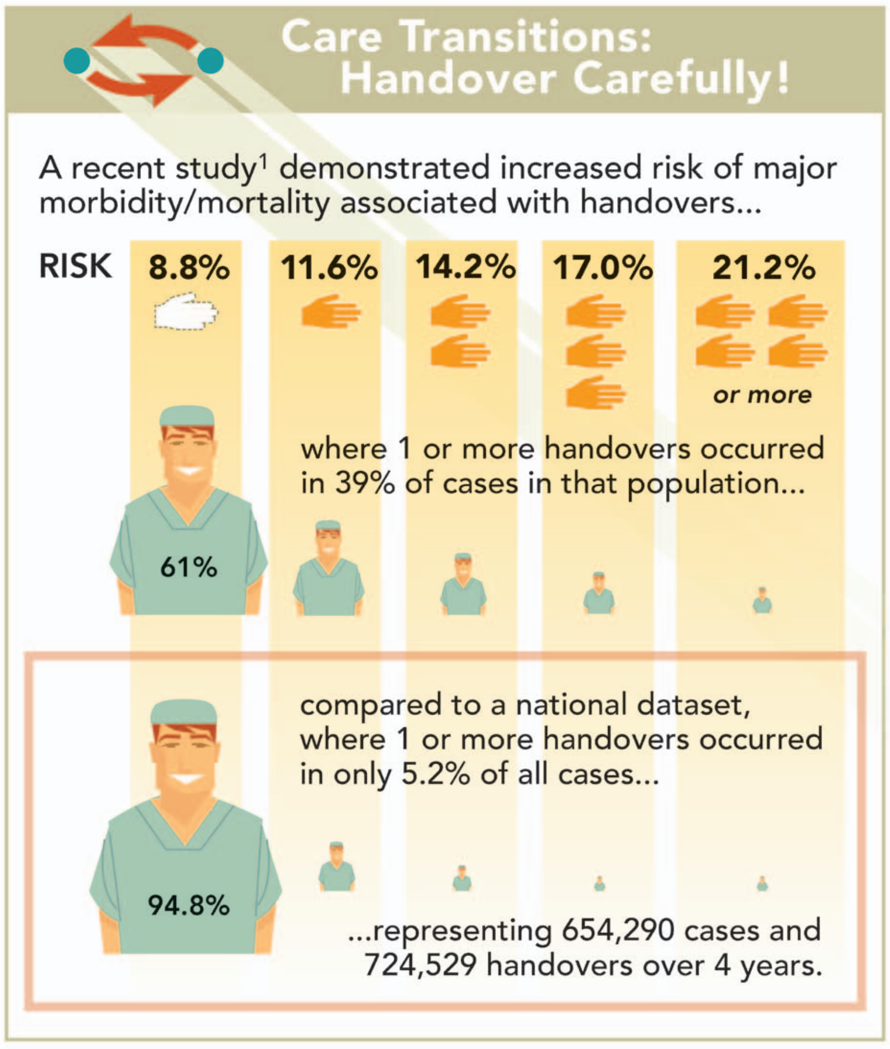
ANESTHESIOLOGY




We extracted the handover prevalence and associated outcomes directly from a recent analysis,[1] and compared the handover prevalence to the National Anesthesia Clinical Outcomes Registry. Queries of the Anesthesia Quality Institute Participant User File from 2010 to 2013 identified 13,744,098 anesthetics with data available that specified distinct providers and had valid anesthesiologist, resident, and certified registered nurse anesthetist (CRNA) provider counts. We identified the number of handovers per case using a case-wise analysis on all possible combinations of provider counts. Unreported counts were imputed as zero and anesthesiologists were assumed to be working in only an oversight role when performing cases with residents and CRNAs. We identified outlier practice patterns and removed these from our dataset. Specifically, of the 179 practices included, we identified 11 practices (6%) that reported four or more providers associated with cases with a duration under an hour; the 1,145,588 cases (8%) from those practices were excluded from this analysis. We then analyzed the distribution of handovers per case.

Infographic created by Jonathan P. Wanderer, Vanderbilt University School of Medicine, and James P. Rathmell, Massachusetts General Hospital/Harvard Medical School. Illustration by Annemarie Johnson, Vivo Visuals. Data provided by the Anesthesia Quality Institute, Richard P. Dutton, M.D., M.B.A., Executive Director. Address correspondence to Dr. Wanderer: jon.wanderer@vanderbilt.edu.

1. Saager L, Hesler BD, You J, Turan A, Mascha EJ, Sessler DI, Kurz A: Intraoperative transitions of anesthesia care and postoperative adverse outcomes. ANESTHESIOLOGY 2014;121:695–706

# Intraoperative Transitions of Anesthesia Care and Postoperative Adverse Outcomes

Leif Saager, Dr. med., Brian D. Hesler, M.D., Jing You, M.S., Alparslan Turan, M.D., Edward J. Mascha, Ph.D., Daniel I. Sessler, M.D., Andrea Kurz, M.D.

## ABSTRACT

**Background:** Transfers of patient care and responsibility among caregivers, "handovers," are common. Whether handovers worsen patient outcome remains unclear. The authors tested the hypothesis that intraoperative care transitions among anesthesia providers are associated with postoperative complications.

**Methods:** From the records of 138,932 adult Cleveland Clinic (Cleveland, Ohio) surgical patients, the authors assessed the association between total number of anesthesia handovers during a case and an adjusted collapsed composite of in-hospital mortality and major morbidities using multivariable logistic regression.

**Results:** Anesthesia care transitions were significantly associated with higher odds of experiencing any major in-hospital mortality/morbidity (incidence of 8.8, 11.6, 14.2, 17.0, and 21.2% for patients with 0, 1, 2, 3, and ≥4 transitions; odds ratio 1.08 [95% CI, 1.05 to 1.10] for an increase of 1 transition category, $P < 0.001$). Care transitions among attending anesthesiologists and residents or nurse anesthetists were similarly associated with harm (odds ratio 1.07 [98.3% CI, 1.03 to 1.12] for attending [incidence of 9.4, 13.9, 17.4, and 21.5% for patients with 0, 1, 2, and ≥3 transitions] and 1.07 [1.04 to 1.11] for residents or nurses [incidence of 9.4, 13.0, 15.4, and 21.2% for patients with 0, 1, 2, and ≥3 transitions], both $P < 0.001$). There was no difference between matched resident only (8.5%) and nurse anesthetist only (8.8%) cases on the collapsed composite outcome (odds ratio, 1.00 [98.3%, 0.93 to 1.07]; $P = 0.92$).

