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REVIEW

Improving intraoperative handoffs for ambulatory anesthesia: challenges and solutions for the anesthesiologist

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Abstract: Permanent transitions of care from one anesthesia provider to another are associated with adverse events and mortality. There are currently no available data on how to mitigate these poor patient outcomes other than to reduce the occurrence of such handoffs. We used data from an ambulatory surgery center to demonstrate the steps that can be taken to achieve this goal. First, perform statistical forecasting using many months of historical data to create optimal, as opposed to arbitrary shift durations. Second, consider assigning the anesthesia providers designated to work late, if necessary, to the ORs estimated to finish the earliest, rather than latest. We performed multiple analyses showing the quantitative advantage of this strategy for the ambulatory surgery center with multiple brief cases. Third, sequence the cases in the 1 or 2 ORs with the latest scheduled end times so that the briefest cases are finished last. If a supervising anesthesiologist needs to be relieved early for administrative duties (eg, head of the group to meet with administrators or surgeons), assign the anesthesiologist to an OR that finishes with several brief cases. The rationale for these recommendations is that such strategies provide multiple opportunities for a different anesthesia provider to assume responsibility for the patients between cases, thus avoiding a handoff altogether.

Keywords: handoff, staffing, staff scheduling, staff assignment, case sequencing, case duration prediction

Patient safety in outpatient or ambulatory surgical centers (ASCs) has garnered increasing attention in the last few years. Scrutiny of ASCs and office-based practices has come as a result of recent media attention to several high-profile adverse events.[1–6] The Joint Commission has emphasized that communication failure is the root cause of most sentinel events.[7] The focus of our paper is on intraoperative transfers of patient care and responsibilities among anesthesia caregivers, commonly referred to as "handoffs." These are periods during which the risk of communication failure is elevated.

There is not much information on adverse outcomes associated with anesthesia handoffs in ASCs. However, there are studies that examine the effects of intraoperative transfers of patient care in inpatient hospital operating rooms (ORs). These four studies are reviewed in Section 1 of this paper and summarized in Table 1. There are substantive differences among the studies in the cohorts and what types of handoffs were included. Notably, the studies with permanent handoffs detected patient harm. We consequently refer in this paper to permanent handoffs between providers as

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Table 1 Summary of inpatient studies of composite outcomes associated with handoffs between anesthesia providers

Reference	**Saager et al[8]**	**Hyder et al[9]**	**Terekhov et al[11]**	**Jones et al[10]**
Institution type	US academic center	US academic center	US academic center	All hospitals in Ontario, Canada
Patients/procedures	138,932 adult non-cardiac surgical patients with ASA PS ≤4 having general and/or regional anesthesia (January 2006 to December 2012)	927 adult surgical patients undergoing elective colorectal surgery for which the CPT code occurred >10 times during the study interval (January 2006 to January 2010)	140,754 adult surgical patients with ASA PS ≤5 undergoing any surgical procedure (2005–2014)	313,066 adult patients having major surgery with expected duration ≥2 hrs and with ≥1 day stay (April 2009 to March 2015)
Handoffs studied	All transitions of care except breaks <40 mins	All transitions of care, including brief breaks	All transitions of care, including brief breaks	Permanent transitions of care from one anesthesiologist to another (Note: no CRNAs in Canada)
Serious AEs included in the composite outcome measure	During the hospitalization: mortality, serious cardiac, respiratory, gastrointestinal, renal, bleeding, and infectious complications	Within 30 days of surgery: death, serious cardiovascular, respiratory, gastrointestinal, renal, bleeding, neurologic, and infectious complications	During the hospitalization: mortality, serious cardiac, respiratory, gastrointestinal, renal, bleeding, infection	Within 30 days of surgery: mortality, readmission, serous cardiovascular, renal, bleeding, neurologic, infection, wound disruption
Overall composite AE rate	10.7%	7.7%	Not reported	29.4%
Summary of principal findings	• Each handoff increased the adjusted risk of a composite AE by 8% (odds ratio 1.08, 95% CI 1.05 –to 1.10) • Effects of handoffs were similar for attending anesthesiologists, medically directed CRNAs, and residents • Effects of handoffs were nearly identical for CRNAs and residents • An adverse effect of handoffs was not shown for cases lasting <1 hr	• The number of anesthesiologists was associated with an adjusted odds ratio of 1.58 (95% CI 1.20–2.08, *P*=0.0012) for a composite AE • The number of in-room providers (CRNAs or residents) was associated with an adjusted odds ratio of 1.39 (95% CI 1.01–1.92, *P*=0.0446) for a composite AE	• Unit increases in the number of handoffs were not associated with an increase in the adjusted risk of a composite AE (odds ratio 0.95, 95% CI 9.895 to 1.022, *P*=0.19) • The presence of a break was associated with a decreased odds ratio for a composite AE (0.933, 95% CI 0.890–9.977, *P*<0.0001)	• Handoff was associated with a relative risk for the composite outcome of 1.23 (95% CI 1.16–1.32, *P*<0.001) • Handoff associated with a relative risk in all-cause death of 1.45 (95% CI 1.19–1.76) • Handoff associated with increase in adjusted risk difference of a major complication of 1.25 (1.16–1.19, *P*<0.001)

