Risk Communication during Robot-Assisted Surgery

by

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Abstract

Effective communication between members of the surgical team is essential for a good outcome. Communication between members of this team may be affected by where each member stands in the operating room hierarchy. Breakdowns in communication have previously resulted in poor patient care and, in some cases, patient fatality. These breakdowns are particularly dangerous during exchanges of risk messages. Ten robot-assisted prostatectomies were examined for effective risk communication between surgical staff of varying hierarchical levels and the effect of the risk message on situational awareness. While there was a significant difference in the effect of hierarchical status on when a risk message was delivered ($p < 0.05$), hierarchy did not have a statistically significant impact on the situational awareness ratings. Proactive messages were significantly more effective at increasing situational awareness than reactive messages. While there were significant findings, further insight is needed to determine the impact of risk communication within the operating room.
Introduction

A multitude of medical mishaps have been found to be the result, if only in part, of poor communication between members of the operating room personnel. These failures account for errors or bad outcomes in anywhere from 60% to 91% of reported cases (Sutcliffe, Lewton, & Rosenthal, 2004; Lingard et al., 2004). These poor outcomes and missteps in communication may be a result of the pervasive hierarchical structure present in the operating room.

Many studies have examined the role of this hierarchy in relation to challenging an individual of higher status on an ethical decision (Sydor et al., 2012; Bould et al., 2015). However, there is a lack of insight into this hierarchical structure’s impact on the learning environment. This study seeks to explore how an individuals’ status influences to whom the risk message is communicated, if that message is given proactively or reactively to the start of a potentially risk situation, and whether or not the message increases either the recipient’s or the team’s situational awareness.

Teams

While task complexity increases, an individual’s cognitive capabilities remains stagnant; thus, the need for a team approach the also increases (Cooke, Salas, Cannon-Bowers, & Scott, 2000). A team is defined as “two or more people who interact dynamically, interdependently, and adaptively toward a common valued goal/objective/mission” (Salas, Fiore, Warner, & Letsky, 1992) and are typically organized in a hierarchy (Salas, Cooke, & Rosen, 2008). Interactions between team members may be in person or facilitated through technology (Kozlowski & Ilgen, 2006).
A team is considered to be a heterogeneous unit; that is to say, team members may not all possess exactly the same knowledge but their knowledge should be compatible with each other’s in order to complete a task (Cooke et al., 2000). Thus, team members have different roles and tasks with interdependent workflows, goals, and outcomes (Kozlowski & Ilgen, 2006).

In order to complete a goal, teams must complete several subtasks: detect and recognize relevant information, use this information to make decisions and solve problems, retain this information and integrate it with future information in order to develop and adapt appropriate work plans (Cooke et al., 2000). Several elements influence how effectively a team may accomplish these subtasks. These include the composition of the team members and available resources, the work organization (ex: a hospital), the task itself (ex: surgery), and individual differences in training and previous experiences (Kozlowski & Ilgen, 2006; Cooke et al., 2000).

Shared knowledge and shared mental models are increasingly important in team settings. These shared mental models allow team members to coordinate activities implicitly when they cannot communicate explicitly (Cooke et al., 2000). Kozlowski and Ilgen (2006) found that team mental models had a greater effect on team communication during novel situations, allowing team members to better adapt to unexpected scenarios.

**Inside the Operating Room**

The operating room is a dynamic, high-risk environment in which every member of the surgical team must perform their individual tasks to the best of their ability in order to produce a good outcome. Surgery is typically envisioned, through popular media such as Grey’s Anatomy and Nip/Tuck, as an open procedure. However, there is a growing body of research focused on
studying aspects of minimally invasive surgeries, either laparoscopic or robot-assisted surgery (RAS). This study will examine communicative interactions during robotic assisted surgery.

There are several advantages to minimally invasive surgeries, making it increasingly popular. These include reduced surgical trauma, such as infection, pain, or other complications and faster recovery periods, meaning shorter hospital stays and a faster return to daily life (Diana & Marescaux, 2015). In laparoscopic surgery, the surgeon is directly next to the patient and manipulates tissue, albeit at some distance, with tools through a fulcrum point in the patient’s abdominal wall. In this scenario, the surgeon is interacting face-to-face with other members of the surgical team. In contrast, in robotic assisted surgery, “the surgeon sits at a console...outside the sterile field, directing and controlling the movements of one or more robotic arms” (Herron, Marohn, et al., 2007).

Additional training is required for all members of the robotic assisted surgical team. This training ensures the ability of those in the room to properly use the device, how to safely dock and undock from the patient, and what to do the system stops working or malfunctions in a way that poses harm to the patient (Herron, Marohn, et al., 2007).

**Surgical roles.**

There are many individuals within the operating room; however, this study will focus only on the surgeon or assistant surgeon, the scrub nurse, and the bedside assistant. While the surgeon’s role is self-explanatory, the scrub nurse’s and bedside assistant’s tasks may not be as obvious.

In robotic assisted surgery (RAS) it is the job of the scrub nurse to ensure patient safety, facilitate the patient’s position in relation to the robot, and preparing the robot for safe use (i.e.,
sterilization of the machine, docking the machine to the patient, and managing the camera) (Raheem et al., 2016; Roth et al., 2004). Yuh (2013) defines the bedside assistant as “the robotic console surgeon’s link to the patient”. That is to say, the bedside assistant is responsible for the use of laparoscopic tools to perform tasks such as suctioning and irrigation, removal of specimens, and clip application among others (Yuh, 2013).

**Surgical hierarchy.**

The hierarchical culture between members of the surgical team is pervasive. While the literature acknowledges this hierarchy and notes the surgeon at the top of the hierarchy and medical residents often at the bottom, there is no other mention of where team members stand in this hierarchy (Sydor et al., 2012; Bould et al., 2015; Grady, 2010). Grady (2010) notes that this hierarchy is in many ways essential as “leadership, direction, and communication are all vital to a well-run [operating room].”

