Operative length independently affected by surgical team size: data from 2 Canadian hospitals

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Background: Knowledge of the composition of a surgical team is the premise for studying efficiency inside the operating room.

Methods: To investigate the team composition in general surgery procedures, we retrospectively reviewed procedures performed by an expert general surgeon in 2007–08 at 2 tertiary hospitals. For each patient, demographic characteristics, procedure type, team members and procedure length were extracted from intraoperative nursing records. We assessed procedure complexity using a calculated index. Multiple logistic regressions were performed to assess the association between procedure length and team size after adjusting for procedure complexity and patient condition.

Results: For the 587 procedures reviewed, the mean procedure length was 88 (standard deviation [SD] 51) minutes. On average, 8 team members (range 4–14), including surgeons, anesthesiologists, nurses and other specialists, were involved in each procedure. Only 47 (8%) procedures were performed by 1 surgeon. Most were performed by 2 (295 [50%]) or 3 surgeons (214 [36%]). Half the team members were nurses (mean 4, range 1–7). Both the complexity of the operation and the team size affected the procedure length significantly. When procedure complexity and patient condition were constant, adding 1 team member predicted a 7-minute increase in procedure length.

Conclusion: This study demonstrates that a frequent change of core team members has a negative impact on surgical performance. Management strategies need to improve to optimize team efficiency in the operating room.

Contexte : Pour étudier l'efficience des équipes chirurgicales au bloc opératoire, il faut en connaître la composition.

Méthodes : Pour analyser la composition d'une équipe de chirurgie générale, nous avons analysé rétrospectivement les interventions effectuées par un chirurgien général d'expérience en 2007–08 dans 2 hôpitaux de soins tertiaires. Pour chaque cas, nous avons extrait les caractéristiques démographiques, le type d'intervention, les membres de l'équipe et la durée de l'intervention à partir des notes infirmières peropératoires. Nous avons évalué la complexité de l'intervention à l'aide d'un indice calculé. Nous avons utilisé le modèle de régression logistique multiple pour établir le lien entre la durée de l'intervention et la taille de l'équipe après ajustement pour tenir compte de la complexité de l'intervention et de l'état des patients.

Résultats : La durée moyenne des 587 interventions analysées a été de 88 (écart-type [ET] 51) minutes. En moyenne, les équipes de chaque intervention se composaient de 8 membres (étendue 4–14), incluant chirurgiens, anesthésistes, infirmières et autres spécialistes mis à contribution. Seulement 47 interventions (8 %) ont été effectuées par un seul chirurgien. La plupart ont été effectuées par 2 (295 [50 %]) ou 3 (214 [36 %]) chirurgiens. Les infirmières formaient la moitié des équipes (moyenne, 4, étendue 1–7). La complexité de l'intervention et la taille de l'équipe ont significativement influé sur la durée de l'intervention. Lorsque la complexité des interventions et l'état des patients demeuraient constants, l'ajout d'un membre à l'équipe permettait de prédire une augmentation de la durée de l'intervention de l'ordre de 7 minutes.

Conclusion : Cette étude démontre que les modifications fréquentes des membres de l'équipe centrale exercent un impact négatif sur le rendement chirurgical. Il y aurait lieu d'améliorer les stratégies de gestion pour optimiser l'efficience des équipes des blocs opératoires.

The introduction of minimally invasive surgery has substantially changed the pattern of surgical practice inside the operating room (OR).[1] Built on image-guided technology, outcomes of a minimally invasive operation require surgeons to work within a collaborative team to complete the

task.[2-6] The awareness of surgical team quality and its impact on OR efficiency has considerably increased among surgeons and educators in Canada over the last decade.[7] In 2007, leading laparoscopic surgeons in Canada participated in a Consensus Conference on the Development of Training and Practice Standards in Advanced Minimally Invasive Surgery in Edmonton, Alberta. In the final report, they argued that surgeons should be trained in teams to maintain the quality of laparoscopic surgery.[7] Evidence has shown that not only do dedicated laparoscopic teams achieve better surgical outcomes with lower operating costs than teams formed ad hoc, but also that newly formed teams were more likely to encounter problems during laparoscopic surgeries.[3,8]

