MAYO CLINIC PROCEEDINGS: INNOVATIONS, QUALITY & OUTCOMES

ORIGINAL ARTICLE

Measurement of Information Transfer During Simulated Sequential Complete Shift-to-Shift Intraoperative Handoffs

Adam Schiavi, PhD, MD; Bommy Hong Mershon, MD; Allan Gottschalk, MD, PhD; and Christina R. Miller, MD

Abstract

Objective: To determine information transfer during simulated shift-to-shift intraoperative anesthesia handoffs and the benefits of using a handoff tool.

Patients and Methods: Anesthesiology residents and faculty participating in simulation-based education in a simulation center on April 6 and 20, 2017, and April 11 and 25, 2019. We used a fixed clinical scenario to compare information transfer in multiple sequential simulated handoff chains conducted from memory or guided by an electronic medical record generated tool. For each handoff, 25 informational elements were assessed on a discrete 0−2 scale generating a possible information retention score of 50. Time to handoff completion and number of clarifications requested by the receiver were also determined.

Results: We assessed 32 handoff chains with up to 4 handoffs per chain. When both groups were combined, the mean information retention score was 31 of 50 ($P<.001$) for the first clinician and declined by an average of 4 points per handoff ($P<.001$). The handoff tool improved information retention by almost 7 points ($P=.002$), but did not affect the rate of information degradation ($P=.38$). Handoff time remained constant for the intervention group ($P=.67$), but declined by 2 minutes/handoff ($P<.001$) in the control group, which required 7 more clarifications/handoff ($P=.003$). In the control group, 7 of 16 (44%) handoff chains contained one or more information retention scores below the lowest score of the entire intervention group ($P=.007$).

Conclusion: Clinical handoffs are accompanied by degradation of information that is only partially reduced by use of a handoff tool, which appears to prevent extremes of information degradation.

 ■ Mayo Clin Proc Inn Qual Out 2023;7(1):9-19

From the Department of Anesthesiology and Critical Care Medicine, Johns Hopkins University School of Medicine, Baltimore, MD

Preventable medical errors remain a major source of harm in hospitalized patients, causing 200,000 to 400,000 deaths annually.[1,2] Communication failure and information loss, particularly during handoffs,[3] are the most common root causes in 80% of medical errors[4] and anesthesia closed claims analysis.[5] Subspecialization and emphasis on duty hours, prevention of fatigue, and work−life balance make transfers of care inevitable, resulting in up to 4000 handoffs per day in the typical teaching hospital.[6] Although many medicine specialties involve a single handoff (although often of multiple patients), sequential handoffs are common and increasingly necessary during perioperative care.[7] These handoffs can be characterized as shift-to-shift rather than transitions of care[8] because there is no movement of patient between locations or change in level of care in the same location. Of the 7.2 million inpatient operations performed each year in the United States,[9] 40% involve a complete anesthesia handoff, where all responsibility for care is transitioned to a new clinician and up to 19% involve 2 or more complete handoffs.[10,11] Such transfers are increasing in frequency[7] and may increase the risk of all-cause death and major complications. Some estimates attribute 600,000 potentially preventable serious adverse events each year worldwide to deficiencies of anesthesia handoffs.[7,10,12−14] Moreover, risk of complications increases by 3% per handoff, from 8.8% with no handoffs to 21.2% with 4 or more handoffs.[11]

The Joint Commission established a National Patient Safety Goal in 2006 and a Provision of Care in 2010 to address patient handoffs.[15] These documents advocate implementation of a standardized handoff system that is easily accessed in the workflow, enhanced by electronic medical record (EMR) technology, and monitored for quality improvement.[4] In 2012, only 8% of medical schools in the United States had a standardized handoff curriculum, and no U.S. residency program used a comprehensive approach to teaching or assessing handoff competency.[16] Accreditation Council for Graduate Medical Education visits in 2016[16] and 2018[17] indicated a continued lack of standardization for change-of-duty handoffs and limited supervision of trainees performing handoffs.[16] In the Agency for Health Care Research and Quality survey in 2021, 53% of respondents endorsed the statement "important patient care information is often lost during shift changes,"[18] essentially unchanged from the 2011 survey.[8]

Although pre—post observational studies indicate a reduction in preventable clinical errors when a handoff program is used,[19] the form and potential benefit of such a program remains unresolved. There is a growing body of literature concerning handoffs with a trend toward conceptual models of team dynamics and systems engineering.[20] However, there is a paucity of research that addresses communication skill and accuracy of information transfer in a controlled environment as most studies are from convenience samples in the clinical environment. Overviews of the field have called for studies that document accuracy of information transfer provided during handoffs, measure the extent that handoffs contain all essential information, and assess recall accuracy of the information provided.[8,21]

Consequently, we adopted the simulation environment to perform repeatable and controlled assessment of clinical information loss and the extent loss is mitigated by use of an EMR—enhanced handoff tool.

MATERIALS AND METHODS

Study Design

This study was approved by the Johns Hopkins institutional review board (IRB00110777), which waived the need for written consent. Our institution is a large academic tertiary care hospital in the mid-Atlantic region that uses Epic (Epic Systems Corporation, Verona, Wisconsin) to generate the EMR. We developed a handoff tool in conjunction with Epic that extracts data automatically according to predetermined parameters from EMR documentation entered by clinicians. The tool uses a structured format on the basis of mnemonic "HANDOFF": (H: How sick is patient? A: Airways, Access, N: New, iNtraop, D: Drugs, Disposition, O: Opioids/Pain Plan, F: Fluids, F: Fears, Future Plans, "Follow Me" [read back]). We introduced the electronic handoff tool into clinical practice in 2017. In 2017 (after 6 months of use) and again in 2019, we prospectively evaluated the tool by creating a simulated perioperative record from which the EMR generated a handoff report. For these studies, we randomized participants to perform a sequence of simulated complete intraoperative transfers of care using either the handoff tool (intervention) or only their memory (control).