**Conclusion:** Intraoperative anesthesia care transitions are strongly associated with worse outcomes, with a similar effect size for attendings, residents, and nurse anesthetists. (ANESTHESIOLOGY 2014; 121:695-706)

TRANSFERS of patient care and responsibility among caregivers, "handovers," are inevitable as care for individuals often extends over shifts—and sometimes over days or weeks. The number of handovers, at least in academic hospitals, has increased as a result of duty-hour limitations.[1–4]

Critical details may be lost during handovers resulting in delays,[5] inefficiencies,[6,7] suboptimal care,[8] or even patient harm.[9,10] Consequently, the Joint Commission on Hospital Accreditation declared in 2006 that "implementing a standardized approach to handoff communications including the opportunity to ask and respond to questions" was a national patient safety goal.* They also identified "communication failure" to be the root cause of 65% of all sentinel events in 2006.† The World Health Organization similarly listed "communication during patient care handover" as one of its "High five" patient safety initiatives.‡ Numerous

### What We Already Know about This Topic

- Intraoperative transfers of patient care and responsibilities among anesthesia caregivers, that is, handovers, are relatively frequent
- Lost critical information during handovers may result in delays, inefficiencies, suboptimal care, or patient harm

### What This Article Tells Us That Is New

- Each anesthetic handover increased the risk of any major in-hospital morbidity or mortality by 8%
- The adverse effects of handovers were similar for attending anesthesiologists and medically directed residents and certified registered nurse anesthetists
- The adverse effects of handovers were virtually identical for residents and certified registered nurse anesthetists

studies have identified challenges associated with handovers and evaluated various systems and methods for enhancing

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* 2009 National Patient Safety Goals, Jt Comm Perspect, 2008. Available at: http://www.jcrinc.com/common/PDFs/fpdfs/pubs/pdfs/JCReqs/JCP-07-08-S1.pdf. Accessed October 20, 2013.

† Joint C: Improving America's Hospitals. The Joint Commission's Annual Report on Quality and Safety, 2007. Available at: http://www.jointcommission.org/assets/1/18/2006_Annual_Report.pdf. Accessed October 20, 2013.

‡ World Health Organization Collaborating Center for Patient Safety: Communication during Patient Handovers. Geneva, Switzerland, WHO Press; 2007. Available at: http://www.who.int/patientsafety/solutions/patientsafety/PS-Solution3.pdf. Accessed October 20, 2013.

communication and information transfer.[11–17] There are also studies evaluating anecdotal complications[18–20] and malpractice cases.[21] But surprisingly, there is little evidence that care transitions worsen patient outcome.

The high-risk perioperative period presents an opportunity to study care transitions and their effect on mortality and serious complications. Typically, a single surgical team provides care throughout an operation. However, handovers among anesthesia providers are common, and may involve attendings, residents, and certified registered nurse anesthetists (CRNAs). Currently, no universally accepted guidelines or recommendations for performing intraoperative handovers exist, and very few studies have investigated anesthesia care transitions.

As with other types of care transition, it remains unknown whether changes in anesthesia providers worsen patient outcome. We, therefore, tested the primary hypothesis that the total number of intraoperative handovers among anesthesia providers is associated with an increase in a composite of postoperative mortality and serious complications. Secondarily, we evaluated independent associations for attending handovers, and for resident and CRNA handovers.

## Materials and Methods

With approval from the Cleveland Clinic Institutional Review Board (Cleveland, Ohio), patient information was obtained from the Cleveland Clinic Perioperative Health Documentation System. The registry contains all patients who had noncardiac surgery since 2005 at Cleveland Clinic's main campus. It integrates preoperative variables (demographics, conditions, *etc.*), intraoperative variables (*via* our Anesthesia Record Keeping System), and postoperative outcomes (by linking to the larger Cleveland Clinic billing data systems).

Handovers among anesthesia providers at the Cleveland Clinic do not follow a formal script, and we do not normally use checklists. Although anesthesia providers are trained to convey all-important information to their relief, no formalized training or standardized process has been implemented.

### *Statistical Analysis*

We assessed the association between the total number of anesthesia handovers during a case and a collapsed composite (any *vs.* none) of in-hospital mortality and six major morbidities including serious cardiac, respiratory, gastrointestinal, urinary, bleeding, and infectious complications (as defined in appendix 1), using multivariable logistic regression. We adjusted for the following prespecified potential confounding variables: age, sex, race, American Society of Anesthesiologists (ASA) physical status, start time of surgery, duration of surgery, and principal diagnosis and procedure.

The total number of anesthesia handovers includes handovers among attending anesthesiologists and handovers among medical-directed anesthesia providers including residents and fellows, CRNAs, and student nurse anesthetists. For medical-directed anesthesia providers, breaks of less than 40 min were not counted as a handover; for example, it was not considered a handover when a provider relieved someone for, say lunch, and then returned within 40 min. The total number of anesthesia handovers was truncated at four because there were more than 4 in only 1,448 (1%) of the patients.

We adjusted for severity of procedure (in terms of risk of outcome) as follows: First, we characterized each patient's primary procedure using the U.S. Agency for Healthcare Research and Quality's single-level Clinical Classifications Software for International Classification of Diseases, 9th Revision, Clinical Modification procedure codes. The single-level Clinical Classifications Software is a tool for aggregating the 1,965 individual procedure codes in our dataset into 207 clinically meaningful procedure categories. Because of this large number of categories, we adjusted for severity of procedure as a continuous covariable by using the incidence of the collapsed composite outcome for each Clinical Classifications Software category. Clinical Classifications Software categories with a frequency less than 20 were collapsed into one category. Diagnosis-related risk for the collapsed composite outcome was estimated and adjusted for in the analysis in a similar manner.

