

Use of Linear Programming to Estimate Impact of Changes in a Hospital's Operating Room Time Allocation on Perioperative Variable Costs

Franklin Dexter, M.D., Ph.D.,* John T. Blake, Ph.D.,† Donald H. Penning, M.S., M.D.,‡ Brian Sloan, M.S.,§ Patricia Chung, M.H.A.,|| David A. Lubarsky, M.D., M.B.A.¶

Background: Administrators at hospitals with a fixed annual budget may want to focus surgical services on priority areas to ensure its community receives the best health services possible. However, many hospitals lack the detailed managerial accounting data needed to ensure that such a change does not increase operating costs. The authors used a detailed hospital cost database to investigate by how much a change in allocations of operating room (OR) time among surgeons can increase perioperative variable costs.

Methods: The authors obtained financial data for all patients who underwent outpatient or same-day admit surgery during a year. Linear programming was used to determine by how much changing the mix of surgeons can increase total variable costs while maintaining the same total hours of OR time for elective cases.

Results: Changing OR allocations among surgeons without changing total OR hours allocated will likely increase perioperative variable costs by less than 34%. If, in addition, intensive care unit hours for elective surgical cases are not increased, hospital ward occupancy is capped, and implant use is tracked and capped, perioperative costs will likely increase by less than 10%. These four variables predict 97% of the variance in total variable costs.

Conclusions: The authors showed that changing OR allocations among surgeons without changing total OR hours allocated can increase hospital perioperative variable costs by up to approximately one third. Thus, at hospitals with fixed or nearly fixed annual budgets, allocating OR time based on an OR-based statistic such as utilization can adversely affect the hospital financially. The OR manager can reduce the potential increase in costs by considering not just OR time, but also the resulting use of hospital beds and implants.

MANY hospitals have a fixed, or nearly fixed, annual budget and little or no ability to generate incremental revenue per patient. This applies, for example, to health maintenance organizations, Veteran's Administration hospitals, and most publicly funded hospitals worldwide.

Administrators at hospitals with fixed annual budgets occasionally need to refocus the hospital's elective surgical care on priority areas to ensure that its community is receiving the highest quality and most appropriate care possible. For example, the hospital may plan to invest in its surgical oncology program while reducing resources in orthopedic surgery. This may be achieved by allocating more operating room (OR) time to surgical oncologists and less to orthopedic surgeons.

This simple approach is insufficient if one-time appropriations will be provided to cover required fixed costs (e.g., renovation of some operating rooms), but increases in operating funds will not be provided to cover new hospital variable costs over the short term. The OR manager should consider the impact of changes in OR time on future hospital costs to ensure such a change is sound fiscally. This is particularly challenging at hospitals with limited managerial accounting information (*i.e.*, those with limited or no knowledge as to how much it costs to care for each patient undergoing elective surgery).

In this study, we used data from a hospital with a detailed cost database to investigate by how much changes in allocation of OR time for elective (scheduled) surgery can increase perioperative variable costs. To represent the plans of a hospital in focusing its surgical services on priority areas, total allocated hours for elective surgery were not changed, just the distribution of those hours among its surgeons. We assumed that focusing elective surgical care on priority areas could increase workload in a priority area by as much as 100% (*i.e.*, by hiring an additional equal number of surgeons), but only at the expense of other surgical specialties. We performed the analysis specifically for the hospital with detailed cost data and then used statistical resampling to estimate by how much other hospitals' costs could be increased. Our results provide financial insight that OR managers at hospitals without access to detailed mana-

* Associate Professor and Director, Division of Management Consulting, Department of Anesthesia, University of Iowa. † Assistant Professor, Department of Industrial Engineering, Dalhousie University, Halifax, Nova Scotia, Canada. ‡ Chief of Anaesthesia, Sunnybrook and Women's Health Sciences Centre, and Associate Professor, Department of Anesthesiology, University of Toronto, Toronto, Ontario, Canada. § Management Engineer, Duke University Medical Center, Durham, North Carolina. || Manager of Decision Support, Hospital Administration, Sunnybrook and Women's Health Sciences Centre, Toronto, Ontario, Canada. ¶ Professor and Senior Vice Chair, Department of Anesthesiology, and Adjunct Professor, Health Sector Management, Fuqua School of Business, Duke University, Durham, North Carolina. Current position: Professor and Chairman, Department of Anesthesiology, University of Miami, Miami, Florida.

