Coordination of Appointments for Anesthesia Care Outside of Operating Rooms Using an Enterprise-Wide Scheduling System

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BACKGROUND: An anesthesia department implemented scheduling of anesthetics outside of operating rooms (non-OR) by clerks and nurses from other departments using its hospital's enterprise-wide scheduling system.

METHODS: Observational studies chronicled the change over 2 yr as non-OR time was allocated by specialty, and nonanesthesia clerks and nurses scheduled anesthesia teams. Experimental studies investigated how tabular and graphical displays affected the scheduling of milestones (e.g., NPO times) and appointments before anesthetics.

RESULTS: Anesthetics performed in allocated time increased progressively from 0% to 75%. Scheduling of anesthetics by nonanesthesia clerks and nurses increased progressively from 0% to 77%. Consistency of patient instructions was improved. The quality of resulting schedules was good. Implementation was not associated with worsening of multiple operational measures of performance such as cancellation rates, turnover times, or complaints. However, schedulers struggled to understand fasting and arrival times of patients, despite using a web site with statistically generated values in tabular formats. Experiments revealed that people ignored their knowledge that anesthetics can start earlier than scheduled. Participants made good decisions with both tabular and graphical displays when scheduling appointments preceding anesthesia.

CONCLUSIONS: Enterprise-wide scheduling can coordinate anesthetics with other appointments on the same date and improve consistency and accuracy of patient instructions customized to the probability of an anesthetic starting early. The usefulness of implementation depends on the value in having more patient-centered care and/or in having patients arrive just in time for non-OR anesthesia, surgery, or regional block placement (e.g., at facilities with limited physical space).

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Radiology procedures are still scheduled manually at many facilities. The process is cumbersome and inconvenient for physicians, schedulers, and patients. More than 75% of physicians' offices surveyed reported that using an information system to schedule radiological procedures was easier than calling an office (1). Nevertheless, almost all respondents considered the inability to schedule multiple procedures on the same patient on the same day to be a limitation of electronic scheduling. This limitation applies to all patients receiving anesthesia for radiological procedures.

In this article, we describe an anesthesia department's implementation of the scheduling of anesthetics outside of operating rooms (non-OR anesthetics) by clerks and nurses from other departments using an enterprise-wide scheduling system. Just as some radiology departments allow clerks at physicians' offices to schedule radiological procedures via a web browser, and some clinics allow patients to schedule

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their own appointments (2), the anesthesia department provided clerks and nurses in other departments with distributed access to the availability of non-OR anesthesia teams and gave them permission to schedule those teams. For example, interventional radiology nurses scheduled patients into their Tuesday anesthesia time (3). We evaluated the extent to which the clerks and nurses from other departments took advantage of their ability to schedule the anesthesia providers versus calling or e-mailing the anesthesia department to create an appointment.

The scheduling of non-OR anesthetics using an enterprise-wide scheduling system versus a stand-alone OR information system has several advantages. One advantage is that, as above, clinic nurses and radiology schedulers do not have to phone the anesthesia department and wait until a scheduler is available. Similarly, the anesthesia department's non-OR scheduling is not beholden to the health or employment of just one or two schedulers.

A second advantage is the consistency of patient instructions. The scheduling system sent each patient a letter based on the primary appointment(s). For example, patients with the primary appointment of "computerized tomography (CT)" are instructed to drink "plenty of fluids up to 1 h before the examination," regardless of whether they are to receive a general anesthetic. Other departments can schedule the anesthetics because an enterprise-wide scheduling system is used. Because other departments do the scheduling, new pseudo appointment types can be used that combine anesthesia with the procedure (e.g., CT with anesthesia). These new appointment types have instructions appropriate for a patient receiving anesthesia.

A third advantage is the coordination of an anesthetic with other appointments on the same day, with the times between appointments based on statistical analysis of historical data. For example, a patient's schedule for the day might include preanesthesia evaluation clinic at 9:30 AM, anesthetic starting at 11:00 AM, CT machine at 11:30 AM, and oncology clinic at 2:00 PM.

Although OR information systems perform many checks to ensure that procedures are scheduled appropriately, the enterprise-wide scheduling system had very few such checks. For example, the non-OR cases were scheduled sequentially, without gaps between successive cases performed by the same anesthesia team on the same day (4). However, the enterprise-wide system permitted cases to be scheduled with any start time. To compensate, data were extracted each morning from the enterprise-wide scheduling system for all pending non-OR anesthetics and sent to an anesthesia department server. A program screened the appointments daily for errors and notified the anesthesia scheduler of the need for review of those appointments.

We assessed the success of implementation of enterprise-wide scheduling by testing the frequency of coordinated appointments, the appropriateness of their scheduled times, the consistency of NPO instructions, the number of scheduling errors committed by the nonanesthesia clerks and nurses, the effectiveness of the methods used to screen appointments, and the quality of schedules upon progressive migration of non-OR scheduling from the OR information system to the enterprise-wide scheduling system.

