Working With a Fixed Operating Room Team on Consecutive Similar Cases and the Effect on Case Duration and Turnover Time

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Hypothesis: If variation in procedure times could be controlled or better predicted, the cost of surgeries could be reduced through improved scheduling of surgical resources. This study on the impact of similar consecutive cases on the turnover, surgical, and procedure times tests the perception that repeating the same manual tasks reduces the duration of these tasks. We hypothesize that when a fixed team works on similar consecutive cases the result will be shorter turnover and procedure duration as well as less variation as compared with the situation without a fixed team.

Design: Case-control study.

Setting: St Franciscus Hospital, a large general teaching hospital in Rotterdam, the Netherlands.

Patients: Two procedures, inguinal hernia repair and laparoscopic cholecystectomy, were selected and divided across a control group and a study group. Patients were randomly assigned to the study or control group.

Main Outcome Measures: Preparation time, surgical time, procedure time, and turnover time.

Results: For inguinal hernia repair, we found a significantly lower preparation time and 10 minutes less procedure time in the study group, as compared with the control group. Variation in the study group was lower, as compared with the control group. For laparoscopic cholecystectomy, preparation time was significantly lower in the study group, as compared with the control group. For both procedures, there was a significant decrease in turnover time.

Conclusions: Scheduling similar consecutive cases and performing with a fixed team results in lower turnover times and preparation times. The procedure time of the inguinal hernia repair decreased significantly and has practical scheduling implications. For more complex surgery, like laparoscopic cholecystectomy, there is no effect on procedure time.

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When looking at an operating room (OR) in an era of cost-constrained health care, it is economically important for medical institutions to effectively schedule expensive surgical resources and use them efficiently. Variation, and thus uncertainty, in procedure times complicates surgical scheduling and reduces operational efficiency. If variation in procedure times could be controlled or better predicted, the cost of surgeries could be reduced through improved scheduling of surgical resources.

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Operating room schedules depend crucially on estimated case durations, and statistical models may help to improve these estimates to support management in the cost-efficient use of expensive surgical resources.[1,2] Therefore, we need to model and thus predict surgical procedure times more accurately. More accurate predictions of case durations ultimately help to achieve meaningful, sustainable service quality improvement in the OR and, as a consequence, in the delivery system through a decrease of unused costly OR capacity/equipment that can be used for new patients and a decrease in the number of cancellations of scheduled surgeries.

See Invited Critique at end of article

The standard personnel for an OR includes a surgeon (with or without an assisting surgical resident) and a surgical nurse, anesthesiologist, nurse circulator, and nurse providing anesthesia. In general teaching hospitals, it is common that

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Table 1. Questionnaire Study Consecutive Planning[a]

	Response
Date of surgery	
Patient No.	
Has the medical procedure been performed as was expected prior to the procedure? If NO, please explain	Yes/No
Were there any problems (other than medical) which may have complicated the execution of the medical procedure? If YES, please explain	Yes/No

[a]Surgeons were required to fill in this questionnaire.

during the course of a day personnel are switched across various ORs. Because the personnel switch across ORs, the switch may also be across type of procedure and OR team. Although every staff member prepares daily for the procedures they are assigned, some staff members noticed that they needed adaptation/familiarization time when starting as a team at the beginning of the surgical procedure or during it. This formed an obstacle for team members to attain a smooth work flow.

Some studies[3-11] focus on working with teams or redesigning processes in the OR. For instance, OR turnover time and daily caseload can be improved by analyzing the routine tasks of the operating team and minimizing inefficiencies. A coordinated multidisciplinary process redesign can significantly reduce OR turnover time.[3] Results demonstrate that a coordinated multidisciplinary process redesign can significantly reduce room turnover time as well as anesthesia induction and emergence time.[4] Recent publications have focused on increased OR throughput without increasing total OR time. Reorganizing the perioperative work process for total joint replacements sustainably increased OR throughput.[6]

Studies in both operations management and health care have found that performance on a procedure improves with increased experience.[12] The implication of the so-called learning curve or experience curve is that "practice makes perfect" and organizations "learn by doing."[13] Yet, some studies show homogeneous learning curves across sites[14] and others show heterogeneity across sites.[15-18] These varying results may be due to differences in the extent of social and organizational changes provoked by a new technology or practice that gives rise to differences in user acceptance and behavior.[19,20]

Much of the world's OR capacity uses consistent teams throughout the day. We took advantage of a unique feature of our OR organization to estimate how much time could be saved in a simple and a complex procedure by establishing consistent teams where previously none had existed. We constructed a study of batch processing of similar procedures in the OR using a fixed OR team. A batch of procedures consisted of the same procedures that are performed during the day by the same fixed OR team in the same OR. We hypothesized that this concept would reduce the adaptation/familiarization time for a specific procedure and hence the OR time.

