The Impact of Service-Specific Staffing, Case Scheduling, Turnovers, and First-Case Starts on Anesthesia Group and Operating Room Productivity: A Tutorial Using Data from an Australian Hospital

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BACKGROUND: In this tutorial, we consider the impact of operating room (OR) management on anesthesia group and OR labor productivity and costs. Most of the tutorial focuses on the steps required for each facility to refine its OR allocations using its own data collected during patient care.

METHODS: Data from a hospital in Australia are used throughout to illustrate the methods. OR allocation is a two-stage process. During the initial tactical stage of allocating OR time, OR capacity ("block time") is adjusted. For operational decision-making on a shorter-term basis, the existing workload can be considered fixed. Staffing is matched to that workload based on maximizing the efficiency of use of OR time.

RESULTS: Scheduling cases and making decisions on the day of surgery to increase OR efficiency are worthwhile interventions to increase anesthesia group productivity. However, by far, the most important step is the appropriate refinement of OR allocations (i.e., planning service-specific staffing) 2–3 mo before the day of surgery.

CONCLUSIONS: Reducing surgical and/or turnover times and delays in first-case-of-the-day starts generally provides small reductions in OR labor costs. Results vary widely because they are highly sensitive both to the OR allocations (i.e., staffing) and to the appropriateness of those OR allocations.

(Anesth Analg 2006;103:1499–516)

This tutorial reviews how to calculate the impact of operating room (OR) management on anesthesia group and OR labor productivity and costs. This calculation translates into the predictability of work hours for health care providers. The methods were developed largely using data from hospitals in the United States (US). To illustrate the methods' broad applicability, the tutorial uses data from a hospital in Australia.

The goal of this tutorial is to assist readers in determining for which of their ORs the statistical methods may be helpful and in interpreting the results of these analyses. Readers with a background in statistics and/or operations research can use the tutorial to perform the analyses.

The end-points of anesthesia group labor productivity, anesthesia group costs, OR productivity, OR labor costs, and predictability of work hours on the day of surgery are combined in one article because they are inextricably linked. All depend on the choices of how many ORs to keep open simultaneously and how to schedule cases into those locations. Evaluation of anesthesia care (productivity, costs, efficiency, and predictability of work hours) within an OR is a surrogate for evaluation of OR management (productivity, costs, and efficiency) and *vice versa*.

For example, cardiac surgeons operate at a hospital every Monday starting at 8 AM (Table 1). They usually finish sometime between 2:00 PM and 2:30 PM (Table 1). Even if turnover times, surgical times, anesthesia times and/or delays in starting first cases of the day were reduced, it is likely that the cardiac surgeons

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Case Scheduling for Dummies

Steven L. Shafer, MD

In 1995, Drs. Franklin Dexter and John Tinker published a manuscript on decreasing the cost of care in the postanesthesia care unit (1). Over the following 11 yr, Dr. Dexter has published nearly 100 manuscripts on using mathematical and statistical approaches to optimizing the management of operating rooms. In the process, Dr. Dexter and his frequent collaborators, Drs. Epstein (Jefferson Medical College), Lubarsky (University of Miami), Macario (Stanford University), O'Neill (University of North TX), Traub (ND State University), and Wachtel (University of IA) have defined a new intellectual discipline for our specialty: operating room management. In the process, Dr. Dexter no longer performs liver transplants, his clinical specialty for many years, but devotes himself full time to helping hospitals improve the efficiency of their operating rooms as the Director of the Division of Management Consulting in the Departments of Anesthesia and Health Management and Policy at the University of IA.

The tools used to optimize operating room management are arcane: stochastic programming, similarity index, structural equation modeling, Monte Carlo simulation, bin packing algorithms, fuzzy constraints, mean variance analysis, data envelopment analysis, and Bayesian prediction bounds. Although the authors of these articles have worked hard to make the material tractable, nevertheless the articles are hard to read. I have heard from my academic colleagues that few understand the work. The only options for a hospital interested in using these advanced methodologies is to hire Dr. Dexter or one of his colleagues to do the analysis or to teach the hospital's financial analysts or management engineers how to do the analysis.

A year ago, I challenged Dr. Dexter to write a "how to" guide for hospitals interested in applying advanced operating room management technologies to surgical case scheduling. Could he condense 10 yr of research and 50+ published manuscripts into a guide that did not require gray matter transfusions to understand and implement? My model was the surprisingly well written "For Dummies" series of publications.

The result is the manuscript "The Impact of Service-Specific Staffing, Case Scheduling, Turnovers, and First-Case Starts on Anesthesia Group and Operating Room Productivity: A Tutorial Using Data from an Australian Hospital" appearing in this issue of *Anesthesia & Analgesia* (2). Constructed around a real-life example of applying operating room management, the manuscript offers definitions and step-by-step instructions on how to go about improving operating room efficiency, using data routinely gathered during health care delivery. Any physician with a basic understanding of addition, subtraction, multiplication, and division should find the work tractable. Any hospital or anesthesia group interested in improving operating room efficiency should start with this article as a broad overview of the concepts and methodologies. The tables can serve as models for the hospital's information system reports (i.e., "this is what we want").

On a separate topic, there is a potential conflict of interest between Dr. Dexter's role as an author of many articles published in *Anesthesia & Analgesia*, and his role as Section Editor for Economics, Education, and Policy. At the time this editorial was written, Dr. Dexter's section included at least two of his articles (2,3). To preclude conflict of interest I handle all

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of his submissions. His manuscripts get reviewed, critiqued, and occasionally rejected, just like any other author. I do the same for submissions from any Section Editor that would otherwise go to their section. Similarly, my submissions are handled by Ron Miller, our emeritus Editor-in-Chief, and I have no more control over their assignment or fate than any other author.

Dr. Dexter's guide "The Impact of Service-Specific Staffing, Case Scheduling, Turnovers, and First-Case Starts on Anesthesia Group and Operating Room Productivity: A Tutorial Using Data From an Australian Hospital" not only survived the peer-review process, but met with enthusiastic endorsement as a "Case Scheduling for Dummies" guide that has long needed to be written. I agree, and hope that it provides insight into a discipline that has previously been veiled by the demanding methodologies needed for scientific validation.

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Table 1. Mean Total Hours of Elective Cases Including Turnover Times

Service	Mon	Tue	Wed	Thu	Fri	Full name
CDS	6.0	7.5	6.6	8.7		Cardiac surgery
CTS		6.3				Thoracic surgery
DEN	3.9				3.6	Oral surgery
ENT	6.5	4.5	1.9	7.5	1.4	Ear, nose, and throat
EYE					1.4	Ophthalmology
GES	8.4	13.9	11.3	6.6	5.1	General surgery (with vascular)
GONC			8.5			Gynecology oncology
GYN	7.9	3.3	4.1	3.5	8.9	Gynecology
NRS	8.5		8.4	7.9		Neurosurgery
ORT	2.6	1.2			2.0	Orthopedics
PDS		4.7	3.9	3.8	1.9	Pediatric surgery
Surg	4.3					One surgeon working alone
Total	49.8	42.1	46.5	38.4	25.4	
OTHER	12.5	14.4	11.7	7.7	11.4	Staffed OR time not allocated to a specific service (see definition of "*Allocated OR time*")

Specialties performing less than a mean of 1 hr of cases on a day of the week are not shown, but are included in the Total. The 3504 elective cases were performed in eight operating rooms between October 2004 and June 2005, excluding weekends and holidays. The sample sizes varied among days of the week: 32 Mondays (Mon), 35 Tuesdays (Tue), 34 Wednesdays (Wed), 36 Thursdays (Thu), and 32 Fridays (Fri), for a total of 169 workdays.

would still have one OR planned for them, and would finish their work in <8 h. The costs to provide the anesthesia care would be the same. The work hours would be predictable.

DEFINITIONS

This section focuses on the meaning of under-utilized OR time, over-utilized OR time, and the efficiency of use of OR time. The definitions preceding these terms serve as the necessary underpinnings of OR efficiency. The definitions following these terms are used to quantify the usefulness of making decisions based on OR efficiency.

Scheduling, Assignment, and Staffing

Staff scheduling is the process of deciding which anesthesia providers work each shift on each day. Staff scheduling for a future date is usually determined before the surgical cases to be performed on that date have been scheduled.

For example, the anesthesia group at the Australian hospital also provides care at a small peripheral hospital. The anesthesiologists create their work schedule every month. Three anesthesiologists are scheduled to work at a small peripheral facility 8 AM to 4 PM on January 19th.

Although staff scheduling is important to the individual anesthesia provider, the topic is not covered in this article. Rather, the tutorial considers the factors that affect the productivity of the anesthesia group (i.e., the collection of anesthesia providers, regardless of how they are paid or organized).

Staff assignment is the process of deciding who will take care of a specific patient on a specific day. Staff assignment is also important to the individual, but much less to the group. Thus, this tutorial will not cover staff assignment as we reviewed this topic earlier (1).

Staffed hours are hours that an anesthesia group schedules its anesthesia providers to cover when not on call (e.g., 8 AM to 4 PM). This article considers this topic in detail.

Elective Cases

We are not aware of any one best answer as to what constitutes an elective versus nonelective case. Still, differentiating among such cases is necessary to plan staffing.

An *elective case* can be defined as one for which the patients can wait at least 3 days for surgery without sustaining additional morbidity (2).

For example, at the studied Australian hospital, some inpatients would wait for surgery from Friday to Monday. Therefore, cases that could wait for 3 days or more were considered elective. All other cases were referred to as nonelective.

This tutorial is limited to staffing and case scheduling for elective cases. We previously reviewed decision making for nonelective cases (1).

Definitions Related to Service-Specific Staffing and OR Allocation

Surgical service refers to a group of surgeons who share allocated OR time (i.e., share service-specific staffing). An individual surgeon, a group, a specialty, or a department can represent a surgical service. *Service* simply refers to the unit of OR allocation.