Abbreviations: AE, adverse event; ASA PS, American Society of Anesthesiologists Physical Status; CRNA, certified, registered nurse anesthetist.

"handoffs," in contrast to "breaks" (eg, for lunch, after which the original provider returns). We use data from an ambulatory surgery center for our review (Section 2). We show how to make anesthesia staffing decisions (ie, durations of the workdays for anesthesia providers) to reduce the incidence of handoffs (Section 3). Anesthesiologists should work in their groups to plan their staffing as described. We show how to make anesthesia staff assignment decisions (ie, which people to assign to the shortest and longest ORs) to reduce the incidence of handoffs (Section 4). Anesthesiologists should implement these processes the working day before surgery. Case sequencing decisions that will not affect surgeons' start times can be used to reduce the incidence of handoffs (Section 5). Anesthesiologists can work on implementation during OR scheduling huddles the working day before surgery. Finally, if there are anesthesiologists who often have other late afternoon responsibilities (eg, head of the group meets with administrators or surgeons), the choice of the OR into which they are assigned can help reduce handoffs (Section 6). Such decisions would too be made by the anesthesiologists the working day before surgery. Our review is unique in combining these topics and including multiple examples made possible with the data.

1. Handoffs and adverse postoperative outcomes in hospitalized patients

Each of the 4 studies of handoffs involved hospitalized adult patients and measured a composite outcome consisting of postoperative mortality and serious adverse outcomes; 3 studies demonstrated deleterious effects and 1 did not detect an association.

In the initial study of nearly 140,000 patients undergoing noncardiac surgery, conducted at the Cleveland Clinic, Saager et al demonstrated a reliable association between handoffs and adverse outcomes during hospitalization.[8] (Once again, throughout this paper, by "handoff" we mean permanent handoffs, excluding brief breaks.) Each handoff increased the adjusted odds of a composite adverse outcome by approximately 8% (odds ratio=1.08, 95% CI 1.05–1.10).[8] However, the negative effect of handoffs on adverse events was absent for cases lasting less than 1 hr. No important differences were seen in the effect of handoffs when made between anesthesiologists or between providers (ie, residents and nurse anesthetists).[8]

Hyder et al subsequently studied a cohort of 927 patients undergoing elective colorectal procedures at the Mayo Clinic.[9] The assessment interval was not only during hospitalization, but extended to 30 days after surgery.[8,9] The end point was a composite of adverse postoperative events. Each additional anesthesiologist involved in the care of the patient (a surrogate for the number of handoffs or short breaks) increased the adjusted odds ratio by approximately 1.58 (95% CI 1.20–2.08, P=0.0012).[9] Each additional anesthesia resident or nurse anesthetist involved in the care of the patient, excluding brief breaks, increased the adjusted odds ratio 1.39-fold (95% CI 1.01–1.92, P=0.0446).[9]

