve quality of care and result in fewer adverse events.

Uncertainty regarding the effect of intraoperative anesthesia handovers on mortality and major morbidity continues to exist. The hypothesis of this large, population-based, multicenter observational study was that the complete intraoperative handover of anesthesia care from one anesthesiologist to another was not associated with higher mortality or major complications up to 30 days postoperatively, relative to the standard case of anesthesia care.

Key Points

Question Is there an association between complete intraoperative handover of anesthesia care and adverse postoperative outcomes?

Findings In this retrospective cohort study that included 313 066 adults undergoing major surgery, complete intraoperative handover of anesthesia care compared with no handover was significantly associated with a higher risk of a composite of all-cause death, hospital readmission, or major postoperative complications over 30 days (44% vs 29%).

Meaning Complete handover of intraoperative anesthesia care was associated with adverse postoperative outcomes.

Methods

Study Design, Setting, and Data Sources

This population-based, retrospective cohort study used administrative health care data from the Canadian province of Ontario and followed the STROBE (strengthening the reporting of observational studies in epidemiology)[1] and RECORD (reporting of studies conducted using observational routinely collected health data)[2] reporting guidelines. All residents of Ontario (approximately 14 million) obtain health care services from a government-administered single-payer system. A unique, encoded identifier permitted linkage across several administrative databases, which were then analyzed at the Institute for Clinical Evaluative Sciences (ICES). Data were obtained from the Canadian Institute for Health Information's Discharge Abstract Database (CIHI-DAD; in-hospital outcomes), the National Ambulatory Care Reporting System (CIHI-NACRS; emergency department [ED] visits), the Same Day Surgery Database (CIHI-SDS), the Ontario Health Insurance Plan (physician billings), the Corporate Provider Database (physician demographic data from Ontario's Ministry of Health and Long-Term Care), and the Registered Persons Database (patient demographics and vital status). Ethics approval was granted through the Sunnybrook Health Sciences Centre Research Ethics Board (Toronto, Ontario), which waived the requirement for informed consent from participants.

Participants

Adult patients (≥18 years) were identified who underwent major surgeries expected to have duration of at least 2 hours and require postoperative admission to hospital for at least 1 night between April 1, 2009, and March 31, 2015. Major surgeries were targeted within the broad subgroup domains of neurosurgery; cardiac; vascular; thoracic; and abdominal, pelvic, and urologic surgery, as identified by surgeon experts using *Canadian Classification of Health Intervention* (*CCI*) codes (eTable 1 in the Supplement).

Patients having multiple surgeries within the accrual period were only included in the cohort for their first eligible surgery. Patients who had surgery within the same surgical subgroup within the previous year were excluded to reduce the probability of complicated surgeries requiring revision or reoperation soon after initial operations (patients were still included if they had surgeries within another surgical subgroup at any time or within the same subgroup if more than 1 year had passed after the previous surgery). In addition, after examining the initial cohort, it was discovered that one Ontario institution systematically billed the code used to define the main exposure in this study for an alternative purpose—specifically, the postoperative care of patients requiring complicated care in the postanesthetic care unit. Because it could not be positively determined which exposures were intraoperative vs postoperative, all patients who had surgery at this institution were excluded (**Figure 1**).

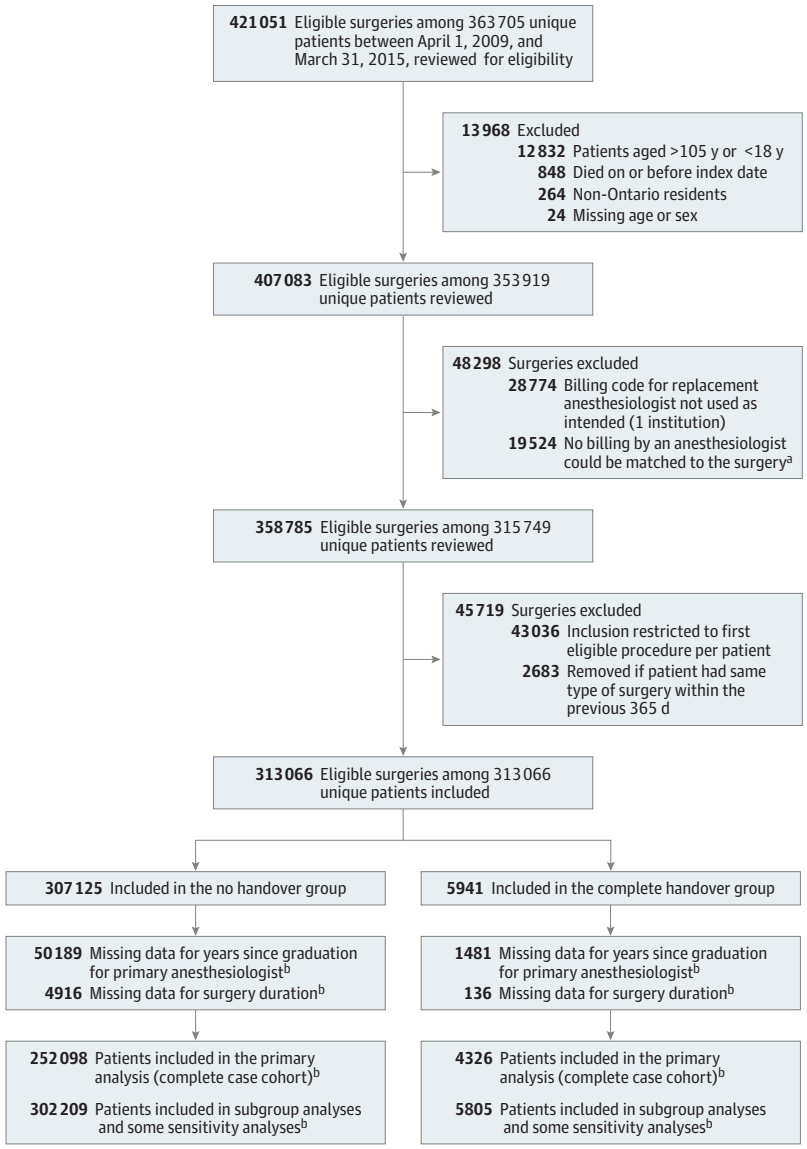
Exposure of Interest

The exposure of interest in this study was the complete intraoperative handover of anesthesia care from one physician anesthesiologist (the primary anesthesiologist) to another physician anesthesiologist (the replacement anesthesiologist). In Ontario, this transition is specifically captured by a unique billing code (E005C). This code is submitted by the replacement anesthesiologist and identifies a surgery in which a replacement anesthesiologist entirely took over a case from the primary anesthesiologist. This billing code was expected to be accurate since it is the only mechanism used to remunerate the replacement anesthesiologist. Patients were considered to be exposed to a complete handover if the code was billed on the day of surgery or the day after surgery (to account for handovers occurring after midnight).