We conducted a sensitivity analysis comparing each positive number of handovers (1, 2, 3, and ≥4) with 0 handovers using propensity score matching to adjust for potential confounders (*i.e.*, a total of four propensity score matching analyses).[22] This was in contrast to the primary analysis in which confounding was adjusted for by multivariable modeling and the association between number of handovers and outcome was assumed to be linear. First, we estimated the probability (*i.e.*, the propensity score) of having exactly one handover (*vs.* none) using logistic regression based on age, sex, race, ASA status, start time of surgery, duration of surgery, and severity of principal diagnosis and procedure. We used a 1-to-2 greedy distance-matching algorithm SAS macro: gmatch,§ which makes the locally optimal choice, employing a maximum propensity score difference of 0.01 units. Specifically, the algorithm tried to match each patient having one handover to a maximum of two patients having no handovers with the smallest propensity score difference (the maximum allowable difference was 0.01). Similarly, we obtained the other three propensity matched sets of patients (*i.e.*, 2 handovers *vs.* 0, 3 *vs.* 0, and ≥4 *vs.* 0). Assessment of covariable balance after matching was performed using

§ Bergstralh EKJ. Gmatch SAS Program, Mayo Clinic Division of Biomedical Statistics and Informatics. Rochester, Mayo Clinic (HSR CodeXchange), 2003. Computerized matching of cases to controls using the greedy matching algorithm with a fixed number of controls per case. Available at: http://www.mayo.edu/research/documents/gmatchsas/doc-10027248. Accessed October 20, 2013.

standardized differences (*i.e.*, difference in means or proportions divided by the pooled SD). Imbalance was very conservatively defined as a standardized difference greater than $1.96\times\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$ ($n_1$, $n_2$, are the number of matched patients in each group) in absolute value; any such covariables would have been entered into our multivariable logistic regression model when comparing the matched groups on outcomes to reduce potential confounding. The significance criterion was *P* value less than 0.0125 for each comparison to maintain the overall alpha at 0.05 across these four analyses.

We conducted another sensitivity analysis in which we assessed individual associations between the number of handovers (as a continuous variable) and specific components of the composite as well as the common effect "global" odds ratio (OR) of the number of handovers across all the components of the composite using separate distinct effects generalized estimating equation multivariate models with unstructured covariance matrix. A Bonferroni correction for simultaneous comparisons was employed to control the type I error, so that *P* value less than 0.007 was considered significant for a particular component (*i.e.*, 0.05/7 = 0.007).

### *Secondary Analyses*

Furthermore, for informational purposes, we conducted four exploratory analyses in which we evaluated the relationships between the total number of anesthesia handovers and the collapsed composite of major morbidities in the following subsets of cases: (1) those not started in regular work hours (before 7:00 AM and 5:00 PM); (2) those patients with ASA physical status 3 or 4; (3) those cases less than 1 h; and (4) those cases more than 4 h. Each analysis used the same statistical method as the primary analysis.

Also, we evaluated the relationship between total number of anesthesia handovers and length of postoperative hospital stay using Cox proportional hazards regression. The outcome event in the model was "discharged alive." Patients who died in-hospital were analyzed as never having the event and were assigned a censoring time equal to the observed longest hospitalization among those discharged alive.

Secondarily, we simultaneously assessed the relationship between number of attending anesthesiologist handovers and number of medical-directed provider handovers with the collapsed composite in-hospital mortality/morbidity using a single multivariable logistic regression. For this analysis, the number of attending anesthesiologist and medical-directed handovers were both truncated to three to facilitate modeling.

Anesthesia care at our institution is provided by residents and CRNAs, and sometimes both are involved in a single anesthetic. Residents and CRNAs are always supervised by an attending anesthesiologist. For training and educational purposes, residents are typically assigned to more challenging or complex cases. Furthermore, night calls and weekend calls are mostly covered by residents. We thus conducted an additional analysis comparing patients who were managed by attending anesthesiologist and residents only, or by attending anesthesiologist and CRNAs only on the collapsed composite outcome, using a multivariable logistic regression. To control for potential confounding, we exactly matched on principal procedure and diagnosis, start time of the case, and ASA status for 31,816 patients who were managed exclusively by attending anesthesiologist and residents to 31,816 patients who were managed by exclusively attending anesthesiologist and CRNAs. We also adjusted for age, sex, race, duration of surgery, and number of handovers.

The significance level was maintained at 0.05 within the primary and secondary analyses. Thus, the significance criterion was *P* value less than 0.006 for each secondary analysis (a total of eight analyses, Bonferroni correction). SAS software version 9.3 (SAS Institute, Cary, NC) was used for all statistical analyses.

## Results

We included data from 138,932 adults who had noncardiac surgery with general and/or regional anesthesia at the Cleveland Clinic between January 06, 2005 and December 31, 2012 and had an ASA physical status 4 or less. Patients with any missing values were excluded. Therefore, 135,810 patients were included in our analyses; 82,644 (61%), 27,982 (21%), 15,102 (11%), 6,172 (5%), and 3,910 (3%) patients had 0, 1, 2, 3, and 4 or more handovers, respectively. Table 1 shows baseline and intraoperative characteristics

The observed incidence of the collapsed composite in-hospital mortality/morbidity was 8.8, 11.6, 14.2, 17.0, and 21.2% for patients with 0, 1, 2, 3, and 4 or more anesthesia handovers, respectively (table 2). More anesthesia handovers during a case were significantly associated with higher odds of experiencing any major in-hospital mortality/morbidity ($P < 0.001$). The estimated OR was 1.08 (95% CI, 1.05 to 1.10) for an increase of one transition category, after adjusting for age, sex, race, ASA status, principal diagnosis and procedure, duration of surgery, and start time of the case (appendix 2). Consistent results were provided by our propensity score matching sensitivity analysis. Increasing numbers of anesthesia handovers during a case (2, 3, and 4 or more) was significantly associated with higher odds of experiencing in-hospital mortality/morbidity compared to no handover (table 3 and appendix 3).

Furthermore, all the evaluated individual associations between number of handovers and specific components included in our composite were in the same direction; more anesthesia handovers during a case was significantly associated with higher odds of experiencing cardiac, gastrointestinal, bleeding, and infectious morbidities (table 2 and fig. 1). The common effect OR of handovers across the individual components of the composite outcome was estimated as 1.15 (95% CI, 1.12 to 1.19) for a difference of one transition category.