Jones et al studied the association between the presence of handoffs between anesthesiologists and an increase in postoperative composite adverse events.[10] In Ontario, Canada, there are no nurse anesthetists practicing, unlike in the USA. Consequently, the investigators could use billing data to examine approximately 313,000 adult patients undergoing non-outpatient major surgery expected to last at least 2 hrs at all hospitals in the province. The relative risk for a composite adverse outcome was 1.23 (95% CI 1.16–1.32, P<0.001).[10] For all-cause death, the relative risk was similarly associated (relative risk=1.45, 95% CI 1.19–1.76, P<0.001), as was the relative risk for major complications (1.25, 95% CI 1.16–1.19, P<0.001).[10]

In contrast to these 3 studies, Terekhov et al did not detect a relationship between the combined number of handoffs and brief breaks, and the prevalence of postoperative adverse events, among approximately 141,000 patients undergoing surgery at Vanderbilt University Medical Center (adjusted odds ratio 0.95, 95% CI 9.895–1.022, P=0.19).[11] In this study, all procedures were included, both handoffs and brief breaks were included, and the number of handoffs by anesthesiologists, nurse anesthetists, and residents were combined. When the authors examined the effect of brief breaks alone, they found a protective effect (odds ratio=0.933, 95% CI 0.890–9.977, P<0.0001).[11] They attributed this beneficial finding as a possible result of having the anesthetic care of the patient reviewed by the provider giving the breaks, who typically was an experienced nurse anesthetist.[11]

In the only other published study, we found that examined the impact of handoffs, Epstein et al quantified the prevalence of discrepancies between the balance of drug dispensed and wasted from the pharmacy records and the amount documented in the anesthesia information management system.[12] The authors demonstrated that when a handoff of care occurred during cases vs cases in which only a single provider was involved, the error rate went from 5.7% (95% CI 5.2%–6.2%) to 12.0% (95% CI

10.7%–13.4%). This study provided evidence of incomplete communication between the relief person and the provider being relieved, as reconciliation of the pharmacy and anesthesia record documentation was part of the expected handoff process. Poor communication is one of the factors that may be related to an increase in complications when handoffs occur. However, it is important to observe from the studies of patient outcomes that there are no simultaneous measures of communication, and the mechanism of injury could be distractions of the surgical team during sign-out performed for the handoff. The mechanism is simply not known. For now, the sole strategy to reduce the effect of handoffs is to avoid handoffs. We describe the methodology in Sections 3 and 4 below.

For ambulatory centers that are only performing brief procedures, that have ≅8 hr workdays, and where patients do not stay overnight, the implications of the inpatient studies related to handoffs are unclear. However, many ambulatory centers are performing longer duration procedures, with patients placed in "observation" status overnight and then discharged the next day. For example, joint replacement, thyroid surgery, and spine procedures are increasingly being performed in ambulatory surgery centers. Because these types of procedures may end later in the workday, safety concerns related to handoffs likely apply.

2. Data used for consideration of how staffing and staff assignment can affect handoffs at ambulatory surgery centers

In the following two sections, we use data from an ambulatory surgery center to provide examples of how to make anesthesia staff scheduling and staff assignment decisions to reduce the occurrence of permanent transfers of care between anesthesia providers ("handoffs"). Staff scheduling is the process of choosing which anesthesia provider works on which dates, and for each such day whether the schedule is for (i) long scheduled day, (ii) brief scheduled day plus being on call to work late if necessary, or (iii) brief scheduled day and without being on call to work late if necessary. In the current paper, we do not consider staff scheduling, because we are not choosing individual anesthesia providers. Rather, we focus on staffing, specifically on the choice of the numbers of anesthesia providers working each of these roles. Staff assignment is the process of choosing the list of cases (typically in a single OR) that an anesthesia provider treats. Staffing generally is performed many months before the day of surgery. Staff assignment often is performed the working day before surgery. Staff assignment decisions can be made, in part, with the objective of reducing the incidence of handoffs.[13]

To provide examples of principles in staffing and staff assignment, we used a de-identified dataset.[14] The Thomas Jefferson University Institutional Review Board approved the study without a requirement for patient consent.[14] The de-identified dataset included 10 years of accurate OR and anesthesia information system data.[14] We limited consideration to the most recent 5 years because the workload in the ambulatory surgery center increased progressively during the first 5 years. We limited consideration to Mondays through Fridays because those were the days of the week when the ambulatory surgery center had cases. We limited consideration to regular workdays due to closure of the ambulatory surgery center on holidays. Finally, for purposes of this paper, we excluded Thursdays because surgical cases started 1 hr later that day of the week for anesthesia, nursing, and surgical department meetings.

