Decrease in Case Duration Required to Complete an Additional Case During Regularly Scheduled Hours in an Operating Room Suite: A Computer Simulation Study

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We used Monte-Carlo computer simulation to determine whether surgical or anesthetic interventions to achieve small decreases in case duration may create enough new open operating room (OR) time to permit an additional case to be scheduled for completion in an OR suite during regular working hours. We used rules for scheduling of cases assuming that OR personnel are compensated so that the OR suite can profit financially from decreasing case duration to complete an additional case during regularly scheduled hours. The decreases in each case’s duration required to create enough new open OR time to reliably (≥95%) schedule another case were 30–39 min, 79–110 min, and 105–206 min for OR suites with 1–15 ORs and mean case durations of 1, 2, or 3 h, respectively. Implications: Computer simulation shows decreasing case duration is unlikely to create sufficient operating room time to reliably permit an additional case to be scheduled for completion during working hours. Additional cases may best be added to the operating room suite schedule by optimizing case scheduling, not by decreasing the duration of all cases in the suite.

(Anesth Analg 1999;88:72–6)

To increase the productivity of an operating room (OR) suite, managers may introduce surgical, anesthetic, or managerial interventions to decrease the duration of surgical cases. For example, intraoperative clinical pathways with recommended sequences and times of interventions can reduce surgical time, resulting in a decrease in case duration (1) (the time interval beginning when a patient enters an OR and ending when the patient leaves the OR). Case duration can also be decreased by using newer anesthetics and techniques that permit faster emergence of patients from general anesthesia. In a previous study, we showed that decreasing case duration of all cases in an OR by reducing the time required for anesthetic induction and emergence would not reliably (e.g., ≥95% chance) permit a surgeon to perform another case in the OR unless the mean case duration for cases in the OR was <1 h (2).

It is unknown whether a decrease in case duration for all cases performed in an OR suite with more than one OR could permit an additional case to be scheduled for completion in any of the ORs during regularly scheduled hours of surgery. In this study, we used computer simulation to test the hypothesis that small decreases in case duration may, in contrast to the setting of one OR, be sufficient to reliably permit an additional case to be scheduled and completed somewhere in the OR suite. Simulation is appropriate for this study because statistical power analysis shows that to study the problem experimentally would require an impractical data collection period (>4000 yr). In Discussion, we consider how the method of compensating OR personnel affects the financial benefit that an OR suite can achieve from a surgical or anesthetic intervention to decrease case duration to permit an additional case to be scheduled and completed somewhere in an OR suite.

Methods

We wrote rules to describe the logical operation of case scheduling and used computer simulation to manipulate them. In Monte-Carlo simulation (3), it is assumed that the behavior of one or more factors can be represented by a probability distribution. Simulation models use random numbers to generate uncertain events by making random draws from probability
distributions. Two parameters—mean case duration for cases performed in the OR suite and the number of ORs in the OR suite—were varied in the analysis. For mean case duration, we considered 1, 2, and 3 h as typical options. The mean values of 2 and 3 h correspond to the mean case durations at the University of Iowa's Ambulatory Surgery Center and main (i.e., tertiary) OR suite, respectively. Random effects analysis of the cases performed at the University of Iowa showed that the standard deviation of the logarithm of case duration in hours equals 0.725 for both of these OR suites.

We used 1, 2, 5, 10, and 15 rooms to represent a range of OR suite sizes.

The analysis assumes that five conditions apply to the simulated OR suites:

1. Each case was assigned a random time duration from a statistical distribution. To choose a statistical distribution for case durations, we evaluated 300 sequential cases performed at the University of Iowa in June 1997. Although case durations were not normally distributed, their logarithms were (Expertfit, Averill M. Law & Associates, 1997), as confirmed by using the distribution function difference plot, density/histogram over plot, and Lilliefors's test ($P = 0.67$). Therefore, simulated case durations were generated using a log-normal distribution using the “polar method” (3), with mean and standard deviation as specified in Parameter 1. Using these parameter values, the 10th and 90th percentiles equaled 0.3 and 1.9 h, 0.6 and 3.9 h, and 0.9 and 5.8 h for mean case durations of 1, 2, and 3 h, respectively. The resulting value was truncated at 8 h. We chose an 8-h day because common working hours for full-time hourly employees are five 8-h shifts each week. Truncating case durations did not imply that the case itself was stopped prematurely but that, for purposes of scheduling the case was considered to have a duration equal to 8 h; otherwise, the case could not have been scheduled into the OR suite. To the extent that truncating case durations at 8 h decreased case durations, our analysis underestimated the decrease in case duration required to schedule an additional case in the OR suite.

