Realistic Distractions and Interruptions Impair Simulated Surgical Performance by Novice Surgeons

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Abstract

Hypothesis: Although the risks for operating room distractions and interruptions (ORDIs) are acknowledged, most research on this topic is unrealistic, inconclusive, or methodologically unsound. We hypothesized that realistic ORDIs induce errors in a simulated surgical procedure performed by novice surgeons.

Design, Setting, and Participants: Eighteen second-year, third-year and research-year surgical residents completed a within-subjects experiment on a laparoscopic virtual reality simulator. Based on 9 months of operating room observations, 4 distractions and 2 interruptions were designed and timed to occur during critical stages in simulated laparoscopic cholecystectomy. The control factor was the absence or presence of ORDIs, with order randomly counterbalanced across the subjects.

Main Outcome Measures: The primary outcome measure was surgical errors measured by the simulator as damage to arteries, bile duct, or other organs. The second outcome measure was whether the participants remembered a prospective memory task assigned prior to the procedure and important to operative conduct.

Results: Major surgical errors were committed in 8 of 18 simulated procedures (44%) with ORDIs versus only 1 of 18 (6%) without ORDIs ($P = 0.02$). Interrupting questions caused the most errors. Sidebar conversations were the next most likely distraction to lead to errors. Ten of 18 participants (56%) forgot the prospective memory task with ORDIs, while 4 of 18 (22%) forgot the task without ORDIs ($P = 0.04$). All 8 surgical errors with ORDIs occurred after 1 PM ($P = 0.001$).

Conclusions: Typical ORDIs have the potential to cause operative errors in surgical trainees. This performance deficit was prevalent in the afternoon.

Introduction

Distractions and interruptions are common in a surgical operating room (OR) occurring as often as every 3 minutes.[1-3] Owing to human fallibilities, distractions and interruptions increase the likelihood of human errors by diverting the attention of the operator from the task at hand or by causing lapses in memory.[4-7] Operating room distractions and interruptions (ORDIs) are occasions when the attention of one of the OR team members is drawn from a more important or urgent task to one that is less important or not urgent, perhaps not even relevant to the surgical procedure.

Although the risks of ORDIs are acknowledged, relatively little is understood with respect to the human errors that ORDIs may induce and the potential adverse effects on patient outcomes. Outside of the OR, a healthcare study on pharmaceutical prescription dispensing found an increase in error rates associated with distractions and interruptions.[8] In an aviation study, distractions were involved in almost two-thirds of flight crew error reports reviewed by the National Aeronautics and Space Administration.[9] While recent studies have suggested that ORDIs increase human error rates, these laboratory studies have either used atypical distractions (eg, mental arithmetic problem solving)[10,11] or confounded realistic distractions with other degraded conditions (eg, non-optimal laparoscopic camera view).[12] Consequently, the objective of this study was to determine whether typical or realistic ORDIs have a negative impact on surgical task outcomes without confounding the study with other factors. Based on human factors research, the hypothesis was that realistic distractions and interruptions in a simulated laparoscopic operation increased the frequency of errors made by surgeons in training.

Methods

Setting

Out of concern for patient safety in the OR, this study was confined to a simulation laboratory setting. An advanced virtual reality surgical simulator called LapVR (Immersion) was used to perform a laparoscopic cholecystectomy. LapVR has face validity in terms of physically manipulating laparoscopic surgical instruments to alter simulated patient's anatomy shown on a flat panel display. Additionally, LapVR has been shown to have construct validity in terms of discriminating between novice and experienced laparoscopic surgeons.[13] LapVR was located in the VirtuOHSU laboratory at Oregon Health & Science University in Portland, Oregon. The setting was advantageous in minimizing noise from outside the laboratory as well as providing a controlled area to exclude uncontrolled distractions, such as extraneous people entering the laboratory.

The study was approved by the institutional review boards at both Oregon Health & Science University and Oregon State University for this jointly conducted research. The study was conducted from June 24, 2009 through March 31, 2010.