There were 969 workdays of data after our exclusion of Thursdays, weekends, and holidays. Among the 107,850 cases performed on those days, there were 12,978 cases performed in the hospital's ambulatory surgery center and 94,872 cases performed in the main (hospital) surgical suites. We report summary measures of those data, below, using the mean of each summary measure among the 5 years ± standard error of the mean of the 5 values. For example, there were 2,596±54 and 18,974±102 cases per year, respectively. CIs are approximately ±2×the standard error. To obtain the standard error of 54 cases per year, the included cases per year in the ambulatory surgery center were calculated for each of the 5 years. The standard deviation was calculated among the 5 counts of cases per year. Then, that standard deviation was divided by the square root of 5 (ie, the definition of the standard error). There were 3.5±0.1 ORs with cases each workday at the ambulatory surgery center and 30.4±0.1 ORs with cases at the main suite.

These are the types of calculations that are needed to make staffing decisions to reduce handoffs.

3. Staffing to reduce permanent handoffs

If a facility does not have an appropriate number of anesthesia providers regularly scheduled and on call to work late if necessary at different hours, the potential for handoffs will be greater. For the ambulatory surgery center, we consider two categories: (1) short-day and (2) long-day.

To estimate staffing for the ambulatory surgery center, the following four data fields can be used: the OR in which each case was performed, the date of the case, the time when the patient entered the OR, and the time when the patient exited from the OR. From the date, a fifth column is created for the year. These are the same data used as for examination of ambulatory surgery centers nationally using the American Society of Anesthesiologists' Anesthesia Quality Institute's database.[15] The results are indistinguishable when the times used are the beginning and end of continuous anesthesia presence (ie, as would be present from anesthesia billing data) or the times of patient entrance into and exit from the OR (ie, as would be present from the OR nursing or anesthesia record).[16] The types of procedures do not need to be considered, because once controlling for the average durations, cases with handoffs are not types of procedures that are more or less common than cases without handoffs.[17]

Sort the data in descending sequence by year, then by date, then by OR, and then by the time at which the patient exited from the OR. Select the latest ending case in each OR. For each combination of date and OR, an estimated labor cost can be calculated. For our example, we did so, for each date, by comparing the time that the latest running OR ended to 7.5 hrs, the latter representing 8 hrs minus the estimated time for the patient to be taken to the PACU, narcotics reconciled, equipment returned to workroom, etc.[18] The estimated labor cost in units of hours was considered to equal approximately 7.5 hrs plus 1.50× the hours exceeding 7.5 hrs, but with a cost of 0 hr if finishing earlier than 7.5 hrs. The value of time and a half represented not only the extra pay that some of the anesthesia providers received when working late, but also the actual cost from a long-term perspective (eg, retention and recruitment costs) when other anesthesia providers designated to work late, if necessary, actually had to work late.[16,19–21]

The time when the latest OR ended was compared with 9.5 hrs. The mean costs using the ratio of 1.50 were 8.6±0.1 hrs and 9.6±0.1, respectively. The first of the two means was much larger than 7.5 hrs, because for 58.9%±2.2% of days, the latest running OR finished more than 7.5 hrs after the start of the workday. The second of the two means was negligibly greater than 9.5 hrs, because only for 11.7% ±1.9% of days did the latest running OR finish greater than 9.5 hrs after the start of the workday. The latter would be an occurrence of once every 2–3 weeks. Because the mean of 8.6 hrs was significantly less than the mean of 9.6 hrs, regularly scheduling anesthesia providers to work 7.5 hrs resulted in greater expected productivity than regularly scheduling for 9.5 hrs. The implication for the topic of handoffs is that all anesthesia providers at this facility could reasonably have been scheduled for shifts of the same duration. That is the staffing plan that we applied below. However, results will be different at some ambulatory surgery centers. What we have provided are examples that show how to perform the calculations, not prescriptive results to be applied at other facilities.