For example, the neurosurgeons practicing at the Australian hospital are allocated OR time. Thus, "Neurosurgery" is a service (Table 1).

For example, two gynecological oncologists practice at the Australian hospital. Because the two oncologists are jointly allocated OR time, their surgical group represents a service.

Table 2. Current and Calculated Operating Room Allocations (Staffing) for the Services Defined in Table 1

Day	Service	Current allocation (h)	Mean used -allocated (h)	Allocation (h)	Change in allocation (h)
Mon	CDS	8	−2	8	0
	ENT	6	1	8	2
	GES	8	0	10	2
	GYN	8	0	10	2
	NRS	8	1	10	2
	DEN	5	−1	0	−5
	ORT	5	−5	0	−5
	Surg	6	−2	0	−6
	OTHER			2 × 8	16
Tue	CDS	8	−1	8	0
	CTS	7	−1	8	1
	GES	14	3	2 × 8	5
	ENT	4	0	0	−4
	GYN	8	−5	0	−8
	PDS	6	−1	0	−6
	OTHER			2 × 8	16
Wed	CDS	8	−1	8	0
	GES	9	2	10	1
	GONC	8	0	10	2
	NRS	8	0	10	2
	GYN	4	0	0	−4
	PDS	5	−1	0	−5
	OTHER	4		10	6
Thu	CDS	8	1	10	2
	ENT	10	−3	10	0
	GES	6	1	8	2
	NRS	8	0	10	2
	GYN	8	−5	0	−8
	PDS	4	0	0	−4
	OTHER			8	8
Fri	GES	4	1	8	4
	GYN	12	−3	10	−2
	DEN	4	0	0	−4
	OTHER	5		10	5

Services' and Days' full-names are given in Table 1. "OTHER" refers to a pseudo-service, sometimes referred to as the open, unblocked, first-scheduled, first-served service. The OTHER time combines all services not allocated its own OR(s) for the day. Negative values in the column "Mean used-allocated (h)" indicate that the total hours of cases including turnovers was less than the allocated hours. Negative values in the column "Change in allocation (h)" indicates a recommended reduction in allocated OR time.

For example, a busy surgeon is personally allocated an OR on Mondays (Tables 1 and 2). From the perspective of allocating OR time and scheduling cases on Mondays, that surgeon represents a surgical service.

Even when a facility does not have a formal organizational plan for allocating ORs (i.e., "block schedule"), there can be service-specific staffing (i.e., OR allocations). In this regard, "services" need not be specific clinical disciplines in the medical staff organizational structure. Rather, they reflect the activities of individuals or groups of surgeons who use the ORs and thus require organized staffing to support those activities.

For example, a 12 OR hospital that one of us (FD) worked with had the official policy that all of its cases were scheduled on a first-scheduled, first-served basis. However, in reality, cases of the same specialty were usually scheduled into the same ORs. In addition, there were specialty teams. Some nurses and anesthesia providers care only for patients undergoing neurosurgery or otolaryngology cases, some only for gynecology or general surgery, and so forth. Thus, the services corresponded to the specialty teams.

Allocated OR time is an interval of OR time with a specified start and end time on a specified day of the week that is assigned by the facility to a service for scheduling cases. Some facilities have OR time that is staffed and available for cases, but not allocated to a specific service. Such OR time has been allocated to a pseudo-service, variably named the open, unblocked, first-scheduled, first-served, or OTHER service.

For example, staffing is planned (i.e., OR time is allocated) for Gynecology from 8 AM to 6 PM on Mondays and Fridays (Table 2). This does not mean that the department's surgeons are limited only to scheduling cases on those two weekdays. They also perform some elective cases on Tuesday through Thursday (Table 1).

OR time of a case is defined as the time from when a patient enters an OR until he or she leaves it.

Table 3. Percentages of Turnovers that are Both Prolonged and Occurred at the Specified Hour of the Day

Hour of the day	Prolonged turnovers (%)	95% Confidence interval (%)
7:00–7:59	0.4	
8:00–8:59	1.0	0.5–1.5
9:00–9:59	1.7	1.0–2.4
10:00–10:59	1.7	1.2–2.3
11:00–11:59	1.6	0.8–2.5
12:00–12:59	1.1	0.5–1.8
13:00–13:59	0.6	
14:00–14:59	0.3	
15:00–15:59	0.1	
Overall	8.7	

The hours of the day that were analyzed were chosen automatically by the statistical method. Confidence intervals were calculated with correction for multiple comparisons. On average, 5.4% ± 0.3% (SE) of assessments have at least one hour of the day where its confidence interval does not include the true percentage of turnovers that are prolonged and occur at that hour of the day (5). The 2414 turnovers briefer than 90 min had a mean of 19.9 min (SE 0.3 min). Among the total of 2483 turnovers, 217 were prolonged, defined as 15 min longer than the mean (i.e., 35 min or longer).

Turnover time is the time from when one patient exits an OR until the next patient on that day's OR schedule enters the same OR (3,4).

For example, staffing is planned for an OR from 8:00 AM to 4:00 PM. A patient arrived at the holding area at 8:45 AM, had her IV placed at 8:50 AM, and entered the OR at 8:59 AM. The trachea was intubated at 9:12 AM. The operative site was prepared at 9:15 AM. The incision was made at 9:23 AM. She left the OR at 11:59 AM. From the perspective of OR scheduling, the case started at 8:59 AM. The OR time of the case was 3 h.

There is a practical difference between routine turnovers (e.g., cleanup times and setup times) versus unusual events. To benchmark routine turnovers, those having a longer than a defined interval can be excluded, and then the mean is calculated (5).

For example, at the studied Australian hospital, 20 min was the average of turnover times briefer than 90 min (Table 3). This value of 20 min is lower than that of all 31 of the US hospitals' turnover times recently reported (5).

Prolonged turnovers have been defined arbitrarily as those taking more than 15 min longer than the average, with the average excluding turnovers longer than 90 min (5). All turnovers are included in assessing prolonged turnovers.

For example, a surgeon is scheduled to perform a thoracoscopic lobectomy. During the initial video inspection of the thoracic cavity, the patient is found to have pericardial metastases. The procedure is aborted and the case ends 3 h earlier than planned. The second case of the day could start 3 h earlier than planned. However, the second case of the day in that OR will be performed by a different surgeon. He is unavailable, caring for patients in his outpatient office. The result is a delay of 3 h. That delay would not contribute to future calculations of the average turnover time. However, it would count as a prolonged turnover.

For example, at the Australian hospital, turnovers were considered to be prolonged if they were at least 35 min, where 35 min = 15 min longer than average + average of 20 min from above. The percentage of turnovers that were prolonged was 8.7% (Table 3), which is small when compared with that reported at other hospitals (5).

Unlike the routine turnovers as aforementioned, the prolonged turnovers are often the result of nonsequential case scheduling or case cancellation. Interventions to reduce prolonged turnover times include decreasing scheduled delays between cases, having sufficient equipment on site to do all cases of the day without reprocessing, and changing schedules of staff (e.g., housekeepers) to focus on the middle of the day when there are the most turnovers. Each such intervention depends on the time of the day (Table 3).

OR workload for a service is its total hours of cases including turnover times. When allocating OR time for elective cases, only the elective cases are included in calculating the OR workload.

For example, the neurosurgeons have an average of 7.9 h of elective cases including turnover times on Thursdays (Table 1).

For example, a hypothetical service's OR allocation is 24 h each Friday. Its OR workload is 24 h each Friday. Thus, the difference between its average OR workload and its OR allocation (as in Table 2) equals 0 h. This does not imply that the service has no under-utilized OR time on Fridays. The service has two surgeons who operate on Fridays, each for 12 h. The OR allocation is 3 ORs, each for 8 h. There are 8 h of under-utilized OR time each Friday. This example shows that for some services on some days of the week at some facilities, the average difference in hours between the OR workload and the allocated OR time is a simple way to report whether the OR allocation is too small or too large. However, it alone can be insufficient for good decision making.

Under-utilized OR time = allocated OR time − OR workload, or zero, if this value is negative (7). This implies that under-utilized OR time equals the allocated OR time minus the OR workload, provided that the allocated OR time is larger than the OR workload. Otherwise, the under-utilized OR time is 0 h.

For example, cardiac surgery's average OR workload on Mondays is 6.0 h (Table 1) and its OR allocation on Mondays is 8.0 h (Table 2). The average hours of under-utilized OR time is *not* 2.0 h, where 2.0 = 8.0 − 6.0. Substituting the average OR workload into the equation for the under-utilized OR time does *not* give the correct answer for the average under-utilized OR time, because that would inappropriately ignore the days when the above term was equal to zero.

Adjusted utilization (4)

$$= 100\% \times (1 - [\text{under-utilized OR time}] \div [\text{allocated OR time}])$$

For example, staffing is planned for the OTHER service on Thursdays from 8 AM to 4 PM (Table 2). An OR's last case of the day ends at 2 PM. The OR workload is 6 h. There are 2 h of under-utilized OR time. The adjusted utilization was 75% on that day (4).

Over-utilized OR time = OR workload − allocated OR time, or zero if this value is negative (7). This is not simply the opposite of under-utilized OR time, because neither under-utilized OR time nor over-utilized OR time can be negative numbers.

For example, General Surgery's ORs on Tuesdays are staffed from 8 AM to 4 PM. The last case of the day in one of the ORs ends at 6 PM. Then, there are 2 h of over-utilized OR time.