This hierarchical environment has both positive and negative influences on the surgical team. In a qualitative examination of medical students’ willingness to challenge a superior on an unethical decision, Bould et al. (2015) found that this hierarchy aided in time-sensitive or otherwise critical situations in which a clear and decisive leader was needed to make decisions. Additionally, the hierarchy was seen as a guaranteed mentorship and the gradual increase of power and movement within the hierarchy was seen as an important milestone in the student’s educational career.

Conversely, numerous anecdotes attributed bad surgical outcomes to this hierarchical structure, which trainees felt could have been avoided had they been allowed greater contribution (Bould et al., 2015). Sydor et al. (2012), in a study that also examined a resident’s response to an
unethical decision, found differing reasons for this inability to challenge a superior. In their study, the resident’s postgraduate year rather than his or her place in the hierarchy affected the strategies and success of those strategies in challenging a superior.

Regardless of the reasons, the lack of communication from members ‘up-the-chain’ may have a negative impact on the surgical outcome. A notable case of this is the death of Elaine Bromiley. Elaine Bromiley suffered a hypoxic brain injury after failed intubation attempts during an elective surgery. The nurses present during the case did not directly confront the anesthesiologists and instead used indirect or passive methods of communication. This ultimately resulted in Elaine’s death (Sydor et al., 2012; Bould et al. 2015; Grady, 2010).

Karsh and Brown (2010) further demonstrate that these hierarchies exist not only for the surgical team, but the greater work environment in which it is nested. The hierarchy is, therefore, not only influenced by the role each team member takes, but also by the policies and procedures, physical environment, cultural norms, and technologies within that workplace. A

**Communication and Risk**

The role of communication in regard to surgical outcome has become increasingly important. Communication is defined as “the imparting or exchanging of information by speaking, writing, or using some other medium” (Oxford Living Dictionaries, 2017).

**Communication failures.**

Communication failures, in addition to the hierarchical culture previously mentioned, have been increasingly cited as a latent factor influencing patient safety (Sutcliffe, Lewton, and Rosenthal, 2004; Lingard, Reznick, Espin, Regehr, & DeVito, 2002; ElBardissi, Wiegman,
Dearani, Daly, & Sundt III, 2007). These communication failures may occur between levels of the hierarchy (ex: surgeon to scrub nurse) or within the same level (ex: scrub nurse to scrub nurse) (Lingard et al., 2004).

The operating room is often thought to have an autocratic communication system. However, Lingard et al. (2002) found that the forms of communications were both varied and often far more subtle. This was particularly evident in moments of high tension. Furthermore, those communication patterns varied from case to case and team to team (Lingard et al., 2004).

Failures in these communications derive from a variety of sources, most commonly: situational factors (ex: the surgical operation), the work environment (ex: a hostile superior), and team members’ interpersonal skills (Sutcliffe et al. 2004; Lingard et al., 2002; ElBardissi et al., 2007). Hierarchy also contributes to communication failures. Factors contributing to a lack of communication upward in the hierarchy include the desire to avoid conflict, a belief that concerns will be ignored, and a fear of seeming incompetent (Sutcliffe et al., 2004; Bould et al., 2015). In light of these factors, Lingard et al. (2002) found residents tended to respond in one of two ways: by either mimicking the surgeon’s communicative behaviors or avoiding communication altogether.

**Communicating risk.**

It is difficult to define ‘risk’ as it is a situationally dependent concept (Fischoff, Bostrom, & Quadrel, 1993). For the purposes of this study, risk will be defined as an action or behavior that could result in a negative effect on the patient. It is easier to define ‘risk communication’. Edwards, Elwyn, and Mulley (2002) define risk communication as “the open two-way exchange
of information and opinion about risk, leading to better understanding and better decisions about clinical management”.

The goals of risk communication on the part of the message initiator are to provide the most necessary information in a proactive manner in a way that it is easily understood by the intended audience (Morgan, Fischhoff, Bostrom, & Atman, 2001). There are three key aspects to creating an effective risk statement. An effective risk message must be detectable, decodable, and considerate (Rowan, 1991). In other words, the message must be easily seen or heard, easily understood, and should not insult the intended audience for not already knowing the information.

The risk message recipient has many goals. In the surgical setting, this goal would fall under process and framing. That is to say, the message recipient needs to learn how the risk may arise and how to prevent or control it (Morgan et al., 2001). This allows the recipient to observe his or her own surroundings and make effective decisions.

Failures within risk communication often derive from people’s inability to properly estimate risk. Risk message recipients are influenced by their own mental models of a scenario, are subject to anchoring bias (estimates of risk influenced by a known scenario), availability bias (frequently seen or remembered scenarios), compression (less dispersion of perceived risk than in actual findings), and overconfidence in their estimations (Fischoff et al., 1993).

Several paradigms exist which focus on the improvement of patient care, specifically in reducing errors during the patient care process. In this case, the process would be the surgical procedure. The first paradigm asserts that errors should be prevented before they occur, the second is that only errors which would reasonably result in a poor patient outcome should be prevented while it is unnecessary to spend time worrying about the others, and finally, evidence
based practices provide the most appropriate and highest quality care (Karsh, Holden, Alper, & OR, 2006). Risk communication must then be viewed through these paradigms in order to see how the health care providers, the surgical team, can best integrate their knowledge of the surgical procedure and the external factors of the work environment to best complete the task.

**Situational Awareness**

Situational awareness is necessary to learn from and adapt to the environment. It is an up-to-the-moment knowledge and perception of the environment and elements within it (National Research Council, 1998). This is especially important in complex systems, such as aviation, military applications, and even everyday activities such as driving a car.