Although clerks and nurses could schedule appointments before and after the anesthetic and had to schedule milestones (e.g., "stop drinking fluids at 9:30 AM"), the enterprise-wide scheduling system did not provide the statistical information necessary for these tasks (e.g., estimated case durations). It was a commercial package that was really just a glorified calendar. We could not modify the source code to customize messages based on appointment or patient characteristics, nor could we include hyperlinks. Therefore, clerks and nurses viewed statistically appropriate values (5–7) in a tabular format at the department's website (www.CaseDuration.com, accessed December 18, 2006) when notifying patients.

We investigated the relative advantages of graphic versus tabular displays to convey these statistical data to the schedulers by using simulated scheduling tasks. Simultaneously, we evaluated the extent to which our implementation results were sensitive to our graphical user interface. A graphical format might improve understanding of the statistical framework on which clerks and nurses should be relying, enabling them to apply that framework more consistently when making decisions.

METHODS

The enterprise-wide scheduling software had been set up at each non-OR site by March 2003. A full-time non-OR anesthesia administrator started working in December 2004 to assist with implementation. The use of allocated time for non-OR anesthesia was initiated in January 2005, but started for each specialty in different months (e.g., pediatric cardiac catheterization before diagnostic radiology). Starting March 2005, the anesthesia department's clerks progressively switched from the OR information system to the enterprise-wide scheduling system for the scheduling of non-OR anesthetics. By May 2005, the anesthesia clerks were comfortable with the setup of the enterprise-wide scheduling system. The department therefore began to give clerks and nurses in other departments permission to schedule the anesthetics. Quantitative data were analyzed through August 2006. Complaints about scheduling (see below) were quantified through November 2006.

Implementation of Allocated Time and Scheduling by Nonanesthesia Clerks and Nurses

The implementation of allocated time and the use of enterprise-wide scheduling were intertwined. Allocated time made scheduling easier because there were fewer start-time options available for each anesthetic.

Allocated time was implemented with a service guarantee by the anesthesia department of no more than a 2-wk wait (4,8,9). Sufficient whole day block time was allocated to (i.e., reserved for) each specialty to accommodate most of its non-OR cases (8,10). When a specialty that was allocated non-OR time had filled that time, then any additional cases were scheduled into open, unblocked, first-come first-scheduled time so that the case could be performed within 2 wk, and usually 1 wk (4,11). Cases of those specialties without allocated time were also scheduled into the open time. Because the workday was 10 h, specialties averaging <10 h every 2 wk scheduled only into open time (4). The hours of allocated and open time were adjusted regularly based on appropriate statistical forecasting methods (11,12). For example, on March 29, 2007, allocations of whole day blocks during each 2-wk cycle were 3 for interventional radiology, 2 for pediatric cardiac catheterization, 2 for diagnostic radiology, 1 for therapeutic radiology, 1 for adult cardiology and electrophysiology, and 3 for open and overflow time. An example of physicians scheduling into open time was dermatologists performing laser destruction of cutaneous vascular lesions in children.

We tested for a progressive change in the monthly counts of cases scheduled into allocated time versus open time over the 20 mo (January 2005 through August 2006) using the two-sided Cochrane-Armitage trend test. We also tested for a progressive change in the monthly percentage of appointments created by nonanesthesia clerks or nurses over the 16 mo using the two-sided Cochrane-Armitage trend test. This statistical method essentially assessed the dose response relationship between the month and the observed percentage (13). These and all other P values were estimated by Monte-Carlo simulation to the nearest 0.001 (StatXact-7, Cytel Software Corporation, Cambridge, MA).

Need For and Effectiveness of Prompt Checking of the Scheduled Appointments

All new appointments were checked every workday. Errors in scheduling that were checked included: late starts (e.g., first case at 8:45 AM instead of 8:00 AM), questionable durations (see below), overlapping cases, scheduled delays between cases, and/or ending the day late. One or more errors were detected and confirmed manually in 23% of the 1090 appointments scheduled by nonanesthesia personnel (see Results for details and more explanation). We progressively improved our error-checking program to reduce the rate of false positive errors. We tested for a change in the proportion of appointments scheduled by clerks and nurses from other departments for which the scheduler was notified about an error using the Cochrane-Armitage trend test applied to the 16 mo of data.

Quality of Resulting Schedules

Ideally, clerks and nurses were scheduling cases for durations that were realistic, and were also considering the uncertainty in case duration when making subsequent scheduling decisions for the same day. We wanted to avoid scheduling a case(s) at a different site(s) if at least one of the preceding cases had a reasonable chance of taking much longer than scheduled. If an interventional radiologist finished his first case markedly late, no physician complaint would be made if the anesthesia team next cared for another patient of the same radiologist. However, if instead the team next cared for a patient at the pediatric gastroenterology suite, the delayed pediatrician may be frustrated and complain. The department's website therefore calculated and displayed the probability of a case taking at least 1 h longer than its scheduled duration (5,14). With our appropriate allocations of non-OR time and scheduling of cases into that time, the latter situation could usually be prevented (4), provided clerks actually used the statistical data at the web site (5,7).