Inefficiency of use of OR time (7,8)

$$= [(\text{cost per hour of under-utilized OR time}) \times (\text{hours of under-utilized OR time})] + [(\text{cost per hour of over-utilized OR time}) \times (\text{hours of over-utilized OR time})]$$

For example, every worker at a surgical suite wants to work as many hours as he can regardless of when he works, and is paid exactly the same per hour regardless of when the cases are performed. Then, the cost per hour of over-utilized OR time would equal the cost per hour of under-utilized OR time. This does *not* mean that the inefficiency of use of OR time would be the same regardless of the OR allocation (7,8). Suppose that for half of days, the OR workload is precisely 7 h and for the other half of days, it is precisely 10 h. If the OR allocation were 0 h, the inefficiency of use of OR time would be proportional to 17 h. If the OR allocation were anything between 7 and 10 h, the inefficiency of use of OR time would be proportional to 3 h. Any increase in the OR allocation beyond 10 h would result in an increase in the inefficiency of use of OR time.

OR efficiency is the value that is maximized when the inefficiency of OR time use has been minimized (7).

"Efficiency" is characteristically thought of as the ratio of an output (e.g., passenger-kilometers) to the necessary input (e.g., liters of fuel). For purposes of service-specific staffing, the output is considered a constant, in that surgeons functionally have open access to OR time on any future workday (see section *Tactical Versus Operational Decisions*). Maximizing "efficiency" is then achieved by minimizing the input. That occurs when service-specific staffing and case scheduling are so good that there are both 0 h of under-utilized OR time and 0 h of over-utilized OR time. Maintaining the production of surgery is always a higher priority in decision making, because otherwise OR efficiency can be maximized by performing no surgery. If you plan no staffing and perform no cases, you would never finish early or late.

For example, why would staffing planned for otolaryngology be one OR for 10 h on Thursdays (Table 2), even though their average OR workload is 7.5 h (Table 1). The average hours of under-utilized OR time and over-utilized OR time are not calculated using the average OR workload (Table 1), but, rather, by the workload on each day. If the department's surgeons were allocated 2 ORs, then much of the OR time would be under-utilized, which would reduce OR efficiency. If the surgeons were allocated one OR for 8 h, then the surgeons would often be working late to finish their cases, resulting in much over-utilized OR time, which would reduce OR efficiency. The choice of one OR for 10 h provided the best matching of staffing to the service's OR workload.

In our experience, the preceding example provides what most facilities consider the objective of OR allocation—providing the right amount of OR time to get the existing cases done. Providing neither too much OR time nor too little results in maximizing OR efficiency (7,8). This is the essence of *operational* OR management decision making which must be differentiated from the longer-term *tactical* stage of OR allocation, wherein an increase or reduction in allocated OR time is expected to result in a change in OR workload (6). Planning copious under-utilized OR time in the hope surgeons will bring more business to a facility is a financial investment decision (6). This tutorial does not consider such longer-term capacity planning (6), just the shorter-term matching of staffing to the existing, current OR workload.

The preceding example also shows why good operational decisions cannot be made on the basis of OR utilization. Obviously, OR allocation would not be two ORs, because there would be many hours of under-utilized OR time. The choice is the same based either on OR efficiency or OR utilization. In contrast, the choice of allocating one OR for 8 h or one OR for 10 h is not clear based on OR utilization, because the resulting hours of over-utilized OR time are ignored. Adjusting staffing based on OR efficiency considers both the expected under-utilized and over-utilized OR time (7,8).

We recommend that readers who do not have experience in the science of OR management pause and ensure that they appreciate the definitions and importance of this concept of OR efficiency. In our opinion, these definitions, their rationale, and the insight of the preceding paragraph are one of the two fundamental concepts of this article. The other is described at the end of the following section.

Managerial Cost Accounting

Variable costs are costs that increase proportionate to the volume of patients receiving care.

For example, the number of endotracheal tubes and the amount of medications used is close to proportional to the number of patients who receive anesthesia care. Hence, disposable equipment and pharmacy costs are variable costs.

Labor cost equals the sum of two products: staffed hours multiplied by the cost per hour of staffed hours and hours worked late multiplied by the cost per hour of hours worked late. More complicated managerial accounting models generally are not needed for purposes of OR allocation and case scheduling. Labor cost can generally be estimated as the sum of the allocated OR time multiplied by the cost per hour of staffed hours and the hours of over-utilized OR time multiplied by the cost per hour of over-utilized OR time. The cost per hour of over-utilized OR time includes the indirect, intangible, retention, and recruitment cost sustained on a long term basis from staff working late.

For example, the combined cost for surgical and anesthetic nurses to staff an OR for an 8-h period for a year of elective surgery equaled approximately Australian $247,800 (approximately US$184,000) at the studied Australian hospital, excluding benefits.

For example, the cost per hour of over-utilized OR time was substantive for the salaried anesthesiologists at the Australian hospital, even though the cost of their salaries was not included in the preceding value. Ignoring the cost per hour of over-utilized OR time would be appropriate only if it would be irrelevant to an anesthesiologist whether she did an elective case at 2 PM Tuesday or 2 AM Tuesday. The fact that people do care at what time they work is evidence of there being an indirect, intangible, retention, and recruitment cost associated with over-utilized OR time.

From above, maximizing OR efficiency is the same as minimizing the sum of under-utilized hours and over-utilized hours multiplied by the relative cost of over-utilized to under-utilized OR hours (8). Thus, the costs of an hour of over-utilized OR time and of an hour of under-utilized OR time need not be known, just the relative costs (8).

For example, the relative cost of an hour of over-utilized OR time to an hour of under-utilized OR time that was used for the Australian hospital was 1.50. This value can be interpreted as a direct cost of overtime at "time and a half" when provided. This value can also represent the indirect/intangible cost of the unpredictable hours and of working late. Other relative cost values that are used commonly are 1.75 and 2.00.

Anesthesia group productivity equals anesthesia workload divided by labor costs.

For example, the anesthesia group at the Australian hospital also provides care at a small peripheral hospital. Staffing is planned for three ORs from 8 AM to 4 PM. There is virtually never any over-utilized OR time. Then, a small increase in OR workload (i.e., the cases performed) would result in an increase in OR and anesthesia group productivity.

Revenue is the money received from third parties to provide care for a specific patient.

The above definitions are of immediate value as they are sufficient to show that decision making on the day of surgery can neglect OR utilization (i.e., under-utilized OR time) (1,9). This result can be put to daily use by each anesthesia provider to reduce costs and increase his or her group's productivity (1). The reason is revealed in the remaining paragraphs of this section.

Many OR nurses are hourly employees who are paid for working for a minimum number of hours. Many anesthesia providers are salaried employees. For these individuals, on the day of surgery, the increment in labor cost from 1 h of under-utilized OR time is negligible relative to the cost from 1 h of over-utilized OR time. Finishing cases early, but still before the end of staffed hours, reduces labor costs negligibly versus the labor cost that would result from over-utilized OR time.

Few anesthesia groups that are paid on a fee-for-service basis can receive significant compensation on a day from an anesthesia provider's work unless the anesthesia provider is scheduled to care for patients on the day, whether scheduled to be in-house or on-call from home. Once the day of surgery is reached, the opportunity cost of an anesthesia provider's time is vanishingly small. If an anesthesia provider was scheduled to care for patients at one hospital, but no patients were assigned to the anesthesia provider, it is unlikely that the anesthesia provider could do work providing fee for service revenue other than by doing work that some other anesthesia provider in the group would have done anyway. Thus, for the anesthesia group, the incremental revenue lost on the day of surgery by having an hour of under-utilized OR time is negligible relative to the costs from working late unexpectedly (10,11).

Consequently, on the day of surgery, the cost per hour of under-utilized OR time is negligible relative to the cost per hour of over-utilized OR time (1,9). Thus, on the day of surgery, minimizing the inefficiency of use of OR time need not be thought of as minimizing the sum of [(cost per hour of under-utilized OR time) × (hours of under-utilized OR time)] and the [(cost per hour of over-utilized OR time) × (hours of over-utilized OR time)]. Only the latter product of the cost per hour of over-utilized OR time and the hours of over-utilized OR time is relevant.

The result is that, on the day of surgery, the inefficiency of use of OR time is minimized by minimizing the hours of over-utilized OR time (1,9). Case scheduling to maximize OR efficiency minimizes hours of over-utilized OR time (12), considered below. The following two examples illustrate the implications.

For example, an anesthesiologist is assigned to an OR staffed from 8 AM to 4 PM, but with one expected hour of over-utilized OR time. The anesthesiologist works quickly. She places every IV catheter and arterial cannula on the first attempt, and a thoracic epidural in min. Because of her rapid work, the cases are finished at 4 PM, preventing an hour of over-utilized OR time. The anesthesiologist increased OR efficiency (9). Adjusted OR utilization was unchanged.

For example, a different anesthesiologist is assigned to another OR, also staffed from 8 AM to 4 PM, but with 8 h of scheduled cases. The anesthesiologist works equally quickly, resulting in cases finishing at 3 PM instead of at 4 PM. Because over-utilized OR time was not reduced, the anesthesiologist did *not* increase OR efficiency (9). Adjusted OR utilization was reduced.

The fact that no facility would want anesthesia providers to slow down to increase OR utilization shows that OR utilization should not be used as a basis for decision making on the day of surgery. In contrast, OR efficiency can be used for operational decision making before and on (1) the day of surgery.

We recommend that readers for whom this material represents new information also pause at this point, as this is the other fundamental concept of this article. What matters on the day of surgery is reducing the hours worked late. OR utilization cannot be used as a basis for sound decision making. Finishing early is irrelevant to cost reduction. Cases should be scheduled to finish as early as possible (9). The time at which "working late" begins is defined by the OR allocation (e.g., 8, 10, or 13 h), a quantity calculated based on reducing under-utilized and over-utilized OR time.

The remainder of the tutorial is organized as follows. The next section describes how to allocate OR time and make case scheduling decisions based on OR efficiency. The issues are how to perform the OR allocation calculations, the usefulness of the calculations, the data for the calculations, the statistical details of the calculations, and how to schedule cases in a manner consistent with the calculations. The subsequent section considers the impact on OR efficiency of reducing surgical, anesthesia, and turnover times. Finally, the tutorial considers when and how the methods should be applied managerially.