Next, repeat the calculations while treating the cost of an anesthesia provider unexpectedly working late as equal to the cost of 4.0 hrs of the regularly scheduled time.[22] Again, the cost does not represent how much anesthesia providers are paid but, rather, the cost from a long-term perspective. The implication of this ratio is that the ambulatory surgery center would rather have an OR end 4 hrs early than 1 hr late. Such large relative costs apply at the many ambulatory facilities that want to open all available rooms at the start of the day, but where most rooms finish by the early afternoon.[15] Although some anesthesia providers are not paid extra when they work late, there is a cost from a long-term perspective; recruitment and retention of anesthesia providers depend on typical work hours and the reliability (ie, variability) of work hours at facilities. Continuing, using the ratio of 4.00, the mean costs per day were 10.5±0.2 hrs when planning a 7.5 OR hour workday versus 9.8±0.1 hrs when planning 9.5 OR hours. The pairwise differences were greater costs, 0.7±0.2 hrs, if staffing was planned for 7.5 OR hours without having an anesthesia provider on call to work late if necessary. Consequently, at least one of the anesthesia providers should have been on call to work late if necessary. To determine if greater than one, these calculations were repeated for the time that the penultimate case ended each workday. The mean costs per day were 8.6±0.1 hrs when planning 7.5 OR hours versus 9.6±0.1 OR hours when planning 9.5 OR hours. Because the pairwise differences were less with 7.5 OR hours (−1.0±0.1 hrs), only one anesthesia provider would be on call to work late if necessary. When we consider assignments, below, this was the staffing decision that was assumed. We note too that this is a typical staffing decision for an ambulatory surgery center. However, this staffing decision will, of course, not apply everywhere (ie, these are the steps to be followed to plan anesthesia staffing).

Statistically, the relative cost ratios of 1.5 and 4.0 result in approximately the 60th and 80th percentiles, respectively.[23] The results are not precisely the same, in part because there cannot be fractions of people. To make a comparison between the preceding analysis and use of the 60th and 80th percentiles, we sorted the data in descending sequence by year, then by date within the year, and then by time at which the patient exited from the OR. For each date, this provided the time of OR exit for the last case of the day and for the penultimate case of the day. At the ambulatory surgery center used for examples, the last case of the day ended 8.2±0.1 (60th percentile) and 9.0±0.1 (80th percentile) from the start of the workday. The penultimate case of the day ended 7.2±0.1 (60th percentile) and 8.0±0.1 (80th percentile) from the start of the workday. The results using the 60th percentile help to explain that staffing can reasonably be based on cases ending 7.5 to 8.0 hrs after the start of the workday. The results of the 80th percentile show, in addition, that having 1 anesthesia provider to be on call to work late if necessary is also reasonable.

Avoidance of handoffs depends on these anesthesia staffing decisions having been made appropriately. Consequently, anesthesiologists need to perform these calculations or have them done for them by providing this paper and references to an analyst.[24] Otherwise, subsequent options are moot.

4. Staff assignment to reduce permanent handoffs

Having described how to calculate appropriate staffing for the ambulatory surgery center, next we consider the staff assignments and their relationship to reducing handoffs.

From the preceding section, for the example ambulatory surgery center, we consider all anesthesia providers to be scheduled for the same period: 7.5 hrs. In addition, there is 1 anesthesia provider daily on call to work late, if necessary. Thus, the staff assignment decision that influences permanent handoffs is the single decision of the OR assignment of the one anesthesia provider on call to work late if necessary. We hope that readers will find this to be a typical decision that they make on the day before surgery.

The anesthesia provider on call could be assigned to the OR that is scheduled to finish the latest. Alternatively, that provider could be assigned to the OR that is scheduled to finish the earliest, with the expectation that he or she would then start whatever case is expected to end latest among those cases that are yet to begin. In the mid-afternoon, more is known about which case that will be, as opposed to on the business day before surgery.[25,26]