For 8 mo starting January 2006, we recorded two measures of the quality of schedules. First, on the working day before appointments, all scheduled anesthetics were reviewed if they followed another anesthetic at a different site(s) to determine if at least one of the preceding cases had a one-third chance or more of taking at least 1 h longer than scheduled (5,14). To put the results into context, about 75% of the anesthetics lasted longer than 1 h, 50% lasted longer than 2 h, 35% lasted longer than 3 h, and 20% lasted longer than 4 h. Second, we evaluated retrospectively what percentage of the anesthetics actually took 1 h or more beyond their scheduled durations and were followed by another anesthetic at a different site. The 95% upper confidence bounds on the two percentages of anesthetics were calculated using the Clopper Pearson method.

Assessing Deterioration of Operational Performance

Because checks of schedules were limited, the anesthesia department could have been adversely affected by the scheduling practices of clerks and nurses in other departments. We assessed several end-points: cancellations, on-time starts, turnovers, and complaints. Each anesthetic could not validly be analyzed as an independent observation because there were correlations among successive days and because specialties' workloads varied systematically within each 2-wk scheduling period (4,15). Thus, percentage cancellations (16), tardiness of scheduled start times (17), bias in scheduled anesthesia times (18), percentage errors in scheduled anesthesia times, turnover times (15), and prolonged turnovers (15) were analyzed after pooling each statistic by month. The Spearman rank correlation coefficient was applied to the monthly averages to test for worsening of the operational end-point over the 16 mo of data collection. We used the Spearman correlation instead of the Cochrane-Armitage trend test because the monthly averages were ratio levels of measurement, whereas Cochrane-Armitage was applied to binary data.

For the cancellation rate, the denominator was the number of scheduled cases as of the working day before anesthesia, just after the anesthesia providers were assigned lists of cases. The Freeman-Tukey double arcsine transformation, which performs better than does the alternative arcsine transformation (19) was applied to the number of cancelled and performed anesthetics each month (16,19). For equations, readers can refer to Eq. (1) of our Ref. 16 in this journal or to the primary Ref. 19. The Freeman-Tukey double arcsine transformation was used to reduce the sensitivity of the variance of the cancellation rate to the rate itself.

Turnover time referred to the time between the end of the billing for one anesthetic and the start of the billing for next anesthetic performed by the same anesthesia team on the same day, excluding intervals exceeding 2 h. The average of the 602 turnovers was 38 min. "Prolonged turnovers" were defined as all turnovers of any duration that were 15 min longer than this mean (i.e., >53 min) (15). The observed values of the prolonged turnovers are reported in the Results using the first 3 mo ($n = 143$) and the last 3 mo ($n = 118$) of data.

All correspondence regarding non-OR anesthetics that was received by the department was sent or forwarded to the non-OR administrator. The subject line and first five sentences of all of the administrator's correspondence were reviewed for criticisms related to NPO times or to an inability to schedule a case on or by a desired date. Each complaint was classified as having occurred either before or after the specialty was assigned allocated time and its clerks and nurses were scheduling the anesthetics. The binomial test was used to test whether significantly more than half of complaints were obtained before or after these time points. The binomial test uses the binomial distribution to compare an observed numerator and denominator to a hypothesized percentage; in this circumstance 1/2.

Consistency of Automated Patient Instructions and Coordination of Appointments

In the Introduction, we listed the creation of consistent instructions and the coordination of appointments to be two of the expected benefits of enterprise-wide scheduling.

Each patient appointment generated an appointment notification, either an automated phone call or an appointment letter. During installation of the enterprise-wide scheduling system at the hospital, sites created instructional paragraphs to be included in appointment letters. For example, "to aid in our evaluation, please bring X-rays and summaries of health records." Clinicians progressively modified these paragraphs. We evaluated the consistency of instructions by counting the number of unique versions of NPO instructions that could be sent automatically by the information system to patients scheduled to undergo anesthesia. These counts were limited to those specialties with at least one non-OR anesthetic performed during 2005. The counts were compared with the number of versions of NPO instructions that the anesthesia department established while implementing the scheduling of non-OR anesthesia.

We estimated the percentage of non-OR anesthetics for which the patient had other appointments scheduled in the enterprise-wide scheduling system and completed on the same day. Only an underestimate could be calculated, because appointments in the system were linked to other appointments by an additional step that the clerks and nurses sometimes skipped. The confidence interval for the percentage was estimated using the Clopper Pearson method. This statistical method was reasonable, because the percentage of anesthetics scheduled in the enterprise-wide system and with a linked appointment did not change systematically over the study period (Cochrane-Armitage trend test, $P = 0.34$).