ALLOCATING OR TIME AND SCHEDULING CASES BASED ON OR EFFICIENCY TO INCREASE PRODUCTIVITY

Allocating OR time (i.e., planning service-specific staffing) and scheduling cases based on OR efficiency can increase OR and anesthesia group productivity by reducing labor costs.

Performing Calculations

Because the day of the week is a strong predictor of a service's workload (8,13) (Table 1), OR allocations calculated based on OR efficiency are done by service and day of the week (Table 2). Calculating an OR allocation means determining how many ORs should be staffed daily for each service and, for each of these ORs, how many hours of staffing should be planned (e.g., 8, 10, or 16 h) (8,13). This process of trying all possible options to find the best one is called *complete enumeration*. The process can be constructed such that each series of cases performed by the same surgeon on the same day is performed in its original sequence (i.e., the only change made is to the time of the start of some of the surgeons' cases).

Increasing the staffed hours causes the efficiency of use of OR time to increase progressively to a maximum, after which it decreases (7). If all possible staffing solutions are considered, start with 0 h and progressively increase staffed hours until additional increases in the staffed hours causes the efficiency of use of OR time to decrease for that service (13).

For example, at the Australian hospital, the successive options used were 0, 8, 10, 16, and 18 h (Table 2). When 8, 10, and 13 h shifts were considered, the successive choices used were 0, 8, 10, 13, 16, 18, etc.

For example, for General Surgery on Tuesdays at the Australian hospital, an allocation of 0 h of OR time was considered. The inefficiency of use of OR time for General Surgery was calculated for each Tuesday. The sum of these inefficiencies was calculated. Next, the process was repeated using several alternative potential allocations: 8 h, 10 h, two ORs for 8 h, and one OR for 8 h and one OR for 10 h. The sum of the inefficiency of use of OR time on Tuesdays for General Surgery was least when the allocation was two ORs for 8 h (Table 2).

The decision can be made whether to use allocations of just 8 h, of 8 and 10 h, etc., based on labor costs. Optimal OR allocations are calculated for each service and day of the week combination using just 8 h staffing. The total labor cost is calculated for each 4-wk period based on those optimal OR allocations having been used. The process is repeated using OR allocations of 8 and 10 h, etc. The pair wise difference in labor cost between allocations for just 8 h, for 8 and 10 h, etc., is calculated for each 4-wk period of data (10,11,13,14). Student's *t*-distribution is used to calculate a confidence interval for these pair wise differences. The sample size is the number of studied 4-wk periods. The use of 4-wk periods serves to prevent variation in labor costs by day of the week from influencing results of the analysis.

For example, 3504 elective cases were performed at the Australian hospital from Monday October 18, 2004 through Friday July 1, 2005. Working backwards from the last day, there were $n = 9$ full 4-wk periods. The use of mixed 8 and 10 h staffing (Table 2) instead of 8 h staffing would be expected to result in an annual reduction in labor costs of Australian $22,800 (95% confidence interval (CI) $4800–$40,300). The use of 8 and 10 h staffing instead of 8, 10, and 13 h staffing would be expected to result in an annual reduction in costs of Australian $10,700 (CI $2000–$19,500). Based on these findings, Table 2 uses 8 and 10 h staffing.

For example, at the Australian hospital, staffing planned both for General Surgery and the open OTHER time on Tuesdays was two ORs for 8 h (Table 2). However, for both, planning one of the two ORs for 10 h instead of 8 h resulted in less than a 5% increase in the total inefficiency of use of OR time. The potential reduction in over-utilized OR time by allocating more OR time closely balanced the expected increase in under-utilized OR time. In contrast, for all other combinations of service and day of the week in Tables 1 and 2, a different OR allocation would have resulted in a larger than 5% increase in the expected inefficiency of use of OR time.

For example, Table 2 answers the Australian hospital manager's question: "How close are current OR allocations to those that would maximize OR efficiency?" The statement "OR time is allocated based on OR efficiency" is close to sufficient to describe precisely what happens in practice, because the choice of the relative cost of over-utilized to under-utilized OR time is invariably close to 1.50 and insensitive (15) to any differences in this multiplier.

In contrast, there is no one answer to the question: "How close are current OR allocations to those that are optimal based on OR utilization?" because then there is a subsequent question of how to determine the optimal OR utilization. The best OR utilization varies among services because it is sensitive to many parameters such as the staffed hours, turnover times, day to day variability in OR workload, statistical distribution of the OR times of cases, and so forth (16). Years of data can be required to estimate these parameter values with sufficient accuracy that they can be used to decide on the OR utilization for use as the service's goal (17). Allocating OR time based on OR efficiency simultaneously takes into account all of these issues.

Calculated OR Allocations Differ from Those in Current Practice

Anesthesia providers' and OR nurses' labor costs are sensitive to OR allocations (i.e., service-specific staffing) and case scheduling. Among US facilities studied and which permitted publication, 10 of 11 allocating OR time based on OR efficiency achieved significantly lower labor costs than the plans that were being used by the local managers (13,14). For nine of these 11 facilities, the statistical method approach resulted in plans that reduced labor costs by at least 10% (13,14). The same was true of a studied German hospital (18).

For example, the original staffing for elective cases at the Australian hospital was five ORs for 10 h and two ORs for 8 h Mon-Thu, and on Fridays three ORs for 10 h and two ORs for 8 h. Differences in labor costs were calculated as described in the preceding section. The estimated reduction in labor costs was 26% (CI 25%–28%) or Australian $594,100. This would be achieved by reducing allocated hours by 25%, while increasing expected over-utilized OR time by <1%. The expected increase in productivity would be from 55% to 74%. By definition, the percentage increase in OR efficiency would be even more.

For example, OR nurses and anesthesia providers at a hospital report that every OR finishes at least an hour or two late everyday. Most likely, staff scheduling and staffing are being confused, as such staffing would be irrational. Suppose that the relative cost of over-utilized to under-utilized OR time were 2.0. Then, it would be twice as expensive to finish late versus early. The ratio of 2:1 is the same as two chances of three. With appropriate service-specific staffing, the odds for each service and OR to finish early should be approximately two chances in three. The odds of finishing late should be approximately one chance in three. If an average of more than 1/3 of ORs are finishing late, OR allocations are not being planned appropriately. Adjusting OR nurses' and anesthesia providers' staffing every 2–3 mo would not affect OR capacity, just reduce labor costs and unpredictable work hours.

For example, a hospital has three of its ORs scheduled as unblocked, open, first-come first-served, OTHER time. The hospital staffs in 8, 10, and 13 h shifts. Then, those three ORs could be allocated as 8/8/8, 8/8/10, 8/10/10, 10/10/10, 8/8/13, 8/13/13/, 13/13/13, 8/10/13, 10/10/13, and 10/13/13. Intuition will not help with this complex scenario.

The number of ORs in a facility does not predict percentage reductions in labor costs (13,14,18). Facilities at which many hours of OR time are allocated to services do not have the largest percentage improvements from applying the operations research to OR management. The principal challenge faced by managers may not be the number of ORs to be allocated to services but, instead, the variability in OR workload from week to week.

The number of ORs allocated to each service does seem to be related to the value of performing a full statistical analysis multiple times. Performing the analysis just once or twice seems sufficient to educate managers in how to interpret existing internal OR workload reports in the appropriate stochastic context.

For example, on Mondays at the Australian hospital, average OR workloads for elective cases include 6 h for Cardiac Surgery and 8.5 h for Neurosurgery. Once the principles of OR efficiency and the higher relative cost of an hour of over-utilized OR time to an hour of under-utilized OR time are understood by managers, sophisticated analysis is unlikely to be needed to make good staffing decisions for these services in the future. The analysis would get the correct answer, but so would the managers (i.e., the analysis would be *valid*, but may not be *useful*).

The preceding example is common for at least some ORs at US community hospitals. Eleven community anesthesiology groups had an average of 6.0 h of anesthesia time per OR per day (19). Nine community hospitals in the Midwestern US averaged 5.6 h of scheduled cases per day in ORs with at least one knee or hip replacement case (20). For such facilities, statistical methods may not be needed to adjust staffing. However, performing the statistical analysis once may be useful to educate stakeholders as to the incremental labor costs sustained by the group or department and which cannot be reduced unless the numbers of ORs were reduced (14).

Source and Amount of Data Required for Effective Calculations

Data for analysis can come from an OR information system, from an electronic anesthesia patient record information system (21,22), or from anesthesia billing data (23).

The remainder of this section and the following two sections will be useful for individuals performing the analyses, not readers interested in judging whether the methods will be useful for their anesthesia group and/or ORs.

To assess how much data are required to produce acceptable results, a long series of data from a hospital was divided into training and testing datasets, with different training periods (24). The statistical methods of the preceding section were applied to the training data. The expected labor costs that would have occurred during the subsequent testing period were then calculated. Each increase in the number of months of data up to 9 mo resulted in a statistically significant reduction in expected labor costs. There were large incremental benefits in using at least 7 mo of data.

For example, at the Australian hospital, 8.4 mo of OR information system data were used (Table 1). All data fields were available that were needed for the analysis.

Facilities with information systems that do not check each field at the time of data entry often have data sets that contain errors or omissions, including incorrect ORs in which some cases were performed (25). This manifests as the false appearance of two cases overlapping in the same OR at the same time. A fix is to change the recorded OR of each case that overlaps to a unique unknown OR (25).

For example, one case is listed as being performed in OR #9 from 10 AM to 11 AM, and another in OR #9 from 10:30 AM to 12 noon. Among all cases in the data set, the latter case is the 49th for which the true OR is unknown. The OR location of the second case can be considered to be "Unknown 49."

