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Barriers to efficiency in robotic surgery: the resident effect

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ABSTRACT

Background: Robotic surgery offers advantages over conventional operative approaches but may also be associated with higher costs and additional risks. Analyzing surgical flow disruptions (FDs), defined as "deviations from the natural progression of an operation," can help target training techniques and identify opportunities for improvement.

Materials and methods: Thirty-two robotic surgery operations were observed over a 6-wk period at one 900-bed surgical center. FDs were recorded in detail and classified into one of 11 different categories. Procedure type, robot model, and resident involvement were also recorded. Linear regression analyses were used to evaluate the effects of these parameters on FDs and operative duration.

Results: Twenty-one prostatectomies, eight sacrocolpopexies, and three nephrectomies were observed. The mean number of FDs was 48.2 (95% confidence interval [CI] 38.6-54.8 FDs), and mean operative duration was 163 min (95% CI 148-179 min). Each FD added 2.4 min ($P = 0.025$) to a case's total operative duration. The number and rate of FDs were significantly affected by resident involvement ($P = 0.008$ and $P = 0.006$, respectively). Resident cases demonstrated mostly training, equipment, and robot switch FDs, whereas nonresident cases demonstrated mostly equipment, instrument changes, and external factor FDs.

Conclusions: Although the FDs encountered in resident training are more frequent, they may not significantly increase operative duration. Other FDs, such as equipment or external factors, may be more impactful. Limiting these specific FDs should be the focus of performance improvement efforts.

Introduction

As the health care system becomes increasingly more complex, the opportunities for errors in patient care also accumulate.[1] Current evidence suggests that organizational complexity, reliance on high-technology equipment, and the lack of systematic communication are the foremost factors that affect the rates of unintentional patient harm in the

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United States.[1,2] The operating room, a unique health care environment at the intersection of all the aforementioned factors, is exceptionally prone to errors in care and patient harm, with 47.7%-50.3% of all inhospital adverse events occurring in the operating room.[3]

The introduction of robotic surgery has changed the delivery of surgical care in the last decade.[4] By providing improved articulation, added magnification, and three-dimensional imagery, robotic surgery has provided surgical tools that, in some fields, have replaced traditional open and laparoscopic techniques. Although this increased sophistication may offer some advantages over conventional operative approaches, it is a significantly more complex system associated with higher costs, additional risks, and new challenges.[5] In addition to requiring the development of new psychomotor and hand–eye coordination skills, these activities also require distinct approaches to communication, teamwork, and the overall surgical process. Despite the use of highly trained, experienced operating room personnel, errors are multifactorial in origin, related to both the machines themselves and the machine–human interface.[4,6] Although not all errors lead to adverse events, observational studies have demonstrated that the accumulation of "minor" events predisposes to "major" events that have the potential for serious patient harm. This is potentially due to the fact that minor events decrease the team's capacity to deal with unexpected major events.[6-8] Understanding the distinct processes related to robotic surgery enables the development of training and standard practices that can increase patient safety, improve efficiency, and reduce costs.[6]

"Human factors" is the study of the relationship between people and systems. It can provide insights into the optimization of tasks, technology, environment, training, teamwork, and organization to provide safe and efficient care.[9-11] New technologies require new competencies related to technical skills, knowledge, teamwork, communication, training, and problem resolution. Although simulation and training programs aim to reduce some of these challenges, they frequently do not capture the more complex aspects of care such as teamwork and communication, equipment reliability, or surgeon decision-making. Previous studies in cardiac, orthopedic, vascular, trauma, and general laparoscopic surgery have successfully used direct observation to understand and address these often "hidden" everyday challenges that reduce efficiency and safety.[9-19]

Surgical flow disruptions (FDs) are defined as "deviations from the natural progression of an operation" and can diagnose system weaknesses in teamwork, equipment, distractions, training, and resource availability.[11] Examples of FDs include when the attending surgeon, resident, or operating room staff cannot hear each other and have to repeat communications; the staff fails to retrieve a suture, instrument, or piece of equipment in a timely manner; or the attending surgeon stops operating to provide instruction to residents or staff. FDs have been empirically associated with surgical errors, adverse events, and inefficiency.[6,11,20,21] Understanding the etiology of FDs in robotic surgery will help to target training techniques and identify opportunities for improvement.

In this study, by observing robotic surgery cases, we sought to explore the deviations from the optimal progression of robotic operations. We investigated the effects of FDs, resident involvement, and other contextual parameters on operative duration and explored the number and types of FDs with and without residents. Our first hypothesis was that the total number of FDs in robotic surgery cases would be affected by the presence of residents and the phase of the operation. Here, we leveraged the unique environment of our academic medical center with a mix of teaching and private (nonteaching) faculty. Our second hypothesis was that surgeon console time would be affected by procedure type, resident involvement, and the number of FDs. Overall, we aimed to identify barriers to efficiency and safety that could be overcome to deliver higher quality, more cost-effective care.

Materials and methods

We performed a prospective observational study of robotic surgery operations at one 900-bed tertiary care medical center, at which approximately 500 robotic surgery operations are conducted per year (50% urology, 25% gynecology, 15% cardiac surgery, and 10% general surgery). An opportunity sample of robotic surgery operations was observed over a 6-wk period. This protocol was approved by the institutional review board within the hospital at which this study was performed (Pro00028833). A waiver of informed consent was granted by the institutional review board provided that patient identifiers, patient demographic information, surgical outcomes, and operating room physician and staff identifiers were not collected.

The methodology for systematically categorizing and measuring surgical FDs used in this study has been previously developed and validated by Human Factors experts.[11,21] Specifically, an experienced Human Factors researcher trained two medical student researchers in the theory of Human Factors and in the observation of FDs. The researchers were also trained to understand the basic steps for each type of operation to be observed and were familiarized with the surgical subspecialties, the operating room environment, and the operation of the robot by an expert robotic surgeon. The surgical teams were informed that researchers would be observing the cases to understand surgical processes and were instructed not to interact with the researchers to reduce bias. In addition, intraobserver bias was minimized through the use of a standard data collection and classification method, practice, cross-observer comparisons, mutual and expert support, and ongoing feedback and discussion during training. The first 10 robotic surgery cases observed were used to train the researchers and were eliminated from the final data analysis. Interclass correlation was calculated to ensure inter-rater reliability.

Robotic surgery operations performed on the Da Vinci S and Si model robots were directly observed from the time the patient entered the operating room to the time the patient left the operating room. The researchers recorded each occurrence that appeared to disrupt the natural progression of the operation, as defined in prior studies[6,11,20] and made notes on each of these FDs. In addition, the operative duration was divided into four phases: Phase 1: Prerobot—patient entry into the operating room to abdominal insufflation; Phase 2: Robot docking—abdominal insufflation to surgeon on robot console;