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Surgical time independently affected by surgical team size

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Abstract

BACKGROUND: Team size and composition provide essential data for the study of operating room (OR) efficiency.

METHODS: Laparoscopic procedures between July 2005 and July 2007 were reviewed retrospectively to record the number of OR personnel and the procedure time (PT).

RESULTS: Of 399 procedures reviewed, 360 cases with complete data were analyzed. The average PT was 148 minutes. A mean of 8 different team members (range, 4–15) were involved. Surgeons and anesthesiologists stayed constant whereas the OR nurses were replaced more than once per procedure (mean, 4 nurses/procedure; range, 2–11). Multiple regression analysis revealed that both complexity of surgery and team size affected the PT significantly. When procedure complexity and patient condition were held constant, we found that adding 1 individual to a team predicted a 15.4-minutes increase in PT.

CONCLUSIONS: The surgical team is a dynamic system with a large amount of member turnover. Efforts to improve OR efficiency should focus on decreasing surgical team size, limiting staff turnover, and enhancing communication between team members.

A surgical procedure is a team task performed by health care providers in the operating room (OR). The surgical team consists of surgeons, anesthesiologists, nurses, and other experts collaboratively working together towards a common surgical goal. Over the past decade, a number of human factor studies conducted in the OR have shown that the surgical outcome relies heavily on the quality of teamwork in addition to individual skills, and showed that effective teamwork is influenced by the quality of team communication and cooperation.[1–5]

As attention regarding surgical error prevention has been shifted from the individual to the surgical team, basic data are needed to describe the average surgical team size and composition. Basic knowledge of team size and team composition would allow us to further explore the communication and coordination patterns inside the OR, and to evaluate factors that facilitate or impede teamwork quality.

On one hand, increasing the team size brings in expertise that is necessary to achieve a team task goal, but on the other hand, larger teams increase barriers for team communication. It is more difficult for team members in a larger team to develop a shared mental cognition.[6] These team-related problems degrade team performance and ultimately will lead to surgical errors. In a study by Lingard et al[4] that looked at the causes of communication failures in the OR and the subsequent effects on patient safety, they found that communication failures in the OR occurred in approximately 30% of exchanges between team members. One third of these cases jeopardized patient safety by interrupt-

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ing the surgical routine, and by increasing the cognitive load and tension in the OR. Another study conducted by Gawande et al[7] found that communication was a causal factor in 43% of errors made in surgery.

The complexity of a procedure affects all measures of team performance. In many ways, the procedure complexity determines the procedure time and who should be assigned to a surgical team. To objectively describe the complexity of a procedure, we developed a measure called the Index of Difficulty of Surgery (IDS). The IDS was calculated based on the relative value unit (RVU) of each procedure established by the American Medical Association in the book of *Current Procedural Terminology* (CPT).[8]

A retrospective study on laparoscopic procedures between 2005 and 2007 was performed by reviewing an institutional administrative database at 3 tertiary hospitals. Data were collected on all team members involved with the procedure, the procedure type, the procedure time (PT), the age of the patient, and the preoperative American Society of Anesthesiologists (ASA) score. In this study *team size* refers to each person assigned to the surgical case throughout the duration of the procedure. We computed the team size, IDS of each procedure, and further investigated their relationships to the PT. We performed a multiple regression analysis on PT using team size, IDS, ASA, and patient age as the predictors with the aim of investigating which of these factors contributes most to the PT.

We hypothesized that larger surgical team sizes would have a significant negative impact on surgical team performance (measured by longer PT) because of the increased difficulty in team communication and coordination. We believed that the impact of team size on the PT would be recognizable even when the IDS and patient condition are held constant.

Methods

Procedures

A retrospective case review was completed on all general laparoscopic procedures that were preformed by the senior author (L.L.S.) between July 2005 and July 2007. Procedures were performed in 3 ORs designed for minimally invasive surgical procedures. Ethical approval was obtained from the Internal Review Boards at Legacy Health System (FWA00001280) and Providence Portland Medical Center (07 A–88 A).