**Table 1.** Demographics Baseline and Intraoperative Characteristics by Total Number of Anesthesia Handovers

| | Total Number of Anesthesia Handovers | | | | |
|---|---|---|---|---|---|
| Variable | 0<br>N = 82,644 | 1<br>N = 27,982 | 2<br>N = 15,102 | 3<br>N = 6,172 | ≥4<br>N = 3,910 |
| Age, yrs | 56 ± 20 | 57 ± 20 | 57 ± 16 | 57 ± 15 | 57 ± 15 |
| Sex (male), % | 44.8 | 47.2 | 47.2 | 48.4 | 49.3 |
| Race (Caucasian), % | 82.2 | 82.3 | 82.0 | 83.5 | 83.8 |
| ASA physical status, % | | | | | |
| I | 6.7 | 5.3 | 4.1 | 3.4 | 2.6 |
| II | 43.2 | 39.7 | 38.0 | 36.0 | 33.8 |
| III | 43.7 | 47.2 | 49.2 | 51.9 | 54.6 |
| IV | 6.4 | 7.8 | 8.8 | 8.8 | 9.0 |
| Principal diagnosis*, % | | | | | |
| Osteoarthritis | 5.1 | 6.1 | 6.4 | 5.1 | 3.4 |
| Spondylosis; intervertebral disc disorders; other back problems | 4.5 | 5.0 | 5.2 | 4.8 | 4.3 |
| Other and unspecified benign neoplasm | 5.0 | 3.9 | 3.6 | 3.3 | 3.4 |
| Complication of device; implant or graft | 3.6 | 4.7 | 5.6 | 6.0 | 7.1 |
| Cancer of prostate | 2.3 | 3.2 | 3.8 | 4.5 | 5.0 |
| Other nutritional; endocrine; and metabolic disorders | 2.4 | 2.4 | 3.0 | 3.0 | 3.0 |
| Abdominal hernia | 2.5 | 2.5 | 2.5 | 2.2 | 2.5 |
| Other nervous system disorders | 3.0 | 1.9 | 1.6 | 1.1 | 1.1 |
| Regional enteritis and ulcerative colitis | 2.1 | 2.4 | 2.7 | 2.9 | 2.5 |
| Prolapse of female genital organs | 2.0 | 2.4 | 2.3 | 2.0 | 1.7 |
| Principal procedure*, % | | | | | |
| Colorectal resection | 3.5 | 4.4 | 5.4 | 6.1 | 5.4 |
| Arthroplasty knee | 3.3 | 4.8 | 5.2 | 4.6 | 3.1 |
| Hysterectomy; abdominal, and vaginal | 3.7 | 4.1 | 4.0 | 5.1 | 4.3 |
| Other OR lower GI therapeutic procedures | 3.4 | 2.7 | 2.6 | 2.5 | 2.5 |
| Spinal fusion | 2.4 | 3.5 | 4.6 | 5.4 | 6.7 |
| Nephrectomy; partial or complete | 2.4 | 3.4 | 4.1 | 4.6 | 5.6 |
| Other OR upper GI therapeutic procedures | 2.9 | 2.7 | 3.4 | 3.6 | 3.4 |
| Hip replacement; total and partial | 3.0 | 2.7 | 2.7 | 2.6 | 2.3 |
| Open prostatectomy | 2.2 | 3.1 | 3.8 | 4.5 | 5.0 |
| Laminectomy; excision intervertebral disc | 2.8 | 2.8 | 2.7 | 2.4 | 1.6 |
| Start time of surgery*, % | | | | | |
| 7:00 AM | 36.3 | 18.0 | 15.0 | 11.3 | 14.0 |
| 8:00 AM | 15.4 | 8.5 | 7.0 | 5.6 | 6.6 |
| 9:00 AM | 7.1 | 4.6 | 3.9 | 3.6 | 2.9 |
| 10:00 AM | 9.1 | 7.6 | 6.5 | 5.8 | 4.7 |
| 11:00 AM | 8.6 | 10.4 | 9.2 | 9.4 | 8.8 |
| 12:00 PM | 6.8 | 10.9 | 11.4 | 11.6 | 11.1 |
| 1:00 PM | 5.5 | 11.1 | 12.4 | 13.6 | 15.2 |
| 2:00 PM | 3.6 | 9.9 | 11.7 | 13.8 | 14.3 |
| 3:00 PM | 2.4 | 6.8 | 8.1 | 10.1 | 10.0 |
| 4:00 PM | 1.5 | 4.1 | 4.9 | 6.1 | 6.2 |
| Duration of surgery, h | 2.6 [1.6, 3.7] | 3.3 [2.2, 4.6] | 3.9 [2.9, 5.4] | 4.7 [3.5, 6.2] | 6.0 [4.6, 8.0] |

Statistics are mean ± SD, median [Q1, Q3], or percent, as appropriate.

* Most frequent categories are listed in the table.

ASA = American Society of Anesthesiologists; GI = gastrointestinal; OR = odds ratio.

In the exploratory analyses, we found that more anesthesia handovers was significantly associated with increased risk of the collapsed composite outcome for those started late ($P < 0.001$), those patients with ASA physical status 3 or 4 ($P < 0.001$), and those cases more than 4 h ($P < 0.001$), but not for cases less than 1 h ($P = 0.92$) (table 4).

Length of postoperative hospital stay was 1 [0, 3] (median [Q1, Q3]), 2 [1, 5], 3 [1, 6], 4 [2, 6], and 4 [2, 8] days for patients with 0, 1, 2, 3, and 4 or more handovers, respectively (univariable $P < 0.001$, log-rank test). However, after controlling for the same set of potential confounding variables as in the primary analysis, the

**Table 2.** Incidence of the Collapsed Composite In-hospital Surgical Mortality/Morbidities and the Individual Components for Each Number of Handovers

| | Total Number of Anesthesia Handovers | | | | |
|---|---|---|---|---|---|
| Outcome | 0<br>N = 82,644 | 1<br>N = 27,982 | 2<br>N = 15,102 | 3<br>N = 6,172 | ≥4<br>N = 3,910 |
| In-hospital mortality | 0.80% | 1.08% | 1.12% | 1.17% | 1.53% |
| Cardiac | 2.12% | 2.93% | 3.97% | 4.71% | 6.16% |
| Respiratory | 0.44% | 0.54% | 0.54% | 0.83% | 0.97% |
| Gastrointestinal | 3.17% | 4.30% | 5.57% | 6.80% | 8.98% |
| Urinary | 0.83% | 1.02% | 1.18% | 1.38% | 1.74% |
| Bleeding | 2.01% | 2.86% | 3.67% | 4.54% | 6.19% |
| Infection | 1.46% | 1.96% | 2.77% | 3.18% | 3.63% |
| Collapsed composite (any of the above) | 8.8% | 11.6% | 14.2% | 17.0% | 21.2% |

**Table 3.** Sensitivity Analysis 1: Comparisons with No Handovers on Composite In-hospital Surgical Mortality/Morbidities Using Propensity Score Matching

| Comparison | OR (98.75% CI)† | *P* Value |
|---|---|---|
| 1 handover (N = 24,275)* *vs.* no handover (N = 40,102)* | 1.06 (0.98–1.14) | 0.05 |
| 2 handovers (N = 12,051)* *vs.* no handover (N = 19,688)* | 1.12 (1.01–1.23) | 0.005‡ |
| 3 handovers (N = 4,769)* *vs.* no handover (N = 7,721)* | 1.24 (1.07–1.43) | <0.001‡ |
| ≥4 handovers (N = 2,358)* *vs.* no handover (N = 3,720)* | 1.48 (1.22–1.79) | <0.001‡ |

* Number of propensity score-matched patients. † CIs were Bonferroni adjusted for multiple comparisons; the significance criterion was 0.0125 (*i.e.*, 0.05/4). ‡ Statistically significant.
OR = odds ratio.

association between number of handovers and length of hospital stay was not significant (hazards ratio [99.4 % CI], 1.00 [0.99 to 1.01] for a difference of one transition category, $P = 0.40$).

