Multimodal team interactions in Robot-Assisted Surgery

Judith Tiferes[1,2], Ann M. Bisantz[1], Matthew L. Bolton[1], D. Jeffery Higginbotham[1],
Ryan P. O'Hara[1], Nicole K. Wawrzyniak[1], Justen D. Kozlowski[2], Basel Ahmad[1,2],
Ahmed A. Hussein[2], & Khurshid A. Guru[2]
[1] University at Buffalo, State University of New York
[2] ATLAS Program, Department of Urology, Roswell Park Cancer Institute

Communication gaps have been systematically linked to failures during surgery; however few studies have addressed challenges related to the remoteness of the surgeon during robot-assisted surgery (RAS). While studies on team communication in the Operating Room (OR) rarely report on nonverbal aspects, our initial work has shown that the vast majority of interaction events between the console surgeon and the right bed side assistant is nonverbal. This study focuses on improving our understanding of the nature of the multimodal interactions between surgeons and right bed side assistants. Six robot-assisted radical prostatectomies were recorded and the interaction events between the surgeon and the right bed side assistant were categorized by type (verbal/nonverbal), topic, and sender. The proportion of verbal and nonverbal events varied with the topic of the interaction. Strategies to improve team communication during surgery should take into account both the use of nonverbal communication means and the change in communication strategies based on purpose.

INTRODUCTION

Robot-assisted surgery (RAS) technology, which includes ergonomic controls that reproduce miniaturized hand movements, three-dimensional vision, and 10x magnification (Diana & Marescaux, 2015), provides technical advantages over open and laparoscopic surgery. Despite these benefits, this new technology has brought some challenges to the surgical team. The surgeon no longer has direct visual access to the operating table, the patient, and the bed side assistants (Cao & Taylor, 2004; Webster & Cao, 2006). During the operation, the surgeon sits at the robot console, placed in the Operating Room (OR), and can only see the console's video feed.

Communication gaps have been linked to human error in surgery. However, studies on team communication during RAS have been extremely sparse. Initial studies in RAS communication have focused on evaluating the differences between RAS and laparoscopic surgery (Cao & Taylor, 2004; Nyssen & Blavier, 2010; Webster & Cao, 2006) or classifying verbal communication during real surgeries (Cunningham, Chellali, Jaffre, Classe, & Cao, 2013; Nyssen & Blavier, 2010).

Nyssen and Blavier (2010) suggested that the interactions between surgeon and one bed side assistant comprised explicit vocalizations and "implicit communication". However, their study only involved verbal communications. This is a common simplification when studying the communication of working teams, especially surgical teams. In a recent systematic literature review that analyzed coding schemes for OR communication, none of the studies included nonverbal interactions (Tiferes, Bisantz, & Guru, 2015). Nevertheless, people communicate in a multimodal fashion, combining speech and other nonverbal aspects such as gestures, visual gaze direction, body positions and movements, facial expressions, or tool manipulations (Goodwin, 2006; Hutchins, 2006; Hutchins & Palen, 1997).

Although team communication issues have been studied in the OR, nonverbal interaction events during surgery (RAS and non-RAS) have not garnered much attention. The importance of nonverbal communications is not new in other domains (Argyle, 1972; Hutchins, 2006; Katz, Kambe, Kline, & Grubb, 2006; Segal, 1995), however it has been overlooked in healthcare and surgery (cf. Kolbe et al., 2014; Moore, Butt, Ellis-Clarke, & Cartmill, 2010). Effective communication is not only achieved verbally; nonverbal means can support or even replace verbal exchanges, especially for team coordinated actions (Segal, 1995). In particular, multiple communication modes are important in creating common ground among team members. Common ground theory states that people shape their interactions with others based on their assumptions of their mutual knowledge and beliefs. Furthermore, the process of updating and improving their *common ground* is affected by both the communication medium and the purpose of the interaction (Clark & Brennan, 1991).