The logistics of making the assignment of the late-call person are quite different between hospital surgical suites and ambulatory surgery centers. For a hospital's surgical suite, the focus of the assignment decision to prevent permanent handoffs generally would be the ORs with 1 very long case (eg, otolaryngologist performing a bilateral neck resection, laryngectomy, and tissue transfer with microvascular anastomosis). Alternatively, there may be 1 surgeon with 2 relatively long cases (eg, a plastic surgeon performing 2 cases involving breast reconstructions using latissimus dorsi flaps). Using our data as an example of a hospital surgical suite, the mean case duration was relatively long, 188±1 mins, as was the standard deviation, 131±1 mins. For 19.7±0.9% of OR days, there was either 1 very long case or 1 surgeon with just 2 cases, and the case or cases totaled >8 hrs of OR time (ie, turnover if present excluded). Thus, efforts to reduce handoffs in anesthesia are conceptually straightforward for hospital surgical suites. Plan for a realistic number of providers who will work late to finish cases (eg, no greater than a 20% chance of unexpectedly working late). Assign them to the OR with the single very long surgical case or the surgeon with 2 moderately long cases. Thus, for hospitals, reducing handoffs is principally a staffing decision (ie, Section 3). What we will show in this section is how for ambulatory surgery centers assignment and case sequencing decisions can be more relevant.

In contrast to hospital surgical suites, the mean duration of cases is much briefer at ambulatory surgery centers. For example, at the ambulatory surgery center whose data we are using for our examples, the mean was 75±2 mins, and the standard deviation was 57±3 mins. Therefore, the case durations were briefer than at the corresponding hospital's surgical suite, and the variability in those durations among cases also was less. This variability does not refer to the predictive error in the OR times of cases comprising the same set of procedures, but rather to the heterogeneity among all cases at the surgical suite in their durations. At the ambulatory surgery center, there were many fewer OR days with one case or the same surgeon performing 2 cases that fill the OR for >7.5 hrs (0.7±0.1%). To emphasize, the 0.7% value contrasts with 19.7±0.9% for the hospital surgical suite, and with an even longer workday in the hospital. This is not surprising because ambulatory surgery centers perform many brief cases. What we consider further are the substantial implications with respect to reducing handoffs of this difference between ambulatory surgery centers and hospitals.

To examine the assignment of anesthesia providers at the ambulatory surgery center, we considered all ORs during a given year to have the same estimated turnover time, as calculated from the preceding year of data. The cases that we reviewed were those cases that had been scheduled as of 7:00 PM the day before surgery. For each case, there was an estimated OR time from the surgeon and the scheduler. In addition, there were historical data from the preceding years classified by the combinations of the categories of surgeon and procedure(s). The updated estimate for the mean case duration was calculated using a Bayesian method to combine the surgeon and scheduler's estimate with the historical data.[27–29] There are multiple other Bayesian methods,[30–33] but we rely on the one used with the data from the ambulatory surgery center. These estimated OR times were summed for each OR.[34] Anesthesia handoffs do not affect surgical case durations.[35]

Often, the OR with the longest scheduled list of cases was not the OR that finished last, the latter occurring on 47.5±2.8% of days. There were, as is typical, very few add-on cases at the ambulatory surgery center, so that was not an important cause: 0.5±0.1% of cases. There were a relatively large number of cancellations at our example surgery center as compared with some ambulatory surgery centers, 3.6±0.2% of cases and 3.0±0.2% of the Bayesian estimated total OR time.[36,37] However, there were still too few cancellations to account for the results. Cases were infrequently moved from the scheduled OR to another OR: there were 2.9±1.1% of cases moved, accounting for only 3.0±1.1% of estimated OR times. There also was a negligible underestimation of OR times (mean case prediction bias=4.0±0.9 mins per case). In contrast, the ratio of the sums of absolute errors divided by sums of the OR times was 25.1±0.3%, resulting in a mean absolute difference of 55.9±1.1 mins. In addition, the mean absolute difference between the actual and annual expected turnover time equaled 13.1±0.1 mins. Consequently, the OR expected to finish the latest was often not the OR finishing the latest because of variability in the operative time and, to a lesser extent, the nonoperative turnover time.