Experimental Investigation of Graphic and Tabular Displays

The scheduling system was designed, in part, based on the results of a psychological study that investigated how best to display information. Although these experiments are described now in the article, they guided the earlier development of the department's website.

Schedulers had to consider uncertainties in procedure durations when coordinating appointments and deciding what time patients should stop eating and drinking. Visits to the preanesthesia evaluation clinic immediately before the anesthetic most commonly took 1 h, but could last from 20 min to 2 h. Patients could drink water 2 h before their anesthetic, but the anesthetic might start earlier than scheduled. Our goal was to ensure that patients would be ready 95% of the time when staff were ready to begin the anesthetic (5,6,20,21).

Statistical information was used to generate optimal times for milestones such as preanesthesia clinic appointment times, NPO times, and patient arrival times for each case (5–7). Schedulers viewed this information in a tabular format at the department's website (www.CaseDuration.com) when speaking with patients (6).

The experimental study used volunteers to investigate the relative advantages of a graphical display (Fig. 1) over our tabular display (Table 1) to convey these time points and their associated uncertainties to schedulers by asking experimental participants to perform simulated scheduling tasks. A graphical format might improve understanding of the statistical framework on which they should be basing their decisions, making it possible for schedulers to apply the statistics more accurately and use their knowledge when making decisions, as explained below.

After approval by the University of Maryland Human Subjects Committee, informed consent was

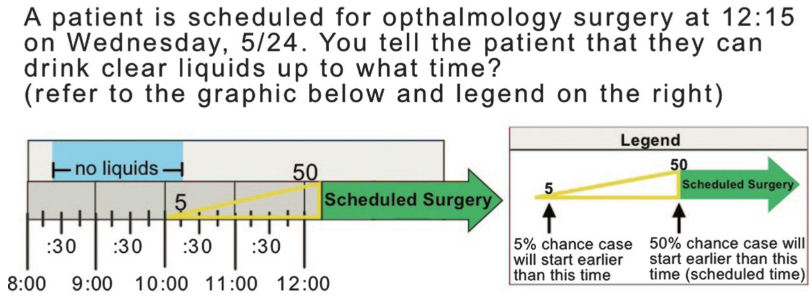

Figure 1. Upper half of graphical display for one of the six scenarios seen by half of the experimental participants. The other half of the experimental participants viewed the corresponding tabular presentation of Table 1. The tabular version had reminder information in textual form to its right. In this figure, we show the corresponding graphical legend. A dropdown box allowed participants to choose the time to stop drinking liquids in 15 min increments. Only 4 of the 10 participants in the graphical group selected 8:15 AM. Two selected 9:15 AM, three selected 10:15 AM, and one selected 10:45 AM.

Table 1. Upper Half of Tabular Display for One of the Six Scenarios seen by Half of the Experimental Participants

Scheduled Procedure Time	5/24/2006 12:15
"Ready to Start" Time	5/24/2006 10:15
Arrival time for appointment	5/24/2006 08:45
Clear liquids up to 2 h before "Ready to Start" time	5/24/2006 08:15
Light meal up to 6 h before "Ready to Start" time	5/24/2006 04:15
Solid foods up to 8 h before "Ready to Start" time	5/24/2006 02:15

The "Ready to Start' Time" was calculated statistically based on a 5% chance that the case might start earlier than the "Ready to Start' Time." The calculation was based on the combination of surgical suite, service, day of the week, and "Scheduled Procedure Time" (6).

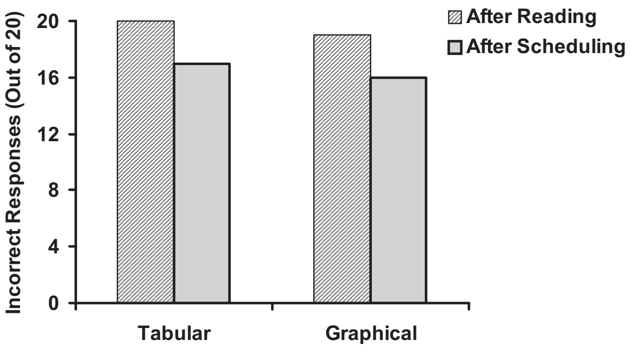

Figure 2. Application of knowledge obtained by reading instructions and participating in the scheduling of six scenarios. Participants had to get a perfect score on knowledge before being given the two study questions that tested their application of that knowledge. Two groups, each consisting of 10 participants, viewed scheduling information in either a tabular or graphical format. Every participant answered the same two multiple choice questions after reading the instructions but before scheduling patients, and then again after scheduling six patients. The first question was: "An OR schedules its nurses to work from 8:00 to 16:00. A patient is scheduled for surgery to start at 8:45. The patient can drink clear liquids up to what time?" Responses of 5:00, 5:45, and 6:00 were considered correct. All other responses were 6:45, an incorrect response. The second question was: "An OR schedules its nurses to work from 8:00 to 16:00. A patient is scheduled for surgery to start at 14:00. The patient can drink clear liquids up to what time?" Responses of 10:00 and 11:00 were considered correct. All other responses were 12:00, an incorrect response. The four participants responding 10:00 did so after scheduling. The response of 11:00 was given by a participant in the graphical group after reading. That participant responded incorrectly after scheduling.