Simulation

We created the simulated clinical case of a patient with complex medical history undergoing spine surgery. In each cohort, 16 postgraduate year (PGY)-2, PGY-3, and PGY-4 residents (Clinical Anesthesia first-, second-, and third-year residents, respectively) were randomized (Random.org) to serve as the first link of 16 individual handoff chains. These participants received materials for the case by e-mail 1 day before the simulation and were asked to learn the information "as if they had been taking care of the patient in the operating room all day." This arrangement provided them with the flexibility to learn the case details at their own pace and did not consume time set aside for performing the handoffs. The materials included the Epic-based anesthesia preoperative evaluation with history, physical, laboratory, and other test results; the anesthetic plan; the intraoperative record of the case in progress; and a written narrative of the case (Supplemental Appendix 1, available online at http://www.mcpiqojournal.org/). This narrative and the handoff tool both included the same 25 clinically relevant elements highlighted in bold that had the potential to lead to patient harm if conveyed

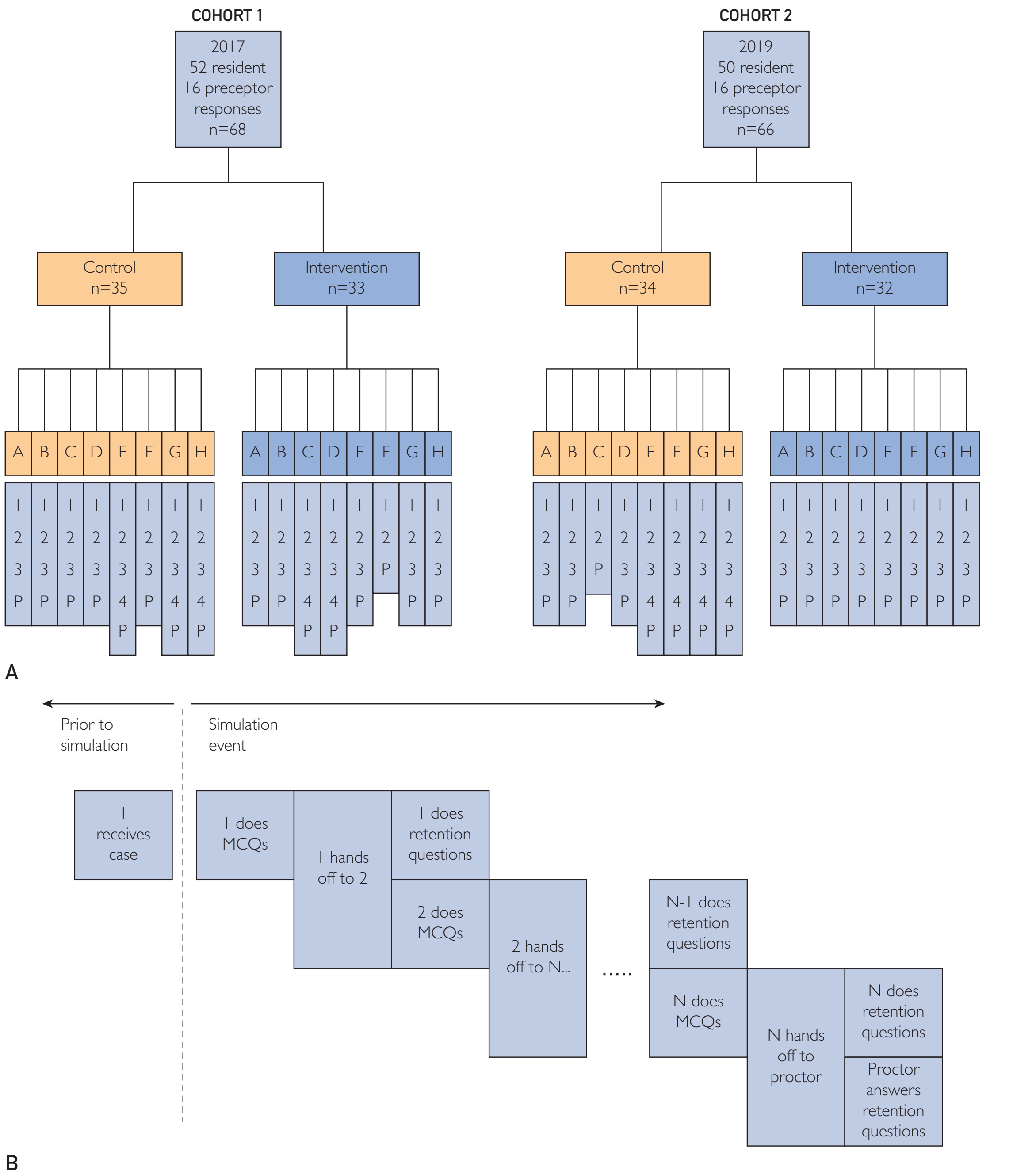

FIGURE 1. A, Schematic of years 2017 and 2019 and the makeup of each handoff chain. The letters indicate the individual chains (A, B, C, etc.), and numbers indicate individual residents within each chain. "P" at the end of each chain indicates the proctor for that chain who received the final handoff and answered the retention questions on the basis of the information they received in the final handoff. B, Schematic of the sequence of events that occurred in each chain. The first resident in each chain received the information contained in the simulated case the day before the simulation. All others received the information during the handoff from the previous resident in the chain. After answering "distraction" MCQs for 5 minutes, the handoff between residents was performed from memory (control group) or with the aid of the EMR handoff tool (intervention group). Retention questions were answered on the basis of what the resident could remember about the case. Neither group could use additional cognitive aids while answering the retention questions. MCQ, multiple-choice question.