Data collection

From the intraoperative nursing records we recorded surgeons, surgeon assistants, anesthesiologists, and all nurses present during the procedures, and recorded their roles and times assisting in surgery. All other staff including radiologists, cardiologists, endoscopists, ultrasound technicians, and industry representatives were recorded under the category of observers. The patient demographics, preoperative diagnosis, type of procedure performed, procedure start time, and procedure end time also were collected. We recorded the anesthesia start time, anesthesia end time, and preoperative ASA score from the anesthesia records.

Measures

Based on the data collected, we developed metrics for measuring team size and team composition. The team size includes all surgical members assigned to a procedure including anesthesiologists, surgeons, scrub nurses, circulating nurses, and observers present during a procedure. The role of each team member was categorized further. We divided the role of the surgeon into primary, fellows, and residents. The roles of the nurses were divided into circulating nurses and scrub nurses. Other people observing the surgery included representatives and specialists, such as radiologists, cardiologists, and endoscopists, students, and observers. For each procedure, the surgical outcome was assessed by PT and anesthesia time in minutes.

Procedure complexity was assessed by the IDS. The IDS was calculated based on the RVU of a performed procedure under the CPT established by the American Medical Association.[8] The RVU values for each case were obtained from the CPT/RVU search engine on the American Medical Association's Web site.[8] A Medicare-based RVU includes 3 components: physician's time spent in preparation and follow-up documentation on the procedure, cost of surgery, and the professional liability insurance expenses. For this study only the cost of the surgery was used for calculation. The higher RVU indicates that a more complicated surgical procedure was performed. If there were multiple procedures performed during surgery, the RVU of a secondary procedure was calculated by half (multiplied by .5) and then added to the RVU of the primary procedure. For example, the laparoscopic Nissen has a RVU value of 938, and the RVU of a laparoscopic cholecystectomy is 624. In the case in which the laparoscopic Nissen was followed by a cholecystectomy, the total RVU was equal to 1350 ($938 + 624 \times .5$). For a reoperative procedure, the RVU was multiplied by 1.25 because the reoperative procedure is more complicated than the case performed the first time, that is, a reoperative Nissen has a RVU of 1,173.

Once the RVU values of procedures were established, the procedure RVU score then was normalized to 100 by dividing the procedure RVU by the maximal RVU within this data set. This relative score is the IDS of this procedure. As a result, a laparoscopic esophagectomy procedure has an IDS equal to 99, contrasting the IDS of a laparoscopic Nissen fundoplication and cholecystectomy, which is equal to 26 and 17, respectively.

Data analysis

Data regarding team size and composition were analyzed descriptively and quantitatively. We described the total

Table 1 Team composition, size, and procedure time

	Anesthesiologist	Surgeon	Scrub nurse	Circulating nurse	Nurse	Others	Team	PT
Mean	1	2	2	2	4	1	8	148
Median	1	2	2	2	4	0	8	131
SD	0	1	1	1	1	1	2	87
Range	1	3	4	5	8	5	11	611
Minimum	1	1	1	1	2	0	4	22
Maximum	2	4	5	6	10	5	15	633

number of people involved in each procedure. We further categorized team members into each specialty group, and reported the data by the minimum, maximum, mean, median, and standard deviation. Data were analyzed using SPSS version 11.0 (SPSS Inc., Chicago, IL, USA).

Multiple regression analysis was used to predict the change of a dependent variable from the change of one or more independent variables. For our study, multiple regression analysis was performed to explore which factor(s) contribute to the change of PT. The regression model used the PT as the dependent variable; the independent variables included IDS, team size, as well as patient age, and the ASA score of a patient. The last 2 variables (patient age and ASA score) described preoperation patient condition. Regression analysis was conducted using SPSS, with hierarchic data entry. Specifically, we entered the IDS into the model first, followed by the team size, and, lastly, the ASA score and patient age at one time. The order of data entry was determined by the correlation coefficients between each predictor and PT. The variable with highest simple correlation was entered into the model first.