2. Each turnover time in the OR (patient out to patient in) was assigned a random time duration from a statistical distribution. Simulated turnover times were generated using a log-normal distribution with a mean $\mu$ of 0.3 and standard deviation $\sigma$ of 0.2 h, as is appropriate for the University of Iowa's Ambulatory Surgery Center.

3. Each case, excluding the additional case to be added into the OR suite's schedule by the intervention, was scheduled into the OR with the most time available, provided that the case could be finished...
4. Every patient in each simulated OR underwent the intervention to decrease case duration. Some interventions to reduce case durations may apply only to a subset of patients in an OR suite (e.g., patients undergoing knee replacement surgery with a clinical pathway). However, for this analysis, we assumed that the intervention to reduce case duration applied to all cases in the OR suite. To the extent that this condition does not apply, our analysis underestimated the decrease in case duration required to have a 95% chance that an additional case could be completed during regularly scheduled hours somewhere in the OR suite.

5. An additional case was considered to be scheduled into the OR suite provided that the decrease in case duration could achieve sufficient new open OR time for there to be a 95% chance that the case could be performed in any of the ORs within the OR suite during the day. This condition applies assuming that there are no constraints restricting the OR in which the additional case can be performed, all anesthesiologists and nurses can perform the case, and the surgeon is available at any time to perform the case. To the extent that these assumptions may not be true, our analysis underestimated the decrease in case duration required to have a 95% chance the case could be completed during regularly scheduled hours.

The computer simulations proceed in the following stepwise manner. The simulated OR suite begins each day with no cases scheduled in any of the ORs. A case duration is generated as described in Condition 1.

1. A turnover time is generated as described in Condition 2. The case is scheduled into an OR as described in Condition 3. The turnover time is used if the OR into which the case is scheduled has a preceding case. If the case is successfully scheduled, then this step (Step 1) is repeated.

2. After Step 1, a case could not be scheduled because there was not sufficient open OR time available in any of the ORs. Record (i) the case duration of this additional case. Because the case could not be scheduled, every OR in the suite contains at least one case. Therefore, the time required in an OR to schedule the case equals the sum of the turnover time and the case duration. Record (ii) the sum of the case duration and turnover time of the case that cannot be scheduled. For each OR, calculate the difference between the sum (ii) and the remaining time in the OR. Divide this difference by the number of preceding cases in the OR. Take the minimum of this number among the ORs in the suite. The resulting value gives the decrease in case duration for each case that would be necessary to complete the additional case on that day. Record (iii) this number. Finally, record (iv) the number of cases in the OR suite that day.

3. Repeat Steps 1 and 2 for 32,764 days of elective surgery. As described in Condition 5, calculate the 95th percentile of the 32,765 values for stored numbers (iii). Calculate the 95% two-sided confidence interval around this 95th percentile (4). It was our desire for the width of the confidence interval for the 95th percentile to be <15 min that required using such a long data collection period (32,765 days/244 elective surgical days a year = 134 yr per simulation).

4. The intervention to reduce case duration would be profitable if the (revenue obtained per hour of OR time) × (additional number of hours of OR time each day over a long time period) > (cost of the intervention for each case) × (number of times the intervention must be applied during the time period). The relevant statistic to be simulated was (mean additional number of hours of OR time each day)/(mean number of times the intervention must be applied each day) = (mean of stored number [i])/ (mean of stored number [iv]).

Computer code was written in Microsoft Excel Visual Basic. We evaluated how changing conditions influences the results. Conditions 1 and 3 specify that regularly scheduled OR hours have a duration of 8 h. Condition 5 specifies that the decrease in case duration of interest is the decrease in duration for all cases in the OR suite necessary to provide sufficient new open OR time for there to be a reliable (defined as 95%) chance that an additional case can be performed in any of the ORs. We repeated the simulations three times, each after making one of the following three modifications of these conditions. We repeated the analysis using a 90% chance that an additional case could be completed in the OR suite. The first case that could not be scheduled was skipped and Step 1 was continued until a second case was generated that could not be scheduled. The duration of regularly scheduled OR hours was changed from 8 h to 10 h.