Second, we found that more anesthesia handovers among attending anesthesiologists and among medical-directed anesthesia providers during a case were both significantly associated with higher odds of experiencing any major in-hospital mortality/morbidity (both $P < 0.001$; fig. 2). The observed incidence of the collapsed composite in-hospital mortality/morbidity was 9.4% (out of 102,516), 13.9% (26,754), 17.4% (5,464), and 21.5% (1,076) for patients with 0, 1, 2, and 3 or more attending handovers, respectively; similarly, the observed incidence was 9.4% (98,412), 13.0 (25,249), 15.4% (9,173), and 21.1% (2,976) for patients with 0, 1, 2, and 3 or more medical-directed handovers, respectively. After adjusting for the potential confounding variables the estimated ORs were 1.07 (99.4% CI, 1.02 to 1.13) for a difference of one in the number of anesthesia attending handovers and 1.07 (99.4% CI, 1.03 to 1.11) for a difference of one in the number of medically directed handovers. Furthermore, there was no interaction between attending anesthesiologist handovers and medical-directed handovers ($P = 0.11$).

Within the matched subset of resident-only and CRNA-only cases, there was no difference between resident-only cases and CRNA-only cases on the collapsed composite outcome: OR, 1.00 (99.4% CI, 0.93 to 1.09) resident *versus* CRNA; $P = 0.92$.

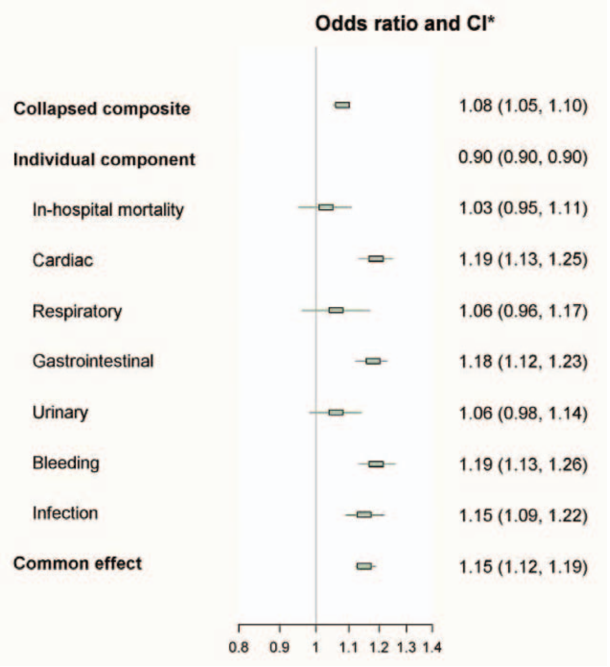


**Fig. 1.** Odds ratios of having any in-hospital mortality/morbidities (collapsed composite), each specific individual component of the composite (individual component), and common "global" odds ratio across the individual components (common effect) for each increase in the total number of anesthesia handovers. *CIs for the individual components were 99.3%, adjusted using the Bonferroni correction.

**Table 4.** Exploratory Analysis: Association between Total Number of Intraoperative Anesthesia Handovers and Collapsed Composite In-hospital Surgical Mortality/Morbidities for Patients in Various Subsets

| | Incidence of the Collapsed Composite Outcome by Total Number of Handovers | | | | | | |
|---|---|---|---|---|---|---|---|
| Subset | 0 | 1 | 2 | 3 | ≥4 | OR (99.4%, CI)*† | *P* Value |
| Cases started late in the day (N = 26,369) | 14.5% | 12.8% | 15.4% | 17.3% | 20.2% | 1.14 (1.09–1.20) | <0.001 |
| Patients with ASA physical status 3 or 4 (N = 71,766) | 12.0% | 15.2% | 18.1% | 21.1% | 25.1% | 1.09 (1.05–1.12) | <0.001 |
| Cases <1 h (N = 8,392) | 5.6% | 6.4% | — | — | — | 0.98 (0.54–1.76) | 0.92 |
| Cases >4 h (N = 40,444) | 15.7% | 17.5% | 18.6% | 20.0% | 23.1% | 1.09 (1.05–1.13) | <0.001 |

* Bonferroni correction. † Odds ratio for an increase of one transition category.
ASA = American Society of Anesthesiologists; OR = odds ratio.

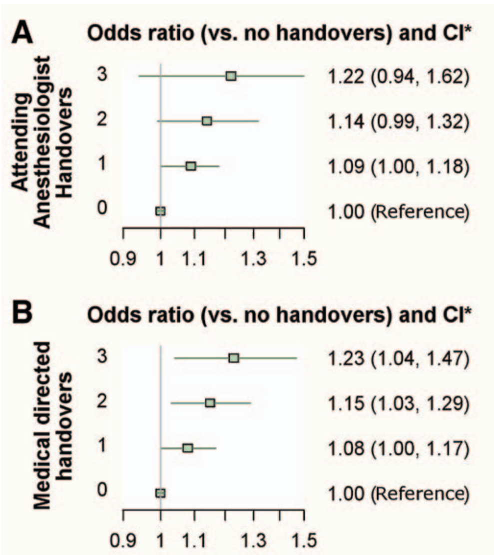


**Fig. 2.** Odds ratios of having any in-hospital mortality/morbidities for (*A*) each level of attending anesthesiologist handovers *versus* no attending anesthesiologist handovers; and (*B*) each level of medical-directed provider handovers (including residents, fellows, certified registered nurse anesthetists, and student registered nurse anesthetists) *versus* no medically directed provider handovers. We adjusted for age, sex, race, American Society of Anesthesiologists physical status, start time of surgery, duration of surgery, and principal diagnosis and procedure. *The significance criterion for each analysis was $P < 0.006$ (*i.e.,* 0.05/8, a total of eight secondary analyses, Bonferroni correction). Multiple comparisons for each analysis were further adjusted using the Bonferroni correction; thus, 99.8% CIs were estimated (significance criterion: 0.006/3, three comparisons for each analysis).

## Discussion

Rather than evaluate a surrogate endpoint such as information transfer, we directly evaluated a composite of in-hospital mortality and serious complications—an outcome that is important to patients and to the healthcare system. Our primary result is that each anesthetic handover increased the risk of composite outcome by a statistically significant 8%.