Results

A total of 399 cases were reviewed retrospectively. Laparoscopic procedures performed included cholecystectomy, hernia repair, various surgical procedures for gastroesophageal reflux disease, bariatric procedures, esophagectomy, and other general surgery procedures. Thirty-nine procedures were deleted from the analysis because of incomplete surgical records, such as missing procedure time, OR staff, or lack of OR report. The analysis was performed on 360 procedures.

Surgical team size

There was a mean of 8 team members assigned to a single procedure. The minimum team size was 4 people, whereas the largest surgical team had 15 team members (Table 1).

Surgical team composition

The surgical team consisted of surgeons, anesthesiologists, nurses, other experts, and observers (Fig. 1).

All procedures analyzed were attended by an anesthesiologist and at least one surgeon. Only 6.9% of procedures were performed by one surgeon (Table 2). An anesthesiologist seldom is assigned to more than one OR because nurse assistants and anesthetic residents are not included at either hospital included in this study. The attending anesthesiologist had full responsibility for the case during that procedure. Most procedures were performed by 2 surgeons

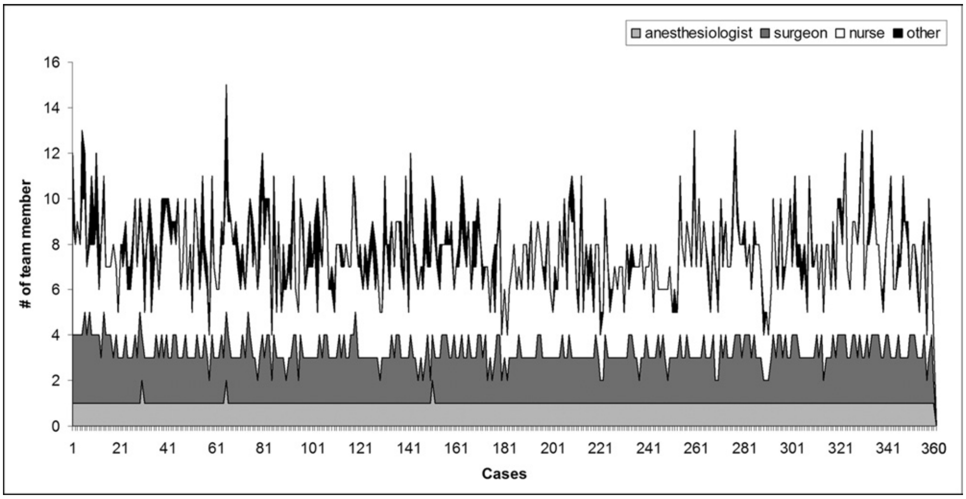

Figure 1 Surgical team composition of 360 laparoscopic procedures. ▨, Anesthesiologist; ▩, surgeon; □, nurse; ■, other.

Table 2 Number of surgeons present in the OR during each case

Number of surgeons	Composition	Frequency	%
1		25	6.9
2		214	59.4
	PF	201	55.8
	PP	1	.3
	PR	12	3.3
3		115	31.9
	PFR	110	30.6
	PPF	3	.8
	PPR	2	.6
4		6	1.7
	PFFR	5	1.4
	PPFR	1	.3
Total		360	100.0

P = primary surgeon; F = fellow; R = resident.

(59.4%) or 3 surgeons (30.6%). Procedures assisted by a surgical fellow or resident did not affect PT significantly ($P < .05$). The effect of the surgeon's team experience on PT will be reported in a separate article. The anesthesiologists and surgeons assigned to a procedure normally stay for the entire surgery, whereas nurses shift their duties for various reasons.