Results
The required decreases in each case’s duration to reliably schedule another case during regularly scheduled OR hours were 30–39 min, 79–110 min, and 105–206 min for OR suites with mean case durations for all cases of 1, 2, or 3 h, respectively (Figure 1, Columns 1, 2, and 4). For example, for OR suites with a mean case duration of 2 h and five ORs, the case...
duration of all cases would have to be decreased by at least 88 min to be able to schedule one additional case in the OR suite on 95% of days.

If the reduction in case duration necessary to schedule the additional case was achieved, the economic benefit of the surgical or anesthetic intervention would need to be assessed. Assuming that revenue to the OR suite is proportional to OR time (e.g., fee for service reimbursement), the cost of the intervention to decrease case durations would include lost revenue from the decrease in case duration. For the intervention that decreases case duration to be profitable, the mean duration of the additional case that is scheduled each day in the new open OR time must be longer than the mean sum of the decrease in case duration required of all previously scheduled cases in the OR suite. This condition is not satisfied for any combination of the two variables (Figure 1, Column 5).

Increasing the chance that an additional case would not be able to be completed in the OR suite to 10% (from 5%) reduces the required decrease in duration of each case (Figure 1, Column 6). For OR suites with mean case durations of 2 or 3 h, case duration would have to be decreased by 71–80 min or 96–157 min, respectively. For OR suites with mean case durations of 1 h, case duration would have to be decreased by 21–29 min.

We changed the scheduling rule so that the first additional case that cannot be scheduled is skipped, and additional cases are scheduled until another case cannot be scheduled. For OR suites with mean case durations of 2 or 3 h, case duration would have to be decreased by 49–62 min or 92–119 min, respectively (Figure 1, Column 7). For OR suites with mean case durations of 1 h, case duration would have to be decreased by 15–19 min.

We extended the regularly scheduled hours of the OR suite from an 8-h day to a 10-h day. For OR suites with mean case durations of 2 or 3 h, case duration would have to be decreased by 79–91 min or 109–176 min, respectively (Figure 1, Column 8). For OR suites with mean case durations of 1 h, case duration would have to be decreased by 23–31 min.

**Discussion**

Regardless of the number of ORs, it is unlikely that anesthetic, surgical, or management interventions that decrease case duration for all cases in an OR suite can reliably permit an additional case to be scheduled in the OR suite for completion during regularly scheduled hours. Examples of these possible interventions include adding a preoperative IV catheter team; adding a preoperative procedure room; using more expensive anesthetic drugs and techniques to achieve a more rapid onset and shorter duration of action; hiring more anesthesia, nursing, or housekeeping staff to decrease turnover time; or using clinical pathways.

Turnover time includes a setup time and a cleanup time. Each OR contains the same number of setup and cleanup times as cases. Therefore, the minimal decrease in turnover time for each case to reliably permit an additional case to be scheduled in the OR suite for completion during regularly scheduled hours equals the minimal decrease in case duration given in Column 4 of Figure 1.

The required decreases in each case’s duration to reliably schedule another case during regularly scheduled OR hours exceeds 50% of the OR suite’s mean case duration (Figure 1, Columns 1 and 4). These results can be understood by considering durations of the additional cases. A case that is shorter than the mean case duration for the OR suite can usually be added somewhere in an OR suite at the end of the day without decreasing case duration of all cases in the suite. In contrast, if cases are scheduled sequentially into an OR suite, the case that has a sufficiently long duration to prevent it from being scheduled into the OR suite without a decrease in case duration of all cases in the suite is likely to be a long case. To the extent that the 90th percentiles for case duration equaled 1.9 h, 3.9 h, and 5.8 h for OR suites with mean case durations of 1, 2, and 3 h, respectively, some of the additional cases were very long. The argument could be made that case duration would not have to be decreased as much as we predicted to reliably schedule a case of a prespecified short duration (e.g., 30 min) into the OR suite. However, this argument does not consider that if the case is short, it most likely could have been scheduled in the OR suite without having required a decrease in case duration. The problem of adding additional cases to the OR schedule may best be solved by optimizing the scheduling of cases, not by decreasing the case duration of all cases in the suite. For example, a waiting list could be used whereby multiple submitted additional cases with different durations would be given equal priority and would be considered for possible addition to the OR schedule at a preset time each day.