Situational awareness (SA) may be broken down into three distinct levels; level 1 involves perception, level 2 is comprehension, and finally, level 3 is projection (Endsley, 1995). In the perceptual level, individuals must identify elements in the environment that are most salient to completing their goal. For a surgeon, this may be attending to the visual surgical field. Comprehension involves taking those perceptual elements from level 1 SA and incorporating them into an understanding of the overall task. Finally, in the projection level, information gathered from the first two SA levels is extrapolated in order to make inferences about the future state of the task (Endsley, 1995; National Research Council, 1998; Gaba, Howard, & Small, 1995).

It therefore follows that an individual’s ability to maintain good situational awareness is tied to the complexity of the task. In increasingly complex tasks, the environment may continuously shift in a shorter time span, meaning the individual must maintain constant vigilance (Endsley, 1995; Saner, Bolstad, Gonzales, & Cuevas, 2009).
Training and practice provide opportunities to increase an individual’s situational awareness to tasks. This ensures the individual will be able to make decisions on a novel situation due to its similarity to a practiced task. This iterative decision making helps reduce human error and aid in an individual moving from level 1 SA to levels 2 and 3 (Gaba et al., 1995).

![Figure 1. Endsley's (1995) Dynamic Decision Making Model of Situational Awareness](image)

**Individual vs. team situational awareness.**

Situational awareness occurs at both the individual and team levels. As each member of the team has a specific role, he or she therefore has a specific set of elements to which he or she attends. Team situational awareness is “the degree to which every team member possesses the SA required for his or her responsibilities” (Endsley, 1995) and is aware of other members’
individual perceptions of the environment (National Research Council, 1998). In complex systems and during complex tasks, team members must integrate their SA to successfully complete their individual subtasks and therefore the overall task (Saner et al., 2009; Cooke, Stout, & Salas, 2001; National Research Council, 1998). Greater communication amongst team members may be required in order to facilitate the achievement of individual, and therefore team, situational awareness (Endsley, 1995).

**Measuring situational awareness.**

There are several methods to measure situational awareness: freeze-probe recall, real-time probe, post-trial subjective ratings, observer ratings, performance measures, and process indices (Salmon et al., 2014). Salmon et al. (2014) identified, of these techniques, freeze-probe recall, observer ratings, and task performance-based measures as adaptable to team assessment.

The operating room is a high stress environment in which “freezing” the scene, as in the freeze-probe recall technique, is not feasible. Performance-based measures and observational techniques can provide a better understanding of situational awareness within the operating room. The Oxford NOTECHS system is an observational method that has been adapted from aviation to measure behavior within the operating room (Mishra, Catchpole, & McCulloch, 2009; Robertson et al., 2014).

NOTECHS, and the subsequent revision NOTECHS II, is used to evaluate an individual or sub-team along four dimension; leadership and management, teamwork and cooperation, problem-solving and decision-making, and situation awareness (Mishra et al., 2009; Robertson et al., 2014). The system looks at three subsystems: surgical, anesthesiology, and nursing. Mishra, Catchpole, and McCulloch (2009) along with a team of subject matter experts created the
assessment with a four-point rating scale. NOTECHS II is structured along an eight-point scale (Robertson et al., 2014).

<table>
<thead>
<tr>
<th>Situation awareness</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Notice</td>
<td>Considers all team elements/asks for or shares information/aware of available of resources/encourages vigilance/checks and reports changes in team/requests reports/updates</td>
</tr>
<tr>
<td>Understand</td>
<td>Knows capabilities/cross checks above/shares mental models/speaks up when unsure/updates other team members/discusses team constraints</td>
</tr>
<tr>
<td>Think ahead</td>
<td>Identifies future problems/discusses contingencies/anticipates requirements</td>
</tr>
</tbody>
</table>

Figure 2. NOTECHS/NOTECHS II Situational Awareness Behavior Scales from Robertson et al., 2014

**Research Question and Hypothesis**

The hierarchical nature of the surgical team, communication mishaps, specifically with risk communication, and the need for a high degree of situational awareness lead to several research questions: How do individuals in the surgical team make statements about risk? Are these statements typically made from individuals of higher status to lower status? Are these statements typically proactive or reactive? Does the language of the message help foster increased individual and/or team situational awareness?

**Hypotheses**

H: Risk messages are formed and conveyed within the bounds of the surgical team composition, the hierarchy within that team, and the environment itself.

There are many reasons one may not wish to speak out against a superior. This may include the pervasive culture of the hierarchy and lack of willingness to challenge that culture (Sutcliffe et al., 2004; Grady, 2010), fear of seeming incompetent, and each individual’s experience level (Sydor et al., 2012). Additionally, Lingard et al. (2004) found that critical information was most often conveyed after the fact.
H1: There will be more instances of risk communication from individuals of high status to low status than low status to high status.

H2: Risk messages will primarily be reactive to a change in the surgical environment.

H2a: Risk messages from individuals of high status to low status will be more proactive whereas risk messages from individuals from low status to high status will be more reactive.

It is a common mistake that risk communicators make in believing the message recipient simply does not understand the severity of the risk (Fischhof et al., 1993). Furthermore, the language used may not reflect the intended message. Terms such as ‘probably’, ‘rarely’, or ‘commonly’ are relative; the message initiator and the message recipient may view the level of risk differently based on these terms (Edwards et al., 2002).

H3: Risk messages do not contain language that facilitates an increase in the message recipient’s situational awareness.

H3a: Risk messages from individuals of high status to low status will be more effective at increasing situational awareness than messages from individuals of low status to high status.

H3b: Proactive risk messages will be more effective at increasing situational awareness than reactive risk messages.
Methods

Data Selection

The data collection process was facilitated by the Applied Technology Laboratory for Advanced Surgery (ATLAS) at Roswell Park Cancer Institute from part of a previous project titled Techno-fields. As part of that project, robotic-assisted surgeries were audio-visually recorded for later analysis of communication among the surgical team members with the goal of improving RAS workflow; this study includes a subset of those surgeries.