Outcomes

The primary outcome was a composite[3] of all-cause death, readmission to any hospital in the province, or major postoperative complications, all within 30 days of the index surgery.

Figure 1. Cohort Build and Missing Data for Surgeries With Complete Handover vs No Handover



[a] Billing code for replacement anesthesiologist not used as intended (1 institution) refers to 1 Ontario institution which systematically billed the code used to define the main exposure in this study for an alternative purpose (ie, the postoperative care of patients with complicated medical needs in the postanesthetic care unit). Since it was not possible to positively determine which exposures among these patients were intraoperative vs postoperative, all patients who underwent surgery at this institution were excluded.

[b] To move from the complete case cohort (256 424 patients) to the subgroup analysis cohort (308 014 patients), 51 670 patients missing data on years since graduation for the primary anesthesiologist were added to the complete case cohort, and 80 patients were subtracted who also had missing data on duration of surgery.

Secondary outcomes were the 3 separate components of the primary outcome, the incidence of postoperative intensive care unit (ICU) admission, hospital length of stay, and the number of ED visits in Ontario within 90 days of the index surgery.

Major complications were defined by *CCI* intervention codes, *International Classification of Diseases, Tenth Revision* (*ICD-10*) diagnostic codes, and the Ontario Health Insurance Plan physician billings (eTable 2 in the Supplement). Major complications were only included if they were diagnosed for the first time postoperatively (ie, atrial fibrillation present before surgery was not counted as a complication). All outcomes were specified a priori.

Statistical Analysis

Analyses were conducted using Stata version 15. Patients in the exposed (handover) and nonexposed (no handover) groups were likely to differ systematically due to confounding by indication. For example, it was probable that handovers occurred more commonly during longer-duration surgeries. Therefore, we controlled for measured confounding using inverse probability of exposure weighting (IPEW) based on propensity scores.[4,5] The propensity score was estimated using multivariable logistic regression with receipt of a handover as the dependent variable and covariates decided upon a priori as the independent variables (sex, age, comorbidities with a 5-year look-back window [hypertension, coronary artery disease, congestive heart failure, peripheral vascular disease, diabetes, previous stroke or transient ischemic attack, chronic liver disease, cancer, chronic renal disease, and chronic obstructive pulmonary disease], duration of the surgery [reported in deciles], years since medical school graduation for the primary anesthesiologist, region within the province, type of hospital [academic or not], whether

Table 1. Baseline Characteristics of the Patients Before and After Inverse Probability of Exposure Weighting[a]

Characteristic	Observed Data (N = 313 066)			Inverse Probability of Exposure-Weighted Data (n = 256 424)[b]		
	No Handover (n = 307 125)	Complete Handover (n = 5941)	Standardized Difference (%)[c]	No Handover (n = 127 569.4)	Complete Handover (n = 128 854.6)	Standardized Difference (%)[c]
Women	171 397 (55.8)	2764 (46.5)	17.9	71 104.5 (55.7)	69 956.3 (54.3)	2.9
Age, y						
Mean (SD)	59.8 (15.6)	59.9 (15.7)	0.4	59.7 (15.5)	60.2 (15.5)	3.3
Median (IQR)	61 (48 to 72)	61 (50 to 72)				
Region						
Metropolitan Toronto	107 800 (35.1)	2776 (46.7)	23.8	44 933.5 (35.2)	39 749.0 (30.9)	−9.3
Southwestern Ontario	102 159 (33.3)	1215 (20.5)	−27.1	42 154.3 (33.0)	43 384.4 (33.7)	1.3
Eastern Ontario	68 581 (22.3)	1617 (27.2)	9.1	28 672.7 (22.5)	32 758.0 (25.4)	6.9
Northern Ontario	28 585 (9.3)	333 (5.6)	−13.6	11 808.9 (9.3)	12 963.2 (10.1)	2.7
Type of hospital						
Academic	147 736 (48.1)	4235 (71.3)	46.5	61 620.2 (48.3)	62 155.6 (48.2)	−0.1
Nonacademic	159 389 (51.9)	1706 (28.7)		65 949.2 (51.7)	66 699.0 (51.8)	
Comorbidities						
Charlson Comorbidity Index[d]						
Mean (SD)	0.86 (1.49)	0.97 (1.63)	7.3	0.87 (1.50)	0.96 (1.57)	6.3
Median (IQR)	0 (0 to 2)	0 (0 to 2)				
No. of conditions						
0	125 467 (40.9)	2152 (36.2)	−9.4	52 261.8 (41.0)	48 730.9 (37.8)	−6.4
1	26 954 (8.8)	536 (9.0)	2.0	11 076.5 (8.7)	10 757.3 (8.4)	−1.2
≥2	80 223 (26.1)	1686 (28.4)	5.8	33 471.3 (26.2)	38 447.5 (29.8)	8.0
No hospitalizations in previous 5 y[e]	74 481 (24.3)	1567 (26.4)	3.3	30 759.8 (24.1)	30 918.9 (24.0)	−0.3
Hypertension	161 498 (52.6)	3234 (54.4)	3.6	67 014.9 (52.5)	66 066.1 (51.3)	−2.5
Coronary artery disease	92 959 (30.3)	1676 (28.2)	−4.7	39 038.5 (30.6)	40 440.6 (31.4)	1.7
Congestive heart failure	25 094 (8.2)	515 (8.7)	1.2	10 406.6 (8.2)	11 328.2 (8.8)	2.3
Peripheral vascular disease	5015 (1.6)	120 (2.0)	2.6	2131.5 (1.7)	2883.4 (2.2)	4.1
Diabetes	72 692 (23.7)	1453 (24.5)	1.9	29 910.9 (23.5)	30 248.4 (23.5)	0.1
Previous stroke or transient ischemic attack	8633 (2.8)	216 (3.6)	3.4	3584.6 (2.8)	3555.7 (2.8)	−0.3
Chronic liver disease	15 167 (4.9)	383 (6.5)	6.1	6218.8 (4.9)	6543.0 (5.1)	0.9
Chronic kidney disease	19 797 (6.5)	469 (7.9)	6.7	8151.8 (6.4)	8843.8 (6.9)	1.9
Chronic obstructive pulmonary disease	54 776 (17.8)	1092 (18.4)	1.4	22 635.2 (17.7)	24 578.9 (19.1)	3.4
Cancer	50 434 (16.4)	1094 (18.4)	5.7	21 228.1 (16.6)	24 698.2 (19.2)	6.6
Surgery						
Time since medical school graduation for primary anesthesiologist, y						
Mean (SD)	22.1 (10.6)	21.0 (10.3)	−11.1	22.1 (10.6)	21.8 (10.6)	−3.2
Median (IQR)	21 (13 to 30)	20 (12 to 29)				
Duration of surgery, min						
Mean (SD)	199.1 (116.3)	320.8 (189.5)	78.7	200.1 (119.6)	206.6 (127.8)	5.3
Median (IQR)	180 (124 to 253)	275 (190 to 410)				
Elective vs urgent/emergent						
Elective	222 704 (72.5)	3446 (58.0)	29.1	92 582.4 (72.6)	91 598.6 (71.1)	3.3
Urgent/emergent	84 421 (27.5)	2495 (42.0)		34 987.0 (27.4)	37 256.0 (28.9)	
Neurosurgery						
Brain, brain stem, spinal canal, pituitary	19 838 (6.5)	1028 (17.3)	33.0	8279.6 (6.5)	7629.2 (5.9)	−2.4
Spine	33 499 (10.9)	903 (15.2)	11.5	14 008.8 (11.0)	12 541.0 (9.7)	−4.1
Cardiac surgery						
Coronary artery bypass grafting and/or valve	52 444 (17.1)	761 (12.8)	−11.3	21 783.8 (17.1)	22 302.3 (17.3)	0.6
Vascular surgery						
Abdominal aortic	6454 (2.1)	197 (3.3)	7.5	2766.1 (2.2)	2889.8 (2.2)	0.5