As attention to surgical quality has shifted from the individual to the team, data are needed to describe team composition, which forms the basis for studies in team communication and coordination in the OR. In a pilot study involving tertiary hospitals in the northwest United States, we revealed that a surgical team is often oversized and subjected to frequent member changes during a procedure.[9] Introducing a new team member to an ongoing procedure predicted a 15-minute increase in procedure length.[9] These results were obtained based on 360 pure laparoscopic procedures, a large percentage of which was foregut surgery, performed by a well-known laparoscopic surgeon.

In the present study, we aimed to quantitatively describe surgical team size in Canadian hospitals with a wider range of both open and laparoscopic procedures and to investigate the impact of team size on performance by Canadian surgical teams, as measured by procedure length. We hypothesized that increasing the size of the surgical team would have a significant negative impact on team performance, regardless of the complexity of the procedure and patient condition.

METHODS

Procedures

We reviewed general surgery procedures performed by a University of British Columbia (UBC) faculty surgeon at 2 tertiary hospitals located in the metropolitan district of Vancouver in 2007–08. The UBC Clinical Research Ethics Board (H09–01653) and Vancouver Coastal Health Research Institutes (V09–0261) approved our study.

Data collection

For procedures performed within the selected time frame, we examined intraoperative nursing records and noted the attendees present. We categorized attendees as surgeons (including surgical assistants, clinical fellows and residents), anesthesiologists, nurses (scrub and circulating) and other (radiologists, cardiologists, endoscopists, ultra-

sound technicians and industry representatives). We also recorded the patient's age, sex, preoperative American Society of Anesthesiologists (ASA) score, procedure type and procedure start time and end time.

Measures

The team size included all team members assigned to a procedure. For each procedure, the length was assessed by start time (the moment of making the first incision) and end time (closure of the surgical wounds).

To determine the complexity of a procedure, we developed an index for difficulty of surgery (IDS). The IDS was calculated using the relative value unit (RVU) of a performed procedure, defined by the Current Procedural Terminology established by the American Medical Association (AMA).[10] We obtained the RVUs for each procedure from the search engine on the AMA website.[10] For each clinical procedure, the RVU includes 3 components: physician's time spent preparing for and following up on the procedure, cost of the operation and professional liability insurance expenses. We used only the cost of the operation in our calculation. For example, laparoscopic Nissen fundoplication has an RVU of 938, and the RVU of a laparoscopic cholecystectomy is 624. In cases where 1 patient underwent multiple procedures, the RVU of the secondary procedure was multiplied by 0.5 and then added to the RVU of the primary procedure. For example, if laparoscopic Nissen fundoplication was followed by cholecystectomy, the total RVU would be 1350, or $(624 \times 0.5) + 938$. For a reoperation, the RVU was multiplied by 1.25 because reoperations are more complicated than the initial procedure. For example, a reoperative Nissen fundoplication would have an RVU of 1173, or 938×1.25.

Once the RVU of each procedure was established, we then normalized the value to 100 by dividing the procedure RVU by the maximal RVU for general surgery, which was 3600. This relative score was the IDS of the procedure. Laparoscopic total esophagectomy had an IDS of 99, whereas the IDS for laparoscopic Nissen fundoplication and cholecystectomy were 26 and 17, respectively.

Statistical analysis

Data were analyzed in 2 steps. First, we described the total number of team members involved in each procedure. We further categorized team members by specialty group. We conducted descriptive analyses using SPSS version 11.0 (SPSS Inc.), and results are reported as minimum, maximum, mean, median and standard deviation (SD).