Design and Measures of Outcome

A within-subjects experiment was conducted in a laboratory setting with the participants performing a simulated laparoscopic cholecystectomy. The control factor was the presence or absence of ORDIs. The primary measure of outcome was the presence of major surgical errors.

For this study, major surgical errors were measured objectively by the surgical simulator as damage to the internal organs, ducts and arteries. These errors were significant and could lead to patient fatalities. In addition, a prospective memory task was prespecified prior to the experiment. The participant was requested to announce that the procedure was approximately three-fourths complete as the gallbladder was separated from the liver. This announcement of operative progress was comparable to advance notice to the anesthetist prior to closure. The outcome measure for remembering the prospective memory task was binary in terms of whether the announcement was made, as detected and recorded by the observer.

The participants were informed prior to the experiment: "The purpose of this research study is to assess surgical task performance and decision-making in an operating room environment." Additionally the participants were told: "During the simulated procedures, you may be asked questions by the observer which you should answer to the best of your capabilities." The subjects were not informed that the study was testing distractibility.

Each participant performed a simulated laparoscopic cholecystectomy under both nondistracted/uninterrupted and distracted/interrupted conditions. The sequential order of the nondistracted/uninterrupted condition was randomly counterbalanced with the distracted/interrupted condition to remove order as a confounding factor.

Realistic ORDIs were based on 9 months of OR observations conducted prior to the experiment. Four distractions intended to catch the attention of the participants were: (1) an unexpected reaching movement by the observer adjacent to the flat panel display and within the participant's field of view, (2) a ringing cell phone answered by the observer, (3) an unrelated side conversation about a hypothetical political situation between the observer and another person who entered the laboratory when discreetly summoned, and (4) the noise from a dropped metal tray. Two interruptions that prompted the participant to take action were: (1) a question to the participant about how to treat a previous surgical patient in the recovery room who was having breathing difficulties, and (2) a question unrelated to the surgical procedure asking why the participant chose this profession. The ORDIs were all initiated by the observer with the timing of the ORDIs occurring at critical decision points during the simulated surgical procedure.

Nonparametric statistical analysis techniques were applied with a 5% level of significance to determine significant differences for a change in the controlled factor.

Participants

Participants were recruited from among novice surgeons in their second, third, and research years (RYs) of residency in general surgery at Oregon Health & Science University. Residents in their RY are clinically equivalent to third-year residents. A total of 18 participants (9 second-year residents, 6 third-year residents, and 3 RY residents) volunteered for and completed this study.

The age of the participants ranged from 27 to 35 years. There were 5 women (2 second-year, 2 third-year, and 2 RY residents) and 13 men (8 second-year, 4 third-year, and 1 RY residents). All residents recruited were proficient in the laparoscopic surgical skills based on experience in an OR. Only 2 of the recruited residents had experience with LapVR, albeit not

with the laparoscopic cholecystectomy module used in this study, and none of the residents had more than an hour of experience with LapVR. The participants were shown a video illustrating a simulated laparoscopic cholecystectomy on LapVR and then completed a practice simulated procedure with LapVR prior to the 2 controlled cases with and without ORDIs.

Results

The primary outcome measure of interest was the frequency of major surgical errors with ORDIs as compared with no distractions or interruptions. Eight of 18 participants committed major surgical errors when distracted and interrupted (44% failure rate) versus only 1 of 18 participants (6% failure rate) when not distracted or interrupted. This increase in surgical error rates with ORDIs for the novice surgeons was statistically significant ($P = 0.02$). The surgical errors were committed by 3 third-year residents, 3 third-year residents, and 2 RY residents.

The Table summarizes the number of times each controlled ORDI was associated with major surgical errors. As indicated in the Table, 10 surgical errors were committed by 8 participants. The discrepancy between the number of errors and number of participants resulted from 2 participants committing 2 errors. As also shown in the Table, the interruption associated with the highest number of major errors was the question about appropriate treatment for the patient in the recovery room. This question was linked to 4 surgical errors, temporally. The distraction associated with the second most major errors was the side communication about a political issue and was linked to 3 surgical errors.