The mean number of nurses per procedure was 4 (Table 1). The nurses were analyzed further by their role of either scrub nurse or circulating nurse. We found that only 29.2% of procedures were assisted by only one scrub nurse (Table 3). Most procedures were assisted by 2 scrub nurses (48.1% of cases) working in succession. Three scrub nurses were present in 18.6% of procedures, 4 scrub nurses were found in 3.1% of procedures, and 5 scrub nurses were present in 1.1% of procedures. Similarly, most procedures (41.7%) were assisted by 2 circulating nurses working in succession, followed by procedures assisted by 1 circulating nurse (28.1%) and 3 circulating nurses (24.7%). In extraordinarily long procedures, there were more than 4 circulating nurses (5.5%) present (Table 3). The high number of nurses involved with the procedures indicates that there was a large amount of nursing turnover.

In 59.7% of procedures there were no observers present in the OR. We found that there was 1 observer in 28.9% of procedures, 2 observers in 8.1%, and more than 3 observers in 3.3% of procedures.

Procedure time and its relationship to team size

The minimum PT was 22 minutes for a diagnostic exploration (Table 1). The maximum PT was a 633-minute esophagectomy for cancer treatment. The average PT for 360 procedures was 147.5 ± 87.3 minutes. The average anesthesia time (AT) was 199.7 ± 93.8 minutes, with the minimum being 29 minutes and the maximum being 732 minutes. The correlation coefficient (r) between PT and AT is .93 ($P < .001$). Results obtained from the PT and AT provide similar information. We therefore only included PT for further analyses.

Surgical team size ($r = .49$, $P < .001$) and IDS ($r = .63$, $P < .001$) correlated with PT, respectively. Specifically, as the procedure complexity increased (Fig. 2A), or the number of team members increased (Fig. 2B), the procedure time was prolonged. The procedure times were correlated strongly with the number of nurses in a surgical team (Pearson's $r = .505$, $P < .001$), but correlated weakly with the number of surgeons in a surgical team ($r = .199$, $P < .001$).

In the following section we further quantify the impact of team size, procedure complexity, and patient condition on the team performance by performing a multiple regression analysis on PT.

Multiple regressions

The impact of team size, procedure complexity, and patient condition on the team performance was investigated by performing a multiple regression analysis based on the PT. The outcome of the multiple regression analysis is summarized in Table 4. In Table 4, R is the value of the multiple correlation coefficients between the predictors and the outcome, and R^2 is the percentage of variance in the dependent variable explained collectively by all of the independent variables. R^2 tells us how much of the variability in the outcome is accounted for by the predictors in a model. The *adjusted* R^2 gives us a value of how well our model is generalized. F values listed after each equation are used to determine the significance of using our model in predicting the PT, compared with a best guess. For each model the P value was less than .001, indicating that all of the models are statistically improving our prediction on the outcome of the PT by using this model.

When using IDS as the sole predictor (PT = 4.4 [IDS] + 9.0; $r = .63$, $R^2 = .40$, $F = 233.76$, $P < .001$), it accounts for 40% of variability in PT, which is high. If team size is added as a second predictor in conjunction with team size (PT = 3.7 [IDS] + 15.1 [team] − 88.7), it accounts for 49% of variability in PT ($r = .70$, $R^2 = .49$, $F = 168.83$, $P <$

Table 3 Presence of scrub nurses and circulating nurses in anti-reflux cases

Number in surgery	Scrub nurses		Circulating nurses	
	Frequency	%	Frequency	%
1	105	29.2	101	28.1
2	173	48.1	150	41.7
3	67	18.6	89	24.7
4	11	3.1	16	4.4
5	4	1.1	3	.8
6			1	.3
Total	360	100	360	100