Second, multiple logistic regression analysis was performed to predict the change of a dependent variable (procedure length) from the change of 1 or more independent variables. The independent variables (predictors) included IDS, team size, patient age and ASA score. The

last 2 variables (patient age and ASA score) were used to describe patient condition. We conducted a regression analysis using SPSS version 11.0 with hierarchic data entry. Specifically, we entered the IDS into the model first, team size second, and ASA score and patient age last. The order of data entry was determined by the correlation coefficients between each predictor and procedure length. The variable with the highest simple correlation was entered in the model first. We reported the results of our regression model using SPSS outputs, and we interpreted the results following guidelines by Howell.[11]

RESULTS

We reviewed 640 procedures performed during the selected time frame; 53 were excluded because of incomplete surgical records (e.g., unknown procedure length, missing information on OR personnel or nursing records). As a result, our analysis was based on 587 procedures. Operations covered a wide range of general surgery procedures, including cholecystectomy, appendectomy, inguinal hernia repair and procedures for solid organs that were performed either open or laparoscopically.

Surgical team composition and size

The surgical team included surgeons, anesthesiologists, nurses and other observers (Fig. 1). Table 1 displays the

mean, SD and range of the team members as well as the procedure length. The mean number of surgical team members for each procedure was 8, and the mean procedure length was 88 minutes. Table 2 reports the number of team members in each category of health care specialties included in a surgical team with different team roles.

All procedures analyzed were attended by at least 1 anesthesiologist and 1 surgeon. Only 47 (8%) procedures were performed by 1 surgeon. Most were performed by 2 (295 [50%]) or 3 surgeons (214 [36%]; Table 2). Data collected from these 2 Canadian hospitals show that 579 (99%) procedures were attended by either 1 or 2 anesthesiologists.

The mean number of nurses present per procedure was 4 (Table 1). The anesthesiologists and surgeons assigned to a procedure normally stay for the entire operation, whereas nurses shift their duties for various reasons. As a result, we found that only 51 (9%) procedures were assisted by 1 or 2 nurses (Table 2). Most procedures were assisted by 3 (276 [47%]) or 4 nurses (171 [29%]). More than 4 nurses assisted in 89 (15%) procedures. The large number of nurses involved with the procedures indicates a great deal of nursing turnover for procedures with a mean length of 88 minutes.

Correlation between procedure length and team composition

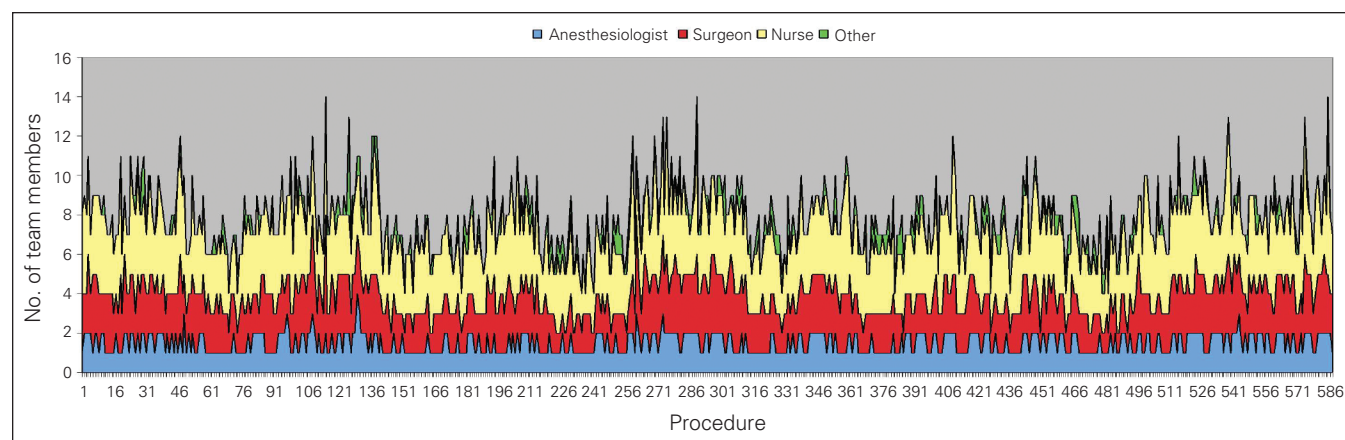Surgical team size ($r = 0.52$, $p < 0.001$) and IDS ($r = 0.67$,

Fig. 1. Composition of surgical teams in 2 Canadian hospitals for 587 general surgical procedures.