For the second outcome measure, 10 of 18 participants (56%) forgot the prospective memory task to announce near completion of the procedure when distracted/interrupted, while just 4 of 18 (22%) forgot in the nondistracted/uninterrupted condition. This difference was statistically significant ($P = 0.04$). Remembering the prospective memory task was required toward the end of the surgical procedure, when the interrupting question about the choice of profession was coupled with the dropped metal tray. Under distracted conditions, 6 of 8 participants who committed major surgical errors also forgot the prospective memory task. The single participant, who made a major surgical error while not distracted, remembered the prospective memory task.

Post hoc analysis of the results produced an interesting finding with respect to the time of day that the experiment was conducted for each experiment. Figure 1 graphs for each participant when the paired outcomes with and without ORDIs occurred based on the time of day. The nondistracted and distracted conditions were conducted back-to-back for each participant, with the order randomly counterbalanced for all trials, so that these paired outcomes occurred at approximately the same time in the day. In Figure 1, success indicates no errors, and failure indicates at least 1 surgical error in the simulated procedure. As readily apparent, all 8 surgical errors with ORDIs occurred after 1 PM. This dependency on time of day was statistically significant ($P = 0.001$). In addition to the time of day effect, the errors based on time on duty (i.e., the elapsed time between the start of duty and the time of the experiment for that day) were analyzed for each experiment trial with the results graphed in Figure 2. This figure has less pronounced dependency about when the failures occurred based on time on duty, and post-hoc analysis indicates the dependency with respect to time on duty was not significant ($P = 0.15$).

Post hoc analysis was also performed on the following self-reported data regarding fatigue level of the participants: (1) number of consecutive day on duty prior to day of experiment, (2) number of days since the participant's last 24-hour on-call duty, and (3) number of hours of sleep during the night prior to the day of the experiment. There were no significant effects for these fatigue measures versus major surgical errors in the presence of ORDIs. Similarly, there was no significant effect for sequential order of controlled factor as to whether the distracted condition occurred first or second during the experiment trials.

Comment

This study provided statistically significant evidence to support the hypothesis that realistic ORDIs increase the likelihood of errors in a simulated laboratory setting with novice surgeons. Under controlled ORDI conditions, almost half of the novice surgeons (44%) committed major surgical errors in the simulated surgical procedure, while only 6% of the novice surgeons committed surgical errors in the nondistracted and uninterrupted conditions. This finding is important because it implies that ORDIs may lead to adverse patient outcomes. The 2 interrupting questions, concerning how to treat a patient in the recovery room and why the surgeon chose this profession, were associated with 4 and 2 surgical errors, respectively. Thus, the 2 interruptions were associated with most of the 10 surgical errors committed with ORDIs. Of the 4 different distractions, the unrelated side conversation had the highest total with 3 surgical errors.

Similarly, more than half of the participants (56%) forgot the prospective memory task important to operative conduct with ORDIs versus approximately one-fifth (22%) forgetting in nondistracted/uninterrupted conditions. This statistically significant finding may have implications regarding patient safety in the event that a patient has a unique condition, which needs to be remembered at a certain point in the surgical procedure to be treated properly.

There may be a correlation between making a major surgical error and subsequently forgetting the prospective memory task since 6 of 8 participants who made major surgical errors with ORDIs also forgot the prospective memory task. If real, this correlation may be owing to the participant dealing with the collateral damage when a major surgical error occurred. This additional task to resolve collateral damage may have increased the cognitive load on working memory and, as a result, may have led to forgetting the prospective memory task. However, not enough data were collected in this study to analyze whether this potential correlation was significant.