obtained from 20 graduate nursing students or undergraduate nursing students in clinical training who were enrolled as volunteer participants. Each was informed that he or she would play the role of a scheduling clerk and make scheduling decisions for patients undergoing surgery. We used "surgery" rather than non-OR anesthesia to avoid confusing the participants. Testing was performed in a quiet computer lab without distractions.

The educational component of training consisted of an introductory web page providing background information on eating and drinking instructions, the likelihood of surgery starting early, and the longest amount of time required for a preceding preanesthesia appointment. Participants could not continue until they correctly answered five multiple-choice questions on the background material. For example, the participant had to choose the answer "2 h" when asked: "A patient is not allowed to have clear liquids for how many hours before surgery?"

Participants were then asked questions about two patients in random sequence (see legend of Fig. 2). The participants had to determine the times that the patients should stop drinking clear liquids. One patient was scheduled for surgery at 8:45 AM and the other at 2:00 PM. Both questions explained that the ORs are scheduled for surgery from 8:00 AM to 4:00 PM. Background information stated that patients could drink clear liquids up to 2 h before surgery. Any response earlier than 2 h before the scheduled start time was scored as understanding that surgery often starts early (5–7). Participants received no feedback about their responses.

Participants were then presented with a web page containing a scheduling scenario from the study hospital. The participants were asked to specify the time that they would instruct the patient to stop drinking clear liquids. Any time in 15 min increments could be selected. The participants also had to schedule a

Table 2. Lower Half of Tabular Display for One of the Six Scenarios seen by Half of the Experimental Participants

Preoperative clinic appointment schedule	
7:00–7:30	Reserved
7:30–8:00	Available
8:00–8:30	Reserved
8:30–9:00	Reserved
9:00–9:30	Available
9:30–10:00	Available
10:00–10:30	Reserved
10:30–11:00	Available
11:00–11:30	Available
11:30–12:00	Available

Notice that in Table 1, the "Arrival time for appointment" is 8:45 AM. However, that time was unavailable, as often happens in the "real world." The participants needed to use their judgment to decide whether the incremental cost was higher to plan an earlier appointment or a later one. The last paragraph of the Results describes the participants' good performance.

preanesthesia clinic visit on the day of the anesthetic, although the ideal time for the appointment was sometimes not available (Table 2). Participants were randomized to view scheduling information in either a tabular or graphical format. The same six scenarios and scheduling tasks were presented to both groups in random sequence, without feedback.

The two questions about the earlier patients were then presented again in random sequence to determine whether learning had occurred during the six scheduling tasks.

Table 1 shows the tabular format viewed by half of the participants for a procedure scheduled to begin at 12:15. To ensure availability 95% of the time that the OR is ready for the patient, the patient should be ready by the "Ready to Start " time (6). The arrival time for a preanesthesia appointment is shown in the table, as are the times the patient should stop eating and drinking. Empirical studies of OR times at the same hospital that implemented enterprise-wide scheduling showed that the "Ready to Start " time, or fifth percentile of case start times, was usually midway between the start of the workday and the scheduled start time of the case (6). This value was used for all scenarios. The 50th percentile was considered the scheduled start time of the case (5). Thus, the tables took into account the reality that the ORs were ready for the patient earlier than scheduled in approximately half of the cases and later than scheduled in approximately half the cases (5,6). The same 50% relationship was used for all scenarios to increase the chance of the participants learning.

Figure 1 shows the graphical format viewed by participants for the same scenario as presented in Table 1. Time is shown along the horizontal axis. An increasing ramp function indicates the increasing probability of the case being ready to start as the scheduled start time is approached. A marking of "5" shows the time at which the patient should be ready to ensure availability 95% of the time. The probability is 5% that the OR would want to start the case even earlier. The time the patient should stop drinking clear liquids is also shown along the time scale. The ramp function conveys the probabilistic nature of the early start, and the fact that it is a continuous function rather than a single time point anchored at the fifth percentile. We expected learning to be better in the graphical group because the visual example provided more probabilistic insight.

Next to each table and graph was a reminder that preceding cases may finish early. The tabular format's "Reminder" had the text: "There is a 5% chance case may start earlier than the 'Ready to Start' time."