(continued)

Table 1. Baseline Characteristics of the Patients Before and After Inverse Probability of Exposure Weighting[a] (continued)

Characteristic	Observed Data (N = 313 066)			Inverse Probability of Exposure-Weighted Data (n = 256 424)[b]		
	No Handover (n = 307 125)	Complete Handover (n = 5941)	Standardized Difference (%)[c]	No Handover (n = 127 569.4)	Complete Handover (n = 128 854.6)	Standardized Difference (%)[c]
Thoracic surgery						
Lung resection	13 810 (4.5)	112 (1.9)	−13.8	5624.2 (4.4)	5237.6 (4.1)	−1.7
Abdominal, pelvic, and urologic surgery						
Gastric, intestinal, rectal	90 059 (29.3)	1872 (31.5)	5.1	37 206.6 (29.2)	42 661.3 (33.1)	8.5
Liver resection	1731 (0.6)	85 (1.4)	9.4	706.3 (0.6)	754.9 (0.6)	0.4
Bladder	4051 (1.3)	160 (2.7)	11.0	1652.1 (1.3)	1644.7 (1.3)	−0.2
Kidney, including renal transplantation	12 683 (4.1)	280 (4.7)	3.2	5276.0 (4.1)	5489.2 (4.3)	0.6
Uterus	72 556 (23.6)	543 (9.1)	−39.6	30 265.9 (23.7)	27 704.6 (21.5)	−5.3

Abbreviation: IQR, interquartile range.

[a] All values are reported as No. (%) unless otherwise specified.

[b] The inverse probability of exposure-weighted data represent a pseudosample after weighting and therefore were not directly observed.[6] The pseudosample also explains the apparent fraction of patients seen after weighting. The sample size for the inverse probability of exposure-weighted cohort (256 424) differs from the overall cohort due to missing data (Figure 1).

[c] Standardized differences compare imbalance among variables without being affected by sample size.[7] Standardized differences of less than 10% are considered by some authors to indicate good balance between groups.[7]

[d] The Charlson Comorbidity Index is a list of 17 comorbidities identified by *International Classification of Diseases, 10th Revision* codes, each of which is assigned a weight from 1 to 6 (score of 0 indicates healthy patients [no comorbidities identified]; higher scores indicate the presence of additional comorbidities). Comorbidities included a 5-year look-back window.

[e] Indicates no data were available for this time frame.

the surgery was elective or urgent/emergent, and the type of surgery [eTable 3 in the Supplement]). Observations were then weighted according to the inverse of the calculated probability of receiving the exposure that the participant actually received and analyzed using the *teffects ipw* package in Stata. Results were expressed as potential outcome means (which reflect the outcomes in the inverse probability of exposure-weighted pseudosample[6]), adjusted risk differences (aRDs), and adjusted relative risks (aRRs). The balance of covariates pre- and postweighting was assessed using standardized differences.[7] For the primary analysis, planned a priori, complete case analysis was implemented when data were missing.

A priori subgroup analysis was planned for the fiscal year of surgery, whether the surgery was elective vs urgent/emergent, and for major surgical subgroup. Homogeneity of subgroup effects were tested via a test of interaction. Results were assessed for robustness to analytical technique by reanalyzing the main outcomes with the following methods: (1) multivariable logistic regression; (2) a doubly robust IPEW with regression adjustment model[4] (using the Stata *teffects ipwra* package); (3) IPEW after excluding the variable with the most missing data (years since medical graduation for the primary anesthesiologist [for which no administrative data were available for fiscal year 2015]); (4) IPEW after adding calendar year of surgery as a covariate; (5) median imputation for missing data for duration of surgery (ie, the median duration of surgery for each surgical subtype was imputed into each record that was missing duration of surgery according to the type of surgery the patient underwent); and (6) multiple imputation for missing data for surgical duration and years since medical school graduation for the primary anesthesiologist (using a multivariate normal regression, iterative Markov chain Monte Carlo method [using the Stata *mi impute mvn* package and incorporating all covariates in the imputation model including the primary outcome[8]] to calculate 20 multiply imputed data sets). Reanalysis of the primary outcome was performed after incorporating age and duration of surgery into the analysis as polynomial variables. A *P* value of less than .05 was considered statistically significant. All hypothesis tests were 2-sided. No corrections were made for multiple comparisons, therefore the comparisons of individual complications between exposure groups were interpreted as exploratory analyses.