One of the most striking post hoc findings of this study was the prevalence of errors that occurred when distracted and interrupted after 1 PM. This time of day effect is particularly noteworthy in that while the participants committed the surgical errors with ORDIs, the same participant did not commit a surgical error when not distracted or interrupted in the same timeframe. This suggests the participants had enough cognitive resources to perform the simulated surgical procedure when not distracted or interrupted, but not enough cognitive resources to simultaneously deal with ORDIs. It is as if the ORDIs put them over the edge after 1 PM. One possible reason for this time of day effect was fatigue, as suggested in research that indicates fatigued task performers are less resistant to the adverse effects of distractions and interruptions.[14] Because time on duty and other self-assessed measures of fatigue failed to show

significant effects, this time of day dependency, if reproducible, indicated there may have been another unknown factor associated with time of day. Potential factors may include diurnal variations in blood concentrations of various nutrients and hormones, when and if lunch was eaten, or timing of last consumption of a cup of coffee or energy drink. This is an opportunity for research to determine whether this time of day effect is reproducible and, if so, to further investigate potential causes.

The principal limitation of the study was that it did not occur in an OR, as we could not ethically attempt to induce errors in an OR setting. However, the benefit of performing this study with a virtual reality platform is the reproducible ability to define and measure the number of errors committed. In studies of laparoscopic skill acquisition, it has been shown that performance in the skills laboratory transfers tightly to performance in the OR. While we will never be able to purposefully induce errors in a human operating room, we believe that these previous studies of performance transference from virtual reality to OR are relevant.[15-17] Understanding that they were in a simulation laboratory, it is possible that the participants might not have given full concentration to the operative task at hand, especially when interrupted or distracted. However, it is our belief that the participants performed to the best of their abilities resulting from their keen sense of workmanship and pride, as well as the intense competitive spirit of residents when they knew that they are being timed, scored, and compared with their peers.

This study was confined to novice surgeons and may not be generalizable to experienced surgeons subjected to a similar array of ORDIs. Human factors research indicates that experienced task performers are more tolerant to distractions or can better manage interruptions.[18-20] This positive effect owing to increased experience was also supported with respect to surgeons in a distraction-rich OR setting.[11] Thus researching the effects of ORDIs on experienced surgeons is an opportunity for follow-on research with this model.

The primary contribution of this research was the development of a model that can be applied to assess whether mediating the adverse effects of ORDIs (eg, through awareness or team-building training) is effective in improving patient outcomes. In addition, this research confirmed the high level priority set by the Agency for Healthcare Research and Quality to reduce distractions and interruptions in an OR to improve patient safety.[21]

Finally, it is hoped that these results are not taken out of context. While almost half of the simulated surgical procedures had errors when the surgeon was distracted and interrupted, it must be noted that the distractions and interruptions were timed to occur at critical points and occurred more frequently than observed in an OR. Consequently, these results should not be used to infer that almost half of all surgical procedures with distractions and interruptions are expected to have major surgical errors.