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Address reprint requests to Dr. Dexter: Division of Management Consulting, Department of Anesthesia, University of Iowa, Iowa City, Iowa 52242. Address electronic mail to: Franklin-Dexter@UIowa.edu. Individual article reprints may be purchased through the Journal Web site, www.anesthesiology.org.

Table 1. Distribution of Workload and Costs by Surgical Department

Service*	Cases (n)	%	Operating Room Time (h)	%	Total Variable Costs (\$ US)	%
Cardiothoracic	1,243	14	4,608	16	11,494,965	26
General, dental, and vascular	2,332	25	6,508	23	9,277,396	21
Gynecology	984	11	2,877	10	3,218,633	7
Neurosurgery	1,021	11	3,204	11	4,587,325	10
Otolaryngology	545	6	1,298	5	1,428,157	3
Orthopedics	1,581	17	5,301	19	9,478,216	21
Plastic surgery	458	5	1,408	5	1,438,882	3
Urology	1,015	11	3,081	11	3,343,298	8
Total	9,184	100	28,290	100	44,269,102	100

* Data are reported for the 98 surgeons who performed at least 15 cases³ during the study year.

gerial accounting data can use for purposes of budgeting and strategic planning.

Methods

Cost accounting data were obtained from a surgical suite at a large, academic, multiple-specialty hospital in the southeastern United States. No physician costs, hospital reimbursements, or physician reimbursements were included in the analysis, just the hospital's direct variable costs. Variable costs are those that increase linearly with the volume of patients receiving care (e.g., vials of propofol used). Fixed costs are those that do not increase directly with the number of patients (e.g., infusion pumps).

Data were obtained for all patients who underwent outpatient and same-day admit surgery at the surgical suite during the 2000 fiscal year (July 1, 1999, to June 30, 2000; table 1). Same-day admit surgical cases were defined as those for which patients were either not admitted or were admitted on the day of surgery. We did not include patients in the analysis who were admitted preoperatively, including emergency and urgent cases, because access to OR time for these patients is largely independent of decisions related to hospital policy. Our assumption in not including these patients was that once such a patient has been admitted to a major hospital, a commitment has been made to provide care to that patient, regardless of the current or future focus of the hospital.

All hospital costs in this analysis were attributed to the patient's first OR visit, because it was the scheduling of the patient for that elective case that was the decision that resulted in the subsequent hospital costs. For example, if a patient returned to an OR during his or her hospitalization (e.g., for postoperative bleeding), then the costs of the second OR visit were ascribed to the first.

Information on the costs of the episode of care were extracted from the hospital's clinical costing system (Transition 1; Eclipsys Corp., Delray Beach, FL). The details of the Transition 1 activity-based costing system

have been described in detail elsewhere^{1,2} and are not repeated here. This accounting system uses actual wage rates, labor efforts, and supply costs to compute variable and fixed costs of patient care. Costs are audited and compared with actual cash expenses on a quarterly basis to ensure that the data are reliable. Total hospital variable costs for a case (e.g., labor and supplies) were estimated by summing the variable costs attributed to each of 18 different hospital departments (e.g., OR, hospital wards, and blood bank). In addition, every item implanted into a patient was recorded, and the original purchase price of that individual item was included as a variable cost of care. Costs were calculated using year 2000 US dollars.

Analysis of the Managerial Accounting Data

We performed the analysis on a per-surgeon basis, under the assumption that focusing elective surgical care on priority areas would be manifested as a change in the hours of OR time allocated to individual surgeons for elective cases. We did not use traditional surgical departments because priority areas usually represent a subset of the care provided by departments. Total variable costs (C_k), hours of OR time (OR_k), hours of hospital ward time (W_k), hours of intensive care unit time (ICU_k), and implant costs (I_k) were calculated for each surgeon. We limited the analysis to the $N = 98$ surgeons who performed at least 15 cases³ during the study year (table 1) to obtain meaningful averages. By doing so we excluded 5% of the cases and variable costs.