Because there were multiple cases per OR, the anesthesia provider scheduled to work late could be assigned to the OR with the fewest scheduled hours of cases. When the cases in that OR are finished for the day, the anesthesia provider would give breaks or assist with patient preparation or anesthesia setup to help reduce turnover times. He or she would then start the case of the day that is predicted to end the latest, as informed by the cases' progress in the suite during that day. We evaluated for what percentage of days the OR with the fewest scheduled hours had its last case end before the OR scheduled to end the latest had its last case begin. For each of the 5 studied years, we calculated the percentage of workdays for which the longest scheduled OR was the latest finishing OR. That was the denominator. For each year, we calculated the percentage of workdays for which the briefest scheduled OR finished before the latest running case had begun. That was the numerator. This relative risk equaled 1.06±0.05, with Student's one-group two-sided *t*-test *P*=0.26. Thus, assignment of the anesthesia provider on call to the briefest OR seems as good a strategy as assigning the provider to the OR expected to finish last. This result does not imply the appropriateness of this approach for the individual ambulatory surgery center, because there often are constraints (eg, small numbers of anesthesia providers are assigned to work with a specific surgeon as an anesthesia "team"). This result shows that handoffs are not necessarily best avoided by assigning the anesthesia provider on call to the longest scheduled OR. We urge readers to consider the opposite strategy (ie, assignment to the room expected to end earliest).

Additional calculations were performed based on the dual objectives of reducing handoffs and avoiding anesthesia providers working beyond regularly scheduled hours. We care about how late the latest finishing OR ends (ie, not relevant when the last case is done earlier than 7.5 hrs from the start of the workday). For each year, we calculated the percentage of workdays for which (i) the longest scheduled OR was the latest finishing OR and (ii) that latest finishing OR finished >7.5 hrs after the start of the workday. That was the denominator. For each year, we calculated also the percentage of workdays for which (i) the briefest scheduled OR finished before the latest running case had started and (ii) the latest running case finished >7.5 hrs after the start of the workday. That was the numerator. This relative risk equaled 1.18±0.02, *P*=0.0003. Thus, assignment of the anesthesia provider on call to the shortest scheduled OR had a slight advantage in magnitude. Nevertheless, the finding was reliable (ie, statistically significant): better to assign the late anesthesia provider to the shortest OR. The implication is that this strategy is just as reasonable as assigning the provider to the OR expected to end the latest in the day.

A third set of calculations used the minutes worked later than 7.5 hrs. For each year, we identified the longest scheduled OR, and if that OR did not finish the latest, we calculated the minutes that the actual latest finishing OR finished past 7.5 hrs. If the latest scheduled OR finished last, the minutes were set equal to 0 min. If the latest finishing OR finished earlier than 7.5 hrs, the minutes were also set equal to 0 min. The sum among days was the denominator. Next, for each year, we calculated that end point based on assigning the on-call anesthesia provider to the OR scheduled to end the earliest. If that case did not end before the latest running case started, then the minutes that the latest running case finished later than 7.5 hrs was counted. The minutes were summed among days. That was the numerator. This ratio of minutes equaled 0.56 ±0.03, P=0.0001. To interpret this finding, suppose that the ambulatory surgery center decides that there will be no handoffs (ie, the anesthesia provider starting a case must finish it, barring illness or other unforeseen circumstances). Then, the 0.56 estimate shows that, at the studied ambulatory surgery center, assigning the late working anesthesia provider to the shortest scheduled OR would result in an approximately 44% reduction in the cost of anesthesia providers unexpectedly working late.

Our recommendation to readers is that if they typically have 1 anesthesia provider on-call to work late each day, unless they will repeat the calculations using their own data, assign that individual to the OR expected to finish the earliest each day. The decision about what the provider will do after his or her assigned list of cases is complete can be made later.

5. Case sequencing to reduce permanent handoffs

The preceding results were based on the sequences of cases followed. We evaluated each pairwise sequence of cases in each OR of the ambulatory surgery center whose data we are using (Section 2). We evaluated whether each to-follow case was briefer or longer in duration than the preceding case in the OR. Based on the actual OR times, shorter cases were first for 51.0±0.3% of cases. Based on the scheduled OR times, shorter cases were first for 41.5±0.3% of the pairwise combinations (ie, cases of longer scheduled duration were more often scheduled to start later in the workday). However, both are close to 50:50. This means that cases were not systematically sequenced; effectively, the sequencing was no different than flipping a fair coin to decide the order. To reduce handoffs, for some surgeons it may be possible to rearrange the sequences of their cases. This would not change the start times of any surgeons. Rather, it is the order of each individual surgeon's cases.