Previous work clearly demonstrates that critical information, including administered medications,[12] is often lost during care transitions.[11,23,24] Although it is logical to assume that improved information transfer will improve patient outcomes, there is in fact limited previous evidence that handovers actually worsen patient outcomes. Our results strongly suggest that they do; furthermore, the effect is substantial—1.08 times more likely to develop serious complications and mortality during hospital stay per transition, 1.17 (*i.e.*, $1.08^2$) times more likely for two transitions, and so forth.

To illustrate this further, we could expect to have 0.4 to 0.8% more patients experiencing at least one major in-hospital morbidity or mortality per transition of care, based on the observed incidence of 8.8% for patients with no handovers. We conducted a sensitivity analysis, where we assessed the common "global" effect of the handovers across all the individual components of the collapsed composite outcome and found that the common effect OR was 1.15 (1.12 to 1.19) for each increase in the total number of anesthesia handovers. This corresponds to approximately 0.2 to 0.3% increase in the incidence of each component of the composite outcome for each transition, based on the observed average incidence of 1.55% for patients with no handovers; thus, an overall of 1.3 to 2.0% increase in the incidence of all components (5 to 7.5 more complications per week). Given all the factors contributing to perioperative mortality and complications, it is remarkable that a single care transition is so harmful.

The adverse effect of handovers was similar for attending anesthesiologists and medically directed residents and CRNAs. Furthermore, the adverse effects were virtually identical for residents (who are still in training) and CRNAs (most of whom have considerable experience). These data suggest that the adverse effects of handovers are not limited to physicians-in-training; handovers even by experienced attendings and CRNAs comparably worsened patient outcomes.

The Cleveland Clinic does not have a formal handover process for anesthesia. Formal protocols for handovers, including checklists, clearly improve information transfer.[25–28] The observed adverse effect of anesthetic turnovers might thus have been ameliorated—or even eliminated—by an enhanced handover process.[29,30] Previous work indicated that checklists improve information transfer during care handovers.[25,27,28,31,32] One reasonable response to our results might thus be to formalize the handover process.

There are compelling reasons to restrict duty hours since fatigue *per se* markedly impairs judgment,[33] to say nothing of concentration and attention.[34] Nonetheless, limits on duty hours for residents have increased the number of handovers in training hospitals.[1] A second reasonable response to our results might thus be workflow redesigns that reduce the number of handovers, while keeping residents within duty-hour limits and CRNAs and attending shift durations within safe limits.

We studied the intraoperative period because surgery is a high-risk procedure; furthermore, anesthetic decisions must often be made quickly and on the basis of information already known to the practitioner without recourse to medical records. Handovers were relatively frequent in our patients, whereas care transitions in critical care units and regular nursing floors typically occur only once at the end of a shift. It remains to be determined whether transitions worsen patient outcomes in these and other clinical situations.

Breaks for most anesthesia providers at most U.S. institutions last 15 to 30 min. We excluded these temporary care transitions because providers who are familiar with a patient and return to continue care seem quite different from a provider adopting a complete new case. Previous research supports our notion that short breaks do not affect patient outcomes.[29,30,35]

Statistical adjustment for potential confounding factors was key to our analysis. For example, it is obvious that handovers are more likely during longer than shorter cases. Similarly, handovers are more likely when cases start later in the day. We thus fully adjusted for these and many other factors including principal diagnosis and procedure. Furthermore, we conducted a sensitivity analysis using the propensity score matching technique comparing each number of handovers with no handovers, which provides some protection against selection bias and confounding due to measured factors.

Although we adjusted for start time and duration, diagnosis, procedure, and ASA physical status, the dataset utilized for this study includes a total of 5,918 (4.4%) emergency surgeries. If emergency surgery is included into the model, the estimated OR is almost identical with our original finding (1.080 [95% CI, 1.058 to 1.103] *vs.* 1.076 [1.054 to 1.099] for each increase in the total number of anesthesia handovers).

Our study was conducted at a single academic medical center. Presumably the association between handovers and adverse outcomes differs among institutions. The frequency of handovers also differs among hospitals, depending on structure, case duration, and scheduling priorities. For example, handovers are relatively rare in private settings.

As with all retrospective analyses, it is important to recognize that our results show a strong association between anesthesia care transitions and adverse outcomes, but causality cannot be assumed.

In summary, intraoperative care transitions between anesthesia providers were associated with significantly worsened patient outcomes. The effect size was similar for attendings, residents, and CRNAs. Our results suggest that reducing the number of care transitions has the potential to improve patient care. It is likely that formalizing the handover process will also help.

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## Competing Interests

The authors declare no competing interests.

## Correspondence

Address correspondence to Dr. Saager: Department of Outcomes Research, Cleveland Clinic, 9500 Euclid Avenue, P-77, Cleveland, Ohio 44195. saagerl@ccf.org. This article may be accessed for personal use at no charge through the Journal Web site, www.anesthesiology.org.

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## Appendix 1. Descriptions of Individual In-hospital Surgical Mortality/Morbidities

| In-hospital Mortality/Morbidity | AHRQ* | ICD-9† | Descriptions |
|---|---|---|---|
| Cardiac | 16.10.2.1 | 429.4 | Functional disturbances after cardiac surgery<br>Cardiac insufficiency after cardiac surgery or due to prosthesis<br>Heart failure after cardiac surgery or due to prosthesis<br>Postcardiotomy syndrome<br>Postvalvulotomy syndrome<br>*Excludes:*<br>*Cardiac failure in the immediate postoperative period (997.1)* |
| | | 458.21 | Hypotension of hemodialysis<br>Intradialytic hypotension |
| | | 458.29 | Other iatrogenic hypotension<br>Postoperative hypotension |
| | | 997.1 | Cardiac: arrest during or resulting from a procedure<br>insufficiency during or resulting from a procedure<br>Cardiorespiratory failure during or resulting from a procedure<br>Heart failure during or resulting from a procedure<br>*Excludes:*<br>*The listed conditions as long-term effects of cardiac surgery or due to the presence of cardiac prosthetic device (429.4)* |

(*Continued*)

