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Operative traffic in orthopedics: A glimpse into surgical team transformations☆

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ABSTRACT

Operative traffic can reduce the sterility of the operating room (OR) and put patients at risk of infection. Such traffic can also change the makeup of the surgical team, yet these transformations have not been investigated. The aim of this study was to analyze operative traffic in regards to the number of people that entered the OR and characterize personnel transformations within operative teams across a surgical day and surgical procedure. Over three months, surgical cases performed by one orthopedic surgeon in an academic hospital were observed. Data were collected on the time of personnel entry and exit, and the characteristics of the case. Transition patterns were classified based on the number of transitions for each personnel role. Overall, 465 individuals (M = 23.21 individuals, SD = 7.25) entered the OR across all 19 surgical days, with 286 identified as surgical personnel (M = 15.05 personnel, SD = 3.05). Six transition patterns were found in the data. Patterns with three or more transitions per role occurred 38.9% of the time and were observed for registered nurses, certified surgical technicians, certified registered nurse anesthetists, and anesthesiologists. The transition patterns of these roles present increased opportunity for errors during a procedure and should be further investigated. In future studies, the authors plan to study other specialties, procedures, and accrue a larger sample to further understand how operative traffic and surgical site infections relate to one another.

1. Introduction

Surgical site infection (SSI) is the most common type of hospital-acquired infection for surgical patients in the United States.[1–4] The Centers for Disease Control and Prevention (CDC) defines SSI for implants only as "infection [that] occurs within 30 days after the operative procedure if no implant is left in place, or within one year if an implant is in place and the infection appears related to the operative procedure."[2] Risk factors that impact patient-acquired SSI include patient factors, surgical factors, and the operating room (OR) environment.[5]

Maintaining a sterile OR environment with clean air is critical for infection prevention[6,7]; however, it cannot be easily sustained when personnel enter and leave the OR during a surgical procedure.[8] As operative traffic occurs over a case, a patient can be exposed to airborne contaminants and possible infection for as long as 50 min per operation.[9] Case schedules, patient needs, and departmental staffing decisions are some of the many reasons operative traffic occurs during a surgical case. In one study of operative traffic, anesthesiologist (65.4%) and nursing (46.2%) changes were identified as the most frequent personnel changes during orthopedic cases.[10] This kind of operative traffic not only impacts the patient, but can have ramifications for the surgical team as well.

Personnel transitions change the composition of the surgical team, since relief personnel are frequently required to step into surgical or assistive roles for a period of time. Research has focused on how patient information is communicated between personnel during transitions,[11] as successful surgical teams are shown to display effective communication, coordination, and cohesion.[12,13] However, as more individuals transition into a given role, critically relevant patient information can be lost or miscommunicated.[11,14] Strategies employed by team members also may not be effective as team composition changes. Transactive memory, for example, allows members of consistent teams to divide cognitive load across the team and use individual members as memory aids.[15,16] The goal of this study is to determine how many individuals transition through each personnel role in a given case or day so that actions that threaten patient safety can be identified.

By understanding the frequency of new and relief personnel entering the OR and how a surgical team transforms, we can develop

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Individuals in the Operating Room