incompletely or incorrectly (Supplemental Appendix 2, available online at http://www.mcpiqojournal.org/). These elements were the basis for the 25 retention questions from which the information retention score, the study's primary outcome, was generated.

The 16 first-link participants were randomized to the intervention or control group (8 participants each). Additional participants were randomly assigned to subsequent second and third positions, etc. in each chain (Figure 1A). Simulations were held over 8 hours on 2 days with 1 control and 1 intervention chain running simultaneously each hour in separate rooms. Participants were aware that the study was evaluating 2 different handoff methods and that they were not being evaluated personally. A schematic of the event sequence in each chain is shown in Figure 1B. The first participant in each chain answered multiple-choice questions (MCQs) on unrelated anesthesia topics for 5 minutes, simulating the burden of balancing multiple cognitive processes in the clinical environment. The answers to these questions were not analyzed. The first participant handed off the patient to the second participant to simulate a complete shift-to-shift handoff between the 2. The participant receiving the handoff could ask as many questions as needed for clarification until both parties were satisfied that the transfer was complete. There was no time limit for the handoff. A hidden faculty proctor recorded time spent completing the handoff and the number of clarification questions asked by the receiver, and ensured that unpermitted cognitive aids were not used.

After the handoff was complete, the first participant in the chain went to a separate quiet examination room to answer 25 retention questions. The second participant, after receiving the handoff, answered MCQs for 5 minutes. This process (receive handoff, MCQs, give handoff, retention questions) was repeated with the second participant handing off to the third, etc. until the final participant handed off to the faculty proctor. Faculty proctors also answered the retention questions with information received from the final participant. The length of the chain ranged from 2 to 4 individuals, reflecting several studies that have evaluated the impact of up to 4 or more handoffs,[11,13] in addition to the faculty proctor who was the last recipient in each chain. The number of handoffs that could be completed within 1 hour limited chain length. Aside from the EMR handoff tool used by the intervention group during the handoff process, all conditions in the intervention and control groups were identical. In an effort to control for variability, neither group was permitted to use notes or outside cognitive aids. Neither group had access to the handoff tool while answering the retention questions.

Two blinded reviewers (B.H.M., C.R.M.) graded the retention questions as 0 (incorrect), 1 (partially correct), or 2 (correct) using a set of predetermined criteria (Supplemental Appendix 2, available online at http://www.mcpiqojournal.org/). Whenever grading discrepancies were present, the reviewers refined scoring criteria until consensus was reached. The scores from the 25 questions were summed to generate an information retention score.

Statistical Analyses

For this initial study, a power analysis was not performed. Data are expressed as number (%) for frequency of a given score for each retention question. Significance of differences between groups for individual questions was determined by using ordered logistic regression, and satisfaction of the proportional odds assumption confirmed. Longitudinal count and continuous data were analyzed with multilevel marginal models with and without random intercepts and where linear and quadratic changes over time were considered. The Akaike information criterion was used to facilitate model selection. Differences were considered significant at $P<.05$, and all reported significance levels are from two-sided tests. Data analyses were performed with Stata 16.0 (StataCorp, College Station, TX, USA).

RESULTS

In 2017 (cohort 1), 52 residents participated in 16 separate handoff chains. Each concluded with a handoff to a faculty proctor, leading to 68 assessments of information retention. In 2019 (cohort 2), 50 residents participated in 16 chains resulting in 66 assessments of information retention. When the cohorts were combined, first-, second-, third-, fourth-, and fifth-order participants numbered 32, 32, 31, 30, and 9, respectively. Longitudinal analysis of the data led to a marginal model with a single autoregressive lag and separate covariance for the control and intervention groups. For parsimony, position along the handoff chain was treated linearly although a quadratic term improved the model slightly but without affecting any of the conclusions. The model revealed no differences between the 2 cohorts (P=.46) and subsequently, all data were treated as a single combined cohort. Resident level of training was not significantly different between the groups and had no influence on retention scores (P=.19).

Retention scores for each handoff chain and their mean are given in Figure 2A (intervention group) and Figure 2B (control group). A comparison between the groups is shown in Figure 2C. Overall, for the first-order participant the mean information retention score was 26.7 in the control group and 35.5 in the intervention group compared with the maximal potential score of 50 (P<.001) and declined by 4 points with each handoff (P<.001). When handoff methods were considered separately, the handoff tool improved information retention by almost 7 points (P=.002), but the methods did not differ in the rate of information decline per handoff (P=.38). The variance in the retention scores from the control group was 2.1-fold greater than that in the intervention group (P=.002). The lowest retention score in the intervention group was 12, whereas 19 of 69 (28%) scores in the control group were below 12 (including 3 scores of 1 and two scores of 2), resulting in 7 of 16 (44%) handoff chains in the control group experiencing at least 1 retention score below the lowest retention score of any in the intervention group (P=.007). In several handoff chains of the intervention group, but in none of the control group, the retention score increased (Figure 2A). In Figure 3, the percentage of correct answers is given for each of the 25 two-point questions from which the retention score is generated. Thirteen of the 25 retention questions exhibited a clear advantage in information retention (P<.01), and 5 additional questions saw a probable advantage with tool use (P<.05 and $P\geq$.01).