As part of the recording process, three cameras were set up to provide a view of all activities within the operating room. All participants wore a lapel-microphone connected to an audio interface to capture up to eight tracks of audio recordings. Consent was obtained for all participants either at a meeting to discuss the study or prior to entering the operating room. The audio and visual recordings were synchronized using Adobe Premiere Pro CS6 and imported into Noldus Observer XT 12, a video coding program, for further analysis (Allers et al, 2016; Tiferes Wang, 2017; Tiferes et al., 2017)

Recordings were made of both robot-assisted radical cystectomies and robot-assisted radical prostatectomies. Due to the differences in procedure and difficulty of these two surgeries, the scope of this study is limited to the recordings and transcriptions from eleven robot-assisted radical prostatectomies. Of these, one was eliminated due to being an outlier at 6 hours; the remaining ten surgeries were an average length of 3 hours 6 minutes (SD = 51 minutes).

These surgeries amounted to approximately 31.7 observable hours. Observable hours are defined as those during the console stage of the RAS workflow (Cunningham et al., 2013).
Cunningham et al. further describe the console stage as the period during surgery beginning when the surgeon sits at the robot console, the surgical procedure occurs, and ending when the first instrument is detached.

Observed interactions were limited to those between the surgeon, assistant surgeon, bedside assistant, and scrub nurse. While the actions and communications of all members of the surgical team contribute to the outcome, these four members have either direct manipulation of instruments or participation through a teaching relationship during the surgery. Therefore, this study will focus on the verbal messages between team members in only these four positions.

There were fifteen participants across the surgeries in varying roles: three lead surgeons, three assisted surgeons, two bedside assistants, and seven scrub nurses. These team members had varying levels of familiarity with each other ranging from less than 24 cases to over 50 cases worked together. Additionally, these team members varied in experience level, from less than 5 years of experience to over 10 years (Tiferes Wang, 2017).

**Risk Message Definition**

The definition of any risk message must be framed by the environment in which the risk occurs. This is because the message initiator must be able to clearly explain required information and the recipient must be able to understand it and learn from it. In a surgical setting, failures to communicate effectively may result in errors or incidents. These errors or incidents are any behaviors or actions taken on the part of the surgical team that could result in a poor patient outcome or events in the work environment which prevent the team from operating effectively and results in a poor patient outcome. Thus, any risk message must be framed with the goal of preventing such a patient outcome.
This study thus defines a risk message as any verbally communicated statement which (1) seeks to prevent a behavior or action that could result in a bad outcome for the patient from occurring, such as “Don’t make the next cut too distally or you’ll be too close to the prostate”; (2) seeks to provide information about such a behavior or action, “If you hold the fascia there you’re not going to be able to see where you’re cutting”; (3) seeks to provide information about the work environment that could lead to such a behavior or action, “The camera is smudged, clean it. I can’t see what I’m doing”. Additional examples of risk messages are in Appendix A.

Procedures and Analysis

For each of the ten surgeries, verbal messages within each transcription were marked. Each message was categorized by sender and recipient pairs, for example surgeon to bedside assistant, scrub nurse to assistant surgeon, etc. Each message was then categorized as a risk message or not.

Following the transcriptions, the audio-visual recording of each surgery was examined for interactions between the assistant surgeon and the surgeon or vice versa, as those were not included in the original transcriptions. In these cases, the surgeon or assistant surgeon would be standing outside the console and acting as an observer to the surgery. While this data had been excluded from the original data set due to the observer’s lack of direct influence on the patient, the surgeon still exerts a great deal of influence on the procedure through being the head of the surgical hierarchy and by acting as a teacher for the assistant surgeon, a medical resident or fellow.

Messages between the surgeon and assistant surgeon were counted to provide an accurate record of the total number of verbally communicated statements within the target surgical team.
members. These statements were only transcribed if they were determined to be a risk message to be used in further analysis. The audio-visual recordings were used to determine if these risk messages and those previously identified from the transcriptions were proactive or reactive.

Proactive risk messages were anticipatory in nature, occurring before a potentially detrimental behavior or action could occur and tends to use prospective language. These messages often identified consequences and provided direction. The example for risk message definition (1) “Don’t make the next cut too distally” anticipates an upcoming action and clearly stated the consequence of that action, getting too close to the prostate. In the second example, for definition (2), the action is where the individual is holding the fascia and the consequence is not being able to see where he or she is cutting. This message could also be reactive if the language changes from prospective to retrospective, “By holding the fascia there you weren’t able to see where you were cutting.” Reactive messages provide insight into actions or behaviors that have already occurred either through human action or environmental changes, such as the camera being smudged.

Proportions of all verbal messages between sender and recipient pairs were calculated to determine the amount of communication between individuals of varying status levels. Additionally, the proportions of only verbal risk messages were calculated. These messages were then further broken down into proportions of proactive vs. reactive messages.

The effectiveness of each verbal risk message was evaluated using the NOTECHS situational awareness rating scale; that is to say, to what degree does the message itself foster noticing, understanding, and thinking ahead as defined in the NOTECHS scale shown in Figure 2.
(Mishra, Catchpole, & McCulloch, 2009). This same subscale is used in NOTECHS II; however, it was not used for this study due to additional training requirements.

Further data analyses were performed using SPSS Statistical Software and were considered to be statistically significant at $p < 0.05$. Two chi-square tests were used to determine the associations between hierarchical status of the message sender-recipient pairs and the timing of the message (proactive vs reactive) and the association between hierarchical status and the situational awareness effectiveness scores (NOTECHS scores). An analysis of variance was used to determine the effect of hierarchical status and message timing on the NOTECHS scores.