The quality of each participant's NPO instructions for each scenario was measured in units of excess waiting (20,21). Monte-Carlo simulations generated 30,000 random times when the OR would be ready for the patient based on a two-parameter log normal distribution of case durations (5,6) with the same fifth and 50th percentiles as the scenario being scored. Patient waiting and OR waiting were summed for all 30,000 simulated cases, with each minute of patient waiting equal to 1/19th the value of each minute of OR waiting (5,6). The 1:19 relationship between the values of patient waiting and OR waiting is consistent with the goal that patients should be ready 95% of the time. The OR will wait for the patient only one time in 20 cases.

The excess waiting times for the six scenarios were compared for the 10 participants in each of the two groups using the Wilcoxon Mann–Whitney test stratified by scenario. Each participant's average excess waiting times among the six scenarios was used to report a median $\pm$ quartile deviation of waiting among participants in each of the two groups. The quartile deviation equals half of the difference between the 75th and 25th percentiles. Finally, a *post hoc* analysis was performed by two-way analysis of variance.

The quality of preanesthesia clinic appointment times was measured similarly. Both the clinic appointment duration and the time the OR was ready to start the case were random variables. The preanesthesia evaluation was considered to be completed before the anesthetic began. For each available clinic appointment time in a scenario, the two variables were estimated using 30,000 Monte-Carlo simulations. Waiting times were calculated for each appointment time in each scenario to judge the quality of the participant's response. The six incremental costs of the 10 participants in each group were compared between the two groups by the Wilcoxon Mann-Whitney test stratified by scenario.

From reading the instructions and/or by participating in the scheduling of the six scenarios, participants' knowledge may have improved. We used the binomial test to evaluate whether at least half of the participants correctly answered at least one of the two questions. Based on our scoring, participants guessing at random would, on average, answer one of the two questions correctly. We expected learning to occur during the process of scheduling because the concept of uncertainty in case start times was presented six times. For example, participants in the tabular group viewed six times that the "'Ready to Start' Time" was always earlier than the "Scheduled Procedure Time" (Table 1). The difference in learning between the tabular and graphical groups was calculated by Fisher's exact test.

RESULTS

Anesthetics performed in allocated time increased progressively from 0% to 75% over 19 mo ($P < 0.0001$). Anesthetics scheduled by nonanesthesia clerks and nurses increased progressively from 0% to 77% over 16 mo ($P < 0.0001$). Scheduling was performed by 17 nonanesthesia clerks and nurses for 10 specialties, five with allocated time.

Consistency of patient instructions was improved by creating new pseudoappointment types (e.g., magnetic resonance imaging with anesthesia). Before implementation, the non-OR sites had instructional paragraphs including 89 versions of NPO instructions. None was appropriate for general anesthesia. The new appointment types had their own sets of paragraphs containing just two versions of NPO instructions, one for adults and one for children.

Each new appointment was reviewed the next business day. Notifications of required changes declined over time ($P = 0.016$) (e.g., 11% vs 7% during the initial versus final 3 mo). Nevertheless, prompt review likely was necessary, being as the overall rate of problems was 8%: late starts 4%, scheduled durations too brief for the site 2%, cases not scheduled sequentially into allocated time 1%, and other causes and combinations 1%. Eleven of the 17 different self-schedulers received at least one such notification. Just 0.5% (95% CI <1.1%) of anesthetics were scheduled to follow case(s) at a different site when at least one of the preceding cases had a one-third chance or more of taking at least 1 h longer than scheduled (5,14). Only 0.1% (95% CI <0.7%) of anesthetics took 1 h or longer than scheduled and were followed by another anesthetic at a different site.

Allocation of non-OR time by specialty and the scheduling of anesthetics by non-OR clerks and nurses were not associated with an increase in:

- overestimation of anesthesia times ($r = -0.07$, $P = 0.60$),
- tardiness from scheduled start times ($r = -0.20$, $P = 0.78$),
- percentage error of scheduled anesthesia times ($r = -0.26$, $P = 0.82$),
- cancellations ($r = -0.37$, $P = 0.92$),
- turnover times ($r = -0.58$, $P = 0.99$),
- percentage of turnovers that were prolonged ($r = -0.82$, $P = 0.99$), or
- written (e-mail) complaints of physicians being unable to schedule non-OR cases at desired dates and times ($P = 0.99$).

Although several of these findings suggest statistically significant improvements, the magnitudes were modest (e.g., prolonged turnovers reduced from 37% to 28%).