The number of clarification questions asked by the receiver during the handoff (Figure 4A, B) and the duration of each handoff (Figure 4C, D) were also determined. Fewer clarification questions were asked when the tool was used (mean, 12; 95% CI, 10−15) than when the tool was not used (mean, 19; 95% CI, 15−23; P=.003). Initially, time spent handing off was approximately 10 minutes and did not differ between the intervention and control groups (P=.18). It declined in the control group by approximately 2 minutes per handoff (P<.001) but remained relatively constant in the intervention group (P=.67).

DISCUSSION

Using a simulation methodology to control for environmental and case heterogeneity, this study reported the extent that clinical information is continuously degraded during sequential handoffs. It also found that a case-specific handoff tool derived from the EMR limits but does not prevent this information loss. Although unable to prevent information loss, the handoff tool averted its most severe and potentially harmful occurrences. Without the handoff tool, almost half of the handoff chains in the control group had an information retention score lower than the lowest value attained with the aid of the handoff tool. Revealing this aspect of the variability of the handoff process was facilitated by simulating handoffs using a fixed complex scenario with multiple handoff chains. Consistent with the amount of information conveyed along each handoff chain, handoff times in the control group grew shorter and required an increasing number of clarification questions. In some isolated instances, the handoff tool appeared to have facilitated large increases in information retention along the handoff chain.

Ultimately, the goal of any handoff tool is to improve patient safety. Agarwala et al[22] reported that integration of a structured checklist into the EMR during anesthesia handoffs in the clinical environment improved receiver satisfaction and information retention. However, retention elements were not controlled for and were those commonly found in most intraoperative cases, but not focused on information critical to preventing harm in specific patients.[22] Several studies have evaluated the

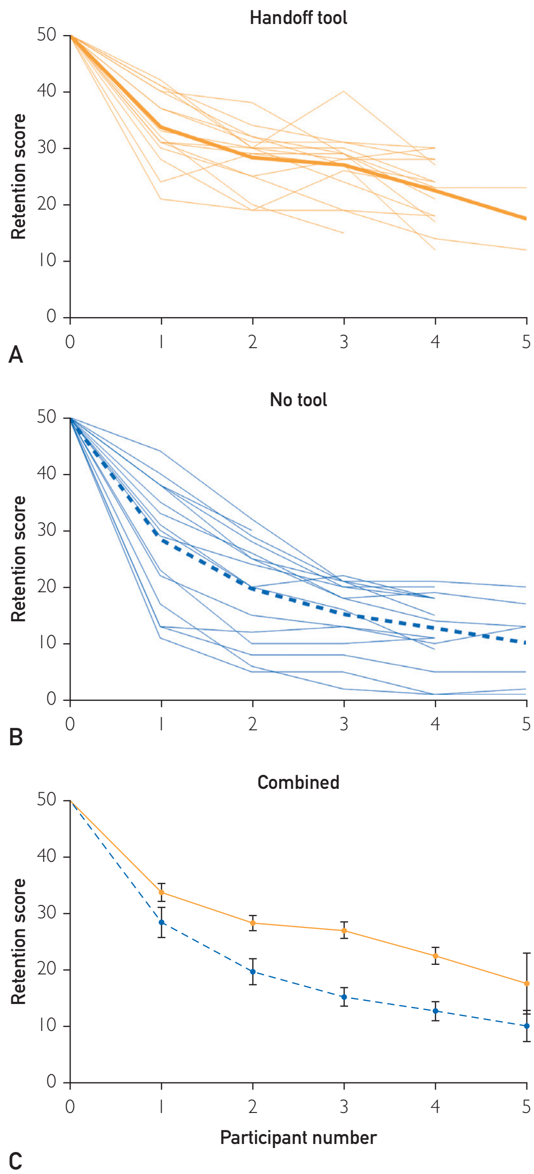

FIGURE 2. Retention scores for each participant in the handoff chain with and without the use of the handoff tool. Retention scores are the sum of 25 responses graded on a scale of 0, 1, or 2 for a potential score of 50. A, Retention scores for each individual handoff chain and mean retention score (solid line) for the group that used the handoff tool. B, Retention scores for each individual handoff chain and mean retention score (dashed line) for the control group. C, The corresponding means with standard errors. Longitudinal marginal modeling revealed differences between the 2 groups ($P<.001$) and found that the variance of retention scores without handoff tool use was approximately double that when the handoff tool was used ($P=.002$). As detailed in the text, 44% of the handoff chains in the control group experience at least 1 retention score below the lowest score of any in the intervention group ($P=.007$) Note that in several examples, the retention score actually increased in the handoff tool group (A).

effect of handoff tools, one-third of which were integrated into the EMR.[21,23] Randomized controlled trials targeted at improving handoffs increase clinician satisfaction, but it has been difficult to report an impact on patient outcomes.[24–27] Although observational studies link ineffective handoffs to increased morbidity and mortality,[7,10–12] they do not account for the correspondence between the number of handoffs and longer surgical time, which are typically associated with more complex procedures and patients. By using simulation to evaluate handoffs for a fixed complex clinical scenario, we reported an increase in the transfer of relevant clinical information and a reduction in the variability of information transferred. Thus, potentially catastrophic losses of clinical information in complex cases could be prevented with a handoff tool.