METHODS

SELECTION OF PROCEDURES

The study started June 6, 2008, and ended April 22, 2009. We defined the following inclusion criteria for the selected procedures: (1) The procedure is not yet part of an OR program with consecutive similar operating procedures. (2) The procedure is done by a surgical resident and an experienced surgeon. (3) One procedure must be relatively low in complexity of performance and the other, relatively high in complexity (as defined by the surgeons/anesthesiologists).

Based on the inclusion criteria, we limited the study to 2 procedures: (1) inguinal hernia repair (according to the Lichtenstein technique) under spinal anesthesia and (2) laparoscopic cholecystectomy under general anesthesia.

STUDY DESIGN ON STUDY DAYS

The design for the study group was based on 3 central factors: (1) a similar type of procedure for all involved patient groups, (2) a fixed OR team on the day of surgery, and (3) a well-defined routine protocol for all members of the operative team. This protocol was explicitly discussed within the OR team at the beginning of the day.

To test our hypothesis, we made a distinction between control days and study days. The control days were the data flow of patients during the study period without applying the consecutive concept. The study days were on Fridays in the odd weeks. Two laparoscopic cholecystectomies and 4 inguinal hernia repairs were performed. The spinal anesthesia for the inguinal hernia repair was given in the holding area. In our hospital, a standard type of mesh is used in inguinal hernia repair. This mesh was fetched by the operative nurse prior to the first operation that took place in that particular OR.

Before starting the study, within the team, we considered performing at least 3 laparoscopic cholecystectomies on every study day by the same fixed team. Based on the available data, we knew that every laparoscopic cholecystectomy takes about 2 hours, meaning that the same OR team would have to be in the OR for at least 6 hours (with turnover time, approximately 7 hours). Consequently, team members noted that there were possible extra risks involved, for instance, fatigue in team members. Because we wanted to perform a study with no compromise at all in the quality of care for our patients, we decided to perform 2 laparoscopic cholecystectomies rather than 3 or more.

On study days, the OR team members could not switch between ORs but must work in their assigned OR. For instance, prior to the study and on control days, nurses and physicians could be substituted during the course of the operative day between the various ORs. Essentially, there was not strict team cohesiveness or team order. At the beginning of every study day, the team was formed and stayed together for the scheduled procedures. On every study day for every selected procedure, the team composition was different. Ten minutes before the first case of the day started, the OR team came together and reviewed the coming day and defined explicitly the roles of each individual team member.

When the OR was ready, the surgeon and nurse transported the patient into the OR. The anesthesiologist provided the patient anesthesia. In the next step, the actual operation, all members of the team were present. At the end of the operation, a nurse and the anesthetist transported the patient to the recovery room. The surgeon filled in a form containing qualitative questions about the procedure. This form gives information about whether the procedure was performed uneventfully (**Table 1**).

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After filling in the form, the surgeon went the preoperative area to welcome the next patient. At the end of the day, the forms were collected by an OR nurse and handed over to the researchers. At the end of the study days, we asked surgeons and nurses how they experienced working within a fixed team on similar cases during the day.

STUDY DESIGN ON CONTROL DAYS

On control days (every Friday) in the even weeks, the normal historical flow of patients occurred. Here, different OR teams performed 2 consecutive scheduled laparoscopic cholecystectomies and 2 inguinal hernia repairs. The earlier-mentioned 3 factors were not explicitly followed. On nonstudy days, the members of the team performed common procedures for general surgery, for example, femur fracture, patella fracture, appendectomy (open and endoscopic), circumcision, acetabulum, lumpectomy mamma, mastectomy, rectosigmoid resection (Hartmann procedure and open), and sigmoid resection.

SCHEDULING PATIENTS

When patients have to undergo a surgical procedure, like the inguinal hernia repair or a cholecystectomy, they are scheduled on regular OR days that suit the patient on a first-come first-served basis. During the study, if it was a Friday in the odd weeks, then the patient was assigned to the study group. If it was a Friday in the even weeks, then the patient was assigned to the control group. The resulting OR schedule was made by a staff member responsible for that job and who had no part or interest in the study. A day before surgery, members of the OR team were selected randomly and assigned to a control group or study group.