## Appendix 1. (*Continued*)

| In-hospital Mortality/Morbidity | AHRQ* | ICD-9† | Descriptions |
|---|---|---|---|
| Respiratory | 16.10.2.2 | 518.7 | TRALI |
| | | 997.3 | Respiratory complications<br>*Excludes:*<br>*Iatrogenic (postoperative) pneumothorax (512.1)*<br>*Iatrogenic pulmonary embolism (415.11)*<br>*Mendelson's syndrome in labor and delivery (668.0)*<br>*specified complications classified elsewhere, such as:*<br>*Adult respiratory distress syndrome (518.5)*<br>*Pulmonary edema, postoperative (518.4)*<br>*Respiratory insufficiency, acute, postoperative (518.5)*<br>*Shock lung (518.5)*<br>*Tracheostomy complications (519.00–519.09)*<br>*TRALI (518.7)* |
| | | 997.31 | Ventilator-associated pneumonia<br>Use additional code to identify organism |
| | | 997.39 | Other respiratory complications<br>Mendelson's syndrome resulting from a procedure<br>Pneumonia (aspiration) resulting from a procedure |
| Gastrointestinal | 16.10.2.3 | 564.2 | Postgastric surgery syndromes<br>Dumping syndrome<br>Jejunal syndrome<br>Postgastrectomy syndrome<br>Postvagotomy syndrome<br>*Excludes:*<br>*Malnutrition after gastrointestinal surgery (579.3)*<br>*Postgastrojejunostomy ulcer (534.0–534.9)* |
| | | 564.3 | Vomiting after gastrointestinal surgery<br>Vomiting (bilious) after gastrointestinal surgery |
| | | 564.4 | Other postoperative functional disorders<br>Diarrhea after gastrointestinal surgery<br>*Excludes:*<br>*Colostomy and enterostomy complications (569.60–569.69)* |
| | | 569.6 | Colostomy and enterostomy complications |
| | | 569.71 | |
| | | 569.79 | |
| | | 579.3 | Other and unspecified postsurgical nonabsorption<br>Hypoglycemia after gastrointestinal surgery<br>Malnutrition after gastrointestinal surgery |
| | | 997.4 | Digestive system complications<br>Complications of:<br>Intestinal (internal) anastomosis and bypass, not elsewhere classified, except that involving urinary tract<br>Hepatic failure specified as due to a procedure<br>Hepatorenal syndrome specified as due to a procedure<br>Intestinal obstruction NOS specified as due to a procedure<br>*Excludes:*<br>*Specified gastrointestinal complications classified elsewhere, such as:*<br>*Blind loop syndrome (579.2)*<br>*Colostomy or enterostomy complications (569.60–569.69)*<br>*Gastrojejunal ulcer (534.0–534.9)*<br>*Gastrostomy complications (536.40–536.49)*<br>*Infection of esophagostomy (530.86)*<br>*Infection of external stoma (569.61)*<br>*Mechanical complication of esophagostomy (530.87)*<br>*Pelvic peritoneal adhesions, female (614.6)*<br>*Peritoneal adhesions (568.0)*<br>*Peritoneal adhesions with obstruction (560.81)*<br>*Postcholecystectomy syndrome (576.0)*<br>*Postgastric surgery syndromes (564.2)*<br>*Vomiting after gastrointestinal surgery (564.3)* |

(*Continued*)

## Appendix 1. (*Continued*)

| In-hospital Mortality/Morbidity | AHRQ* | ICD-9† | Descriptions |
|---|---|---|---|
| Urinary | 16.10.2.4 | 997.5 | Urinary complications<br>Complications of:<br>External stoma of urinary tract<br>Internal anastomosis and bypass of urinary tract, including that involving intestinal tract<br>Oliguria or anuria specified as due to procedure<br>Renal:<br>Failure (acute) specified as due to procedure<br>Insufficiency (acute) specified as due to procedure<br>Tubular necrosis (acute) specified as due to procedure<br>*Excludes:*<br>*Specified complications classified elsewhere, such as:*<br>*Postoperative stricture of:*<br>*Ureter (593.3)*<br>*Urethra (598.2)* |
| Bleeding | 16.10.2.5 | 998.1 | Hemorrhage or hematoma or seroma complicating a procedure<br>*Excludes:*<br>*Hemorrhage, hematoma, or seroma:*<br>*Complicating cesarean section or puerperal perineal wound (674.3)*<br>*Due to implanted device or graft (996.70–996.79)* |
| | | 998.11 | Hemorrhage complicating a procedure |
| | | 998.12 | Hematoma complicating a procedure |
| | | 998.13 | Seroma complicating a procedure |
| Infection | 16.10.2.6 | 519.01 | Infection of tracheostomy<br>Use additional code to identify type of infection, such as:<br>Abscess or cellulitis of neck (682.1)<br>Septicemia (038.0-038.9)<br>Use additional code to identify organism (041.00-041.9) |
| | | 536.41 | Infection of gastrostomy<br>Use additional code to identify type of infection, such as:<br>Abscess or cellulitis of abdomen (682.2)<br>Septicemia (038.0-038.9)<br>Use additional code to identify organism (041.00-041.9) |
| | | 530.86 | Infection of esophagostomy<br>Use additional code to specify infection |
| | | 997.62 | Infection (chronic)<br>Use additional code to identify the organism |
| | | 998.5 | Postoperative infection<br>*Excludes:*<br>*Bleb associated endophthalmitis (379.63)*<br>*Infection due to:*<br>*Implanted device (996.60–996.69)*<br>*Infusion, perfusion, or transfusion (999.31–999.39)*<br>*Postoperative obstetrical wound infection (674.3)* |
| | | 998.51 | Infected postoperative seroma<br>Use additional code to identify organism |
| | | 998.59 | Other postoperative infection<br>Abscess: postoperative<br>Intraabdominal postoperative<br>Stitch postoperative<br>Subphrenic postoperative<br>Wound postoperative<br>Septicemia postoperative<br>Use additional code to identify infection |
| | | 999.3 | Other infection<br>Infection after infusion, injection, transfusion, or vaccination<br>Sepsis after infusion, injection, transfusion, or vaccination<br>Septicemia after infusion, injection, transfusion, or vaccination<br>Use additional code to identify the specified infection, such as: septicemia (038.0-038.9)<br>*Excludes:*<br>*The listed conditions when specified as:*<br>*Due to implanted device (996.60–996.69)*<br>*Postoperative NOS (998.51–998.59)* |

* Multilevel Clinical Classifications Software for International Classification of Diseases, 9th Revision, Clinical Modification diagnosis codes. Available at: http://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp. Accessed October 20, 2013. † eICD9.com. Medical Billing and Coding. Available at: http://www.eicd9.com. Accessed October 20, 2013.

AHRQ = Agency for Healthcare Research and Quality; ICD = International Classification of Diseases; NOS = not specified; TRALI = transfusion-related acute lung injury.