Results

Patients

This study included 313 066 patients (307 125 in the no handover group; 5941 in the complete handover group) (Figure 1). There were missing data for 2 variables: 51 670 (16.5%) patients were missing data on years since medical school graduation for the primary anesthesiologist, and 5052 (1.6%) patients were missing data on the duration of surgery (Figure 1). The total number of complete handovers for all surgeries (ie, not just the surgeries meeting inclusion criteria for this cohort study) in Ontario from 2004 until 2015 increased every year as did the yearly percentage of patients in this cohort whose surgery had a complete handover during the study period (eFigure in the Supplement). Important baseline differences between the no handover and complete handover groups were noted on several characteristics (**Table 1**).

Unadjusted Main Outcomes

The primary outcome (all-cause death, hospital readmission, or major complication within 30 days of the index surgery) occurred in 90 306 (29%) of the no handover group and in 2583 (44%) of the complete handover group (risk difference [RD], 14.1% [95% CI, 12.8% to 15.3%]). Having a complete handover was associated with worse outcomes for each component of the primary outcome (**Table 2**). The mean hospital length of stay was longer in the complete handover group as was the

Table 2. Main Outcomes in the Study Cohort[a]

Outcome	Unadjusted Values				Adjusted Values[b]			
	No Handover (n = 307 125)	Complete Handover (n = 5941)	RD, % (95% CI) (N = 313 066)[c]	RR (95% CI) (N = 313 066)[c,d]	No Handover Potential Outcome Mean, % (95% CI) (n = 127 569.4)	Complete Handover Potential Outcome Mean, % (95% CI) (n = 128 854.6)	RD, % (95% CI) (n = 256 424)[c]	RR (95% CI) (n = 256 424)[c,d]
Primary outcome[e]	90 306 (29.4)	2583 (43.5)	14.1 (12.8 to 15.3%)	1.48 (1.44 to 1.52)	29.1 (28.9 to 29.3)	35.9 (33.6 to 38.2)	6.8 (4.5 to 9.1)	1.23 (1.16 to 1.32)
P value			<.001				<.001	
All-cause death within 30 d	8255 (2.7)	314 (5.3)	2.6 (2.0 to 3.2)	1.97 (1.76 to 2.19)	2.7 (2.6 to 2.8)	3.9 (3.2 to 4.7)	1.2 (0.5 to 2.0)	1.45 (1.19 to 1.76)
P value			<.001				.002	
Readmission within 30 d	21 302 (6.9)	544 (9.2)	2.2 (1.5 to 3.0)	1.32 (1.22 to 1.43)	6.9 (6.8 to 7.0)	8.1 (6.6 to 9.6)	1.2 (−0.3 to 2.7)	1.18 (0.98 to 1.41)
P value			<.001				.11	
Major complication within 30 d	72 347 (23.6)	2143 (36.1)	12.5 (11.3 to 13.7)	1.53 (1.48 to 1.58)	23.3 (23.1 to 23.4)	29.0 (26.9 to 31.2)	5.8 (3.6 to 7.9)	1.25 (1.16 to 1.34)
P value			<.001				<.001	
Secondary Outcomes[e]								
Intensive care unit admission	92 640 (30.2)	2363 (39.8)	9.6 (8.4 to 10.9)	1.32 (1.28 to 1.36)	30.3 (30.1 to 30.5)	34.0 (32.0 to 36.1)	3.7 (1.7 to 5.8)	1.12 (1.06 to 1.19)
P value			<.001				<.001	
Hospital length of stay, d								
Mean (SD)	8.4 (13.3)	13.2 (18.2)	4.8 (4.5 to 5.2)[f]		8.5 (8.4 to 8.5)[f]	9.7 (9.2 to 10.2)[f]	1.2 (0.7 to 1.7)[f]	
P value			<.001				<.001	
Median (IQR)	5 (3 to 9)	8 (5 to 15)						
ED visits <90 d after index surgery[g]								
Mean (SD)	0.54 (1.27)	0.63 (1.48)	0.09 (0.06 to 0.12)[f]		0.51 (0.51 to 0.51)[f]	0.54 (0.48 to 0.60)[f]	0.03 (−0.03 to 0.09)[f]	
P value			<.001				.36	
Median (IQR)	0 (0 to 1)	0 (0 to 1)						
Any ED visit <90 d after index surgery	91 944 (29.9)	1953 (32.9)	2.9 (1.7 to 4.1)	1.10 (1.06 to 1.14)	29.5 (29.4 to 29.7)	29.3 (27.0 to 31.6)	−0.2 (−2.5 to 2.1)	0.99 (0.92 to 1.07)
P value			<.001				.86	

Abbreviations: ED, emergency department; IQR, interquartile range; RD, risk difference; RR, relative risk.

[a] Complete case analysis resulted in some missing data in the cohort on 2 variables only: an entire year of missing data for years since medical school graduation for the primary anesthesiologist (51 670 records [16.5%]) and missing data for duration of surgery (5052 patients [1.6%]). The results were similar when years since medical school graduation was excluded from the statistical model (eTable 4 in the Supplement).

[b] Adjusted results obtained from inverse probability of exposure weighting based on propensity scores. The propensity score was estimated using multivariable logistic regression with receipt of a handover as the dependent variable and a vector of covariates decided a priori as the independent variables (sex, age, comorbidities with a 5-year look-back window [hypertension, coronary artery disease, congestive heart failure, peripheral vascular disease, diabetes, previous stroke or transient ischemic attack, chronic liver disease, cancer, chronic renal disease, and chronic obstructive pulmonary disease], duration of the surgery [in deciles], years since medical school graduation for the primary anesthesiologist, region of the province, type of hospital [academic or not], whether the surgery was elective or urgent/emergent, and the type of surgery performed).

[c] RDs and RRs are for the complete handover group relative to the no handover group. For example, the RD for the primary outcome of 6.8% indicates that the complete handover group had a 6.8% absolute increase of all-cause death, hospital readmission, or complication within 30 days compared with the no handover group (or [equivalently], for every 15 patients exposed to a complete handover, 1 additional patient would be expected to experience the primary outcome). Potential outcome means reflect the outcomes in the inverse probability of exposure-weighted pseudosample (ie, postadjustment) and therefore were not directly observed outcomes.[6]

[d] RRs are calculated for binary outcomes.

[e] Outcomes for the 3 components of the composite primary outcome (all-cause death, readmission, or major complication, all within 30 days) were not mutually exclusive. Therefore the sum of the events in the components is greater than the composite event rate. Diagnostic and intervention codes used to define outcomes are specified in eTable 2 in the Supplement.

[f] Values indicate number of days for hospital length of stay and No. of ED visits (not percents as displayed with other values in the same column).

[g] Indicates ED visits within Ontario.