The anesthesia department continued to receive written (e-mail) complaints from nurses, physicians, and parents about perceptions of NPO times. For example, a nurse wrote that "it is extremely difficult to keep an outpatient 14 month old NPO all day for an elective procedure scheduled at 4:30 PM" These complaints were unlikely to be because of a change in scheduling, as the median scheduled start time of 9:15 AM was unchanged over the 16 mo ($r = 0.03$, $P = 0.92$), and 90% of anesthetics were scheduled to start before 2:00 PM. In addition, these complaints were unlikely to be because of lack of knowledge that NPO times were based on the 'Ready to Start' time instead of midnight, as there was an extensive educational campaign and the department's web site was being used daily by the nurses for calculation of NPO times (6). An explanation for these complaints was that the clerks and nurses were providing appropriate instructions to patients and parents by rote reading from the web site's table, but the clerks and nurses were ignoring the information that they were reading. Experimental participants were required to show that they had learned the instructional material, but fewer than half applied this knowledge to even one of the two test questions ($P < 0.0001$), even after having scheduled six patients ($P = 0.021$, Fig. 2). Not only did a graphical format instead of the web site's tabular format not improve the application of knowledge (Fig. 2, $P = 0.99$), there was significantly more unneeded simulated anesthesia team and patient waiting per case with our studied graphical format (graphical 17 ± 17 min, tabular 0.7 ± 2.0 min, median ± quartile deviation, $P < 0.0001$, analysis of variance $P = 0.0005$).

More than 65% of the non-OR anesthetics at the study hospital were coordinated with other appointment(s) that day (95% CI >62%; 49% excluding preanesthesia evaluation clinic). Experiments studied the quality of scheduling of preceding clinic appointments. Choices of appointment times resulted in just 2.4 min of simulated excess anesthesia provider waiting time per case. There was no difference between groups (tabular 2.4 ± 1.1 min, graphical 2.4 ± 4.2, $P =$

0.80). The results differed from scheduling the milestone of NPO time, because participants could get an overall score of only 1.9 min of excess anesthesia waiting time per case even while neglecting the possibility that preceding anesthetics often finish early. Specifically, as explained below, the participants could do so by basing their choices of the preceding clinic appointments on the differences between the scheduled start times of the anesthetics and longest possible duration of the preceding clinic appointments.

DISCUSSION

Implications of Our Results

First, nonanesthesia clerks and nurses can successfully schedule anesthetics outside of ORs using an enterprise-wide information system. This conclusion applies to a system that includes the audit of appointments the next business day, and the tabular display of case duration estimates (5,7) and NPO instructions (6,7) that are calculated statistically to incorporate uncertainty (i.e., are not simply the averages of historical values) (5–7,20,21).

Second, most appointments for non-OR anesthesia are coordinated with other appointments on the same day. Each such appointment takes an uncertain amount of time. The time when the patient's anesthesia provider will be ready is also uncertain. Choosing the appropriate time for the other appointment, while considering the costs of patient waiting versus anesthesia team waiting, involves the convolution of probability distributions (21,22). Nevertheless, our implementation and experimental findings show that schedulers handle the decision-making well. The task shown in Table 2 seems complicated because judgment must be used. Nonetheless, schedulers approached the issue by ignoring the possibility of the anesthetic starting early and relying on the longest amount of time that the preceding appointment may take. This result was insensitive to the use of a graphical or tabular user interface. However, the important implication is that the scheduler's screen must show the longest time the patient's appointments may take, not just the average duration. This implication likely applies to the scheduling of any activity preceding an anesthetic or entrance into an OR.

Third, when patients have multiple appointments on the same day (e.g., anesthesia and magnetic resonance imaging), enterprise-wide scheduling systems can generate several inconsistent appointment letters or a letter with successive paragraphs that are inconsistent. The same problem can arise when patients undergo non-OR procedures on the same date as surgery (e.g., diagnostic imaging before neurosurgery or needle localization before breast surgery). We showed that a practical solution is the creation of new appointment types for the combinations of appointments. This approach also prevents the possibility of the primary appointment being cancelled or rescheduled but not the appointment for the anesthesia team. However, the creation of new appointment types relies on the anesthesia department understanding scheduling and assuming responsibility for proper modification of the enterprise-wide scheduling software. An alternative, but usually unacceptable approach is for the hospital to modify the source code of both the enterprise-wide and OR scheduling systems.

Fourth, schedulers have trouble providing instructions for milestones (e.g., time for NPO or time to arrive at the facility) before appointments that can start early (e.g., anesthesia). They may set NPO times so far in advance as to avoid the issue (e.g., midnight). Alternatively, they may set milestones a fixed number of hours before the appointment (e.g., 2 h before the scheduled start of anesthesia). Neither solution is appropriate (5,6,7,21). Providing instructions customized to the probability of an anesthetic starting early is particularly relevant to facilities that have limited physical space to handle patients and families, and thus want patients to arrive just in time for surgery or regional block placement. Facilities wanting to reduce patient fasting times and/or waiting times to have more patient-centered care while not increasing anesthesia costs should address people's tendency to ignore the fact that anesthetics often start early. Otherwise, inconsistent or poor instructions will be provided to patients. Our experiments show that a solution is for computers to provide recommendations to people, because even when people are presented with statistical probabilities and have learned their meaning, they do not apply this knowledge to decision-making.