STATISTICAL CONSIDERATIONS

Because of indications of log normality of surgical and procedure times,[2,21-23] the recorded times were transformed to their natural logarithm. Consequently, any calculations with case durations should be done with the log-transformed OR time. For every group for every included procedure, we calculated the mean times, standard deviation, 95% confidence intervals for the mean of the log normal times, and Bayesian prediction intervals. Confidence intervals were calculated to test if they were sufficiently narrow as to be managerially meaningful. We used a modified version of the Cox method[24,25] to calculate the 95% confidence interval for the mean. For sample data with mean $\bar{Y}$ and variance S^2, the confidence level was calculated: Exp $\{\bar{Y} + S^2/2 \pm t_{95\%}[S^2/n + S^4/2(n-1)]^{1/2}\}$. The prediction intervals were Exp $\{\bar{Y} + t_{0.05,0.95n\text{-}1}[S^2 \times (1+n)/n]^{1/2}\}$.

THE 4 INTERVALS STUDIED

The 4 intervals we studied were (1) preparation time: time between anesthesia-ready time and procedure start time, (2) surgical time: time between incision start and closing the wound, (3) procedure time: time between patient entering and leaving the OR, and (4) turnover time: interval between previous patient leaving the OR and the following patient entering it.

Differences in mean OR time, surgical time, and turnover time between the control group and study group were investigated with an independent-samples *t* test. We used the Levene test to test the null hypothesis that the population variance of the study group was equal to the control group. For the Levene test at $P < .05$, we accepted the hypothesis that the 2 populations had unequal variances. For the *t* test, at a *P* value less than .05, we concluded that there was a statistically significant difference in mean times between the control group and the study group.

Table 2. Results Questionnaire

	Procedure	
	Inguinal Hernia	Laparoscopic Cholecystectomy
Performed as was expected prior	No=0 Yes=68	No=2 (extra surgery needed) Yes=24
Any problems (other than medical)	Yes=1 (software data management system delayed start-up 5 min) No=67	No=26
Total respondents	68 of 68	26 of 26

The clinicians (W.W.V. and M.dQ.) were explicitly excluded from participating in the practical part of the study. To prevent any possibility of conflict of interest, they were not part of any OR team. The clinicians declared before the study that their one and only interest in the study was to contribute to science, whatever the outcome of the study. Statistical work was performed by 2 of us (P.S.S. and C.H.). The results of this statistical work were presented to the clinicians.

RESULTS

The first step in evaluating the results was to compare the 3 measured intervals between the historical data (2005 to May 2008), the study group, and the control group. There were no statistically significant differences between the intervals measured for the historical data and control group for both procedures. In **Table 2**, we present the results of the questionnaire.

INGUINAL HERNIA REPAIR

For the hernia repair, we had 68 patients on 17 study days (4 hernia repairs/d in 1 OR, consecutively performed by the same team) and 68 patients on 17 control days (4 hernia repairs/d in 2 ORs; per OR, 2 consecutively performed not by the same team and 4 different teams). The number of different teams on control days was 68.

Equal variances were not assumed for preparation time, surgery time, or procedure time ($P < .001$). The *t* test results were on equal means of log times for preparation time (15.2 minutes vs 6.8 minutes; $P < .001$), surgery time (51.2 minutes vs 48.0 minutes; $P = .051$), and procedure time (71.2 minutes vs 59.8 minutes; $P < .001$) (**Table 3**).

The **Figure** shows a graph representing the preparation time of the 200 hernia repairs before starting the study and the 68 during the study.