To test the worst-case scenario for the increase in hospital perioperative costs from the reallocation of OR time, we used linear programming⁴ to determine the amount of OR time to allocate to each surgeon (A_k) to maximize total hospital perioperative variable costs (T):

$$T = \max \sum_{k=1}^{k=N} A_k \left(\frac{C_k}{OR_k} \right) \quad (1)$$

A_k is a decision variable because the analysis applies to hospitals with fixed OR hours and access to hospital resources is the factor limiting surgical caseload (see

Table 2. Variability among Surgeons in Their Perioperative Hospital Resource Use

	Annual (Total) OR Time (h)	Hospital Variable Costs per OR Hour (\$ US)	Routine Nursing Ward Hours per OR Hour	ICU Nursing Hours per OR Hour	Implant Costs per OR Hour (\$ US)	Hospital Variable Costs Excluding Nursing and Implants per OR Hour (\$ US)
10th percentile*	68	830	5.7	0.000	30	270
25th percentile	109	960	11	0.002	50	350
50th percentile	222	1,250	16	0.053	120	470
Mean	289	1,410	17	0.15	220	560
75th percentile	422	1,590	20	0.18	300	570
90th percentile	597	2,290	28	0.50	520	940

* The percentiles among surgeons are listed for each of the variables independently of the other variables. Thus, the 68 h in the first row, first column of data is not from the same surgeon as the \$830 in the first row, second column.

OR = operating room; ICU = intensive care unit.

constraints below). Because this “resource allocation planning”⁴ model is designed to provide long-term (annual) hospital perioperative variable costs (T), the ratio (C_k/OR_k) is defined as the average over a year’s worth of patients (table 2).⁴

The decision to maximize perioperative variable costs was derived from our desire to determine the worst-case scenario for the increase in variable costs under the assumption of fixed resources (e.g., no increase in OR time). In each of the four phases of the analysis, we added progressively more constraints on the availability of additional resources.

In the first phase of the analysis, we included three constraints. First, we assumed that each surgeon could expand his or her use of OR time by as much as twice the number of OR hours that he or she used during the baseline fiscal year:

$$A_k \leq 2 \cdot OR_k \quad \forall k = 1, \dots, N \quad (2)$$

This upper bound can be thought of as representing the decision to hire another surgeon who performs the same category of surgical procedures. Second, no lower limit was placed on each surgeon’s use of OR time, to represent the situation in which a surgeon’s OR time is reduced sufficiently that he or she chooses to stop practicing at the hospital:

$$0 \leq A_k \quad \forall k = 1, \dots, N \quad (3)$$

This constraint assures that the linear programming results are nonnegative. Setting a lower bound of zero on a surgeon’s allocation may be unrealistic in that it permits the wholesale elimination of surgical services at a hospital. However, our objective in this analysis was to determine the worst-case scenario for the increase in costs. Third, we included a constraint prohibiting the total hours of OR time for elective surgical cases from increasing:

$$\sum_{k=1}^{k=N} A_k = \sum_{k=1}^{k=N} OR_k \quad (4)$$

This constraint also had the effect of capping the component of nonnursing costs that is proportional to OR

time. For example, the variable costs for surgical supplies and anesthetic agents were limited by this constraint, at least in part, because these costs are significantly correlated to OR time.⁵

Constraints (2) to (4) used in the first phase of the analysis did not prevent an increase in hospital ward or intensive care unit nursing hours. Thus, this first phase of the analysis considered implicitly only those direct patient care nursing activities outside of the surgical suite that are variable costs proportional to the amount of OR time assigned to a surgeon. No limit was included on the availability of nursing staff needed to support the hospital’s new priority areas.