Table 3. Details of Complications (Exploratory Analyses)[a]

Complication[b]	Unadjusted Values				Adjusted Values			
	No Handover (n = 307 125)	Complete Handover (n = 5941)	RD, % (95% CI) (N = 313 066)[c]	RR (95% CI) (N = 313 066)[c]	No Handover Potential Outcome Mean, % (95% CI) (n = 127 569.4)[d]	Complete Handover Potential Outcome Mean, % (95% CI) (n = 128 854.6)[d]	RD, % (95% CI) (n = 256 424)[c]	RR (95% CI) (n = 256 424)[c,e]
Postoperative ventilation for ≥48 h	50 874 (16.6)	1561 (26.3)	9.7 (8.6 to 10.8)	1.59 (1.52 to 1.66)	16.7 (16.6 to 16.9)	18.7 (17.0 to 20.4)	1.9 (0.2 to 3.6)	1.11 (1.02 to 1.22)
P value			<.001				.03	
Major disruption of surgical wound	11 887 (3.9)	422 (7.1)	3.2 (2.6 to 3.9)	1.84 (1.67 to 2.02)	3.5 (3.4 to 3.6)	6.4 (5.3 to 7.6)	2.9 (1.8 to 4.1)	1.85 (1.54 to 2.22)
P value			<.001				<.001	
Bleeding	6678 (2.2)	262 (4.4)	2.2 (1.7 to 2.8)	2.03 (1.80 to 2.29)	2.2 (2.1 to 2.2)	4.7 (3.6 to 5.7)	2.5 (1.4 to 3.6)	2.14 (1.70 to 2.70)
P value			<.001				<.001	
Pneumonia	4112 (1.3)	151 (2.5)	1.2 (0.8 to 1.6)	1.90 (1.62 to 2.23)	1.3 (1.3 to 1.4)	2.0 (1.4 to 2.6)	0.7 (0.1 to 1.2)	1.51 (1.14 to 2.00)
P value			<.001				.02	
Unplanned return to operating room	4039 (1.3)	165 (2.8)	1.5 (1.0 to 1.9)	2.11 (1.81 to 2.46)	1.3 (1.2 to 1.3)	3.1 (1.9 to 4.3)	1.8 (0.6 to 3.0)	2.39 (1.61 to 3.55)
P value			<.001				.004	
Atrial fibrillation or flutter (new-onset)	3943 (1.3)	94 (1.6)	0.3 (−0.02 to 0.6)	1.23 (1.01 to 1.51)	1.0 (1.0 to 1.1)	1.3 (0.8 to 1.8)	0.3 (−0.2 to 0.8)	1.27 (0.86 to 1.88)
P value			.04				.29	
Hemodialysis (new-onset)	2292 (0.7)	100 (1.7)	0.9 (0.6 to 1.3)	2.26 (1.85 to 2.75)	0.8 (0.7 to 0.8)	1.6 (1.0 to 2.1)	0.8 (0.3 to 1.3)	2.07 (1.48 to 2.90)
P value			<.001				.002	
Myocardial infarction	1821 (0.6)	40 (0.7)	0.08 (−0.01 to 0.3)	1.14 (0.83 to 1.55)	0.6 (0.6 to 0.7)	1.0 (0.4 to 1.5)	0.4 (−0.2 to 0.9)	1.56 (0.89 to 2.76)
P value			.42				.21	
Acute kidney injury	1398 (0.5)	54 (0.9)	0.5 (0.2 to 0.7)	2.0 (1.52 to 2.62)	0.4 (0.4 to 0.5)	0.6 (0.3 to 0.9)	0.2 (−0.1 to 0.5)	1.42 (0.88 to 2.30)
P value			<.001				.22	
Cardiac arrest or other life-threatening postoperative incident	1240 (0.4)	50 (0.8)	0.4 (0.2 to 0.7)	2.08 (1.57 to 2.76)	0.4 (0.4 to 0.4)	0.4 (0.2 to 0.6)	0.04 (−0.2 to 0.2)	1.11 (0.71 to 1.74)
P value			<.001				.66	
Shock	1121 (0.4)	48 (0.8)	0.4 (0.2 to 0.7)	2.21 (1.66 to 2.95)	0.4 (0.3 to 0.4)	0.5 (0.2 to 0.8)	0.1 (−0.1 to 0.4)	1.36 (0.81 to 2.29)
P value			<.001				.31	
Stroke	1034 (0.3)	59 (1.0)	0.7 (0.4 to 0.9)	2.95 (2.27 to 3.83)	0.3 (0.3 to 0.3)	0.5 (0.2 to 0.7)	0.2 (−0.1 to 0.4)	1.55 (0.94 to 2.57)
P value			<.001				.16	
Sepsis	922 (0.3)	44 (0.7)	0.4 (0.2 to 0.7)	2.47 (1.83 to 3.33)	0.3 (0.3 to 0.3)	0.4 (0.2 to 0.5)	0.08 (−0.1 to 0.2)	1.27 (0.84 to 1.91)
P value			<.001				.31	
Pulmonary embolism	279 (0.09)	20 (0.3)	0.2 (0.1 to 0.4)	3.71 (2.36 to 5.83)	0.1 (0.1 to 0.1)	0.3 (−0.1 to 0.6)	0.2 (−0.2 to 0.5)	2.96 (0.87 to 10.00)
P value			<.001				.29	
Deep venous thrombosis	285 (0.09)	12 (0.2)	0.1 (−0.005 to 0.2)	2.18 (1.22 to 3.88)	0.1 (0.1 to 0.1)	0.1 (−0.01 to 0.3)	0.04 (−0.1 to 0.2)	1.47 (0.50 to 4.34)
P value			.007				.56	

(continued)

Table 3. Details of Complications (Exploratory Analyses)[a] (continued)

Complication[b]	Unadjusted Values				Adjusted Values			
	No Handover (n = 307 125)	Complete Handover (n = 5941)	RD, % (95% CI) (N = 313 066)[c]	RR (95% CI) (N = 313 066)[c]	No Handover Potential Outcome Mean, % (95% CI) (n = 127 569.4)[d]	Complete Handover Potential Outcome Mean, % (95% CI) (n = 128 854.6)[d]	RD, % (95% CI) (n = 256 424)[c]	RR (95% CI) (n = 256 424)[c,e]
Coma	44 (0.01)	6 (0.1)	0.09 (0.006 to 0.2)	7.05 (3.01 to 16.54)	0.01 (0.01 to 0.02)	0.06 (0.001 to 0.12)	0.05 (−0.01 to 0.1)	4.23 (1.49 to 11.99)
P value			<.001				.13	

Abbreviations: RD, risk difference; RR, relative risk.