Multimodal Interactions in RAS

In RAS, the Physician Assistant (PA), located to the right of the patient, is in charge of changing the robotic tools on the right-side robotic arms and assisting the surgeon by means of laparoscopic tools (e.g., suction, laparoscopic grasper, or laparoscopic scissors). The interactions between the surgeon and the right bed side assistant are multimodal, combining vocalizations and nonverbal actions that can be seen in the shared view of surgery (which is available to the entire surgical team via four screens inside the OR). For instance, the surgeon may request the right bed side assistant to retract tissue by saying "hold this" while holding the target area with their robotic tool. Thereafter, the right bed side assistant introduces the laparoscopic grasper and retracts the tissue the surgeon is holding. Next, the surgeon says "yes" and stops grasping the tissue. This example shows a multimodal interaction. Even though the right bed side assistant has not

 DOI 10.1177/1541931213601118

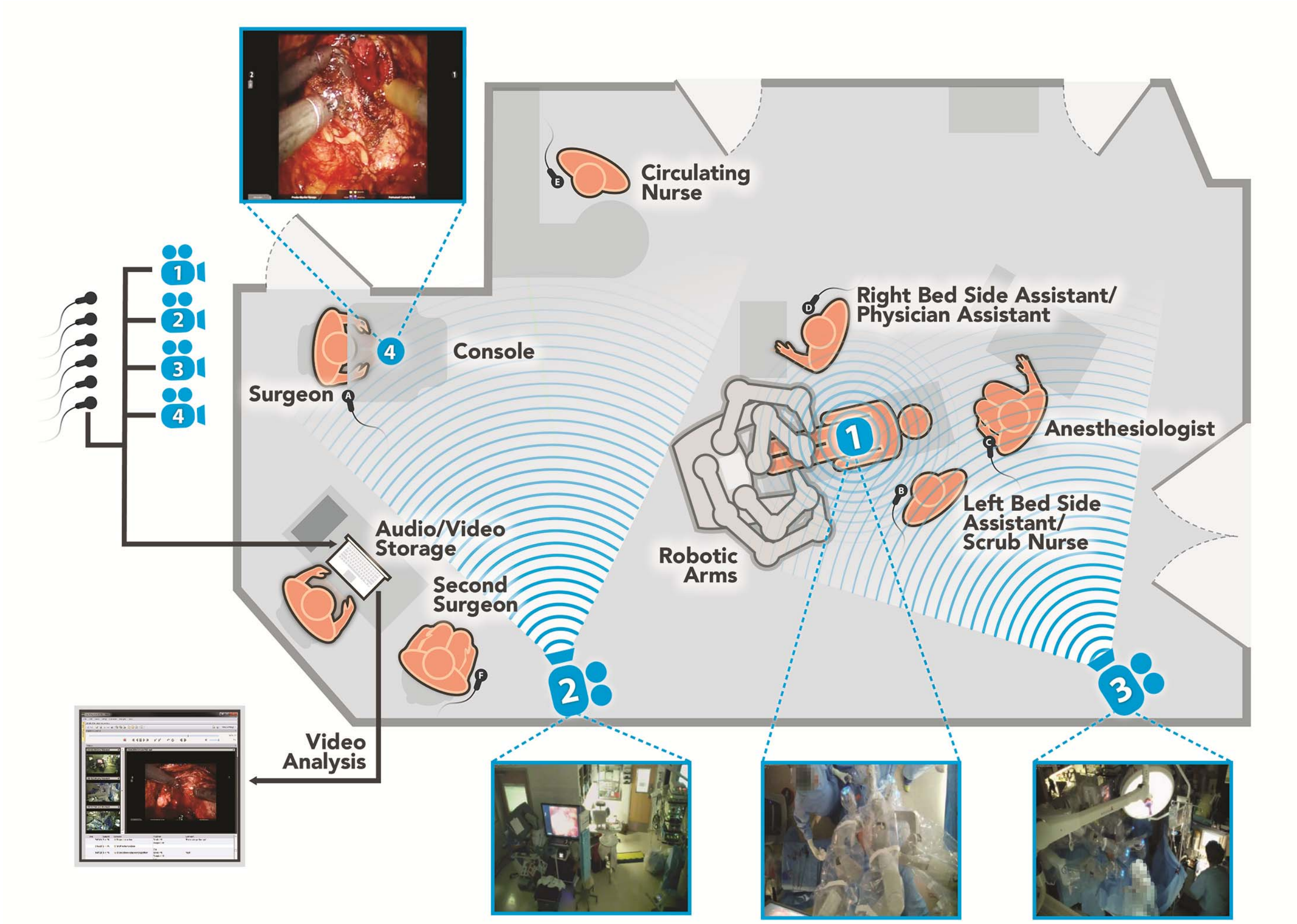

Figure 1: Digital data collection system including three aerial views of the OR environment, the console feed to provide operative context, and audio tracks of each team member.

said a word, their relevant nonverbal actions mean that they understood what the surgeon requested.