In the second phase of the analysis, we repeated the analysis from the first phase after adding the constraint that intensive care unit hours would not be allowed to exceed that of the previous year:

$$\sum_{k=1}^{k=N} A_k \left(\frac{ICU_k}{OR_k} \right) = \sum_{k=1}^{k=N} ICU_k \quad (5)$$

This constraint represents the situation at many hospitals in which use of the intensive care units is always high during the days when elective surgical cases are performed. The logic behind this constraint was that if management elected to not open new intensive care unit beds for elective surgery as part of the change in hospital surgical policy, intensive care unit nursing variable labor costs could not increase in the short term. This constraint also has the effect of capping nonnursing costs that vary proportionally with intensive care unit length of stay (e.g., blood products, sedatives, antibiotics, and respiratory care equipment).

Third, we repeated the second phase of the analysis after adding the constraint that hospital ward hours would not be permitted to exceed that of the previous year:

$$\sum_{k=1}^{k=N} A_k \left(\frac{W_k}{OR_k} \right) = \sum_{k=1}^{k=N} W_k \quad (6)$$

The rationale and interpretation are the same as in the previously described first and second phases of the analysis.

Fourth, we repeated the third phase of the analysis after adding a final, additional constraint that the total costs of surgical implants for the year would not be permitted to exceed the previous year's costs:

$$\sum_{k=1}^{k=N} A_k \left(\frac{I_k}{OR_k} \right) = \sum_{k=1}^{k=N} I_k \quad (7)$$

We did this because implants are an easily identifiable and tracked subset of costs that can be controlled (see Discussion).

We report the increase in variable costs from the linear programming (equation 1) relative to the total hospital costs before the reallocation of OR time:

$$R = T \left/ \sum_{k=1}^{k=N} C_k \right. \quad (8)$$

We also estimated the maximum possible expected increases in costs using simulated resampling of the data. Specifically, we chose at random and with replacement, 98 surgeons from the population of 98 surgeons to simulate a mix of surgeons and surgical specialties at another (unspecified) hospital. Equations 1-4 and 8, with or without equations 5-7, were applied to maximize the increase in costs (R_1) for this random sample of 98 surgeons (*i.e.*, different hospital). This process was repeated 1,999 times, giving $R_2, R_3, \dots, R_{2000}$. The 95th percentile of ($R_1, R_2, \dots, R_{2000}$) gave an estimate of the worst-case scenario on the mix of surgeons among many hospitals. The analysis was performed by writing Visual Basic 6.0 computer code to call Microsoft (Redmond, WA) Excel 2000's Solver linear programming⁴ function 8,000 times, where 8,000 optimizations = 2,000 sets of resampled data \times four phases of the analysis applied to each resampled data.

Results

Overall hospital perioperative variable costs per hour of OR time were observed to vary significantly among surgeons at the hospital with detailed cost data (fig. 1, table 1, table 2). For example, the two surgeons with variable costs less than \$600 per hour of OR time performed dental and pediatric urology cases, respectively. The 10 surgeons with variable costs more than \$2,500 per hour of OR time performed cardiothoracic surgery or hip and knee replacements. The most expensive 20% of OR hours accounted for 33% of hospital perioperative variable costs (fig. 2). The least expensive 20% of OR hours accounted for 9% of hospital perioperative variable costs.

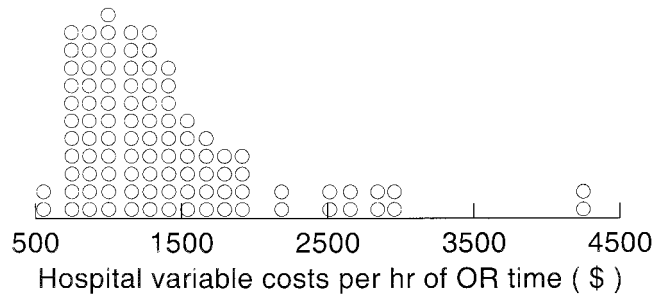


Fig. 1. Hospital variable costs per hour of operating room (OR) time for patients undergoing elective surgery. Each circle represents one surgeon. The 10 surgeons with variable costs more than \$2,500 per hour of OR time performed cardiothoracic surgery or hip and knee replacements.