Table 1. Team composition, size and procedure length

Statistic	Surgeons	Anesthesiologists	Nurses	Other*	Team size	IDS	ASA score	Patient age, yr	Procedure length, min
Mean	2.4	1.5	3.6	0.4	7.9	23.1	2.1	56.8	88.2
Median	2.0	1.0	3.0	0	8.0	17.8	2.0	57.0	77.0
Standard deviation	0.7	0.5	1.0	0.6	1.7	12.1	0.8	16.9	50.6
Minimum	1.0	1.0	1.0	0	4.0	5.6	1.0	15.0	5.0
Maximum	6.0	4.0	7.0	5.0	14.0	66.3	4.0	94.0	405.0

ASA = American Society of Anesthesiologists; IDS = index of difficulty of surgery.
*Includes radiologists, cardiologists, endoscopists, ultrasound technicians and industry representatives.

$p < 0.001$) correlated significantly with procedure length. Specifically, as the number of team members (Fig. 2A) or the procedure complexity (Fig. 2B) increased, the procedure length was prolonged. The procedure length correlated moderately with the number of surgeons ($r = 0.40$, $p < 0.001$) and nurses ($r = 0.47$, $p < 0.001$) on the team and correlated weakly with the number of anesthesiologists ($r = 0.23$, $p < 0.001$) on the team.

We investigated the impact of team size, procedure complexity and patient condition on the team performance by performing a multiple regression analysis on the procedure length (Table 3).

When using IDS as the sole predictor (model 1 in Table 3), it accounted for 45% of the variability in procedure length ($R^2 = 0.45$). When team size was added as a second predictor (model 2 in Table 3), it accounted for 51% of

the variability in procedure length ($R^2 = 0.51$). In other words, team size accounted for an additional 6% of the variability in procedure length. When ASA and patient age were added (model 3 in Table 3), the 4 predictors accounted for 53% of the variability in procedure length ($R^2 = 0.53$), which is reasonably high. However, from model 2 to model 3, adding patient age and ASA score only increased the variation in procedure length by 2% (Table 3).

For each regression model, SPSS also reported standardized regression coefficients (β) alone with the partial regression coefficients (B, often called slop; Table 4). The β tells us to what degree each predictor affects the outcome when the effects of all other predictors are constant.[11] For example, in model 3, the β values of the IDS, team size, ASA score and patient age are 0.55, 0.24, 0.12 and –0100, respectively (Table 4). This means that an increase in IDS of

Table 2. Surgical team composition by specialty

No.	Surgeons			Anesthesiologists			Nurses			Other*		
	Frequency	%	Cumulative %	Frequency	%	Cumulative %	Frequency	%	Cumulative %	Frequency	%	Cumulative %
1	47	8.0	8.0	309	52.6	52.6	2	0.3	0.3	368	62.7	62.7
2	295	50.3	58.3	270	46.0	98.6	49	8.3	8.7	203	34.6	97.3
3	214	36.5	94.7	7	1.2	99.8	276	47.0	55.7	13	2.2	99.5
4	28	4.8	99.5	1	0.2	100.0	171	29.1	84.8	2	0.3	99.8
5	2	0.3	99.8	0	—	—	61	10.4	95.2	1	0.2	100.0
6	1	0.2	100.0	0	—	—	19	3.2	98.5	0	—	—
7	0	—	—	0	—	—	9	1.5	100.0	0	—	—