**Results**

A necessary sample size of risk messages was calculated based on an unknown population according to Equation (1). There is a wide array of conversation that occurs during surgery, including passing information about the work environment unrelated to risk, teaching, and requests for instruments or information (Tiferes Wang, 2017). Therefore, this formula was calculated with the assumption that 10% of communication during surgery is about risk ($p = 0.1$). The confidence level was set at 95% and a margin of error of 5%. The resulting necessary sample size was 139 risk messages.

$$n = \frac{Z^2pq}{e^2}$$

where:
- $n$ = sample size
- $Z$ = $Z$-score
- $p$ = estimated percentage of the population with the given attribute
- $q = 1 - p$
- $e$ = margin of error
The time to analyze the videos took between five and nine hours depending on the length of the surgery itself. Each surgery yielded an average of 560 verbally communicated statements between the team members of interest: surgeon, assistant surgeon, bedside assistant, and scrub nurse. This made for a total of 4,583 verbal statements across the eight surgeries. Of these, 329 were risk messages. Table 1 depicts a breakdown of communication by sender-recipient pairs.

<table>
<thead>
<tr>
<th>Sender-Recipient Pair</th>
<th>Risk Messages (% of total risk messages)</th>
<th>Total Statements (% of total verbal messages)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeon – Assistant Surgeon</td>
<td>73 (22.22)</td>
<td>1,241 (27.08)</td>
</tr>
<tr>
<td></td>
<td>14 (4.26)</td>
<td>220 (4.80)</td>
</tr>
<tr>
<td></td>
<td>59 (17.96)</td>
<td>1,021 (22.28)</td>
</tr>
<tr>
<td>Off the console</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgeon – Bedside Assistant</td>
<td>79 (24.01)</td>
<td>747 (16.30)</td>
</tr>
<tr>
<td>Surgeon – Scrub Nurse</td>
<td>17 (5.17)</td>
<td>132 (2.88)</td>
</tr>
<tr>
<td>Assistant Surgeon – Surgeon</td>
<td>29 (8.80)</td>
<td>743 (16.21)</td>
</tr>
<tr>
<td></td>
<td>14 (4.26)</td>
<td>327 (7.14)</td>
</tr>
<tr>
<td></td>
<td>15 (4.54)</td>
<td>416 (9.07)</td>
</tr>
<tr>
<td>Off the console</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assistant Surgeon – Bedside Assistant</td>
<td>17 (5.17)</td>
<td>247 (5.39)</td>
</tr>
<tr>
<td>Assistant Surgeon – Scrub Nurse</td>
<td>4 (1.21)</td>
<td>22 (0.48)</td>
</tr>
<tr>
<td>Bedside Assistant – Surgeon</td>
<td>22 (6.68)</td>
<td>287 (6.26)</td>
</tr>
<tr>
<td>Bedside Assistant – Assistant Surgeon</td>
<td>10 (3.04)</td>
<td>121 (2.64)</td>
</tr>
<tr>
<td>Bedside Assistant – Scrub Nurse</td>
<td>29 (8.80)</td>
<td>460 (10.04)</td>
</tr>
<tr>
<td>Scrub Nurse – Surgeon</td>
<td>12 (3.65)</td>
<td>97 (2.12)</td>
</tr>
<tr>
<td>Scrub Nurse – Assistant Surgeon</td>
<td>5 (1.52)</td>
<td>19 (0.42)</td>
</tr>
<tr>
<td>Scrub Nurse – Bedside Assistant</td>
<td>32 (9.73)</td>
<td>467 (10.19)</td>
</tr>
<tr>
<td>Total</td>
<td>329 (100)</td>
<td>4,583 (100)</td>
</tr>
</tbody>
</table>

Table 1. Frequencies of messages by sender-recipient pair.

Ten percent of the risk statements were used to determine inter-rater reliability of the NOTECHS situational awareness ratings. This amounted to 33 statements to be given to a second coder. Each statement was numbered in a list and a random number generator was used to determine which statements would be used to verify the inter-rater reliability. These selected statements were then compared between the reference rater (myself) and the second coder.
according to Equation (2). Acceptable inter-rater reliability was 70% agreement or greater. This study found an inter-reliability of NOTECHS ratings of 72%.

\[
Percent\ Agreement = \frac{A}{n} \times (100)
\]

where:

\[A = \text{number of agreements}\]
\[n = \text{number of events}\]

Statements were most often directly related to the surgical task at hand or preparation, but also included statements about the patient’s information, equipment, or upcoming steps in the procedure. Examples of these statements can be found in Appendix A. These statements are then further framed by the hierarchical status of the sender-recipient pair, the timing of the message (proactive or reactive), and the language used that affects the situational awareness ratings.

**High-to-Low vs. Low-to-High Status**

The status levels of each of the message-recipient pairs can be found in Table 2. Based on previous research, the surgeon is the highest status and the assistant surgeon, as a medical resident or fellow, is the lowest status. The placement of the bedside assistant and scrub nurse in the hierarchy were chosen due to their job descriptions. The bedside assistant directly manipulates laparoscopic tools during the surgical procedure and, therefore, has more direct interaction with the patient during the surgery. Therefore, for the purposes of this study, the bedside assistant is ranked higher in the hierarchy than the scrub nurse. The hierarchy used in this study is, from highest status to lowest: surgeon, bedside assistant, scrub nurse, and assistant surgeon. The status levels of each of the message-recipient pairs can be found in Table 2.
Table 2. Message sender-recipient pairs by hierarchical status level.