[a] Complete case analysis resulted in some missing data in the cohort on 2 variables only: an entire year of missing data for years since medical school graduation for the primary anesthesiologist (51 670 records [16.5%]) and missing data for duration of surgery (5052 patients [1.6%]). The results were similar when years since medical school graduation was excluded from the statistical model (eTable 4 in the Supplement).

[b] Diagnostic and intervention codes used to define outcomes are specified in eTable 2 in the Supplement.

[c] RDs and RRs are for the complete handover group relative to the no handover group. For example, the risk difference of 0.8% (95% CI, 0.3 to 1.3%) for new-onset hemodialysis indicates that after adjustment, the complete handover group had a 0.8% absolute increase in the risk of new-onset hemodialysis compared with the no handover group.

[d] Potential outcome means reflect the outcomes in the inverse probability of exposure-weighted pseudosample (ie, postadjustment) and therefore were not directly observed outcomes.[6]

[e] Adjusted results obtained from inverse probability of exposure weighting based on propensity scores. The propensity score was estimated using multivariable logistic regression with receipt of a handover as the dependent variable and a vector of covariates decided upon a priori as the independent variables (sex, age, comorbidities with a 5-year look-back window [hypertension, coronary artery disease, congestive heart failure, peripheral vascular disease, diabetes, previous stroke or transient ischemic attack, chronic liver disease, cancer, chronic renal disease, and chronic obstructive pulmonary disease], duration of the surgery [in deciles], years since medical school graduation for the primary anesthesiologist, region of the province, type of hospital [academic or not], whether the surgery was elective or urgent/emergent, and the type of surgery performed).

mean number of ED visits within 90 days of the index surgery, postoperative admissions to an ICU, and the proportion of the study cohort with any ED visit (Table 2).

Adjusted Main Outcomes

After adjustment, a complete handover of anesthesia care remained statistically significantly associated with an increased incidence of the primary outcome (Table 2; adjusted risk difference [aRD], 6.8% [95% CI, 4.5% to 9.1%]) and an increase in all-cause death and major complications within 30 days of the index surgery but not with hospital readmissions. The mean hospital length of stay was longer in the complete handover group, as was the incidence of postoperative ICU admission (Table 2).

Sensitivity Analyses

Across multiple sensitivity analyses, similar point estimates and 95% CIs were found, including when the variable with the most missing data was excluded from the statistical models (allowing for analysis of 308 014 patients), when multiple imputation was performed (allowing for analysis of 313 066 patients), and when age and/or duration of surgery were incorporated into the analysis as polynomial variables (eTable 4 and eTable 5 in the Supplement).

Secondary Outcomes

After adjustment in exploratory analyses, complete handover was statistically significantly associated with a higher incidence of postoperative ventilation for 48 hours or more, a major disruption of the surgical wound, bleeding, pneumonia, an unplanned return to the operating room, and new-onset hemodialysis (**Table 3**).

Subgroup Analyses

In subgroup analyses, heterogeneity was observed in the subgroup of year of surgery for the hospital readmission and major complication outcomes, for the subgroup of type of surgery for the primary outcome, and for the all-cause death and major complication outcomes. No statistically significant heterogeneity was observed between elective or urgent/emergent surgeries (**Figure 2**; and eTable 6 in the Supplement).

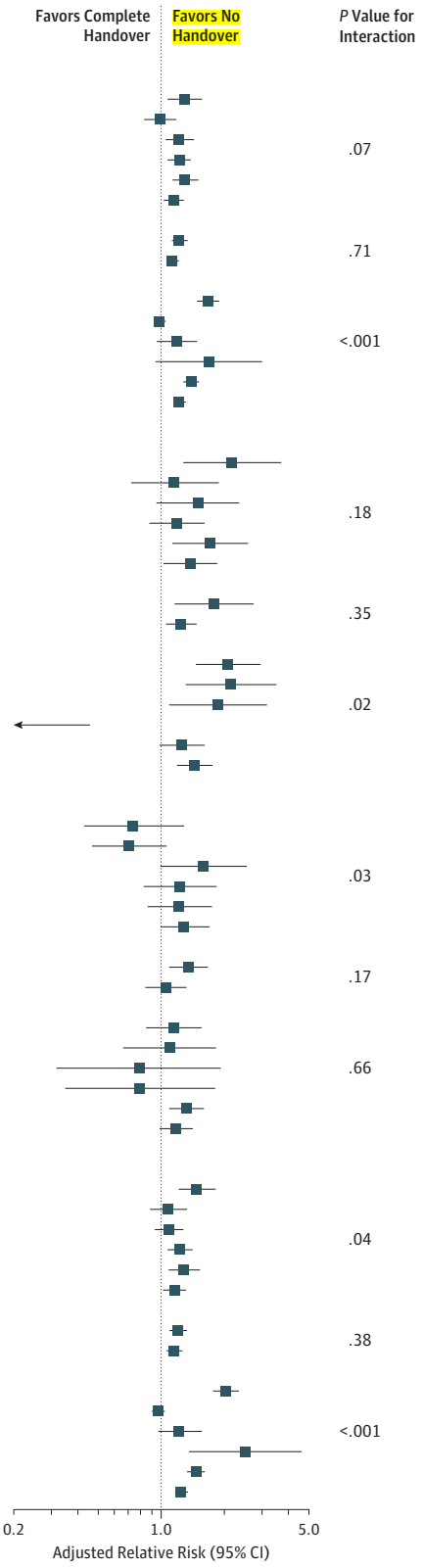
Discussion

In this large population-based study, a clinically important and statistically significant detrimental association between the complete handover of anesthesia care during major surgery and adverse postoperative outcomes was found. On average, for every 15 patients exposed to a complete anesthesia handover, 1 additional patient would be expected to experience the primary outcome. Intraoperative handovers were also associated with an increase in ICU admissions and longer hospital lengths of stay.