The 95% confidence interval for the mean procedure time in the study group was 56 to 64 minutes vs 66 to 77 minutes in the control group. For mean preparation time, these intervals were 6 to 7 minutes in the study group and 14 to 17 minutes in the control group. The mean turnover time for the study group was 7.6 minutes (95% confidence interval, 7.4-7.8 minutes) and for the control

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Table 3. Results of the Study and Control Groups

	Log-Transformed Time, Mean (SD)	Time, min, Mean (SD)	95% CI	95% Prediction Interval
Laparoscopic cholecystectomy				
Procedure time				
Control (n=26)	4.79 (0.21)	123.0 (26.1)	113-134	79-183
Study (n=26)	4.76 (0.13)	117.7 (15.4)	111-125	88-154
Historical data[a] (736)	4.77 (0.24)	121.4 (29.6)	119-124	74-189
Surgical time				
Control (n=26)	4.43 (0.31)	88.1 (28.0)	77-100	45-156
Study (n=26)	4.40 (0.18)	82.8 (15.0)	77-90	57-117
Historical data[a] (736)	4.43 (0.37)	89.9 (34.4)	87-93	41-173
Preparation time				
Control (n=26)	3.23 (0.13)	25.5 (3.3)	24-27	19-33
Study (n=26)	3.09 (0.14)	22.2 (3.1)	21-24	17-29
Historical data[a] (736)	3.12 (0.13)	22.8 (3.0)	22-23	18-29
Inguinal hernia repair				
Procedure time				
Control (n=68)	4.22 (0.30)	71.2 (21.8)	66-77	38-123
Study (n=68)	4.06 (0.25)	59.8 (15.2)	56-64	35-95
Historical data[a] (n=704)	4.22 (0.28)	70.8 (20.2)	69-72	39-118
Surgical time				
Control (n=68)	3.87 (0.36)	51.2 (19.0)	47-57	24-98
Study (n=68)	3.81 (0.35)	48.0 (17.3)	44-53	23-90
Historical data[a] (n=704)	3.89 (0.36)	52.2 (19.4)	51-54	24-99
Preparation time				
Control (n=68)	2.66 (0.35)	15.2 (5.5)	14-17	7-29
Study (n=68)	1.90 (0.21)	6.8 (1.5)	6-7	4-10
Historical data[a] (n=704)	2.62 (0.36)	14.7 (5.5)	14-15	7-28

Abbreviation: CI, confidence interval.
[a]Historical data: 2005 to May 2008.

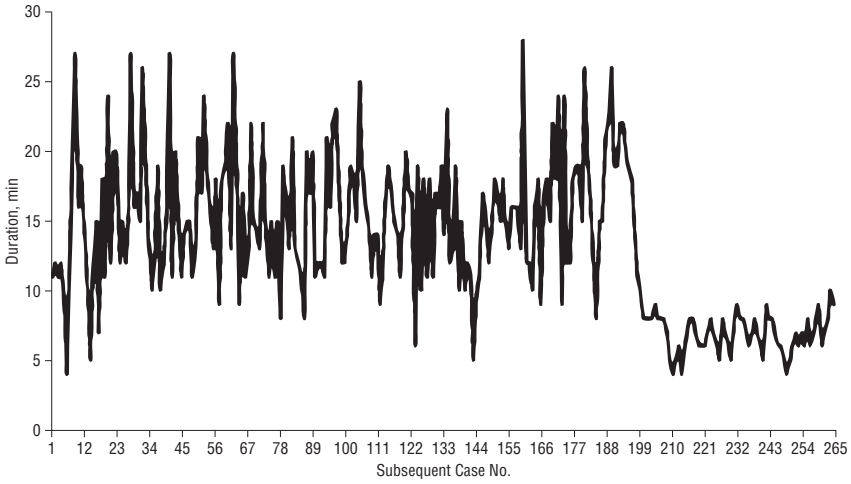


Figure. Preparation time of 200 inguinal hernia repairs prior to starting the study and 68 during the study.

group, 9.3 minutes (95% confidence interval, 9.1-9.5 minutes). Equal variances were not assumed ($P=.007$); the t test for difference in mean turnover time resulted in a P value of .001.

LAPAROSCOPIC CHOLECYSTECTOMY

For the cholecystectomy, we had 26 patients on 13 study days (2 consecutively performed by the same team) and 26 patients on 13 study days (in 1 OR, 2 consecutively performed laparoscopic cholecystectomies not by the same team). The number of different teams on control days was 26.

In 2 cases on study days, extra procedures had to be done: an umbilical hernia repair and a nevus stomach repair (Table 2). These cases were included in the analyses since doing something unexpectedly different in the OR is a reflection of reality.