Using the linear programming, a new mix (table 2) of surgeons was selected. In general, surgeons with high costs per OR hour (fig. 1) were substituted for those with the lower costs by the linear programming model. Such a change in elective surgical care was found to increase perioperative variable costs at the hospital with detailed cost data by up to 20% (table 3). However, this value may actually overestimate the true potential increase in hospital costs, because additional resources may not be available or provided to support the selected allocation. For example, at the hospital with detailed cost data, a 12% increase in hospital ward hours and a 55% increase in intensive care unit hours was observed. This occurs, in part, because surgeons with relatively high variable costs per hour of OR time used many hours of intensive care unit time for each hour of OR time (*e.g.*, cardiac surgeons; fig. 1). If intensive care unit occupancy was sufficiently high that intensive care unit hours for elective surgical cases could not be increased or was limited by management dictate, perioperative variable costs would then increase less, by up to 13% for the hospital with the cost data. If, in addition, hospital ward occupancy was sufficiently high that it could not be increased by the change in surgical focus or was similarly limited by edict, perioperative variable costs would be increased by as much as 8.6% at the hospital with cost data. Finally, if, in addition, implant use was tracked and capped, perioperative costs would increase by no more than 4.3% at this hospital with costing data.

We explored these results further for the hospital with detailed cost data in three ways. Hospital perioperative variable costs were classified as equaling direct nursing labor costs, implant costs, and everything else (*e.g.*, blood, surgical supplies, drugs, linens, and patient food; fig. 2). Specifically, OR nursing labor, intensive care unit nursing labor, hospital ward nursing labor, implants, and everything else accounted for 22, 4.3, 16, 20, and 38% of hospital variable costs, respectively. By assuring that the first 62.3% of costs (*i.e.*, OR, intensive care unit, and ward time and implants) do not increase, the adminis-

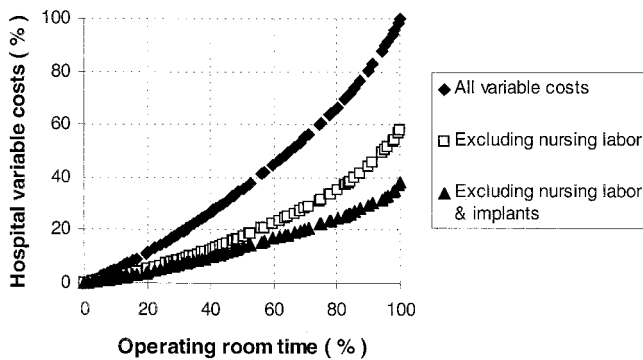


Fig. 2. Data for each surgeon from figure 1 plotted on a cumulative basis after having been sorted in ascending order of hospital variable costs per hour of operating room time. Operating room time (%) refers to the cumulative percentage of operating room time used, starting with the surgeon with the lowest hospital variable costs per hour of operating room time. The plot shows, for example, that the least and most expensive 20% of operating room hours accounted for 9 and 33% of hospital perioperative variable costs, respectively. We classified hospital perioperative variable costs as equaling direct nursing labor costs, implant costs, and everything else (e.g., blood, surgical supplies, linens, and food). We repeated the analysis after excluding nursing labor costs or nursing labor costs and implant costs.

trator can limit the increase in the remaining 38% of costs to, at most, 4.3% (table 3).

Multiple least squares linear regression was performed with the $N = 98$ surgeons' total hospital variable costs as the dependent variable. Sequentially adding hours of OR time, implant costs, hours of intensive care unit time, and hours of hospital ward time as independent variables yielded $r = 0.87, 0.94, 0.97,$ and $0.98,$ respectively; $P < 0.001$ for all four of the variables. The overall percentage

of the variance in total hospital variable costs predicted by these four variables was 97%.