Initial analyses of verbal and nonverbal communication events in RAS found that nonverbal interaction events are even more frequent than verbal ones. More specifically, 67% of the interaction events between the surgeon at the console and the right bed side assistant were nonverbal (Tiferes et al., 2016a). The current study focuses on improving our understanding of the nature of the multimodal interactions between surgeons and right bed side assistants during RAS.

In RAS, the available communication mediums between the surgeon at the console and the right bed side assistant are constant. They can interact either auditorily or through actions in the shared operative field view. While we have shown the prevalence of nonverbal interactions (Tiferes et al., 2016a), we have not analyzed how the utilization of nonverbal means is affected by purpose. Given the importance that purpose of interaction has on establishing common ground (Clark & Brennan, 1991), we hypothesized that interaction activities with different purposes would show different interaction configurations (proportions of verbal and nonverbal events). Below we describe how we investigated this hypothesis by analyzing and categorizing surgeon-right bed side assistant interactions from recordings of robot-assisted surgeries.

METHODS

Recordings from six robot-assisted radical prostatectomies were analyzed. These surgeries included a combination of three lead surgeons, three assistant surgeons, and two right bed side assistants (PAs).

Participants

OR staff and patients were invited to take part in this IRB-approved study (RCPI: I 244113). Meetings with OR personnel (nurses, PAs, surgeons, and anesthesiologists) were organized prior the start of the data collection to discuss the purpose and methodology of the study. Those agreeing to participate provided informed consent valid for one year. Additional staff consent was obtained just prior to surgery when necessary. Consent was also obtained from patients before each surgery (Tiferes et al., 2016b).

Technical Setup

Video feed from the operative field as well as three cameras in the OR were utilized to collect and monitor team interactions during RAS (Figure 1). Camera 1 (top-down view) captured the OR table and the nonverbal interactions between the right (PA) and left (scrub nurse) bed side assistants; Camera 2 captured the console surgeon and the circulating nurse's station; and Camera 3 recorded the left side assistant, the anesthesia station, and the OR door. The surgical console feed provided the operative context in addition to nonverbal interactions that may occur in this shared view. Each team member wore a lapel microphone to facilitate speaker identification and speech comprehension during analysis. All of these recordings were then synchronized via movie editing software, resulting in four audiovisual streams per surgery that were later analyzed in video coding software.

Case Recording Process

The setup process for each surgery started after verifying consents from the patient and surgical team. Surgeries were recorded only when the patient and all surgical staff present had given consent. Efforts were made not to interfere with patient care during data collection (e.g., staff members and researchers were asked not to engage in conversation). Microphones were given to participants before they started their duties. Surgery recording was initiated after the patient's face was draped and covered after timeout concluded to ensure the patient's anonymity. Recording was stopped right after the robot's undocking but before the drapes were removed and the patient was woken.

Coding Scheme

Interaction events were coded based on an *a priori* coding scheme (Tiferes et al., 2015) that categorized each interaction into four dimensions: Sender, Recipient, Type (verbal or nonverbal), and Topic. "Topic" identified the theme of the interaction and included nineteen categories (i.e., bag, camera angle/position, camera clean, camera focus, case-irrelevant, catheter, clip, cut, dissecting needle, hold, patient condition/information, remove, staple, stitching/needle, suction, tool change, tool preparation/organization, wash, and workflow/time management). A randomly selected portion of each surgery (10% of overall recording time) was selected and coded by two researchers to calculate inter-rater reliability (IRR) for each dimension.

Data Analysis

The most frequent interaction topics were identified. A Chi-square test was performed to determine the relationship between *interaction type* (verbal or nonverbal) and *topic.*

RESULTS

Coding tasks required between fifteen and twenty hours of coding per hour of surgery and resulted in an acceptable IRR (88% agreement on average). The total recording time for the six procedures was 19.8 hours.

Table 1. Description of most frequent interaction topics

Topic	Description
Suction	Removal of excess fluid (saline, urine, blood) present in the surgeon's operative field with the laparoscopic suction tool.
Wash	Cleaning the surgeon's working area by irrigating saline solution and suctioning it once clean
Hold	Assisting the surgeon by retracting tissue with a laparoscopic tool.
Clip	Placing a surgical clip to control/seal a blood vessel.
Catheter	Manipulation of the urethral Foley catheter.
Stitching/ Needle	Manipulation of the needle and assistance during stitching.