In Ontario, the absolute number of complete handovers is increasing year-by-year. Knowing that fatigue exacerbates many human limitations,[9] some departments have implemented policies of restricted duty hours for medical staff, residents, or both.[10] It is likely that these policies have some

Figure 2. Risk of Adverse Outcomes (Complete Intraoperative Handover of Anesthesia Care vs no Handover Groups) in the Prespecified Subgroups

Subgroup	No. of Patients With Event/Total No. of Patients: No Handover	Complete Handover	Adjusted Relative Risk (95% CI)	P Value for Interaction
Primary outcome				
Fiscal year of surgery[a]				
2010	13844/51 854	223/468	1.29 (1.07-1.56)	
2011	13455/49706	230/567	0.99 (0.83-1.18)	
2012	15494/51674	378/853	1.22 (1.05-1.43)	.07
2013	15103/49044	519/1195	1.22 (1.07-1.38)	
2014	15344/50002	545/1248	1.30 (1.13-1.50)	
2015	15215/49929	617/1474	1.15 (1.03-1.28)	
Elective vs urgent or emergent surgery				
Elective	51810/219881	1304/3377	1.22 (1.12-1.33)	.71
Urgent or emergent	36645/82328	1208/2428	1.13 (1.06-1.21)	
Type of surgery				
Neurosurgery	8674/52150	664/1875	1.67 (1.48-1.88)	
Cardiac surgery	37732/52245	551/750	0.98 (0.92-1.05)	
Vascular surgery[b]	2881/6368	143/194	1.19 (0.95-1.48)	<.001
Thoracic surgery[b]	2509/13666	38/112	1.68 (0.94-3.00)	
Abdominal, pelvic, and urologic surgery	36659/177780	1116/2874	1.39 (1.27-1.51)	
Overall effect			1.23 (1.16-1.32)	
All-cause death within 30 days				
Fiscal year of surgery				
2010	1515/51854	27/468	2.18 (1.27-3.73)	
2011	1365/49706	28/567	1.16 (0.72-1.89)	
2012	1350/51674	42/853	1.50 (0.95-2.35)	.18
2013	1302/49044	67/1195	1.19 (0.88-1.61)	
2014	1229/50002	62/1248	1.71 (1.13-2.59)	
2015	1253/49929	77/1474	1.38 (1.03-1.85)	
Elective vs urgent or emergent surgery				
Elective	2036/219881	73/3377	1.79 (1.16-2.75)	.35
Urgent or emergent	5978/82328	230/2428	1.24 (1.05-1.48)	
Type of surgery				
Neurosurgery	1478/52150	91/1875	2.08 (1.46-2.97)	
Cardiac surgery	1158/52245	45/750	2.16 (1.31-3.55)	
Vascular surgery[b]	386/6368	≤5/194	1.87 (1.09-3.20)	.02
Thoracic surgery[b]	269/13666	≤5/112	0.16 (0.05-0.46)	
Abdominal, pelvic, and urologic surgery	4723/177780	137/2874	1.25 (0.98-1.61)	
Overall effect			1.45 (1.19-1.76)	
Readmission within 30 days				
Fiscal year of surgery				
2010	3422/51854	39/468	0.74 (0.43-1.29)	
2011	3322/49706	43/567	0.71 (0.47-1.06)	
2012	3554/51674	81/853	1.59 (0.99-2.55)	.03
2013	3417/49044	114/1195	1.23 (0.83-1.83)	
2014	3581/50002	121/1248	1.22 (0.86-1.74)	
2015	3638/49929	140/1474	1.29 (0.99-1.69)	
Elective vs urgent or emergent surgery				
Elective	14165/219881	348/3377	1.35 (1.09-1.67)	.17
Urgent or emergent	6769/82328	190/2428	1.05 (0.84-1.32)	
Type of surgery				
Neurosurgery	2988/52150	132/1875	1.15 (0.85-1.55)	
Cardiac surgery	4617/52245	62/750	1.10 (0.66-1.82)	
Vascular surgery	428/6368	11/194	0.79 (0.32-1.92)	.66
Thoracic surgery	941/13666	11/112	0.79 (0.35-1.81)	
Abdominal, pelvic, and urologic surgery	11960/177780	322/2874	1.32 (1.09-1.59)	
Overall effect			1.18 (0.98-1.41)	
Major complication within 30 days				
Fiscal year of surgery				
2010	10744/51854	202/468	1.48 (1.21-1.81)	
2011	10473/49706	193/567	1.08 (0.89-1.32)	
2012	12558/51674	313/853	1.09 (0.93-1.27)	.04
2013	12348/49044	427/1195	1.23 (1.07-1.41)	
2014	12420/50002	442/1248	1.29 (1.08-1.53)	
2015	12284/49929	503/1474	1.16 (1.02-1.31)	
Elective vs urgent or emergent surgery				
Elective	40818/219881	1062/3377	1.20 (1.09-1.33)	.38
Urgent or emergent	30009/82328	1018/2428	1.15 (1.06-1.26)	
Type of surgery				
Neurosurgery	5405/52150	543/1875	2.02 (1.75-2.33)	
Cardiac surgery	36130/52245	526/750	0.97 (0.90-1.04)	
Vascular surgery	2560/6368	134/194	1.22 (0.97-1.55)	<.001
Thoracic surgery	1608/13666	32/112	2.49 (1.35-4.61)	
Abdominal, pelvic, and urologic surgery	25124/177780	845/2874	1.46 (1.33-1.61)	
Overall effect			1.25 (1.16-1.34)	



See Statistical Analysis for calculation methods of subgroup effects. Because of missing data, years since graduation for the primary anesthesiologist was excluded as a covariate in these analyses (Figure 1).

[a] Data were plotted in the year the fiscal year ended (end date, March 31).

[b] Small cell sizes (≤5) cannot be reported and were obscured to create ambiguity.

effect on the increase in the volume of handovers (since the policies may require anesthesiologists to hand over the care of more partially completed surgeries to colleagues when their working hours end).

Previous studies were from single institutions and included patients undergoing either narrow[11,12] or broad[13,14] ranges of surgeries. Three studies[11-13] had CIs for the primary outcome that were consistent with a significant association between handovers and harm, the largest of which[13] found that each anesthesia care transition was associated with increased odds of in-hospital mortality and major complications (odds ratio 1.08 for each transition [95% CI, 1.05 to 1.10]). The fourth study[14] was compatible with the others since its 95% CI for the odds of the primary outcome (0.90 to 1.02), while not statistically significant, included a potentially clinically important effect. Most studies were conducted in the United States, where anesthesia care involves certified registered nurse anesthetists, physicians, or both. This differs from some other countries including Canada,[15] where physicians typically care for one patient directly.