*Includes radiologists, cardiologists, endoscopists, ultrasound technicians and industry representatives.
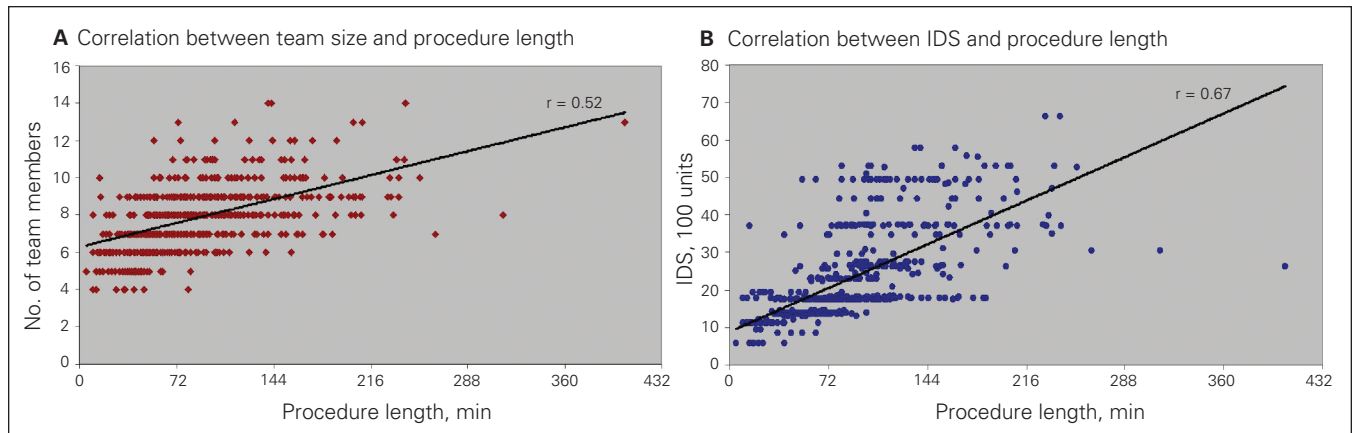

Fig. 2. Correlation between procedure length and team size and index of difficulty of surgery (IDS).

Table 3. Multiple regression analysis*

Standard regression equation	r	R^2	Adjusted R^2	F	p value
Model 1. Procedure length = 2.8 (IDS) + 23.9	0.67	0.45	0.45	477.9	< 0.001
Model 2. Procedure length = 2.3 (IDS) + 8.1 (team) – 27.7	0.71	0.51	0.51	304.8	< 0.001
Model 3. Procedure length = 2.3 (IDS) + 7.1 (team) +7.9 (ASA) – 0.3 (age) – 20.2	0.72	0.53	0.52	160.8	< 0.001

Age = patient age; ASA = American Society of Anesthesiologists; IDS = index of difficulty of surgery; team = number of team members.
*r denotes the correlation coefficients between the predictors and procedure length. R^2 (especially the adjusted R^2) is the percentage of variance in the dependent variable explained collectively by all of the independent variables. F is used to determine the significance of using the model to predict procedure length compared with a "best guess." The p value is used to estimate the improvement of the model in predicting the change in procedure length.

1 unit (i.e., a difference of 1 SD of IDS, or a value of 12.1) would be associated with 0.552 units (i.e., 27.9 min, or 0.552×50.6) of variation in procedure length. This interpretation is valid when all other predictors in the equation (team size, ASA score and patient age) are constant.

The factor with the second greatest impact on procedure length is team size: 1 unit of change in team size (i.e., 1 SD of team size, or 1.7 team members) would be associated with 0.24 units (i.e., 12.4 min, or 0.24×50.6) of change in procedure length. To make it simple for interpretation, every team member added would prolong the procedure by 7.3 minutes.

The ASA score had a mild impact on procedure length. Every 1 SD of ASA score (0.8 units, or 0.12×50.6) predicted a 6.3 minute change in procedure length. One ASA class change predicted an 8.8 minute change in procedure length. The impact of patient age on the procedure length was minor (data not shown).

DISCUSSION

The present study achieves 2 research goals: quantifying surgical team size and composition and examining the impact of team size on performance.