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Comparing the study group and the control group, equal variances were not assumed for surgery time ($P=.01$) and procedure time ($P=.02$). The *t* test results were on equal means of the log times for surgery (study group, 82.8 minutes vs control group, 88.1 minutes; $P=.74$) and procedure (control group, 123.0 minutes vs study group, 117.7 minutes; $P=.65$). The assumption of equal variances was not rejected for preparation time ($P=.93$). The *t* test showed a significant difference in preparation time (control group, 25.5 minutes vs study group, 22.2 minutes; $P=.003$). The mean turnover time for the study group was 11.3 minutes (95% confidence interval, 11.0-11.5 minutes) and for the control group, the mean turnover time was 13.6 minutes (95% confidence interval, 13.3-14.0 minutes). The difference in mean turnover time was significant. The assumption of equal variances was rejected ($P=.02$).

COMMENT

This study on the impact of similar consecutive cases on the turnover, surgical, and procedure time confirms that repeating the same manual tasks may reduce the duration of these tasks. These results are well known for manufacturing processes and they form the basis of the lean manufacturing system. Based on our findings, we affirm that organizations "learn by doing."[13,14] By maintaining a fixed team for similar consecutive cases throughout the entire day, we found a significant reduction in preparation time and turnover time for both studied procedures. Teams prepared the procedures in a more structured fashion in the study group. This explains the shorter preparation time in the study group, as compared with the control group. Surgery time was not significantly different in the study group as compared with the control group. Surgeons did not work "faster or slower" when working on consecutive similar cases and surgeons did not compromise on quality of care to increase speed.

For the inguinal hernia repair, we saw significantly shorter preparation and procedure times in the study group, as compared with the control group. Also, the variation in the study group of the 3 intervals was significantly lower, as compared with the control group. The average decrease of the procedure time in the study group (10 minutes per procedure), as compared with the control group, has practical implications for planning purposes. A reason for the decreased operative time (because of the decrease in preparation time) may be the effect of the roles of each individual team member being explicitly defined before the start of the day.

In the study group, a significantly lower mean preparation time was found for laparoscopic cholecystectomy. The mean procedure time for laparoscopic cholecystectomy was not significantly lower in the study group. A possible technical explanation for this is that both study group and control group patients were included who experienced a cholecystis or an obstruction necessitating an endoscopic retrograde cholangiopancreatography. Both problems may involve a technically demanding operation that may require more dissection time.

Based on the results, we may conclude that the consecutive concept helps to decrease the preparation time. Further, we assume that using consecutive planning with a fixed team has more effect on case durations of relatively less medically complex procedures than on more complex ones. The latter hypothesis should be further investigated in future studies.

We asked surgeons and nurses on study days to describe their experiences during the study. In general, they all experienced team spirit among the team and a smooth work flow on study days when performing the inguinal hernia repair. The opposite was true for cholecystectomy. One explanation for this difference is the duration and complexity of cholecystectomy as compared with inguinal hernia repair. Team members identified some benefits of working a large part of the day together: because there was an extended briefing at the beginning of the day, everybody in the team was made explicitly aware of their role. This effect of consecutive similar case planning on team spirit may be one of the factors causing reduced overall handling times in the OR.

Scheduling similar consecutive cases and performing with a fixed team results in lower turnover times and preparation times. The surgical time of the inguinal hernia repair decreased significantly and has practical scheduling implications. For more complex surgery, like laparoscopic cholecystectomy, there is no effect on surgery time.

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INVITED CRITIQUE

Importance of Teamwork in the Operating Room

Stepaniak and colleagues present compelling evidence that OR efficiency can be improved using 2 simple methods. First, they clustered similar types of surgical cases on the same day. For example, they grouped all inguinal hernia repairs on one day and all laparoscopic cholecystectomies on another. Of the 2 methods, this one is most likely to be under control of the surgeon. Thus, we could all use this strategy, at least to some extent, to improve our efficiency starting today.

The second method was to maintain the same operative team for the entire day, which is quite an improvement on the status quo. The idea of a single team working together to finish cases is in stark contrast to the well-known game of musical chairs, with a constant flux of nurses, surgical technicians, and anesthesiologists, that characterizes many of our practices. Unfortunately, changing the status quo will prove difficult, as it involves reaching out to other professions.

Nonetheless, I commend Stepaniak and colleagues on generating evidence that these 2 practices can improve operating efficiency. The findings are not surprising, and they agree with what many of us believe to be true. However, the scientific evidence provided by this article can act as a starting point to help convince our colleagues in other professions that the status quo—the game of musical chairs—should be exchanged for a team-based approach that will help create a more efficient (and likely safer) environment for surgery.

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