Stage of Surgical Day																	
BRIEF	S_1	R_1		RN_1		CST_1		CSA_1		A_1	$CRNA_1$						
Patient 1				RN_1		CST_1	CST_2			A_1	$CRNA_1$	$CRNA_2$	$CRNA_3$				
		R_1	R_2	RN_1		CST_1	CST_2			A_1	$CRNA_1$	$CRNA_2$	$CRNA_3$				
	S_1	R_1		RN_1		CST_1		CSA_1		A_1	$CRNA_1$						
	S_1					CST_1	CST_2			A_1	$CRNA_1$						
						CST_1	CST_2			A_1	$CRNA_1$						V_1
		R_1	R_2	RN_1		CST_1	CST_2			A_1	$CRNA_1$		$CRNA_3$				
		R_1	R_2	RN_1		CST_1	CST_2				$CRNA_1$						
	S_1	R_1	R_2	RN_1		CST_1	CST_2				$CRNA_1$						V_2
	S_1	R_1	R_2	RN_1		CST_1	CST_2				$CRNA_1$						V_3V_4
	S_1	R_1	R_2	RN_1		CST_1	CST_2				$CRNA_1$						$V_3V_4V_5$
	S_1	R_1	R_2	RN_1		CST_1	CST_2				$CRNA_1$			$CRNA_4$			V_3V_4
	S_1	R_1	R_2	RN_1		CST_1	CST_2			A_1							V_3V_4
	S_1	R_1	R_2	RN_1		CST_1	CST_2			A_1	$CRNA_1$		$CRNA_3$				V_3V_4
	S_1	R_1	R_2	RN_1		CST_1	CST_2				$CRNA_1$						V_3V_4
	S_1	R_1	R_2		RN_2	CST_1	CST_2				$CRNA_1$						V_4V_5
	S_1	R_1	R_2		RN_2	CST_1	CST_2				$CRNA_1$				$CRNA_5$	$CRNA_6$	V_4
	S_1	R_1	R_2		RN_2	CST_1	CST_2				$CRNA_1$						V_4
		R_1	R_2		RN_2	CST_1	CST_2				$CRNA_1$						V_4
				RN_1		CST_1	CST_2	CSA_1	CSA_2	A_1	$CRNA_1$						V_4
Patient 2				RN_1		CST_1	CST_2		CSA_2	A_1	$CRNA_1$						V_4
			R_2	RN_1		CST_1	CST_2		CSA_2		$CRNA_1$						V_4
		R_1	R_2	RN_1		CST_1	CST_2		CSA_2		$CRNA_1$						V_4
	S_1	R_1	R_2	RN_1		CST_1	CST_2		CSA_2		$CRNA_1$						V_4
	S_1	R_1	R_2	RN_1		CST_1	CST_2	CSA_1			$CRNA_1$						V_3V_4
	S_1	R_1	R_2	RN_1		CST_1	CST_2	CSA_1			$CRNA_1$						$V_3V_4V_6$
	S_1	R_1	R_2	RN_1		CST_1	CST_2	CSA_1		A_1							V_3V_4
	S_1	R_1	R_2		RN_2	CST_1	CST_2	CSA_1		A_1							V_3V_4
	S_1	R_1	R_2		RN_2	CST_1	CST_2	CSA_1		A_1							$V_3V_4V_7$
		R_1	R_2		RN_2	CST_1		CSA_1			$CRNA_1$						
		R_1	R_2	RN_1		CST_1		CSA_1			$CRNA_1$						
END				RN_1		CST_1		CSA_1			$CRNA_1$						

** S_X=surgeon, R_X= resident, RN_X=circulating nurse, CST_X=certified surgical technician, CSA_X=certified surgical assistant, $CRNA_X$=certified registered nurse anesthetist, A_X=anesthesiologist, V_X=visitor, X=number of personnel transitioned into a personnel role.*

Fig. 1. Surgical team transformation across a surgical day. * S_X = surgeon, R_X = resident, RN_X = circulating nurse, CST_X = certified surgical technician, CSA_X = certified surgical assistant, $CRNA_X$ = certified registered nurse anesthetist, A_X = anesthesiologist, V_X = visitor, X = number of personnel transitioned into a personnel role.

better informed interventions that address issues such as team communication, cohesion, and transactive memory. Therefore, the aim of this study was to analyze operative traffic in regards to the number of people that entered the OR and characterize personnel transformations within operative teams across a surgical day and surgical procedure.

2. Methods

2.1. Setting and participants

A prospective, observational study was performed at a 794-bed non-profit academic tertiary medical center with an individual orthopedic surgeon and his surgical team. For this study, the surgical team included the following roles: surgeon, resident, circulating nurse (RN), certified surgical technician (CST), certified surgical assistant (CSA), certified registered nurse anesthetist (CRNA), and anesthesiologist. Every morning a briefing was held for the surgical team on the procedures held in a single OR that day. The briefing addressed all the procedures performed in that OR for the full operative day, as well as any equipment and prosthesis needs for each patient. Study approval was granted by the Mayo Clinic Institutional Review Board.