Challenges in the Scheduling of Milestones Before an Anesthetic

People make probabilistic scheduling decisions daily. For example, a simple decision is how early to leave work to drive to a child's 6:00 PM soccer game. In contrast, suppose that the child's game will start 15 min after the end of a preceding game that is scheduled to start at 4:00 PM. The soccer games average 1 h 45 min, but have been as brief as 1 h 15 min. Knowing when to leave work is difficult, because now the child's game could start before 6:00 PM. This problem is equivalent to picking a time to start fasting or to arrive at a hospital. Previously, we developed statistical methods to choose (5–7,20,21) and update (5,7,20,21) the earliest start time of the anesthetic (i.e., soccer game). In this article, we studied how to present those estimates.

People often make decisions by relying on simplified, rule-of-thumb approaches that use some information but ignore most data (23). We previously showed that this is how clinicians make managerial decisions on the day of surgery (24,25). In the current study, our experimental participants tended to ignore their knowledge that anesthetics can start early when making managerial decisions before the day of surgery. Participants learned that when scheduled durations are chosen based on the 50th percentiles, half of cases will take less time than scheduled. Minutes later when making decisions, they then ignored that knowledge that cases often start early. Therefore, our experiments show the need to mitigate the tendency of schedulers to rely on the simplified assumption that anesthetics do not start earlier than scheduled. Our use of a tabular presentation of arrival and NPO times eliminated the need for the scheduler to think *how* to make a decision. He or she just *read* the line. Other formats designed to promote learning may also be less effective than a script.

Instead of providing schedulers with instructions calculated statistically (5,6), patients can simply be instructed not to eat or drink after midnight. However, this results in long NPO times and does not address the problem of choosing arrival times. Having all patients for the day arrive at 5:30 AM results in long patient waits, expensive requirements for physical space and amenities, and does not address the problem of choosing appointment times for the more than 65% of non-OR anesthetics with other appointments on the same day.

Another alternative to use of a web site with statistical (5–7) results is the use of one set of instructions for patients scheduled to have anesthesia at or before 12 noon and another set for patients after 12 noon. One drawback of this approach is that most patients would not benefit. For example, at the study hospital, only 20% (95% CI 20% to 21%) of patients were scheduled to undergo anesthesia (OR or non-OR) after 12 noon. Another drawback is the marked heterogeneity in cancellation rates and scheduling practices among different sites, specialties, and days of the week at a hospital (6). For example, in the experiments, a patient scheduled to undergo anesthesia starting at 12:15 PM at a facility with a start time of 8:00 AM was considered to have a 5% chance of starting before 10:08 AM (Fig. 1), where 10:08 AM is 50% of the time from 8:00 AM to 12:15 PM. Consumption of liquids would stop at 8:08 AM (Table 1). However, at the study hospital, actual times to stop drinking liquids would range from 6:45 AM to 9:30 AM, depending on the anesthetizing location, surgical specialty, and day of the week (6).

Limitations of Application of Our Results

Our experimental results showed that our observational findings were sensitive to the user interface. Consequently, we would expect that a graphical design different from that of Figure 1 would produce different results relative to the performance of Table 1.

Our results are limited to the scheduling of anesthesia time: 1) allocated as open time, 2) allocated to groups of physicians in which more than one physician performs each type of procedure, or 3) allocated to individual physicians when no other physician at the hospital performs the same type of procedure. Our results do not apply to scheduling of anesthesia time allocated to individual physicians who are not the only physicians at the hospital performing certain procedures (26), for the following reason. The e-mail complaints showed that at least some of the non-OR physicians and clerks thought that the bottleneck to reducing the number of days that patients waited was the anesthesia department. Some of the clerks who scheduled anesthetics also scheduled clinic appointments. The logical consequence of these two facts is that those clerks should choose a physician for each patient based on future availability of anesthesia time. However, the proportion of patients who undergo anesthesia, and the interval between the clinic appointment and the anesthetic are both random variables. Therefore, oscillations in anesthesia workload would result, with reduced efficiency of use of anesthesia time (26).

A previous study from a Veterans' Administration hospital reported that enterprise-wide scheduling could be used to predict each patient's risk of failing to appear for surgery. The risk depended on the patient's failure to show for preadmission clinic visits (27). Our data were insufficient to explore the use of enterprise-wide scheduling to predict which non-OR patients would not appear on the day of their anesthetic. At our study hospital, the rate of no shows on the day of non-OR anesthesia was too low (0.8%, 95% CI <1.1%) for forecasting to be useful.

CONCLUSIONS

We implemented scheduling of anesthetics outside of ORs by clerks and nurses from other departments using a hospital's enterprise-wide scheduling system. There was improved coordination of anesthetics with other appointments on the same day and improved consistency and accuracy of patient instructions customized to the probability of an anesthetic starting early. Results likely are useful not just for non-OR anesthesia, but also for having patients arrive just in time for surgery and/or regional block placement. However, our experimental studies showed that our observational findings are sensitive to both the user interface and to the use of appropriate statistical methods.

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