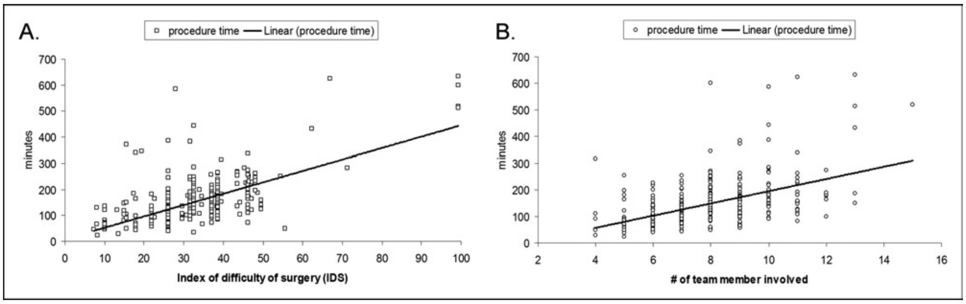

Figure 2 Correlation between the procedure time and the index of difficulty of surgery (A), and the surgical team size (B).

.001). In other words, team size accounts for an additional 9% of variability in PT. When ASA and patient age are added into the model (PT = 3.4 [IDS] + 15.2 [team] + 16.8 [ASA] + .1 [age] − 127.4; $r = .71$, $R^2 = .50$, $F = 89.47$, $P < .001$) these 4 predictors account for 50% change in PT, which is reasonably high. However, adding the patient's age and ASA did not dramatically influence PT variation. Because R^2 is very close to the *adjusted* R^2, this indicates that the cross-validity of these models is exceptional (Table 4).

The number before each predictor (ie, partial regression slope coefficients), tells us the degree that each predictor affects the outcome when the effects of all other predictors are held constant. For example, in model 3, a β value of 15.2 indicates that as team size increases by 1 U (equal to the standard deviation [SD]), the procedure time increases by 15.2 U. This interpretation is true when the effects of IDS, ASA, and age are held constant.

By using these values we can determine the specific impact of each of the predictors on the PT. The largest impact on PT is the IDS. One SD change of IDS (12.6 points) predicts a 43.2-minute change of the PT. The second largest impact factor on PT is team size, 1 SD change (1.8 team members) in team size predicts a 27.8-minute increase in PT. Patient ASA classification impacts PT with 1 SD (0.6 U) change predicting a 10.6-minute change in PT. Patient age had the least impact on PT, 1 SD (14.3 y) change in the patient age predicts a 1.9-minute change in the PT. In other words, every 10 points of IDS change predicts a 34.2-minute change in PT, one team member change predicts a 15.4-minute change in PT. One ASA class change predicts a 17.7-minute change in PT, a 10-year change in patient age predicts only a 1.3-minute change in PT.

Comments

On average, 8 people were assigned to a 2.5-hour laparoscopic procedure in the hospitals studied. When we categorized the role of each team member, we found that the anesthesiologists and surgeons assigned to a procedure normally stayed for the entire surgery; however, the nurses often shifted their duties for varied reasons such as lunch, shift change, and coffee breaks. We found that the 2 nursing roles (scrub nurse and circulating nurse) were replaced more than once for each surgical procedure. In complicated procedures we found as many as 4 nurses could be assigned to a single nursing position. Both hospitals in the study (Legacy Good Samaritan and Providence Portland Medical Center) retained OR nurses with special training pertaining to laparoscopic procedures. However, there are not an adequate number of specialized OR nurses available to cover all laparoscopic procedures performed daily. A large portion of laparoscopic procedures were assisted by nurses or OR technicians who did not have advanced training in this area. Unfortunately, the data available for analysis did not group nurses based on their specialties, and we were unable to further examine the impact of nurse specialty on OR time.