Creating unique unknown ORs affects calculated turnover times, and thus may affect OR allocations. Nonetheless, analysis demonstrated that the impact of this adjustment on the labor costs that result from poor OR allocations is of negligible importance, for three reasons (25,26). First, OR allocations are based on each service's total hours of cases, a large number, plus total hours of turnover times, a smaller number. Second, for cases that have a preceding and a following case in the same OR, creation of a unique unknown OR results in the loss of two turnover times. Yet, the turnover time, between the two cases surrounding the reassigned case, is increased to the default maximum turnover time (25). Third, the effect of allocating OR time only in fixed increments (15) (e.g., 8 or 16 h) is of larger importance.

Assessing Trends, Seasonal Variation, and Data Errors

This section is written for individuals who will be performing the analyses. Readers not interested in statistical details can skip it.

The statistical methods described earlier assume that there are no systematic differences among weeks in the expected OR workload (13). National survey data show that these assumptions will hold for most facilities (27). Raw data were reanalyzed from the 1994 to 1996 National Survey of Ambulatory Surgery.

A positive control was used to ensure that seasonal variation could be detected if present. The average number of myringotomy tubes inserted each day in US ambulatory surgery centers was examined. As expected, myringotomy tube insertions peaked each winter, corresponding to the peak incidence of middle ear infections. The average number of tubes inserted each day varied systematically among months for all 26 of the overlapping 11-mo periods in the 36 mo of the survey.

In contrast, the average number of ambulatory surgery cases performed with an anesthesia provider each day in the US per 10,000 population was found not to vary systematically month-to-month on an 11-mo basis. The implication is that, for most facilities, the assumption can reasonably be made that there are no trends or seasonal variation. Nevertheless, we recommend strongly that this important assumption be tested for each facility. Violation of this assumption occurs when data are unknowingly incomplete.

For example, the runs test was applied to the Australian hospital's total labor cost over each consecutive 4-wk period (13,28). The total labor cost was calculated for each 4-wk period (10,11). The median was subtracted from each value. Zero differences were deleted. A "+" was assigned to positive differences and a "−" was assigned to negative differences. The number of runs of +'s and −'s was not significant ($P > 0.05$) when compared with the critical value from statistical tables for the runs test (28).

In addition to using the runs test, each service's OR workload is plotted for the days of the week when the service is allocated OR time. The graphs are helpful to detect unrecognized errors in the data.

For example, the Australian hospital's OR workloads were plotted for each service against time to ensure that each service did not lack cases for a portion of the data period. This usually occurs when the data sent for analysis include one or more surgeons who recently left the facility. However, in this circumstance what was identified was an extended holiday period. Although national holidays had been excluded, between the Christmas holiday (Monday, December 27th) and Friday January 7th there were fewer cases than on any other day in the dataset. Therefore, this 2-wk period was excluded from all results reported in this tutorial. Its inclusion would have provided unrepresentative results.

Services with Low OR Workloads

OR allocation for operational decision making represents service-specific staffing. Therefore, if the minimum staffed workday is 8 h, the minimum duration of an OR allocation is 8 h. A facility's rule for the minimum OR workload, or equivalently adjusted utilization, to receive an OR allocation needs to be applied to the minimum staffed workday. Short increments such as half day blocks are constructs for longer term tactical decision making, as described below.

For example, at the Australian hospital, a surgeon had his own allocated OR time on Mondays. He averaged 4.3 h of cases (Table 1). An adjusted utilization of at least 60% was used for OR allocation. Thus, an 8 h OR was not planned for the surgeon (Table 2).

Each service not receiving an OR allocation on a given day can be combined into an OTHER service (i.e., open, unblocked, first-scheduled, first-served time) (Tables 1 and 2). Alternatively, and usually equivalently, services are pooled to form pseudo-services representing how an OR is filled for the workday.

For example, at the Australian hospital, the surgeon who was allocated his own time had an average OR workload of 4.3 h each Monday. Oral Surgery's OR workload was 3.9 h. Suppose that, each Monday, Oral Surgery was working in the morning and the Surgeon in the afternoon. Then, a pseudo-service of Oral Surgery-Surgeon would have been created for purposes of the service-specific staffing. This was not done because in practice the surgeon was being allocated an OR for most of the day, and simply not using the time (Table 2). Allocation of OR time and scheduling of cases into OTHER OR time would hopefully motivate such a change. Regardless, eliminating the OR allocation to the surgeon is predicated on all of the surgeon's cases being performed on their original dates, and likely in their original sequence. The difference is that a start time is not being reserved months in advance for the first of each of the surgeon's list of cases.

Importantly, for the reader interested in performing the analyses, we recommend strongly not simply to measure the average OR workload of a service, observing that it is too low for an allocation of an 8 h OR for the day, and then automatically pooling it into OTHER service time. Apply the graphical methods of the preceding section to ensure that the reason for a low OR workload reflects an actual low workload, not a service that operates every other week on the studied day of the week. Likewise, ensure that incomplete data or a trend in OR workload is not being observed.

Case Scheduling to Maximize OR Efficiency

Allocating OR time to increase OR efficiency is of little value unless cases are also scheduled into the OR time appropriately.

A series of thought experiments and computer simulations were performed to evaluate case scheduling based on maximizing OR efficiency (9). The performances of different case scheduling heuristics were compared. The analyses showed that managers can achieve efficient OR scheduling, while leaving case scheduling decisions to the convenience of the surgeons and patients, provided three simple scheduling rules are followed. In other words, there were small differences in resulting OR efficiency among several different scheduling heuristics, with these three exceptions.

The first of three scheduling rules is that a service should not schedule a case into another service's OR time if the case can be completed within its own allocated OR time (9).

For example, staffing planned for the gynecologists on Monday is an OR for 10 h (Table 2). One of the gynecologists has scheduled 6 h of cases into the OR time, leaving 4 h of allocated, but unscheduled OR time. Just a 2 h case has been scheduled into the otoloaryngologists' OR time. Ten days before the day of surgery, another gynecologist wants to schedule a new 2 h case. The available start time would be after her partner who has already scheduled cases. The case would not be scheduled into the otolaryngologists' OR time, even if the second gynecologist wants to start earlier. The reason is that the gynecologists have available OR time for the case.

The reason for the above result is that OR allocations are calculated on the basis of expected OR workload on the day of surgery. Services fill their allocated OR time at different rates (29). The fact that the otolaryngologists have not yet filled their allocated time does not mean that they will not.

Almost all facilities with allocated OR time follow the preceding scheduling rule. Thus, the importance of the science was not the improvement in case scheduling. Rather, the importance was revealing that, in practice, decisions are being made based on maximizing OR efficiency (9). In the brief history of the science in this tutorial, that insight proved enlightening.

The second of the three scheduling rules is that a service should not schedule a case into over-utilized OR time if the service can perform the case in another of its ORs without causing over-utilized OR time (12). This applies to services allocated two or more ORs. If the OR workload was 27 h, then the earlier mathematics for allocating OR time would expect the hours of over-utilized OR time to be slightly (≅2 h) less if two OR were allocated for 13 h (total 26 h) vs three OR for 8 h (total 24 h). Simulations show that this is generally true provided that cases are packed into the allocated OR time to reduce hours of over-utilized OR time (9,30).

For example, the OTHER pseudo-service was allocated two ORs on Mondays from 8 AM to 4 PM (Table 2). Orthopedic and Oral Surgery scheduled into the OTHER time (Table 2). An orthopedic surgeon (Table 1) has scheduled cases in OR #1 to finish around 2:30 PM. OR #2 is empty. An oral surgeon (Table 1) wants an afternoon start. He asks to start an elective 3 h case at 3 PM in OR #1. Even though OR workload would be the same, scheduling the case into OR #1 would be expected to result in 2 h of over-utilized OR time, and thereby reduce OR efficiency. So, his request should be rejected. The surgeon should either take his service's first-case-of-the-day start in OR #2, or choose a different workday.

The preceding example matches with what is done at most facilities. Cases generally are not scheduled in over-utilized OR time when a service has another allocated OR that is empty. Likewise, on the day of surgery, a nonelective case is not performed in over-utilized OR time if it can wait safely to be performed in what would otherwise be under-utilized OR time (1). Just as for the first rule above, the science revealed that scheduling cases based on maximizing OR efficiency accurately represents what is commonly done in practice (9). Changes resulting from decision making on the basis of OR efficiency are generally not in case scheduling. Rather, they are in OR allocations (as above) and in the third rule regarding how OR time is released.

The third scheduling rule is that a service should not schedule a case into over-utilized OR time if the case can instead be scheduled into another service's OR time (9,29).

For example, 5 days from now, on next Wednesday, General Surgery has filled its 10 hr of allocated OR time (Table 2), but has another 1.5 h case to be scheduled. If the OR time of another service were not released, the case would be performed in over-utilized OR time. OR efficiency is greater by performing that case in OR time allocated to another service that otherwise would be OR time that is under-utilized on the day of surgery.

For example, suppose that on Fridays, an ophthalmologist (Table 1) was subverting the case scheduling system for the OTHER first-scheduled, first-served OR time (Table 2). The surgeon sometimes holds the desirable 8 AM start time by contacting the booking clerk weeks ahead of time, and providing the medical record number of a patient whom the surgeon knows is unlikely to have surgery. At a Surgical Services Committee meeting, a manager suggests that there be a policy that, when a case is cancelled, first access to cancelled OR time goes to other surgeons with waiting cases, not the surgeon canceling the case. That recommendation is not sound. There should not be other surgeons with cases waiting because a start time was not offered, when a safe option could have been provided. If a service had filled its allocated OR time and had another case to schedule, OR efficiency would have been enhanced by releasing the OR time of the service expected to have the most under-utilized OR time.

To evaluate which service should have its OR time released, simulations were performed scheduling new hypothetical cases into actual OR schedules (29). Services fill their allocated OR time at different rates. Thus, theoretically, the service that should have its OR time released for a new case should be the service that is predicted, at the time when the new case is booked, to be the service that will have the most under-utilized OR time on the scheduled day of surgery. Yet, performance was only slightly better versus scheduling the case into the OR time of the service with the largest difference between allocated and scheduled OR time at the time when the new case is scheduled (29). The latter is far easier to implement practically.