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Figures

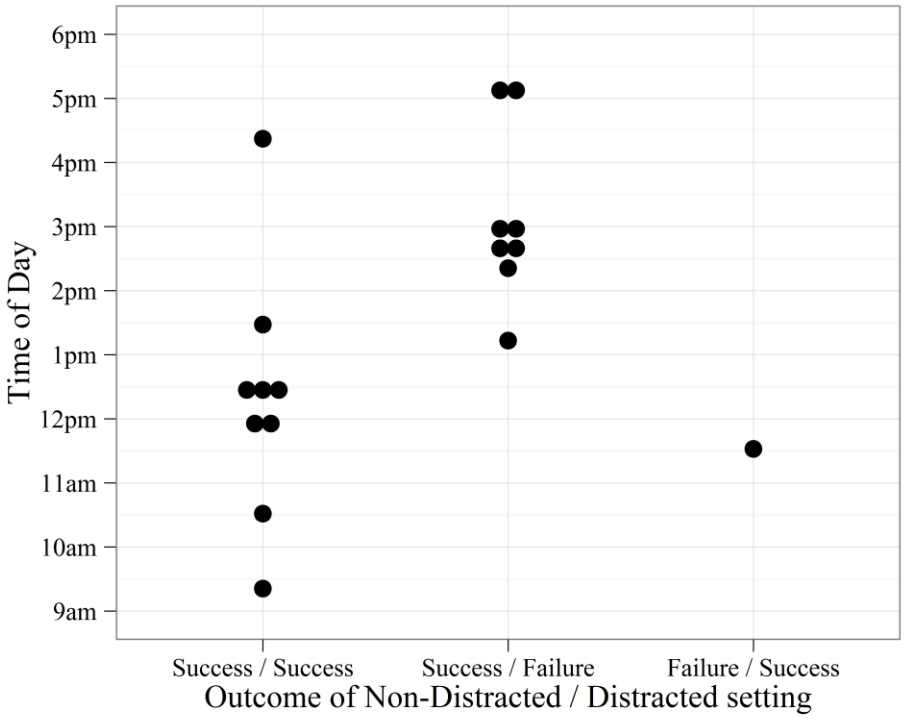

Figure 1 Time of Day Paired Outcomes

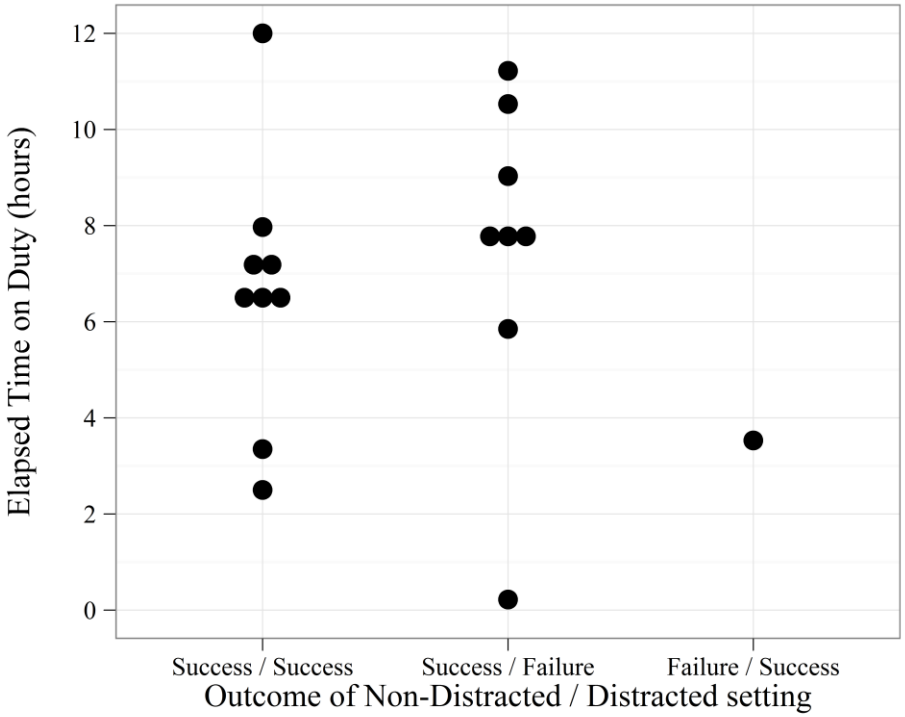

Figure 2 Time on Duty Paired Outcomes

Table

Table. Distractions and Interruptions Associated with Major Surgical Errors

Distractions and Interruptions in Sequential Order	**Surgical Errors, No.**
Observer reaching for an item by the flat panel display within the field of view of the subject	0
Cell phone ringing and answered by observer	1
Question about recovering patient having difficulties from previous surgical case and requiring treatment	4
Person entering room and conducting side conversation with the observer about a political issue	3
Question to surgeon participant about career choice	2
Sound of a small metal tray falling to the floor	0
Total Associations	10

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