<table>
<thead>
<tr>
<th>Surgeon-to-Assistant Surgeon</th>
<th>Assistant Surgeon-to-Surgeon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeon-to-Bedside Assistant</td>
<td>Assistant Surgeon-to-Bedside Assistant</td>
</tr>
<tr>
<td>Surgeon-to-Scrub Nurse</td>
<td>Assistant Surgeon-to-Scrub Nurse</td>
</tr>
<tr>
<td>Bedside Assistant-to-Assistant Surgeon</td>
<td>Bedside Assistant-to-Surgeon</td>
</tr>
<tr>
<td>Bedside Assistant-to-Scrub Nurse</td>
<td>Scrub Nurse-to-Surgeon</td>
</tr>
<tr>
<td>Scrub Nurse-to-Assistant Surgeon</td>
<td>Scrub Nurse-to-Bedside Assistant</td>
</tr>
</tbody>
</table>

Descriptive statistics were calculated for all verbal communicative statements as well as just risk messages. Of the total 4,583 statements, 2,720 were from individuals of higher status to those of lower status (approximately 60%); of the 329 risk messages, 212 (approximately 64%) were from higher status individuals to lower status. This is consistent with hypothesis H1.

<table>
<thead>
<tr>
<th>Risk Messages</th>
<th>High-to-Low</th>
<th>Low-to-High</th>
<th>Total Verbal Messages</th>
</tr>
</thead>
<tbody>
<tr>
<td>212 (64.44%)</td>
<td>117 (35.56%)</td>
<td>329 (7.18%*)</td>
<td>2,720 (59.35%)</td>
</tr>
</tbody>
</table>

*Percentage of risk messages to total verbal messages.

Table 3. Message frequency based on hierarchical status.

Proactive vs. Reactive Risk Messages

The risk messages were categorized as either proactive or reactive based on the risk message definition. Proactive messages are those which match risk definition (1) and some matching definition (2); reactive messages are those in which some match risk definition (2) and all that match risk definition (3). Of the risk messages, 124 of these were proactive messages and 205 were reactive.

A chi-square test was conducted to compare the effects of hierarchical status on the timing of the risk message (proactive or reactive). There was a significant effect of hierarchical status on the timing of the risk message ($p < 0.05$). Risk messages made by individuals of high
status to low status were significantly more proactive than messages from individuals of low status to high status. Results of the chi-square test can be found in Figure 3 and are graphically depicted in Figure 5. These findings support hypotheses H2 and H2a.

### Chi-Square Tests

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymptotic Significance (2-sided)</th>
<th>Exact Sig. (2-sided)</th>
<th>Exact Sig. (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>8.265</td>
<td>1</td>
<td>.004</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuity Correction</td>
<td>7.596</td>
<td>1</td>
<td>.006</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>8.466</td>
<td>1</td>
<td>.004</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

N of Valid Cases 329

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 44.10.
b. Computed only for a 2x2 table

Figure 3. Chi-Square test of hierarchical status of message sender-recipient pairs and risk message timing.

### Status_Level * Proactive_vs_Reactive Crosstabulation

<table>
<thead>
<tr>
<th>Status_Level</th>
<th>Proactive</th>
<th>Reactive</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>high-low</td>
<td>92</td>
<td>120</td>
<td>212</td>
</tr>
<tr>
<td>low-high</td>
<td>32</td>
<td>85</td>
<td>117</td>
</tr>
</tbody>
</table>

Total Count 329

% of Total

Status_Level high-low % of Total 28.0% 36.5% 64.4%
low-high % of Total 9.7% 25.8% 35.6%
Total % of Total 37.7% 62.3% 100.0%

Figure 4. Total risk messages of hierarchical status and message timing groups.
Situational Awareness Ratings

The original Oxford NOTECHS situational awareness subscale was used to rate each risk message on a scale of 1 to 4; 1 is considered below average and 4 excellent. The risk statements had an average rating of 2.03 ($SD = 0.87$). Statements which received a low rating were primarily about the work environment, fitting risk message definition (3). Messages of this nature were typically short statements such as “The camera is blurry” and “Careful”. Higher rated messages were longer statements, consisting of multiple utterances, primarily fitting risk message definitions (1) or (2). Examples of this message begin with “You’ve got to be careful because this is a needle. You can tear the iliacs or something like that” followed by an explanation of the next steps in the surgical procedure and “I would use the cautery here otherwise…” These ratings are consistent with hypothesis H3.
A 2 (risk message sender-recipient status) x 2 (proactive vs. reactive) between-subjects ANOVA was conducted to compare the effects of hierarchical status and timing of the risk message on the situational awareness ratings. There was a significant effect of timing on the situational awareness ratings \(F(1,325) = 48.85, p < 0.05\). As seen in Figure 4, proactive messages were rated as significantly better at increasing situational awareness than reactive messages. Neither hierarchical status \(F(1,325) = 0.23, p = 0.63\) nor the interaction of hierarchical status and timing had a significant effect on effectiveness of the risk message \(F(1,325) = 0.22, p = 0.56\). Means and statistics for all cases can be found in Table 4.

<table>
<thead>
<tr>
<th>Status Level</th>
<th>Proactive vs. Reactive</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-to-Low</td>
<td>Proactive</td>
<td>2.48</td>
<td>0.91</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>Reactive</td>
<td>1.72</td>
<td>0.78</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.05</td>
<td>0.92</td>
<td>212</td>
</tr>
<tr>
<td>Low-to-High</td>
<td>Proactive</td>
<td>2.47</td>
<td>0.84</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Reactive</td>
<td>1.82</td>
<td>0.71</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.00</td>
<td>0.80</td>
<td>117</td>
</tr>
<tr>
<td>Total</td>
<td>Proactive</td>
<td>2.48</td>
<td>0.89</td>
<td>124</td>
</tr>
<tr>
<td></td>
<td>Reactive</td>
<td>1.76</td>
<td>0.75</td>
<td>205</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>2.03</td>
<td>0.88</td>
<td>329</td>
</tr>
</tbody>
</table>

Table 4. Means and standard deviations of NOTECHS ratings by hierarchical status and message timing.