In contrast, releasing the OR time of the service with the second most allocated but unscheduled OR time, instead of the service with the most allocated but unscheduled OR time, has a large negative effect on OR efficiency (29). The reason is that, usually, a particular case can only be scheduled safely into a few services' OR time without resulting in over-utilized OR time. The differences among those few services in their amount of expected open OR time is often large. This occurs because day-to-day variability in the OR workload of services on a day of the week generally exceeds variability due to the timing of how quickly different services fill their allocated OR time.

The process of releasing allocated OR time is predicated on cases being scheduled sequentially into allocated OR time. Otherwise, the expected OR workload is not a predictor for the expected hours of over-utilized OR time. OR managers at facilities generally know whether cases are scheduled sequentially. When they answer "sometimes," its importance can be evaluated by studying the incidence of prolonged turnovers (5). The reason is that unfilled holes in the OR schedule manifest as prolonged turnovers (see the definitions discussed earlier).

For example, Table 3 shows the incidence of prolonged turnovers by time of day at the Australian hospital. Cases were scheduled sequentially under almost all circumstances as evidenced by the low (5) incidence of prolonged turnovers.

The timing of when allocated OR time should be released has also been studied (31). When a new case is being scheduled, potentially the scheduling office could wait to release the allocated OR time until closer to the day of surgery. Then, data may be available on subsequently scheduled cases, thereby improving the quality of the decision.

There were two conditions, for postponing the decision of which service has its OR time released for the new case until the day before surgery, which had a negligible effect on resulting OR efficiency versus releasing the allocated OR time when the new case was scheduled (31). One condition was ambulatory surgery centers with brief cases. At such facilities, when the decision is made, typically there is one service that clearly should be the one to have its OR time released and no good alternatives (29). Thus, there is no reason to wait in making the decision. The other condition was large facilities in which cases are scheduled as if there are many smaller facilities.

For example, at a 25 OR facility, one nursing and anesthesia team may staff the five ORs used for cardiac, thoracic, and vascular surgery services. From the perspective of safely releasing OR time for a new case, there are only five ORs that are available, and not all 25 ORs.

For example, a hospital contains a team cross-trained in Neurosurgery and Otolaryngology. One week later, on next Monday, Neurosurgery has been allocated one 8 h OR. Otolaryngology has been allocated one 8 h OR also. The otolaryngologists have scheduled 9 h of cases into their OR. A third otolaryngologist wants to schedule another 2 h case. The neurosurgeons have scheduled just one case into their OR, from 7 AM to 10 AM. Provided the otolaryngologist is available at 10:30 AM, then the neurosurgeons' OR time would be released. There is no advantage in waiting to schedule the case. Later, if the neurosurgeon with the 7 AM to 10 AM case was to schedule another case, ideally the otolaryngologist could be persuaded to start his case later in the day.

Despite this consideration of how best to release allocated OR time, it is important to appreciate that results are highly sensitive to the OR time being allocated appropriately based on OR efficiency. Issues of when to release allocated OR time pale in practical importance versus OR allocation and staffing. This section of the tutorial has considered OR management problems that are observed on the day of surgery. However, their root cause and often the only practical way to fix the problem is to plan OR allocations and staffing properly several weeks or months before the day of surgery (32).

For example, if, at the Australian hospital, General Surgery was not allocated two ORs for 8 h on Tuesdays (Table 2), but just one OR for 10 h, then the thoracic surgeons would likely complain often that their allocated OR time on Tuesdays is being released. Each time, General Surgery would be filling its own allocated OR time and then booking its extra case(s) into the thoracic surgeons' OR time. The thoracic surgeons may word their displeasure personally, that schedulers are treating them unfairly by repeatedly releasing their allocated OR time. Although they schedule many of their cases a couple of days before the day of surgery, their OR workload is consistently at least 6 h each Tuesday (Table 1). The thoracic surgeons' concerns would be well founded. This should not be happening. However, the problem would not be the schedulers, who are making the proper decision to maximize OR efficiency. The problem is that the General Surgery's allocation is too small for the cases that they are performing.

Table 4. Lower 95% Confidence Bounds for Underestimation of Operating Room (OR) Time (min) Reported Per 8 h of Used OR Time

NRS	−1	Neurosurgery
DEN	−1	Oral surgery
CDS	−1	Cardiac surgery
GES	−2	General surgery (with vascular)
CTS	−2	Thoracic surgery
VAS	−2	Vascular
GYN	−2	Gynecology
GONC	−3	Gynecology oncology
ENT	−3	Ear, nose and throat
PDS	−4	Pediatric surgery
POR	−5	Orthopedics

Methodology is described in the section "Underestimation of OR Times." The services listed had at least five 4-wk periods with at least 10 cases and at least 8 h of used OR time.

Underestimation of OR Times

The earlier analyses of case scheduling were all performed with OR times scheduled without systematic bias, be it consistent overestimation or the more common underestimation of OR times to get cases added to the OR schedule (9,29,31). Monitoring of bias in scheduled OR times can identify those services for which the OR manager should consider having case durations chosen by analysis of historical data (33,34). In the absence of bias, improving OR time prediction is unlikely to be able to result in reductions in labor costs or increases in productivity (34).

The remainder of the section is details for individuals who will be performing the analyses.

For each 4-wk period, a ratio is computed for each service. The numerator for each service equals the sum over all cases of the differences in minutes between actual OR times and scheduled OR times. The denominator equals the sum in hours of the actual OR times of all of the service's cases. The ratio is multiplied by 8 h to yield the number of minutes of under-estimated OR time per 8 h of OR time during the 4-wk period. The ratios consistently follow normal distributions for each service (33). Using Student's *t*-distribution, 95% lower confidence bounds are calculated for the average underestimate of OR time, expressed per 8 h of used OR time.

For example, Table 4 shows analysis of underestimation of OR times at the Australian hospital. The booking clerk is responsible for the estimation of OR times based in part on the estimate provided to her by the surgeons. There was no significant consistent underestimation by the booking clerk. This example highlights that over-utilized OR time (Table 2) is rarely caused by underestimation of OR times (Table 4), but instead inadequate staffing is planned for the existing OR workload. Anesthesiologists

Table 5. Reduction in Operating Room (OR) Time (min) Per 8 h of Staffed OR Time When Maximum Turnover Time Reduced from 90 to 25 min

Service	Mon	Tue	Wed	Thu	Fri	
CDS	4	5	3	0		Cardiac surgery
CTS		10				Thoracic surgery
ENT	9			10		Ear, nose, and throat
GES	3	7	***17***	8	6	General surgery (with vascular)
GONC			***49***			Gynecology oncology
GYN	***49***				2	Gynecology
NRS	7		6	6		Neurosurgery
OTHER	7	12	***20***	9	12	Staffed OR time not allocated to a specific service
Grand total	13	9	20	6	7	

Days' full-names are given in Table 1.

Table 6. Explanations of Results of Table 5, Showing Service-Specific Impact on Labor Costs of Reductions in Turnover Times

Day	Service	OR allocation (h)	Under-utilized OR time (h) (mean ± SE)	Over-utilized OR time (h) (mean ± SE)	Turnovers per day (mean ± SE)	Turnover time (min) (mean ± SE)	Prolonged turnovers (%)
Mon	CDS	8	2.4 ± 0.5	0.4 ± 0.1	2.0 ± 0.2	18 ± 3	6
	ENT	8	2.4 ± 0.5	0.9 ± 0.4	4.7 ± 0.6	18 ± 1	10
	GES	10	1.8 ± 0.5	0.3 ± 0.2	4.1 ± 0.3	17 ± 1	8
	GYN	10	2.1 ± 0.5	0.1 ± 0.0	4.9 ± 0.3	18 ± 1	10
	NRS	10	1.8 ± 0.5	0.4 ± 0.2	4.0 ± 0.2	19 ± 1	7
Tue	CDS	8	1.3 ± 0.4	0.9 ± 0.2	1.9 ± 0.1	24 ± 1	11
	CTS	8	2.3 ± 0.5	0.6 ± 0.1	3.4 ± 0.2	20 ± 2	12
	GES	2 × 8	3.5 ± 0.7	1.5 ± 0.4	6.6 ± 0.5	21 ± 1	10
Wed	CDS	8	2.0 ± 0.5	0.7 ± 0.2	2.4 ± 0.2	19 ± 1	4
	GES	10	1.4 ± 0.4	2.8 ± 0.7	4.5 ± 0.5	19 ± 1	12
	GONC	10	1.7 ± 0.3	0.2 ± 0.1	3.9 ± 0.2	25 ± 1	18
	NRS	10	2.1 ± 0.5	0.5 ± 0.1	2.8 ± 0.2	23 ± 3	11
Thu	CDS	10	1.9 ± 0.4	0.6 ± 0.2	1.8 ± 0.1	24 ± 1	3
	ENT	10	3.6 ± 0.6	1.1 ± 0.3	5.9 ± 0.6	20 ± 1	7
	GES	8	2.2 ± 0.5	0.9 ± 0.3	2.8 ± 0.3	25 ± 2	17
	NRS	10	2.8 ± 0.6	0.8 ± 0.2	2.9 ± 0.2	18 ± 3	12
Fri	GES	8	3.5 ± 0.5	0.7 ± 0.3	3.4 ± 0.2	20 ± 1	5
	GYN	10	1.3 ± 0.3	0.3 ± 0.2	7.6 ± 0.4	15 ± 1	5

OR represents operating room. SE represents standard error. Services' and Days' full names are given in Table 1. OR workloads are given in Table 1. OR allocations are as in Table 2. Hours of under-utilized OR time and over-utilized OR time are calculated after applying the listed Allocations. Turnover time attributes each turnover to the Service of the finishing case. Because historically OR allocation and case scheduling did not result in cases of the same service necessarily following each other, this issue of how turnovers were attributed is arbitrary and may affect this value but not the values in Table 5. The same limitation applies to the Prolonged Turnovers. SE are not given for the prolonged turnovers since we are not aware of a validated method to calculate such SEs, unlike for the results of Table 3.

generally work late because of extra cases, not because of an underestimation of the time to complete each case, as rarely does the underestimation change whether and when the case is performed (1,9,34).