2.2. Observational method

Two researchers with clinical and human factors expertise developed a data collection tool to identify personnel who entered and left the OR. Prior to data collection, the clinical expert received training in human factors and qualitative research methodology. Researchers observed a surgical day together to reinforce training and reach consensus agreement on the data collected.[17,18] Over a period of three months, researchers observed surgical cases and surgical days performed by a specific orthopedic surgeon. For each case, one researcher observed the entire case from within the OR but remained outside the sterile field, in order to remain unobtrusive.

2.3. Data collection tool and analysis

To record the occurrence of staff entry and exit from the OR, team members present at the start of each surgical day during the briefing were recorded. In this study, a surgical day is defined as beginning at the initial briefing for the first patient and ending when the final patient leaves the OR for that day. The data collection tool was used so that researchers could track initial team members, their entry and exit, and record any relief and additional staff that entered after briefing. The tool collected multiple data types. Researchers recorded the time of staff entry and exit, whether it was the first or second case of the day, and the procedure performed.

Following the briefing, data collection started at the time of patient arrival. From that point on, the researchers observed OR workflow and noted individuals that entered or exited the OR, including their surgical role and time of entry or departure from the OR. Any person that was not categorized as one of the roles above was considered a visitor. Door openings as a result of the research team were minimal and not included in this analysis. Data collection temporarily stopped during patient turnover and restarted when the next patient entered the OR. Researchers only observed scheduled surgical days for the specific surgeon during data collection.

2.4. Data analysis

Descriptive statistics were calculated on the data collected using the tool using Microsoft Excel (Microsoft Corporation, Redmond, Washington). Patterns of personnel role transitions were then identified based on the frequency of transitions.

3. Results

A total of 5977 operative minutes were observed in 38 orthopedic cases with one surgeon. Data collection occurred across 19 surgical days. The procedures were limited to total hip arthroplasties (THA),

total knee arthroplasties (TKA) and one ankle hardware removal procedure.

3.1. Personnel and visitors

3.1.1. All individuals

In total, 465 individuals entered the OR across all 19 surgical days (M = 23.21 individuals, SD = 7.25). Within a surgical day, an average of 11.63 individuals (SD = 3.62) entered the OR for each case. An example of how the surgical team and OR transformed over a surgical day can be seen in Fig. 1.

3.1.2. Visitors and personnel

Visitors were parsed out from the data in order to understand surgical team transformations. A total of 155 visitors entered the OR across the observed surgical days (M = 8.16 visitors, SD = 5.12). Within a surgical day, an average of 4.08 visitors (SD = 2.73) entered the OR for each case.

In total, 286 surgical personnel entered the OR across the observed surgical days (M = 15.05 personnel, SD = 3.05). Within a surgical day, an average of 7.53 surgical personnel (SD = 1.53) entered the OR. A breakdown of personnel role can be seen in Table 1.

3.2. Transition patterns in a surgical role

Six transition patterns were identified across the 19 surgical days observed, as shown in Table 2. Transition patterns with three or more people in a single role occurred 38.9% of the time and were observed in the RN, CST, CRNA, and Anesthesia roles. The CRNA role experienced two instances of six different personnel transitioning in the role during a single surgery. Within a surgical day, a total of 3 transition patterns were identified for each case, as shown in Table 3.

4. Discussion

This study aimed to analyze operative traffic by the number of personnel that entered the OR and transitioned into or out of surgical roles. The data was then used to characterize operative team transformations for both surgical days and procedures.

Operative traffic was frequent, supporting findings of previous studies.[9,10,19] The total number of unique individuals that entered the OR across a surgical day was higher than expected; however, visitors comprised more than 35 percent of the total. Because the study was conducted at a teaching hospital, the additional individuals identified as visitors may have been in the OR for educational purposes. Regardless, the high rate of visitors entering and leaving the operating suite presents unnecessary risk to SSI exposure and potential distraction to the surgical team performing the procedure.