A chi-square test was conducted on the association of hierarchical status and the NOTECHS ratings to confirm these results, as seen in Figures 6-8. These findings do not support hypothesis H3a, however there is evidence supporting hypothesis H3b.
Chi-Square Tests

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>df</th>
<th>Asymptotic Significance (2-sided)</th>
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</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>3.676</td>
<td>3</td>
<td>.299</td>
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<tr>
<td>Likelihood Ratio</td>
<td>3.930</td>
<td>3</td>
<td>.269</td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>329</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 7.47.

Figure 6. Chi-Square test of hierarchical status of message sender-recipient pairs and message NOTECHS ratings.

Status_Level * NOTECHS_Rating Crosstabulation

<table>
<thead>
<tr>
<th>NOTECHS_Rating</th>
<th>1.00</th>
<th>2.00</th>
<th>3.00</th>
<th>4.00</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status_Level</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high-low</td>
<td>67</td>
<td>85</td>
<td>43</td>
<td>17</td>
<td>212</td>
</tr>
<tr>
<td>% of Total</td>
<td>20.4%</td>
<td>25.8%</td>
<td>13.1%</td>
<td>5.2%</td>
<td>64.4%</td>
</tr>
<tr>
<td>low-high</td>
<td>33</td>
<td>55</td>
<td>25</td>
<td>4</td>
<td>117</td>
</tr>
<tr>
<td>% of Total</td>
<td>10.0%</td>
<td>16.7%</td>
<td>7.6%</td>
<td>1.2%</td>
<td>35.6%</td>
</tr>
</tbody>
</table>

Total

<table>
<thead>
<tr>
<th>Count</th>
<th>100</th>
<th>140</th>
<th>68</th>
<th>21</th>
<th>329</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Total</td>
<td>30.4%</td>
<td>42.6%</td>
<td>20.7%</td>
<td>6.4%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Figure 7. Total risk messages of hierarchical status and NOTECHS ratings groups.

Figure 8. Association of hierarchical status and NOTECHS ratings of risk messages.
Discussion

This study found that the majority of communicated risk messages were from individuals of higher status to lower status individuals, which is consistent with past findings (Bould et al., 2015; Sydor et al., 2012; Grady, 2010). However, the disparity between the number of communicated statements from high-to-low status and from low-to-high status is far less than previously implied. This may be due to a number of factors. The hierarchy within the operating room is not explicitly known beyond the surgeon being at the top of the hierarchy and medical residents and fellows being at the bottom. The status of individuals in the middle of the hierarchy is currently unknown and, as such, was only approximated during this study. This hierarchy may change with differing surgical specialties or differing hospitals with varying work cultures (Lingard et al., 2002). Further insight is needed into discerning the specific hierarchy within Roswell Park Cancer Institute’s urology department in order to assess the influence of hierarchy on verbally communicated risk statements.

As demonstrated by previous research, individuals of lower status may not make statements contradicting the actions or behaviors, or perceived intended actions or behaviors, of superiors for a variety of reasons (Sydor et al., 2012; Bould et al. 2015). This is consistent with the findings of this study, as seen number of high-to-low status interactions versus low-to-high status. In the case of lower status individuals, they may have made fewer risk statements for fear of being ignored or conflicting with the individual of higher status. In the case of the assistant surgeon, they may be more reluctant to make a risk statement in front of the surgeon, their teacher, if their statement as incorrect to avoid seeming incompetent.
The risk messages seen in this study were largely reactive rather than proactive at a ratio of 33:20. A multitude of these reactive messages were due to changes in the work environment that could hinder the procedure rather than an action or behavior of the surgical team. These included information about the functionality of surgical instruments and requests for cleaning or focusing the laparoscopic camera. For inventory purposes, a record is kept of each instrument's use and the expected life as indicated by the manufacturer; however, this is only an estimate and there may be unanticipated variation to that expectancy. Many factors contribute to the need for camera cleaning or focusing. An obstruction in the port or unintended splashing during surgical tasks can require the camera to be clean. The camera may need to be refocused as well as different angles are used or a different individual (the surgeon or assistant surgeon) is sitting at the console.

Proactive risk messages tended to be longer statements than reactive messages and typically provided information about the patient state as it related to the surgical procedure or simply about the procedure itself. These messages were typically from individuals of higher status to lower status, as seen in Table 2. This corresponds with previous studies of surgical teams in which participants reported looking to a specific individual as the leader (Bould et al., 2015).

As seen in Table 4, the timing of each message played a significant role in how effective the risk messages were in increasing situational awareness, depicted by the average NOTECHS ratings. Reactive risk messages may be shorter and less deceptive due to the fast pace of the operating room and the need for efficiency; conversely, individuals making proactive risk messages may take more time to describe how and why an action, behavior, or environment state may lead to a poor outcome.
Limitations and Further Considerations

There are several factors which may influence the way in which surgical team members communicate risk that were not considered in this study. Further research will be needed to expand on this work and address the influence of these potentially confounding factors.

This study focused solely on robot- assisted prostatectomies. However, within the field of urology alone there are a multitude of other surgeries such as cystectomies (removal of the bladder) and nephrectomies (removal of one or both kidneys). These surgeries may be of differing length and difficulty than prostatectomies, meaning there may be differing types and amounts of communication and risk. Furthermore, there may be differences within different surgical departments other than urology. Varying surgeries may have greater or lesser time constraints in which to avoid a poor patient outcome. The pace of each surgery can dictate the ability of team members to anticipate risk and make statements accordingly; the timing and detail of each message may be considerably different than observed in this study. Consideration in future studies should be given to addressing communication among surgical staff of varying fields.