IMPACT OF REDUCING TIMES ON PRODUCTIVITY

Impact of Reducing Surgical and Turnover Times

The impact of interventions on labor costs can be forecast using each facility's own data (10). Turnover times can be reduced between each case (10). Surgical times can be reduced to national average values for each procedure (11) (e.g., to calculate the impact of longer OR times at academic hospitals because of factors such as teaching time and development of skills in trainees) (35,36).

For both interventions, first the labor cost is calculated assuming that OR time is allocated and cases are scheduled based on OR efficiency. Second, the intervention is performed, thereby reducing OR workload by service. Third, using the revised workload values, OR time is reallocated based on OR efficiency, and the new estimates for labor costs projected. Fourth, the differences are calculated. Confidence intervals can be calculated for the differences by pooling differences within 4-wk periods (10,11,13).

For example, when calculating OR allocations for the Australian hospital, prolonged turnovers needed to be included, as the staff were present during the interval. Hopefully, the few prolonged turnovers due to case scheduling would not be present in the future. The compromise used was to set turnovers longer than 90 min equal to 90 min (10). Then, the average turnover time at the Australian hospital was 22 min, 2 min longer than when turnovers longer than 90 min were excluded. The 22 min value was very brief, matching that reported by facilities using dedicated induction rooms and corresponding staffing (37). Therefore, we considered a small (5 min) overall reduction in the average turnover time. That was achieved by reducing the maximum turnover time to 25 min. The resulting impact on labor costs, for each service, is shown in Table 5, expressed in units of time.

The impact of reducing turnover time on labor costs varied more than 1000% among services (Table 5) because of the combined effects of four important factors (Table 6). First, reductions in labor costs expressed in minutes exceed total reductions in turnover time because 1 min of over-utilized OR time is more expensive than 1 min of staffed OR time. Second, baseline hours of under-utilized and over-utilized OR time vary among services. Third, each service's average turnover times vary among days of the week, because different procedures are performed. Fourth, numbers of turnovers per OR per day vary among services. Often the impact of reducing turnover times is relatively small, because there are few turnovers per OR per day (10,38).

For example, Cardiac Surgery on Mondays at the Australian Hospital reveals the importance of the first and second factors. The OR workload averaged 6.0 h (Table 1). With an OR allocation of 8 h, there would have been only 0.4 h of over-utilized OR time (Table 6). Staffing is in increments of at least 8 h. Therefore, the only way for reducing turnover time to reduce labor costs is by reducing the rare and small over-utilized OR time. The potential reduction in staffing is only 4 min per workday (Table 5). The average reduction in over-utilized OR time is even less, 1.5-fold less, to be precise, as 1.5 was the value used for the ratio of the cost of 1 min of over-utilized OR time to 1 min of regularly staffed OR time.

For example, Gynecology on Mondays reveals the importance of the second and fourth factors. Gynecology would receive a 10 h allocation, as that maximizes the efficiency of use of OR time (Table 2). However, the service would then have an average of 2.1 h of under-utilized OR time (Table 6). Thus, even a small reduction in the daily average OR workload would be sufficient for their OR allocation to be reduced to 8 h. They have many turnovers per day. Thus, the large potential benefit of reducing turnover times on labor costs and anesthesia productivity (Table 5) is unrelated to their average turnover time, which is only 18 min (Table 6).

For example, Gynecology Oncology on Wednesdays has many turnovers, of which many (18%) are prolonged (Table 6). The service also has a 10 h allocation (Table 2), which can be reduced to 8 h. Thus, reducing their turnover times would be financially beneficial (Table 5).

Overall, because the Australian hospital had so many services with OR workloads between 8 and 10 h, the expected overall impact of achievable reductions in turnover times on labor costs (2.6%) was larger than the 0.8%–1.8% reported for four US hospitals (10).

The important issue we re-emphasize is that the reduction in labor costs from reducing the turnover times can only be achieved provided the OR allocations (i.e., staffing) will be reduced. The findings are equivalent when reductions in surgical times are considered (11).

Impact of Reducing Delays in First-Case-of-the-Day Starts

First-case-of-the-day starts can be considered by the same methodology, except that they are added back into the data. First, the labor cost is calculated assuming that OR time is allocated and cases are scheduled based on OR efficiency. Second, the intervention is performed, thereby increasing OR workload by the service. In this circumstance, the intervention is the addition of a pseudo-case from the start of the workday until the time at which the first case enters its OR. Third, using the revised values for OR workload, the OR time is reallocated based on OR efficiency, and the new estimates for labor costs projected. Fourth, the differences are calculated. As aforementioned, confidence intervals are calculated for the differences by pooling differences within 4-wk periods (10,11,13).

For example, the first column of numbers in Table 7 shows that the Australian hospital has 46% of its first cases of the day starting at least 15 min late, a large incidence. The last column shows that the impact of these delayed first cases of the day on labor costs is the same as adding 16 min of staffing to each 8 h workday. The effect of a late first-case-of-the-day start can be thought of as an increase in turnover times, with the increase each day being the time for the first case of the day to start divided by the number of turnovers in the same OR on the same day. Specifically, including the late first-case-of-the-day starts was effectively the same as lengthening the turnover times by an average of 5.6 min.

TACTICAL VERSUS OPERATIONAL DECISIONS

This tutorial has considered operational service-specific staffing decisions made months before the day of elective surgery and the resulting impact on case scheduling. Decision making on the day before and the day of surgery was reviewed earlier (1). Reallocating OR time tactically (e.g., once per year) was not considered in this article (6,39). The reason is discussed in this final section.

Although, at the studied Australian hospital, misrepresentation of estimated OR times of cases was not affecting OR efficiency (Table 4), at other facilities it can (33).

For example, staffing is planned from 8 AM to 4 PM. Cases cannot be scheduled unless they will finish by 4

Table 7. Impact on Labor Costs of Adding Existing Delays in Starting First Cases of the Day

Day	Service	First cases starting >15 min late (%)	Tardiness of first case starts per turnover (min)	Increase in overutilized OR time (min)	Increase in OR time per 8 h of staffed time (min)
Mon	CDS	13 ± 4	6.3 ± 3.3	2 ± 2	3 ± 3
	ENT	53 ± 6	4.0 ± 1.1	6 ± 2	11 ± 3
	GES	39 ± 5	4.5 ± 0.8	4 ± 1	4 ± 2
	GYN	21 ± 4	2.2 ± 0.4	3 ± 1	3 ± 1
	NRS	48 ± 5	4.4 ± 0.9	6 ± 2	8 ± 2
Tue	CDS	7 ± 3	2.0 ± 0.9	1 ± 0	1 ± 1
	CTS	32 ± 5	4.1 ± 0.8	7 ± 2	9 ± 2
	GES	44 ± 4	7.3 ± 1.0	13 ± 4	11 ± 3
Wed	CDS	9 ± 4	1.9 ± 1.2	3 ± 2	3 ± 2
	GES	28 ± 4	5.1 ± 1.2	8 ± 2	11 ± 3
	GONC	23 ± 4	2.7 ± 0.6	3 ± 1	3 ± 2
	NRS	44 ± 5	6.0 ± 0.8	7 ± 2	8 ± 3
Thu	CDS	4 ± 2	0.7 ± 0.6	0 ± 0	0 ± 0
	ENT	78 ± 4	8.7 ± 1.2	17 ± 4	17 ± 4
	GES	81 ± 5	14.3 ± 2.3	12 ± 3	16 ± 4
	NRS	24 ± 5	3.6 ± 0.9	2 ± 1	2 ± 1
Fri	GES	41 ± 5	8.1 ± 2.2	6 ± 3	8 ± 4
	GYN	33 ± 5	2.1 ± 0.3	5 ± 1	5 ± 2
Grand total		46 ± 1	5.6 ± 0.3	0 ± 1	16 ± 2

Services' and Days' full-names are given in Table 1. Of the 3504 elective cases, there were 733 first cases of the day. Cases are considered to have started when the patient entered his or her OR (operating room). SES for the percentage of first cases of the day starting >15 min late were calculated from Clopper–Pearson confidence intervals. "Tardiness first case start per turnover (min)" equals a ratio calculated independently for each OR on each day. The numerator is the minutes that the first case of the day in the OR started late, and 0 min if early. The denominator is the number of turnovers in the OR. The confidence intervals are calculated using Student's *t*-distribution. The Grand Total and overall percentage increase in labor costs was 3.0% (95% confidence interval 2.8%–3.3%). The overall percentage includes the OTHER first-come first-served pseudo-service (Table 2). The Grand Total does not include an overall increase in over-utilized OR time because of increased OR allocations for the OTHER service (not shown).

PM. The cardiac surgeon operating on Thursdays always underestimates the OR times for his cases. He never finishes before 4 PM, and often ends between 6 and 7 PM. The anesthesia providers and OR nurses have complained repeatedly about working late almost every Thursday. Administrators setup a committee that discussed the surgeon's lack of respect for rules and hospital resources. Nevertheless, nothing changed.

The surgeon's behavior may be overall good or bad practice depending on whether the perspective taken is that of society, the hospital, the surgeon, the patient, the anesthesiologists, etc. However, this tactical issue has little relevance to anesthesia productivity. The operational decision is clear: change staffing to match the reality of the existing workload (Table 2). Doing so neither increases nor reduces OR capacity or convenience for the surgeon and his patients. What it does is reduce labor costs and increase anesthesia productivity by reducing the hours worked late in lieu of staffed hours.