The operative team consisted of seven personnel roles (surgeon, resident, RN, CST, CSA, CRNA, and anesthesiologist). More than 15 new staff members entered the OR per surgical day on average, providing opportunity for miscommunication, or for information to be excluded or inaccurately received particularly within individual roles.[14] This is particularly concerning as the RN, CST, CRNA, and anesthesiologist roles required three or more individuals to transition into those roles at least once during the data collection period. When relief personnel transition into an operative team role and replace initial personnel, a 'threat window' opens in which there is opportunity for errors or adverse events to occur.[20] As more individuals transition into a personnel role, the threat window widens and poses a higher risk for errors, such as miscommunication, to occur. Therefore, we believe transitions of three or more people into a single personnel role during one procedure or surgical day (i.e., entire day with multiple patients) should be designated as high risk to patient safety.

Team transformations with multiple personnel transitions can have negative effects on team coordination, cohesion, and performance. Where consistent teams (i.e. minimal transitions and low risk) benefit from shared mental models,[13] implicit coordination,[12] team trust,[21] and relational coordination,[22] inconsistent teams (i.e. multiple transitions and high risk) exhibit poor communication and can have a measurable negative impact on surgical team performance.[11,14] High risk transitions may also interrupt the transactive memory of the team.[23] Although critical patient information may be effectively shared between two personnel involved in a transition, the physical appearance of the initial staff member served as a visual external memory aid to others in the team. Consequently, when the original team member departs, the knowledge that member represented for the other individual team members also departs. Therefore, high risk personnel transitions potentially may create problems for the individual team and entire system.[16]

The authors recognize the limitations to this study. A single surgeon was observed in a single institution, limiting generalization; however, the purpose of this study was exploratory in nature, with the focus on understanding the changing surgical team. Operative personnel may have changed their behavior as a result of the presence of researchers; however, they were not informed of the true purpose of this study. Furthermore, a previous study of OR traffic found that monitoring had no significant effect on OR traffic.[10] As with all observational studies, human fallibility is possible. It is possible staff entrances or exits may have been missed or incorrectly marked. Lastly, due to the small number of procedures observed, it was not possible to determine a relationship between operative traffic and SSI. In future studies, the authors plan to use a far larger population across various surgical specialties to further understand how operative traffic and SSIs relate to one another.

Table 1
Number of personnel that enter the OR per surgical day, by role.

Personnel	Average (SD)	Range (min, max)
Surgeon	1.16 (0.37)	(1, 2)
Resident	1.63 (0.60)	(1, 3)
RN	2.95 (1.03)	(2, 5)
CST	2.21 (0.71)	(1, 4)
CSA	1.37 (0.50)	(1, 2)
CRNA	3.68 (1.34)	(2, 6)
Anesthesiologist	2.05 (0.91)	(1, 4)
Total	15.05 (5.45)	

Table 2
Transition patterns per surgical day, by role. *RN = circulating nurse, CST = certified surgical technician, CSA = certified surgical assistant, CRNA = certified registered nurse anesthetist.*

Patterns	RN	CST	CSA	CRNA	Anesthesia	Total
A	0	2	12	0	6	20
A-B-A-B	8	12	7	4	7	38
A-B-A-C-A	4	4	0	6	5	19
A-B-A-C-D	6	1	0	3	1	11
A-B-A-C-D-E	1	0	0	4	0	5
A-B-C-D-E-F	0	0	0	2	0	2
Total	19	19	19	19	19	95

Table 3
Transition patterns per surgical case, by role. *RN = circulating nurse, CST = certified surgical technician, CSA = certified surgical assistant, CRNA = certified registered nurse anesthetist.*

Patterns	RN	CST	CSA	CRNA	Anesthesia	Total
A	4	18	26	9	19	76
A-B-A-B	30	20	12	24	13	99
A-B-A-C-A	4	0	0	5	2	11
Total	38	38	38	38	34	186

5. Conclusion

Through identifying operative traffic during orthopedic surgery, this study was able to identify personnel changes that put the surgical team at higher risk for miscommunication and potential performance failures. The authors of this study believe that no one has truly determined what level of operative traffic is essential and whether it could be standardized across specialties or institutions. Future research should look into what traffic is actually necessary and how surgical teams have achieved it.

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