First, we have quantified the size and composition of teams performing general surgery operations in 2 Canadian hospitals. For a procedure with a mean length of 88 minutes, 8 health care providers were assigned to the operation. Surgeons and anesthesiologists made up half of the surgical team, and they were usually present for the entire operation. The other half of the surgical team consisted of nurses in 2 roles: scrub nurse and circulating nurse. We recorded a mean of 4 nurses joining the team per operation, indicating that each nursing role was performed by more than 1 nurse during the procedure. In fact, nurse shifting was commonly seen in the OR.[12] In some situations, such as a difficult procedure or a procedure starting later in the afternoon, as many as 7 nurses were involved in the operation. For a team with a high frequency of member turnover, better communication strategies are needed to keep team members sufficiently informed about task progression and patient condition.[13,14] However, the results of the present study indicate that surgical teams in 2 Canadian hospitals failed to fix the problem that arose from team member replacement. Based on the evidence collected from our multiple regression analysis, we believe that methods to strengthen this weaker aspect of team cooperation need to be implemented.

Second, we examined the impact of surgical team size on performance. The data from our regression analysis revealed that a 7-minute delay could be explained by the addition of 1 team member, controlling for procedure complexity and patient condition. This finding is corroborated by our previous results from a study involving laparoscopic teams from 2 hospitals in the northwest United States, where a change in 1 team member was associated with a 15-minute change in procedure length.[9]

The exact reasons for the differences in procedure length found in our 2 studies are difficult to determine. The data were extracted from different ORs in 2 institutes with different OR management systems. In addition, patients presented with different problems and were treated with different techniques. However, a simple and clear message from our 2 studies is that procedure length is affected directly and significantly by the frequent change of core team members. It is important for us to further explore why team changes happen and how to prevent the negative impact on team efficiency.

Studies of surgical team composition and its impact on performance are sporadic.[15] However, data from other industries show that an oversized team degrades performance and overall efficiency. In software engineering, productivity started to decrease when the number of team members working on the same project increased beyond a certain point.[16] Members in an oversized team encountered difficulty passing and receiving information and anticipating team mates' activities. Similar results were observed among emergency department teams during patient hand

Table 4. The SPSS version 11.0 multiple regression output for regression coefficients

| Model | Variable* | Unstandardized coefficients | | Standardized coefficient | | |
		B	SE	β	t	p value
1	(Constant)	23.95	3.32	—	7.21	< 0.001
	IDS	2.78	0.13	0.67	21.86	< 0.001
2	(Constant)	−27.70	6.81	—	−4.07	< 0.001
	IDS	2.27	0.13	0.55	16.90	< 0.001
	Team size	8.07	0.95	0.28	8.54	< 0.001
3	(Constant)	−20.23	7.80	—	−2.59	0.010
	IDS	2.29	0.13	0.55	16.97	< 0.001
	Team size	7.14	0.98	0.24	7.31	< 0.001
	ASA class	7.92	2.13	0.12	3.73	< 0.001
	Age of patient	−0.30	0.09	−0.10	−3.15	0.002

ASA = American Society of Anesthesiologists; IDS = index of difficulty of surgery; SE = standard error.
*The dependent variable is procedure length.

over.[17–19] The difficulty level of communication increased as the number of health care providers involved with patient care increased.[19,20] When measures to improve interpersonal communication were used, miscommunication between team members was minimized, and error rates associated with health services were reduced.[21,22]

Based on evidence reported in the present study, we emphasize the importance of maintaining the stability of core team members, especially when a surgical procedure has a short operative duration. During difficult procedures with longer durations, we recommend implementing measures to reinforce the quality of communication among team members when role changes occur. One strategy we recommend is to formulate a time-out period when a new team member is introduced. During this time-out period, the team is required to relay information to the new member and ensure that all members are up to date regarding task goals, equipment used and the patient's condition. Eliminating ambiguity among team members should have a positive impact on the quality of service provided.[23]

Conclusion

We have described the size and the composition of surgical teams for general surgical procedures. We found that each addition to the operative team significantly increased procedure length, 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 better management strategies to optimize surgical teams and facilitate efficiency in the OR. Efforts to improve efficiency in the OR should focus on decreasing surgical team size and limiting unnecessary staff turnover.

Competing interests: None declared.

Contributors: B. Zheng and O.N.M. Panton designed the study and analyzed the data. B. Zheng wrote the article. All authors acquired the data, reviewed the article and approved its publication.

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