Simulation has been used to evaluate handoffs by third-year medical students[28] and in pediatrics.[29] We observed an even greater deterioration in information retention than reported in those studies, possibly because our clinical scenario was more complex. Clinical trials have shown that use of checklists for transitions between operating room and intensive care unit[30] and between operating room and post-anesthesia care unit,[31] result in a greater number of items transferred that are deemed "must" and "should" be handed over, further reporting that essential clinical information may not be adequately conveyed without a formalized tool or process. By simulating multiple handoff chains for a standardized complex clinical scenario, we were able to quantify the amount of clinical information lost during handoffs, and the extent that a handoff tool could limit this loss. Moreover, this methodology provides the means to test and refine newer handoff tools, and may be valuable to medical educators in the training and evaluating the handoff process.[16–18] It is likely that improved patient safety will follow more rigorous training and competency evaluation of the handoff processes.[32]

As already emphasized, transfers of care are inevitable, particularly at large training centers. Concern that fatigue has a measurable detrimental effect on both patient care and clinician wellness has resulted in duty-hour

 Mayo Clin Proc Inn Qual Out ■ February 2023;7(1):9-19 ■ https://doi.org/10.1016/j.mayocpiqo.2022.11.001
www.mcpiqojournal.org

limitations for trainees overall. Consequently, anesthesiology increasingly requires one or more complete intraoperative handoffs for long cases or those extending into the evening.[19,33,34] Nonetheless, working hours may also have an inflection point, before which handoffs are likely harmful, and after which handoffs are likely beneficial by introducing rested clinicians.[7] Regardless, handoffs should intend to minimize potentially catastrophic information loss.

As exemplified by use of a handoff tool, one method for minimizing clinical information loss is use of a cognitive aid to filter the vast amount of patient data generated in the perioperative environment. Such tools decrease cognitive load by supporting working memory,[35,36] which can hold 2−9 independent information elements concurrently.[37] From this, one can readily see how cognitive load can exceed working memory capacity and lead to communication failure in complex cases, particularly in the face of stress and fatigue.[38] Our results highlight the advantage of using a cognitive aid for a complex case although the handoff tool included a great deal of data, which may have masked critical information. Conversely, the oral tradition likely included less extraneous data because the clinician extracted relevant details from memory. The oral tradition however, as shown in the current study, almost certainly led to the loss of critical information in many of the handoff chains.

One limit to the current study is that measurement of information lost and preserved is only an approximation. Information theory[39−41] posits that the self-information of an event, clinical or otherwise, is inversely related to the probability of that event occurring. Therefore, it is unlikely that the true information value of each question was perfectly reflected in our scoring system. More broadly, such considerations emphasize the need for some formalized handoff process as well as the difficulties in devising one. The choice of what to convey about a given case and how that is received will depend highly on the particulars of the case as well as the individual knowledge and experience of both participants, because what is rare and unexpected to one participant may be familiar and foreseen to another. A practical handoff tool would seek a necessarily imperfect balance.

Apart from the quantification of information, this study has several additional limitations. Although we addressed intraoperative complete transfers of anesthesia care by resident trainees, we did not study other types of handoffs in health care, or those by other clinicians. However, no aspect of the methodology reported here would preclude its adaptation to other handoff scenarios that are pervasive in health care. Participants had varying experience levels, and we did not provide handoff training with or without the tool. We also did not independently quantify participant's proficiency in performing handoffs overall or their familiarity with specific handoff tools. Certainly, the utility of cognitive aids may be limited if introduced without adequate familiarization and training.[42] Moreover, the simulation was performed in a controlled environment that did not reflect distractions that typically complicate clinical care, and may have removed time pressure that typically accompanies shift endings. Similarly, the sequential handoffs occurred without intervening clinical care or progression of the case for the purpose of using a standard set of retention questions. Although these features of simulation are not reflective of clinical practice, they would likely bias the actual results toward more complete transfers of clinical information. Participant awareness that we were evaluating 2 different handoff methods may have introduced bias toward greater effort with a method they perceived to be better. Although all first participants in the chain were given identical materials in advance, the time and effort they spent absorbing that information was not controlled for, perhaps reflecting variation in individual practice in the clinical environment. Our control group handed off solely on the basis of memory, without benefit of notes or outside cognitive aids, possibly biasing their results in a negative direction. Although national regulatory bodies have advocated using a standardized handoff system enhanced by the EMR for over a decade, recent evidence indicates that implementation and adherence is inconsistent,[16,17] and experience indicates that many clinicians still handoff from memory. Faculty proctors were involved in the study design or familiar