Table 2. Frequency of interaction events by topic and type

Topic		Interaction Type	
		Nonverbal	Verbal
Suction	%	87	13
	Count	*986*	*144*
Wash	%	86	14
	Count	*784*	*132*
Hold	%	70	30
	Count	*406*	*178*
Clip	%	56	44
	Count	*323*	*249*
Catheter	%	40	60
	Count	*178*	*263*
Stitching/Needle	%	65	35
	Count	*272*	*144*

Topic and Interaction Type Relationship

We evaluated those events that involved the most frequent interaction topics (Table 1), which accounted for 78% of all interactions: *suction* (22%), *wash* (18%), *hold* (11%), *clip* (11%), *catheter* (9%), and *stitching & needle* (8%).

The frequency of verbal and nonverbal events by topic is presented (Table 2). The relationship between *interaction type* and *topic* and was found significant, χ^2 (5, n=4059) = 519.24, p<0.001. Our hypothesis that the proportion of interaction event types differed among topics was supported.

The distribution of interaction events by topic and a further classification by sender is shown (Figure 2). Area sizes represent the proportion of events by condition.

DISCUSSION

Few reports have specifically studied team communication during RAS, and nonverbal interactions have been largely overlooked in OR settings. The Joint Commission (2014) has identified that communication failures in healthcare are among the leading factors implicated in sentinel events, thus studying team interactions during RAS is crucial to improve patient safety.

The present study focused particularly on the multimodal communication between surgeons and right bed side assistants during RAS as well as how that communication varied according to the purpose of the interaction. We have found that the proportion of verbal and nonverbal events between the surgeon and right bed side assistant was different depending on the topic of their interaction.

Multimodal Communication by Topic

Results showed that each topic employs different communication strategies, as some interaction topics exhibited more verbal events than others.

Suction and *wash* interactions required minimal verbalizations, as PAs largely did not wait for the surgeon to verbally request it and performed the wash or suction action when they saw that it was needed.

That was also the case in many *hold* interactions, in which the PA used their laparoscopic tool to improve the field of view of the surgeon proactively and without any prior verbal command. However, on other occasions (as exemplified in the introduction) the surgeon would need the PA to retract in a particular way that was not completely obvious, and they would engage in more negotiations, requiring more verbalizations.

The typical *clip* interaction showed more verbal events. This may be explained by the number of steps it often requires: (i) the surgeon requests a clip, (ii) the surgeon indicates the desired location for the clip (typically via nonverbal means, such as pointing at the location, holding the section to be clipped, or/and adjusting the camera position and zoom), (iii) the PA introduces the laparoscopic clip applicator with a clip into the operative field, (iv) the PA places the clip at the required location without closing it, (v) the surgeon confirms that the location is correct, and, finally, (vi) the PA closes the clip and removes the laparoscopic clip applicator.

In contrast, the *catheter*-related interactions showed more verbal than nonverbal interactions events. This is because the catheter movements requested by the surgeon, and performed by the PA, cannot always be seen in the shared view, making spoken communication inevitable.

On the other hand, the *stitching & needle* interactions presented a greater balance between the interaction events done by the surgeon and the PA. For example, when the surgeon asked for a needle, the PA handed it over to the surgeon. Also, when the thread needed to be cut, the surgeon would tie the knot and tighten the thread while the PA cut the suture.

Interestingly, while the RAS technology was designed to facilitate surgical procedures, here we have seen instances in which the uses of the robotic tools go beyond their intended design: the robotic tools became the extension of the surgeon's hands for pointing, or camera positioning and zooming was used to draw the PA's attention to a certain location. This is not particularly surprising, as medical providers often need to adapt existing technologies to meet the unique and changing challenges of their work (Cook & Woods, 1996).

Finally, it is worth noting that while this study has identified a series of single verbal and nonverbal interaction