Next, we demonstrate which sequence would reduce permanent handoffs. Suppose that the OR with the shortest scheduled workday has 2 cases expected to take 5 hrs. The OR with the longest expected workday has 3 cases: 1.5 hrs, 1.5 hrs, and 4 hrs. If the 4-hr case was scheduled to start last, there would be little chance that the shortest OR of the day would finish sooner than the start time of the 4-hr case. There would also be little opportunity to move the 4-hr case to another OR that unexpectedly finishes early. In contrast, suppose that the 4-hr case was performed first. Then, with the last case of the day being 1.5 hrs, it would be far more reliable for that last case to be started by a different anesthesia provider and possibly OR nurses from the shortest OR.

The following is the implication for anesthesiologists. The day before surgery, or two days ahead, at the OR scheduling huddle, consider case sequencing for the OR that is expected potentially to have a need for a handoff. For the ambulatory surgery center, that would be the OR with the longest expected duration of the workday. If all the cases are brief, the issue of sequencing is moot. However, if a surgeon has a list of cases including one especially long case, consider starting the long case early in the day, rather than late in the day, to reduce the chance of needing an anesthesia handoff at the end of the day. Contact the surgical team to evaluate if such sequencing is an option.

6. Nonclinical activities

As described at the end of Section 1, the ambulatory surgery centers for which handoffs might be associated with worse patient outcomes are those with longer duration cases and patients staying overnight or having long periods in recovery. These ambulatory surgery centers can have notably longer work hours than those of the ambulatory surgery center we used for examples (Section 2). Most ambulatory surgery centers in the USA have sufficiently brief workdays that may negate even the need for a single anesthesia provider to be scheduled to be on call to work late if necessary.[15] Nevertheless, even with brief workdays, there may still be handoffs. The reason is that in many groups, there are 1 or 2 anesthesia providers with important nonclinical activities.[38] For example, the anesthesiologist managing informatics for the anesthesia group may routinely be assigned to the briefest of ORs.[39] Another example is the OR manager.[40,41] A third example is the chief nurse anesthetist. The concepts we presented in Sections 4 and 5 show that it often would not be advantageous to assign one of these individuals to the OR with the fewest scheduled hours of cases. Rather, if there were two ORs each with similar total hours, but one OR is finishing with a couple of brief cases and the other OR is finishing with a longer duration case, choose the OR with shorter cases later in the workday. Handoffs can be avoided while having the anesthesiologist or nurse anesthetist available for meetings for other group activities.

7. Summary

Permanent transitions of care from one anesthesia provider to another are associated with adverse events and mortality. There are currently no available data on how to mitigate these adverse patient outcomes other than to reduce the occurrence of such handoffs. In this review, we used data from an ambulatory surgery center to demonstrate the steps that can be taken to achieve this goal. First, perform statistical forecasting using many months of historical data to create optimal, as opposed to arbitrary, shift durations. Second, consider assigning the anesthesia providers designated to work late, if necessary, to the ORs estimated to finish the earliest, rather than latest. Multiple analyses show the quantitative advantage of this strategy for ambulatory surgery centers with multiple brief cases. Third, sequence the cases in the 1 or 2 ORs with the latest scheduled end times so that the briefest cases are finished last. If a supervising anesthesiologist needs to be relieved early for administrative duties (eg, the head of the group to meet with administrators or surgeons), assign the anesthesiologist to an OR that finishes with several brief cases. The rationale for these recommendations is that such strategies provide multiple opportunities for a different anesthesia provider to assume responsibility for patients between cases, thus avoiding a handoff altogether.

Disclosure

Dr Franklin Dexter is Director of the Division of Management Consulting, Department of Anesthesia, University of Iowa. The Division provides consultations to corporations, hospitals, and individuals helping them with staffing analyses. In addition, the Division offers a course that Dr Dexter teaches that includes this topic. Dr Dexter receives no funds personally other than salary and allowable expense reimbursements from the University of Iowa, and has tenure with no incentive program. Dr Dexter has no financial holdings in any company related to his work, other than indirectly through mutual funds for retirement. The authors report no other conflicts of interest in this work.

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