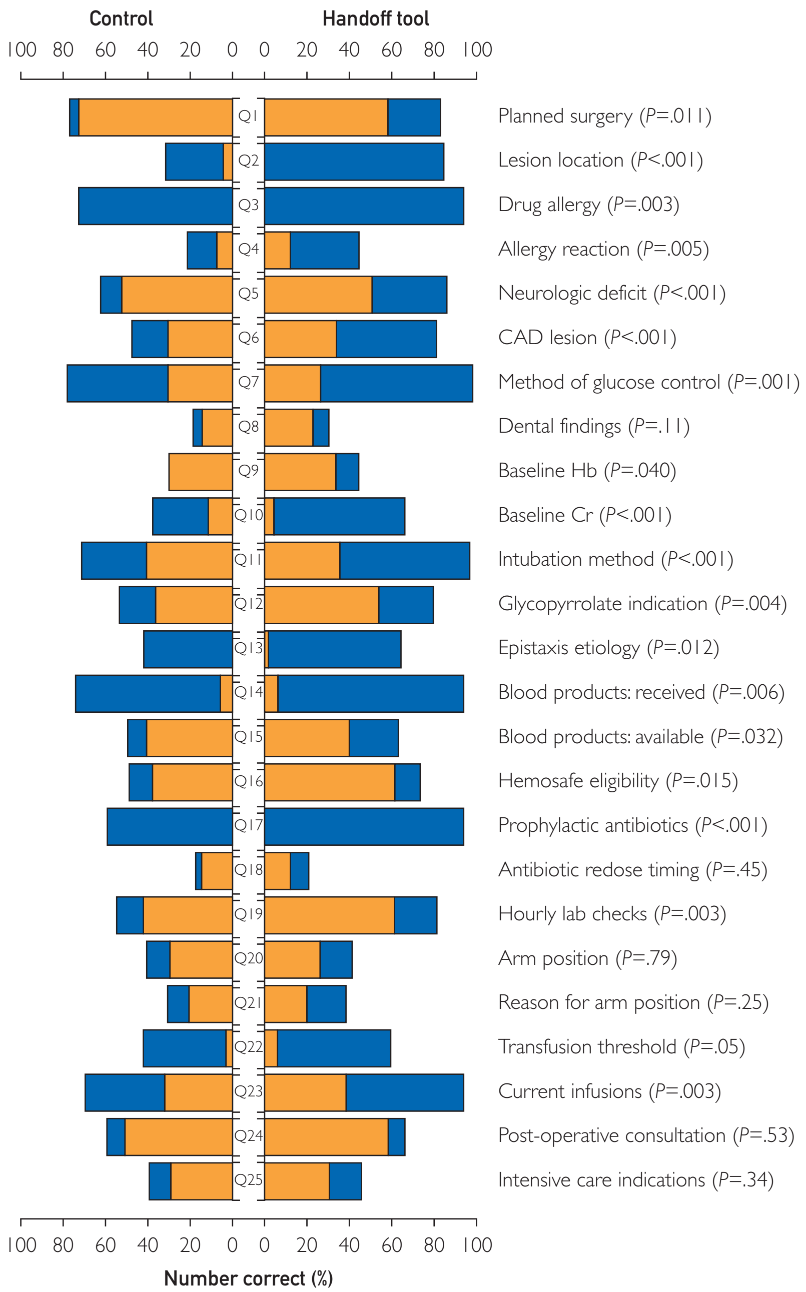

FIGURE 3. Distribution of all scores for each of the 25 individual questions whose sum is the retention score depicted in Figure 2. For each question, the percent of all participants in each group who scored 1 (light gray) or 2 (medium gray) is shown. The concept associated with each potential response is given to the right of each bar. The significance of differences between those who used the handoff tool and those who did not was determined for each question by ordered logistic regression, with the corresponding *P* values are given at the right of each concept. CAD, coronary artery disease; Hb, hemoglobin; Cr, creatinine.

Mayo Clin Proc Inn Qual Out ■ February 2023;7(1):9-19 ■ https://doi.org/10.1016/j.mayocpiqo.2022.11.001
www.mcpiqojournal.org