The congruity of these results with the majority of the previous research suggests that anesthesia handovers during major surgeries are associated with unintended harmful consequences. If the percentage of handovers observed in the final year of this study cohort (2.9%) were reflected worldwide, more than 9 million patients per year would potentially undergo surgery with a complete anesthesia handover.[16] Given the large number of patients and the increase in adverse outcomes observed in this study, the public health implications of its findings are concerning. The most prudent approach at the current time may therefore be to invoke the precautionary principle[17] and minimize unnecessary anesthesia handovers until future research has demonstrated that these harmful associations have been attenuated. However, determining which handovers are unnecessary remains a significant challenge. For example, since fatigue will, at some point, have a measureable and detrimental effect on clinicians,[9] handovers performed for reasons of fatigue may be reasonable. Determining when the risk of a fatigued clinician exceeds the potential risk of a complete handover is an important subject for future research.

It is possible that an improved system of anesthesia handovers (in which critical components of handovers are mandated by a checklist) would eliminate the signal of harm while maintaining lifestyle benefits for clinicians. Although attempts to improve the quality of handovers are common and invoke many differing theoretical frameworks (eg, information processing, stereotypical narratives, distributed cognition), no unified approach has been identified.[18] The potential for important intangible information loss during handover remains a latent threat. Attempting to demonstrate improved outcomes with the use of handover tools is an important area of research.

Subgroup analyses demonstrated statistical evidence of heterogeneity for some of the outcomes, particularly for the type of surgery performed. However, the majority of point estimates indicate an association between handovers and both the primary and all-cause death outcomes. Although the absolute risks of these outcomes may differ among surgery types, these results indicate consistent findings of harm among most subgroups.

A strength of this study is its large sample of patients representing a wide variety of surgeries at many hospitals. This is important since the majority of previous studies excluded important patient populations (often cardiac surgery) and were conducted at single centers. Many outcome events occurred, increasing the statistical power to detect important differences. Because this was a population-based study based in the largest Canadian province, patients in this cohort are likely representative of other Canadians in terms of sex, age, socioeconomic groups, comorbidity distributions, and other important prognostic factors. Unlike other countries where there are distinct regional differences in anesthesia practice (eg, the use of nurse anesthetists), this cohort involved only physician anesthesiologists. This allowed the research to focus more directly on the issue of handovers rather than on the types of clinicians involved.

This study has several limitations. Because the exposure of complete handover was determined using a billing code, there is a risk of misclassification if the code was used improperly. *ICD-10* diagnostic codes may not have captured all adverse postoperative outcomes. The primary anesthesiologist's career experience was controlled for, but the career experience of the replacement anesthesiologist and the surgeon was not. It was not possible to determine the precise time of handover because this information was not captured by physician billings, which limited the ability to investigate the effect of the handover's time of day on outcomes. Cases in which a primary anesthesiologist had the assistance of a second anesthesiologist or took breaks during an operation and then returned to the operating room were not identified; nor was the presence of anesthesia trainees during the surgeries.

Conclusions

Among adults undergoing major surgery, complete handover of intraoperative anesthesia care compared with no handover was associated with a higher risk of adverse postoperative outcomes. These findings may support limiting complete anesthesia handovers.

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REFERENCES:

1. Vandenbroucke JP, von Elm E, Altman DG, et al; STROBE Initiative. Strengthening the reporting of observational studies in epidemiology (STROBE): explanation and elaboration. *PLoS Med*. 2007;4(10):e297.

2. Benchimol EI, Smeeth L, Guttmann A, et al; RECORD Working Committee. The reporting of studies conducted using observational routinely-collected health data (RECORD) statement. *PLoS Med*. 2015;12(10):e1001885-e22.

3. Irony TZ. The "utility" in composite outcome measures: measuring what is important to patients. *JAMA*. 2017;318(18):1820-1821.

4. Austin PC. The performance of different propensity-score methods for estimating differences in proportions (risk differences or absolute risk reductions) in observational studies. *Stat Med*. 2010;29(20):2137-2148.

5. Haukoos JS, Lewis RJ. The propensity score. *JAMA*. 2015;314(15):1637-1638.

6. Ukoumunne OC, Williamson E, Forbes AB, Gulliford MC, Carlin JB. Confounder-adjusted estimates of the risk difference using propensity score–based weighting. *Stat Med*. 2010;29(30):3126-3136..

7. Austin PC, Stuart EA. Moving towards best practice when using inverse probability of treatment weighting (IPTW) using the propensity score to estimate causal treatment effects in observational studies. *Stat Med*. 2015;34(28):3661-3679.

8. Sterne JAC, White IR, Carlin JB, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *BMJ*. 2009;338:b2393.

9. Howard SK, Rosekind MR, Katz JD, Berry AJ. Fatigue in anesthesia: implications and strategies for patient and provider safety. *Anesthesiology*. 2002;97(5):1281-1294.

10. Ahmed N, Devitt KS, Keshet I, et al. A systematic review of the effects of resident duty hour restrictions in surgery: impact on resident wellness, training, and patient outcomes. *Ann Surg*. 2014;259(6):1041-1053.

11. Hudson CCC, McDonald B, Hudson JKC, Tran D, Boodhwani M. Impact of anesthetic handover on mortality and morbidity in cardiac surgery: a cohort study. *J Cardiothorac Vasc Anesth*. 2015;29(1):11-16.

12. Hyder JA, Bohman JK, Kor DJ, et al. Anesthesia care transitions and risk of postoperative complications. *Anesth Analg*. 2016;122(1):134-144.

13. Saager L, Hesler BD, You J, et al. Intraoperative transitions of anesthesia care and postoperative adverse outcomes. *Anesthesiology*. 2014;121(4):695-706.

14. Terekhov MA, Ehrenfeld JM, Dutton RP, Guillamondegui OD, Martin BJ, Wanderer JP. Intraoperative care transitions are not associated with postoperative adverse outcomes. *Anesthesiology*. 2016;125(4):690-699.

15. Tenedios CN, O'Leary SJ, Desai SP. A Historical Examination of Nurse Anesthesia Practice in the United States and Other G-7 Countries. *J Anesth Hist*. 2016;2(3):120. doi:10.1016/j.janh.2016.03.019

16. Weiser TG, Haynes AB, Molina G, et al. Estimate of the global volume of surgery in 2012: an assessment supporting improved health outcomes. *Lancet*. 2015;385(suppl 2):S11.

17. Weir E, Schabas R, Wilson K, Mackie C. A Canadian framework for applying the precautionary principle to public health issues. *Can J Public Health*. 2010;101(5):396-398.

18. Abraham J, Kannampallil T, Patel VL. A systematic review of the literature on the evaluation of handoff tools: implications for research and practice. *J Am Med Inform Assoc*. 2014;21(1):154-162.