In addition to differences between surgical fields, there may be differences in the work environment of different hospitals. Roswell Park Cancer Institute, Oshei Children's Hospital, and Buffalo General are just a few of the many hospitals in the Buffalo, New York region. These hospitals may all have unique priorities with varying work cultures and personnel demographics. It may therefore follow that the hierarchical status of each team member, and how they communicate with each other, may vary at each hospital.
This study presumed a hierarchy in which the surgeon has the highest status followed by the bedside assistant, scrub nurse, and, lastly, the assistant surgeon. As a typical hierarchy is unknown beyond placement of the surgeon and assistant surgeon as a resident or fellow (Bould et al., 2015, Sydor et al., 2012), the hierarchy used for this study was designed based on the job descriptions of each team member. This may not reflect the actual status of each team member.

The assumed hierarchy of this study also ignores social factors which may influence an individual's place in the order. Experience and familiarity have impact on the amount of communication between team members (Lingard et al., 2002; Lingard et al., 2004; Sydor et al., 2012). A team member may be performing a surgical role that is typically low status but considered to be higher in the hierarchy due to his or her expertise. Additionally, the more familiar team members are, the more likely they are to communicate and therefore may more readily convey risk messages regardless of the hierarchy. In this case, the surgical team members had a high degree of familiarity with each other (Tiferes Wang, 2017).

This study focused solely on the verbally communicated risk message. Verbal communication in many ways cannot be studied without also assessing non-verbal communication (Knapp, Hall, & Horgan, 2007). Knapp, Hall, and Horgan (2007) assert that this non-verbal communication is also influenced by the environment, both physical and spatial, the physical characteristics of the individuals communicating, and their body movement and position, such as gestures, facial expressions, etc. In the case of the operating room, body movements and facial expressions may be limited by the need to perform certain tasks and the surgical masks guarding the face, there are still a variety of non-verbal cues for which to account.
Statements do not exist without context. The full exchange of conversation is needed to determine whether these statements effectively communicated risk rather than simply a teaching statement. Since Roswell Park Cancer Institute is a teaching hospital, it is of greater importance to make this distinction. By examining the entire exchange in which the potential risk statement occurs, it is possible to infer if the potential statement is in fact about risk or simply used as a teaching tool.

These surgeries were all successful without adverse events. While risk statements were made to prevent such adverse events from occurring, this did not provide a comparison to assess risk communication during these time sensitive and high-stress events. It is possible that during an adverse event, the language used to communicate risk will change due to the decrease in the time in which statements can be made and the increase of the mental and potentially physical workload of the surgical task.

**Conclusions**

Effective communication is critical in all fields of life. It is even more so during medical procedures such as surgery. Furthermore, risk communication is critical to a successful patient outcome. Throughout the course of the observed ten surgeries, this risk communication totaled only approximately 8% of the total communication and most did not meet the goals of the risk message sender or recipient. However, these statements may provide key insight into the situational awareness of the operating room. Further research is required to discern how additional factors influence the way in which surgical team members form risk messages.
Bibliography


### Appendix - Risk Statement Examples by Definition

<table>
<thead>
<tr>
<th>Risk Definition</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any verbally communicated statement which seeks to prevent a behavior or action that could result in a bad outcome for the patient.</td>
<td>You’re a little too close to the prostate; when you’re cutting that come towards me.</td>
</tr>
<tr>
<td></td>
<td>Yeah don’t do that cauterize it; it’s going to weep otherwise.</td>
</tr>
<tr>
<td></td>
<td>Don’t go too far. Yeah right there. No, no, that's too... come back a little toward the prostate.</td>
</tr>
<tr>
<td></td>
<td>I would touch it with cautery a little bit otherwise it will weep.</td>
</tr>
<tr>
<td></td>
<td>Make sure we remember to pull that lap out of the [cavity].</td>
</tr>
<tr>
<td></td>
<td>Now remember his tumor is right up here in this region so anything that's funny we need to be worried about.</td>
</tr>
<tr>
<td></td>
<td>You’re too much on the cautery just let mother nature show you the planes.</td>
</tr>
<tr>
<td></td>
<td>Get down more proximally you're too close to the apex.</td>
</tr>
<tr>
<td></td>
<td>You're going to cut into the bladder if you keep doing that.</td>
</tr>
<tr>
<td></td>
<td>You keep turning your camera, fix that, ok, see you’re more behind [the prostate] than you think.</td>
</tr>
<tr>
<td></td>
<td>I need you to grab this one down. It's in my way.</td>
</tr>
<tr>
<td></td>
<td>Now a lot of times you have to be careful here because if you miss the seminal vesicles completely you could end up in the rectum.</td>
</tr>
<tr>
<td></td>
<td>You’ve got to be careful, because this is a needle. You can tear the iliacs or something like that.</td>
</tr>
<tr>
<td></td>
<td>This won't peel easily because of the 4 biopsies.</td>
</tr>
<tr>
<td></td>
<td>Watch your hook. [hook is in the way of the laparoscopic grasper]</td>
</tr>
<tr>
<td></td>
<td>This, what you’re seeing is bone so you don't need to go deeper.</td>
</tr>
<tr>
<td></td>
<td>I just want to make sure I'm not getting too close to the prostate.</td>
</tr>
<tr>
<td></td>
<td>Yeah obviously but disease is the limiting factor here.</td>
</tr>
<tr>
<td></td>
<td>That's a little artery that carries over to the nerve. That's why the nerve was popping. That's the only thing I saw.</td>
</tr>
<tr>
<td></td>
<td>See where you have your bladder neck at the midline... you're making a new bladder neck.</td>
</tr>
<tr>
<td></td>
<td>Am I hitting something on the outside?</td>
</tr>
<tr>
<td></td>
<td>It got stuck in the port.</td>
</tr>
<tr>
<td></td>
<td>Let me clean these tips. I have to clean them after a while.</td>
</tr>
<tr>
<td></td>
<td>Does your hook need to be clean?</td>
</tr>
<tr>
<td></td>
<td>Is it focused? Or is it not clean? I think is not clean. Can you focus and then see if it clears out? If it doesn't then we'll need to clean.</td>
</tr>
</tbody>
</table>