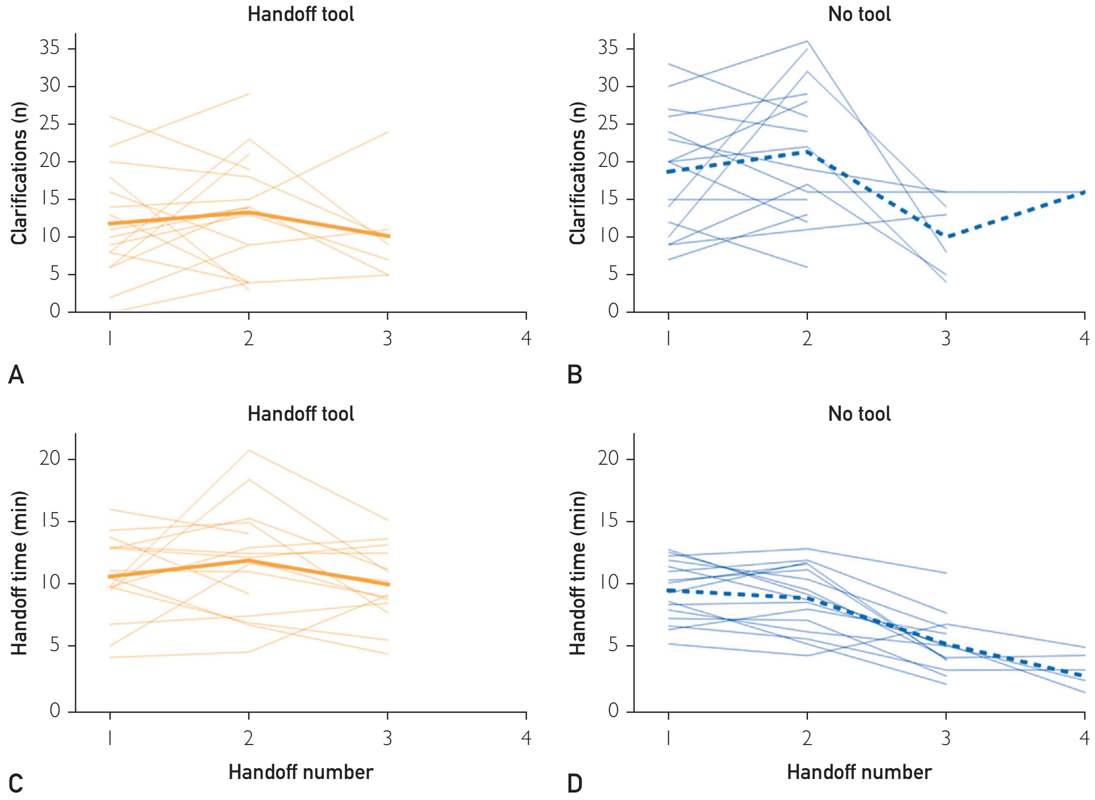

FIGURE 4. The number of clarifications requested and duration of the handoff process for each handoff. (A, B) Fewer clarification questions were asked in handoffs that used the tool (A) than in handoffs with no tool (B, *P*=.003), as revealed by longitudinal multilevel analysis appropriate for counts. (C, D) The time expended by participants in the handoff process was greater for those using the handoff tool (C) than for those who did not use the tool (D, *P*<.001) as revealed by longitudinal multilevel analysis. In contrast to participants using the handoff tool, the duration of the handoff process declined with successive handoffs for participants who did not have the handoff tool (*P*=.002).

with the case before the study date, which may have introduced bias in their recording of responses in the final handoff. Finally, because we embedded information elements within a large data set of a simulated case, we can only speculate whether successful conveyance of these elements would be essential to prevent patient harm.

In conclusion, sequential handoffs lead to substantial, perhaps inevitable, degradation of clinical information that is somewhat ameliorated by use of a handoff tool. However, the major clinical benefit of such a tool may be to reduce variability in information transfer and limit the most deleterious losses of clinical information. We anticipate the methods described here will be of value to those wishing to evaluate and compare various handoff methods in a controlled environment and to educators involved in the training and evaluation of learners in a variety of clinical fields.

POTENTIAL COMPETING INTERESTS

The authors report no competing interests.

SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mcpiqojournal.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbreviations and Acronyms: **EMR**, electronic medical record; **MCQ**, multiple-choice question

Grant Support: Support was provided solely from institutional and/or departmental sources.

Correspondence: Address to Adam Schiavi, PhD, MD, Department of Anesthesiology and Critical Care Medicine, 600 N. Wolfe Street, Phipps 455, Baltimore, MD 21287 (aschiav1@jhmi.edu).

ORCID

Adam Schiavi: https://orcid.org/0000-0001-6351-7419; Bommy Hong Mershon: https://orcid.org/0000-0003-3057-2635; Allan Gottschalk: https://orcid.org/0000-0003-0471-728X