The method of compensating OR personnel (e.g., anesthesiologists, anesthetists, nurses, and technicians) changes the optimal method of scheduling patients in the OR suite to minimize labor costs.

1. Employees can be paid an hourly wage and have no minimal number of hours of work each week. The Fair Labor Standards Act requires that employees be paid 1.5 times the regular hourly wage for work beyond 40 h/wk. The OR suite minimizes labor costs by employing part-time staff to avoid the payment of overtime. Labor costs are the same throughout the day. There are
no regularly scheduled (staffed) hours of cases in the suite. An intervention to decrease case duration may be financially advantageous by decreasing labor costs, but not by permitting an additional case to be scheduled. For hourly employees with no minimal number of hours of work each week, there is no need to decrease case duration to permit an additional case to be scheduled—just schedule the additional case.

2. The designation of professional status permits pay on a salary basis and exempts employees from the overtime requirements. Salaried employees receive a set salary regardless of the number of hours worked. Labor costs are the same throughout the day. The argument is then the same as for hourly employees with no minimal number of hours worked each week.

3. There are also “full-time” hourly (i.e., not salaried) employees with frequent overtime. Because overtime is frequent, cases are scheduled outside of regularly scheduled hours. Overtime costs more than the regular wage. Therefore, if an OR suite can decrease the case duration for all cases, decreasing overtime costs is more financially advantageous for the OR suite than permitting an additional case to be scheduled during regularly scheduled hours.

4. There are also “full-time” hourly (i.e., not salaried) employees with no minimal number of hours of work each day. For each day that an employee works >8 h, there will usually be another day within 1–4 wk when that person can stop working sufficiently early without pay to ensure that the mean work week does not exceed 40 h. An intervention to decrease case duration to permit another case to be scheduled during an 8-h day could increase profits.

As specified in Condition 3, our computer simulations assume that cases are scheduled in the OR suite in a manner consistent with the OR suite employees being full-time hourly with no minimal number of hours of work each day. Cases must be scheduled to be finished within 8 h so that the mean time that ORs run each day is <8 h. Unused OR time produced by this method of scheduling would be balanced, in part, by the hours of those cases that were considered for purposes of scheduling to have durations equal to 8 h, although they exceeded 8 h.

In a fee for service setting in which OR suite revenues are usually proportional to OR time, reductions in case duration would only be profitable to the hospital if the reductions are less than the OR time of the additional case that can be scheduled each day from the newly freed OR time. Stated in terms of the quantity given in Figure 1, Column 5, a minimal criterion for adding the additional case is that the required decrease in case duration for all cases in the OR suite should be less than the additional minutes of cases that can be scheduled each day on a per-case basis. If it was not considered necessary to reliably schedule the additional cases, then the corresponding value in Figure 1, Column 5, would need to be reduced appropriately. Consequently, subject to the conditions considered in our simulations, an OR suite that is reimbursed proportional to OR time cannot profit financially from decreasing the case duration for all cases in an OR suite.

For OR suites with mean case durations of 1 h, the required decreases in each case’s duration to reliably schedule another case during regularly scheduled OR hours were 30–39 min. With a 90% definition of reliably scheduling an additional case, the decrease equals 21–29 min. Skipping the first case that cannot be scheduled, the decrease equals 15–19 min. Our methodology and assumptions tended to underestimate the decrease in case duration that would be required to permit another case to be scheduled during regularly scheduled hours. Nevertheless, the decreases in case duration required for OR suites with mean case durations of 1 h might be achievable. We recommend that such OR suites evaluate whether: employees are paid in the appropriate manner to gain financially (i.e., full-time hourly with no minimal number of hours of work each day); the necessary decrease in case duration can be reliably achieved; and the decrease in case duration would result in a decrease in revenue that exceeds the increase in revenue from performing the additional case.

References