For example, an anesthesiologist's job description says that work hours are from 8 AM to 4 PM. Yet, every Friday for years, she has finished working around 7:30 PM, because of many add-on cases. Staffing should be planned to 7:30 PM, because that is the reality of the existing OR workload. Regardless of tactical (1–2 yr) decisions that may be implemented to change the situation, the anesthesiologist should plan next week to work to 7:30 PM (23). This is an operational decision.

In the two preceding examples, the surgeon and patient are choosing the day of surgery. Cases are not being turned away, provided they can be done safely, even if they will likely be performed in over-utilized OR time (40). There is open access to the day of surgery. Subject to that priority, OR time can be allocated and cases can be scheduled based on maximizing OR efficiency, as above. To describe operational (not tactical) reality, mathematics need to be based on the surgeon and patient having open access to OR time on the workday of their choosing.

For example, at the Australian Hospital, on Mondays Cardiac Surgery had an average OR workload of 6.0 h (Table 1). With an OR allocation of 8 h, its adjusted utilization averaged 70%. There would be an average of only 0.4 h of over-utilized OR time (Table 6). For Cardiac Surgery on Mondays, allocating OR time based on OR efficiency gives precisely the same result as allocating OR time based on adjusted utilization. It is valid to consider the surgeons to have open access to OR time on the workday of their choosing, and that they have chosen to perform elective cases only when they can be completed within allocated hours.

The preceding examples demonstrate that service-specific staffing can be validly considered for any facility when decisions are made based on OR efficiency and on surgeon and patient open access to OR time on any future workday. The next scenario shows that the assumption of fixed hours is invalid for most facilities (7,8).

For example, an ambulatory surgical center has a policy that OR time is allocated based on OR utilization. Staffing is planned from 8 AM to 3:30 PM. This is enforced strictly. A surgeon asks to book a case to start at 1:30 PM, with an expected (realistic) OR time for the case of 2.5 h. He is told that this would not be acceptable, because the case will likely end at 4 PM.

The preceding scenario will seem unreal to most clinicians and that is the point. Scheduling cases only if they can reasonably be expected to finish by the end of allocated OR time is not the reality of short-term operational decision making at many facilities. Although considering a facility to have fixed hours of OR time is an accurate and useful model from a tactical perspective (6,39,41,42), it is not realistic for day-to-day decision making (1,40), which is good (43). If, in the preceding scenario, 15 min or so of flexibility were added for the surgeon, that would be no different than increasing the OR allocation (30). Thus, fixed hours are literally fixed, which rarely matches with the reality for scheduling elective cases.

Although fixed hours of OR time can be achieved by cancelling cases on the day of surgery that would finish in over-utilized OR time, doing so would be counter-productive. Canceling a case to prevent small amounts of over-utilized OR time results in overall increased costs, whether analyzed from a societal, hospital, physician, or patient perspective (43).

Not having fixed hours of OR time is particularly common at hospitals at which surgeons mischaracterize cases as "urgent" or nonelective to get them onto the OR schedule.

For example, an academic department is allocated two ORs from 8 AM to 4 PM on all weekdays. No case is scheduled unless it will fit into the 8 h based on historical OR time data from the OR information system. The service schedules 20% of its OR hours as nonelective cases. Many of these patients likely could have waited safely for several days for surgery. Thus, these were elective cases. The surgeons called the cases "urgent" to achieve open access to OR time on the workday of their choosing. OR efficiency would have been greater had more OR time been allocated originally, so that the cases could have been performed in allocated, rather than over-utilized, OR time.

Suppose that, on a long-term (tactical) basis, the behavior of the academic surgeons was considered so bad that penalties are applied. Then, there would be very little over-utilized OR time. The methods described in this tutorial would still be *valid*, but likely not a *useful* improvement. The validity is important, because in practice, many facilities have a mixture of scheduling behaviors. One behavior or another cannot be assumed a priori, and thus the analysis needs to be valid, regardless of how cases are scheduled. However, the potential lack of usefulness is important too. Consequently, there is reason to consider whether the behavior of the above surgeons is inherently bad.

First, increasing numbers of countries are migrating payment systems to reimbursement based on diagnosis and/or procedure (i.e., fee-for-service prospective payment), including almost all of Europe (44). Contribution margin is revenue minus variable costs. Hospitals receiving fee-for-service reimbursement achieve an overall positive contribution margin for the elective cases of almost all surgeons (6,41,45), because a large percentage of OR costs are not variable. If professional revenues for the anesthesia providers and surgeons were also considered, then every surgeon would provide an overall positive contribution margin for their elective cases. The implication, then, is that if a case can be performed safely, when there is fee-for-service reimbursement, it is economically irrational not to perform the case (6,41).

Second, in contrast to operational decisions that are based on existing OR workload, tactical decisions are often based on near guesses (6) as to potential growth in workload. Providing open access to OR time on any future workday for elective cases reduces the labor costs sustained from a poor tactical decision.

For example, based on the Regional Health Authority's request for more joint replacements, more OR time is allocated tactically for those orthopedic surgeons. However, there is little to no increase in the knee and hip replacement cases, because of limited orthopedic clinic budgets. This does not result in much under-utilized OR time, because the time is released to prevent other services from having over-utilized OR time (29,31).

Third, at many, if not most facilities, anesthesiologists are heavily involved in OR management operational decisions, but less so in tactical decisions. Making operational decisions based on the assumption of open access removes the potential and reasonable argument that the anesthesia group is causing patients to wait unnecessarily long for surgery. Often the bottleneck to providing prompt patient care is not the ORs.

For example, General Surgery requests more OR time based on "patient demand" and "long waiting lists." Yet, they have virtually no over-utilized OR time. They explain that current OR workload does not include the patients that they could have had, but who went elsewhere because of queues. However, operational decisions have been made based on providing open access for elective cases on any future workday. Anytime their OR time was full and they had a new case to schedule, the OR always provided at least one possible scheduled start time, unless limited by safety concerns. Thus, the bottleneck could not have been the ORs and/or the anesthesia group, but instead the surgeons.

Good management of hospital ORs needs to focus not only on the operational performance of the ORs, but also on the interaction of the surgical suite with other parts of the hospital. The rationale for making operational (not tactical) OR management decisions based on providing surgeons with open access to OR time on any future workday makes particular sense for hospitals with intensive care units (ICU) that are often full. For patients needing such care, the ICU is a frequent bottleneck that results in delays or cancellations of surgical cases. There are two ways to approach this problem, other than simply providing and staffing more ICU beds.

One strategy to reduce the risk of delays or cancellations is to adjust the days that services are scheduled to perform surgery (46). Although such techniques can be implemented practically (46), the incremental benefit to hospitals can be small. If most surgeons schedule patients for ICU admission on the same days of the week, usually the cause of case cancellations is visible to the surgeons. The surgeons generally suffer more financially from case cancellations and delays than do hospitals and anesthesia providers. In this situation, the hands-on facilitation of a local OR manger or an expert in managing organizational conflict can help. Such interventions are valuable and important (47). However, they are not commonly decisions made by anesthesia providers and OR managers, although they can facilitate such processes.

The second of the two strategies is to provide surgeons with flexibility in the days when they have OR time. Cases should get onto the OR schedule to ensure that the expensive bottleneck (the ICU) is always full. For example, although 90% of patients may have coronary artery bypass graft surgery length of stays <48 h, there can be marked variability in length of stay (48). Consequently, it can be very difficult to predict when a relatively full ICU will have an open bed because of a patient transfer. When the bottleneck to doing surgery is downstream from ORs, and the service time for that downstream process is highly variable, then to maximize throughout, there needs to be flexibility in scheduling the OR cases.

The same applies to expensive capital equipment, which, like the ICUs, are costs that, on a short-term basis, are not related to the volume of patients receiving care. ORs constructed or remodeled in the future will include more imaging and robotics, resulting in even higher capital costs. The percentage of hospital costs for surgery that are attributed to labor will likely decrease as the capital costs increase to support these and other expensive technologies. To maximize the use of that equipment, surgeons should have open access to OR time to do a case on whatever future workday they and the equipment are available.

Reiterating, this issue of making operational decisions based on open access to OR time on any future workday has nothing to do with expanding OR capacity and/or doing additional cases (10,49). Formulating operational decisions as being based on open access is *not* inconsistent with the presence of waiting lists for surgery in some countries. Rather, the issue is how mathematically to model the existing reality for many services and surgeons with disparate scheduling practices at a facility. Longer-term tactical decisions affecting OR capacity and queues are a separate topic (6,39). The referenced paper (6) shows that the operational decisions described in this paper are appropriate when considered mathematically as following a preceding tactical decision.

CONCLUSIONS

OR allocation is a two-stage process (6,39). During the initial tactical stage of allocating OR time, considering OR hours to be fixed is reasonable. For operational decision making on a shorter-term basis, such a conceptual model produces results markedly inconsistent with how facilities are being managed currently. Consider the workload to be fixed on a short-term basis. Provide staff flexibly to match the existing workload, not *vice versa*. Do so by making operational decisions based on maximizing OR efficiency, as this is an important step in maximizing anesthesia group productivity. This model produces an analysis of operational decision making that is valid at virtually all surgical suites, although the results of the analysis may not necessarily be useful or different from current practice. The tutorial explained how these analyses are done.

Scheduling cases and making decisions on the day of surgery to increase OR efficiency are worthwhile interventions to increase anesthesia group productivity. However, by far the most important step at most facilities is to allocate OR time (i.e., plan service-specific staffing) appropriately 2–3 mo before the day of surgery. Reducing surgical and/or turnover times, and delays in first-case-of-the-day starts, generally provides small increases in anesthesia group productivity. Nevertheless, results vary widely because they are highly sensitive both to the OR allocations (i.e., staffing) and to the appropriateness of those OR allocations.

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