REFERENCES

1. Starfield B. Is US health really the best in the world? *JAMA*. 2000;284(4):483-485.
2. James JT. A new, evidence-based estimate of patient harms associated with hospital care. *J Patient Saf*. 2013;9(3):122-128.
3. Institute of Medicine (US). *Committee on Quality of Health Care in America. Crossing the Quality Chasm: A New Health System for the 21st Century*. Washington (DC): National Academies Press; 2001.
4. Commission TJ. *Joint Commission Center for Transforming Healthcare Releases Targeted Solutions Tool for Hand-Off Communications*. Joint Commission on Accreditation of Helathcare Organizations. 2012: https://www.jointcommission.org/assets/1/6/tst_hoc_persp_08_12.pdf. Accessed April 18, 2019.
5. Schulz CM, Burden A, Posner KL, et al. Frequency and type of situational awareness errors contributing to death and brain damage: A closed claims analysis. *Anesthesiology*. 2017;127(2):326-337.
6. Vidyarthi A. Triple handoff. AHRQ Web M&M. https://psnet.ahrq.gov/webmm/case/134. Accessed April 18. 2019. Published 2006.
7. Jones PM, Cherry RA, Allen BN, et al. Association between handover of anesthesia care and adverse postoperative outcomes among patients undergoing major surgery. *JAMA*. 2018;319(2):143-153.
8. Riesenberg LA. Shift-to-shift handoff research: Where do we go from here? *J Grad Med Educ*. 2012;4(1):4-8.
9. Steiner CA, Karaca Z, Moore BJ, Imshaug eC, Pickens B. Surgeries in hospital-based ambulatory surgery and hospital inpatient settings. 2014. https://www.hcup-us.ahrq.gov/reports/statbriefs/sb223-Ambulatory-Inpatient-Surgeries-2014.pdf. Accessed April 18, 2019. Published 2018.
10. Hyder JA, Bohman JK, Kor DJ, et al. Anesthesia care transitions and risk of postoperative complications. *Anesth Analg*. 2016;122(1):134-144.
11. Saager L, Hesler BD, You J, et al. Intraoperative transitions of anesthesia care and postoperative adverse outcomes. *Anesthesiology*. 2014;121(4):695-706.
12. Hudson CC, McDonald B, Hudson JK, 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.
13. 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.
14. Mattei TA, Ordookhanian C, Kaloostian PE. Dear anesthesiologist, please don't abandon us": Excessive anesthesia handovers and adverse perioperative outcomes in neurosurgery. *World Neurosurg*. 2018;115:254-256.
15. Commission TJ. The Joint Commission 2009 Requirements Related to the Provision of Culturally Competent Patient-Centered Care Hospital Accreditation Program (HAP). Published 2009. Accessed April 18, 2019.
16. Wagner R, Koh N, Bagian J, Weiss K. CLER 2016 National Report of Findings, Issue Brief #5: Care Transitions. Chicago, IL: Accreditation Council for Graduate Medical Education; 2016. 13: 978-1-945365-10-2.
17. Co J, Wieiss K, Koh N, Wagner R. *CLER National Report of Findings 2018: Executive Summary*. Accreditation Council for Graduate Medical Education; 2018. https://www.acgme.org/Portals/0/PDFs/CLER/CLER_2018_Executive_Summary_DIGITAL_081418.pdf. Accessed May 15, 2019.
18. Quality AfHRa. Survey on Patient Saftey Culture (SOPS) Hospital 1.0 Survey: 2021 User Database Report. https://www.ahrq.gov/sops/databases/hospital/index.html. Published 2021.
19. Starmer AJ, Spector ND, Srivastava R, et al. Changes in medical errors after implementation of a handoff program. *N Engl J Med*. 2014;371(19):1803-1812.
20. Webster KLW, Keebler JR, Lazzara EH, Chaparro A, Greilich P, Fagerlund A. Handoffs and teamwork: a framework for care transition communication. *Jt Comm J Qual Patient Saf*. 2022;48(6-7):343-353.
21. 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.
22. Agarwala AV, Firth PG, Albrecht MA, Warren L, Musch G. An electronic checklist improves transfer and retention of critical information at intraoperative handoff of care. *Anesth Analg*. 2015;120(1):96-104.
23. Barbeito A, Agarwala AV, Lorinc A. Handovers in perioperative care. *Anesthesiol Clin*. 2018;36(1):87-98.
24. Lee SH, Terndrup C, Phan PH, et al. A randomized cohort controlled trial to compare intern sign-out training interventions. *J Hosp Med*. 2017;12(12):979-983.
25. Nanchal R, Aebly B, Graves G, et al. Controlled trial to improve resident sign-out in a medical intensive care unit. *BMJ Qual Saf*. 2017;26(12):987-992.
26. Kashiouris MG, Stefanou C, Sharma D, et al. A handoffs software led to fewer errors of omission and better provider satisfaction: A randomized control trial. *J Patient Saf*. 2020;16(3):194-198.
27. Parent B, LaGrone LN, Albirair MT, et al. Effect of standardized handoff curriculum on improved clinician preparedness in the intensive care unit: A stepped-wedge cluster randomized clinical trial. *JAMA Surg*. 2018;153(5):464-470.
28. Jensen AM, Sanders C, Doty J, Higbee D, Rawlings AL. Characterizing information decay in patient handoffs. *J Surg Educ*. 2014;71(4):480-485.
29. Lazzara EH, Riss R, Patzer B, et al. Directly comparing handoff protocols for pediatric hospitalists. *Hosp Pediatr*. 2016;6(12):722-729.
30. Salzwedel C, Mai V, Punke MA, Kluge S, Reuter DA. The effect of a checklist on the quality of patient handover from the operating room to the intensive care unit: A randomized controlled trial. *J Crit Care*. 2016;32:170-174.
31. Salzwedel C, Bartz HJ, Kuhnelt I, et al. The effect of a checklist on the quality of post-anaesthesia patient handover: a randomized controlled trial. *Int J Qual Health Care*. 2013;25(2):176-181.
32. Davis J, Roach C, Elliott C, Mardis M, Justice EM, Riesenberg LA. Feedback and assessment tools for handoffs: A systematic review. *J Grad Med Educ*. 2017;9(1):18-32.
33. Gaba DM, Howard SK. Patient safety: Fatigue among clinicians and the safety of patients. *N Engl J Med*. 2002;347(16):1249-1255.

34. DeRienzo CM, Frush K, Barfield ME, et al. Handoffs in the era of duty hours reform: A focused review and strategy to address changes in the Accreditation Council for Graduate Medical Education Common Program Requirements. *Acad Med*. 2012;87(4):403-410.
35. Little JJ. Cognitive load theory and library research guides. *Inter Ref Services Quarterly*. 2010;15(1):53-63.
36. van Merrienboer JJ, Sweller J. Cognitive load theory in health professional education: Design principles and strategies. *Med Educ*. 2010;44(1):85-93.
37. Young JQ, Wachter RM, Ten Cate O, O'Sullivan PS, Irby DM. Advancing the next generation of handover research and practice with cognitive load theory. *BMJ Qual Saf*. 2016; 25(2):66-70.
38. Lingard L, Espin S, Whyte S, et al. Communication failures in the operating room: An observational classification of recurrent types and effects. *Qual Saf Health Care*. 2004;13(5):330-334.
39. Gallager RG. *Information Theory and Reliable Communication*. New York: John Wiley & Sons; 1968.
40. Shannon CE. A mathematical theory of communication—Part I. *Bell System Techn J*. 1948;27:379-423.
41. Shannon CE. A mathematical theory of communication—Part II. *Bell System Techn J*. 1948;27:623-656.
42. Goldhaber-Fiebert SN, Howard SK. Implementing emergency manuals: Can cognitive aids help translate best practices for patient care during acute events? *Anesth Analg*. 2013;117(5): 1149-1161.