Complete involvement with a procedure enables a surgeon and anesthesiologist to develop a comprehensive shared mental model regarding tasks and goals. In contrast, high turnover and short-term involvement of other team members requires better communication strategies to keep them updated with the current state of the procedure.[2,9,10] Some may argue that staff turnover is necessary to maintain a high level of vigilance and involvement; however, frequent turnover within a team also hinders team performance, and leads to distraction and loss of focus. Our results confirm that when team size was increased, the procedure time was prolonged independently of other factors such as

Table 4 The summary table of multiple regression analysis

Model	R	R^2	Adjusted R^2	F value	P
PT = 4.4 (IDS) + 9.0	.63	.40	.39	233.76	.000
PT = 3.7 (IDS) + 15.1 (team) − 88.7	.70	.49	.48	168.83	.000
PT = 3.4 (IDS) + 15.2 (team) + 16.8 (ASA) + .1 (age) − 127.4	.71	.50	.50	89.47	.000

surgical complexity. As we found through performing a multiple regression analysis, adding 1 individual to a surgical team predicts a 15.4-minute increase in PT, when all other variables (including complexity of surgery) are held constant. Therefore, better strategies need to be developed to construct surgical teams inside the OR without constantly changing the composition of the team, especially for nurses in a team. This might minimize the chance that communication errors could result in critical team compromise and patient harm.

It is important to enforce communication before surgery and during staff turnover to build effective surgical teams. Normally, surgical teams are formed shortly before the patient is moved into the operating room, which leaves little time for information exchange between the surgeon, assistants, and nurses before the start of surgery. During staff turnover important information regarding patient condition, specific task requirements, and equipment used for the procedure may not be transferred from one team member to the next. The ambiguity presented in team goals and movement coordination has been proposed to be the root of surgical errors in the OR.[11] Studies based on other team-dependent industries outside of the OR have shown that communication and cooperation quality are affected significantly by the size of the team.[6] Increasing team size beyond a certain point may increase coordination demand and communication workload. Members in a larger team also displayed lower involvement in participating in team activities. In industries such as software design, the lack of communication between team members and overlapping responsibility of software designers leads to "reinventing the wheel" and results in biases in software testing.[6]

One strategy to enforce communication during turnover, is to formulate a system that forces team members to pass on information to the newly assigned team member before the procedure and during staff turnover.[4] The outcomes of these efforts are promising.[12] Passing information among team members will provide an opportunity for all surgical team members to develop a shared mental model regarding a common surgical goal.

In the future, we plan to study the procedure times of identical procedures performed by a trainee (either a resident or a fellow) in his/her first 2 weeks of working with the attending surgeon, to the last 2 weeks of the training phase. This study will help to quantify the impact of teaching in the OR on the surgical performance. We also plan to further study the impact of procedure starting time on the task performance of a surgical team. Preliminary data show that procedures that started around lunchtime had longer PTs than those that started either before or after lunchtime. Procedures that started after 5 PM did not have a significantly increased PT.[13] Results suggest that the surgical performance was affected by team turnover rather than team fatigue.

Lastly, we would like to emphasize the importance of training surgical teams outside of the OR. The acquisition of team skills and team identity should be established outside of the OR so that efficiency, time, cost, and patient safety are not compromised. This type of technical and nontechnical training already has been implemented in the field of aviation,[14,15] anesthesia,[16] and intensive care units.[17,18] Bench top models statistically have been shown to be equivalent to cadavers in training effectiveness and are readily transferable to the human model.[19] Bench top models such as the legacy inanimate system for endoscopic team training,[20] the simulated operating theater developed by Moorthy et al,[21] and the simulated operating theater used in the crisis simulation study by Undre et al[22] focus on creating a team-oriented simulator that mimics the OR environment.

Conclusions

In this study, we have described the size and the composition of surgical teams for laparoscopic procedures. We found that each addition to the OR team significantly increased the PT independent of other factors. Understanding the surgical team size and composition will allow us to design better educational tools for improving team composition and communication, and to develop better management strategies to optimize surgical teams and facilitate OR efficiency. Efforts to improve OR efficiency should focus on decreasing procedure team size and limiting unnecessary staff turnover.

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