## Appendix 2. Multivariable Association between Number of Anesthesia Handovers and the Collapsed Composite of In-hospital Mortality/Morbidity (N = 135,810)

| Effect | Odds Ratio (95% CI) | *P* Value |
|---|---|---|
| Total number of anesthesia handovers | 1.08 (1.05–1.10) | <0.001 |
| Covariates adjusted for in the model | | |
| Age (per increase of 10 yr) | 1.08 (1.06–1.09) | <0.001 |
| Sex (male *vs.* female) | 1.10 (1.06–1.15) | <0.001 |
| Caucasian (yes *vs.* no) | 0.99 (0.94–1.04) | 0.68 |
| ASA status (per increase of 1) | 1.39 (1.34–1.43) | <0.001 |
| Severity of primary diagnosis (risk of having the outcome; per increase of 10%) | 1.64 (1.63–1.68) | <0.001 |
| Severity of primary procedure (risk of having the outcome; per increase of 10%) | 1.47 (1.44–1.49) | <0.001 |
| Duration of surgery (per increase of 1 h) | 1.18 (1.16–1.19) | <0.001 |
| Start time of surgery (*vs.* 12:00 AM) | | <0.001 |
| 1:00 AM | 1.02 (0.56–1.87) | |
| 2:00 AM | 1.38 (0.75–2.54) | |
| 3:00 AM | 1.17 (0.60–2.28) | |
| 4:00 AM | 1.15 (0.61–2.17) | |
| 5:00 AM | 0.53 (0.30–0.96) | |
| 6:00 AM | 0.68 (0.43–1.07) | |
| 7:00 AM | 0.73 (0.48–1.11) | |
| 8:00 AM | 0.80 (0.53–1.21) | |
| 9:00 AM | 0.75 (0.49–1.14) | |
| 10:00 AM | 0.78 (0.51–1.19) | |
| 11:00 AM | 0.72 (0.48–1.10) | |
| 12:00 PM | 0.81 (0.53–1.24) | |
| 13:00 PM | 0.75 (0.49–1.14) | |
| 14:00 PM | 0.87 (0.57–1.32) | |
| 15:00 PM | 0.84 (0.55–1.28) | |
| 16:00 PM | 0.99 (0.65–1.52) | |
| 17:00 PM | 1.04 (0.67–1.60) | |
| 18:00 PM | 1.15 (0.73–1.79) | |
| 19:00 PM | 1.20 (0.75–1.89) | |
| 20:00 PM | 1.08 (0.67–1.76) | |
| 21:00 PM | 1.45 (0.89–2.38) | |
| 22:00 PM | 1.34 (0.80–2.24) | |
| 23:00 PM | 1.13 (0.64–2.00) | |

ASA = American Society of Anesthesiologists.

## Appendix 3. Demographics Baseline and Intraoperative Characteristics for Each Propensity Score-matched Subset

| | | | | Total Number of Handovers | | | Total Number of Handovers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | 1 N = 24,275 | 0 N = 40,102 | STD‡ | 2 N = 12,051 | 0 N = 19,688 | STD‡ | 3 N = 4,769 | 0 N = 7,721 | STD‡ | ≥4 N = 2,358 | 0 N = 3,720 | STD‡ |
| Age, yr | 56 ± 16 | 56 ± 16 | 0.02 | 57 ± 16 | 56 ± 16 | 0.03 | 57 ± 16 | 56 ± 16 | 0.02 | 57 ± 15 | 56 ± 15 | 0.05 |
| Sex (male), % | 46 | 47 | 0.01 | 46 | 47 | 0.01 | 48 | 48 | 0.00 | 49 | 48 | 0.02 |
| Race (Caucasian), % | 82 | 82 | 0.01 | 82 | 82 | 0.00 | 83 | 83 | 0.00 | 84 | 84 | 0.00 |
| ASA physical status, % | | | 0.03 | | | 0.06 | | | 0.14 | | | 0.22 |
| I | 6 | 6 | | 4 | 5 | | 3 | 4 | | 3 | 5 | |
| II | 41 | 40 | | 39 | 40 | | 36 | 39 | | 34 | 37 | |
| III | 45 | 47 | | 49 | 46 | | 52 | 45 | | 54 | 44 | |
| IV | 8 | 8 | | 9 | 9 | | 9 | 11 | | 9 | 14 | |
| Severity of principal diagnosis*, % | 6 [4, 15] | 6 [4, 12] | 0.05 | 7 [4, 16] | 6 [4, 15] | 0.07 | 7 [5, 17] | 7 [4, 16] | 0.08 | 8 [5, 17] | 7 [4, 17] | 0.10 |
| Severity of principal procedure*, % | 7 [3, 15] | 7 [3, 12] | 0.06 | 8 [4, 15] | 8 [3, 13] | 0.09 | 9 [5, 19] | 8 [3, 15] | 0.16 | 9 [5, 21] | 8 [3, 15] | 0.18 |
| Start time of surgery†, % | | | 0.13 | | | 0.12 | | | 0.08 | | | 0.11 |
| 7:00 AM | 20 | 23 | | 17 | 19 | | 12 | 13 | | 13 | 15 | |
| 8:00 AM | 9 | 10 | | 8 | 8 | | 6 | 6 | | 6 | 6 | |
| 10:00 AM | 8 | 9 | | 7 | 8 | | 7 | 7 | | 6 | 5 | |
| 11:00 AM | 11 | 12 | | 10 | 11 | | 10 | 10 | | 10 | 9 | |
| 12:00 PM | 11 | 11 | | 12 | 12 | | 12 | 12 | | 12 | 12 | |
| Duration of surgery, h | 3.1 [2.1, 4.4] | 2.9 [1.8, 4.3] | 0.11 | 3.6 [2.6, 4.9] | 3.3 [2.2, 4.8] | 0.17 | 4.2 [3.3, 5.7] | 3.9 [2.7, 5.6] | 0.22 | 5.1 [4.0, 6.7] | 4.6 [3.3, 7.0] | 0.20 |

Statistics are mean ± SD, median [Q1, Q3], or percent, as appropriate.
* Most frequent categories are listed in the table. † We matched on the severity of diagnosis and severity of procedure in t-s of risk (incidence) of the collapsed composite outcome. ‡ Absolute difference in means or proportions divided by the pooled SD. Imbalance was defined as an absolute standardized difference greater than $1.96 \times \sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$ ($n_1$ and $n_2$: number of matched patients). Thus, variables with an STD of >0.02, 0.02, 0.04, and 0.05 were adjusted for in the analysis comparing patients who had one handover and who had no handovers, patients who had two handovers and who had no handovers, and so forth.
ASA = American Society of Anesthesiologists; STD = absolute standardized differences.