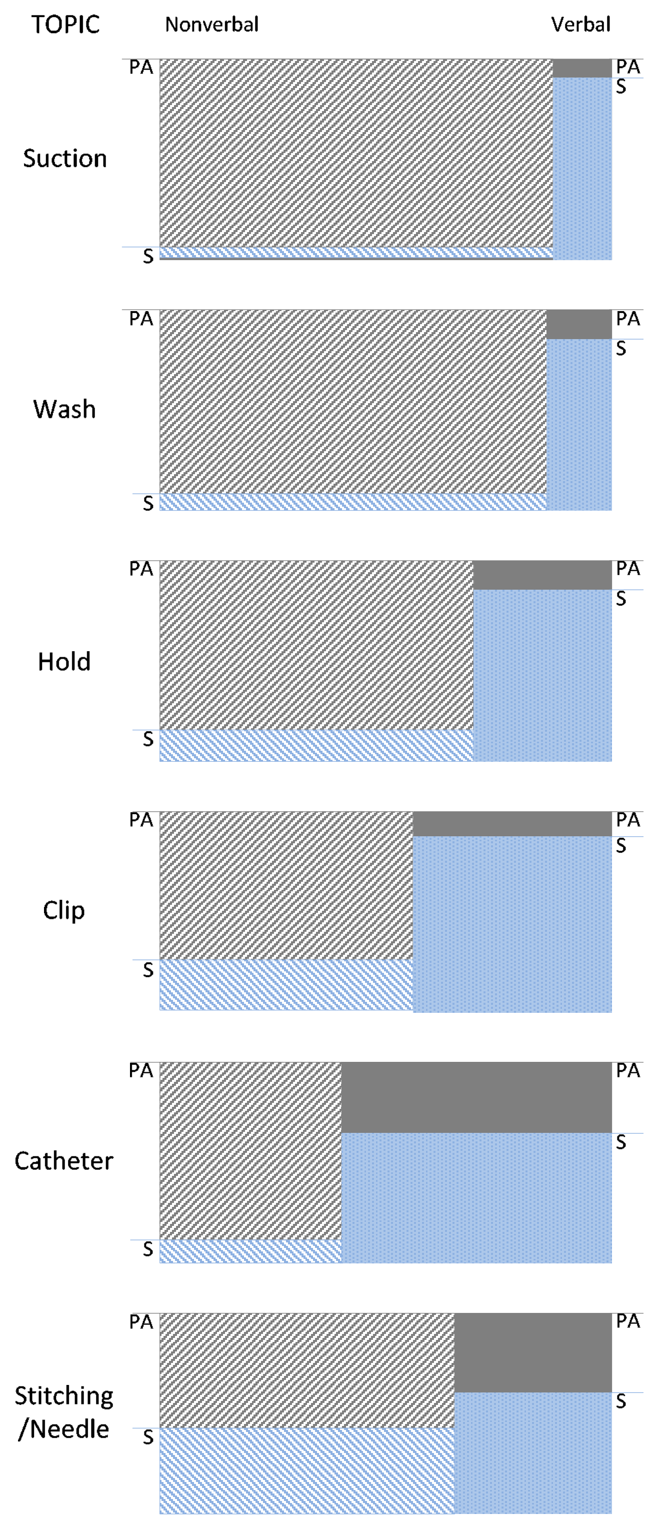

Figure 2: Proportion of nonverbal (dashed) and verbal (solid) events by topic and sender where **S** indicates interaction events produced by the surgeon at the console and **PA** those produced by the Physician Assistant located to the right of the patient.

events, this is a false dichotomy as communication is not purely verbal or nonverbal, but multimodal. A single interaction event cannot be understood in isolation. Meaning emerges from the combination of multiple verbal or nonverbal interaction events embedded in a certain environment. Nonverbal aspects are embedded in the multimodal nature of communication.

Limitations

This study has several limitations. The communication styles reported in this paper are inherently limited to the specific surgeons and PAs who participated. Here, all PAs seemed to act proactively and did not always wait for the surgeons to request an action before assisting. However, we acknowledge that other surgeons prefer for the PAs not to act at all unless explicitly asked. This could change the use of verbal and nonverbal strategies among the identified topics. Similarly, as all cases were recorded in the same OR, our results do not take into account the possible implications that OR layout design may have on communication.

Implications for OR Team Communication Research

OR communication is not exclusively spoken; other aspects are involved, such as shared displays, gestures, and tool manipulations. Research and intervention initiatives that seek to improve team communication in the OR cannot overlook nonverbal aspects, as team interaction strategies are multimodal. In addition, this research suggests that interventions to improve team communication not only need to include nonverbal aspects but also need to be tailored by activity.

Future research in RAS team communication should include other RAS team members besides the surgeon and PA, as they do not work in isolation. The OR team may have six or more members, including additional surgeons, circulating nurses, scrub nurses, and anesthesiologists.

Other potentially confounding factors, such as team familiarity, should be included regarding their effect on communication given that studies in other domains have found a possible association (Foushee, Lauber, Baetge, & Acomb, 1986; Smith-Jentsch, Cannon-Bowers, Tannenbaum, & Salas, 2008; Xiao, Parker, & Manser, 2013). However, such associations have limited support in surgery (Tiferes et al., 2015).

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