We tested the hypothesis that predictions for the maximum possible increase in perioperative variable costs from changing the mix of surgeons would be sensitive to the amount by which we assumed that each surgeon could expand his or her use of OR time. The preceding analyses assumed that each surgeon could double his or her use of OR time, representing hiring another surgeon. To test the sensitivity of the results to this constraint, we repeated the analyses while permitting an increase of only 25%. This value of 25% represents the most that we would expect that a surgeon could increase his or her personal OR workload. For this hospital with detailed cost data, the percentage increases in perioperative variable costs were reduced from 20, 13, 8.6, and 4.3% to 8.7, 6.1, 3.6, and 2.1%, respectively. Restricting increases in OR time, intensive care unit time, ward time, and implant costs limited the increase in perioperative variable costs to a few percent.

Simulated resampling of the surgeons was performed 2,000 times to assess the sensitivity of the results to the mix of the surgeons at the hospital. In all replications, the same number of hours of OR time for elective cases was maintained (table 3). When each surgeon could double his or her use of OR time, representing hiring another surgeon, the 95th percentile for the increases in costs among many simulated hospitals was 34% (90th percentile, 33%; 99th percentile, 36%; SE, $< 0.1\%$). If increases were prevented in intensive care unit hours, hospital ward hours, and implant costs, then the 95th percentile for the increase in costs was 10% (90th per-

Table 3. Results of the Linear Programming Analysis of How Changes in Operating Room Allocation Can Increase Hospital Perioperative Variable Costs for Outpatient and Same-day Admit Surgery Cases

Constraints	Maximum Achievable Increase in Costs at the Hospital with Detailed Costing Data (Tables 1 and 2) (%)	95th Percentile for Increase in Costs from 2,000 Resamples of the Surgeons to Represent Different Hospitals (SE)* (%)
No increase in total hours of allocated OR time Maximum 100% change in each surgeon's OR time allocation	20	34 (SE < 0.1)
No increase in total hours of allocated OR time Maximum 100% change in each surgeon's OR time allocation No increase in total hours of intensive care unit time	13	24 (SE < 0.1)
No increase in total hours of allocated OR time Maximum 100% change in each surgeon's OR time allocation No increase in total hours of intensive care unit time No increase in total hours of hospital ward time	8.6	19 (SE < 0.1)
No increase in total hours of allocated OR time Maximum 100% change in each surgeon's OR time allocation No increase in total hours of intensive care unit time No increase in total hours of hospital ward time No increase in total implant costs	4.3	9.9 (SE < 0.1)

* Standard errors (SEs) were estimated using the jackknife method¹⁵ (note, not the jackknife-after-bootstrap method¹⁶). Specifically, the process of resampling was repeated 98 times, each with one surgeon excluded. Absolute differences between means of these 98 values of the 95th percentile (not shown in the table) and the original 95th percentiles (given in the table) were less than 0.21% among the four sets of constraints. The standard errors were less than 0.1%.

OR = operating room.

centile, 9%; 99th percentile, 11%; SE, 0.1%). When each surgeon could increase his or her use of OR time by up to 25%, the restrictions limited the increase in costs to 3%.

Discussion

Implications for Changing Surgical Service Priority Areas for Elective Surgery

Although many hospitals worldwide have fixed or nearly fixed annual budgets, OR time is typically allocated on the basis of OR utilization or some other OR-based statistic. Yet changes in OR time allocation affect the wider hospital budget.⁶ One reason for this management disconnect between hospital operations and strategic goals is a lack of data on how changes in OR allocations affect the hospital budget. In this study, we showed that considering just OR, intensive care unit, and ward time and implant costs is sufficient to predict accurately total hospital perioperative variable costs. An administrator needs to limit access to OR time, inpatient beds, and implants to control costs, but can safely neglect the tens of thousands of other items generating costs.

Our work can also be helpful to hospital administrators contemplating changing the focus of their perioperative care program, while being unable to expect additional operating funds. Our financial analysis applies regardless of the rationale for reallocating OR time (*e.g.*, to better serve community healthcare needs, to improve hospital finances, or to meet a mandate from a healthcare system). We showed what steps such hospitals need to make to reduce substantially the chance of sustaining a large increase in perioperative variable costs.

Hospitals need to ensure that there be no increase in OR, intensive care unit, or hospital ward length of stay. In practice, this situation is generally straightforward at hospitals with fixed budgets, because typically the budget is fixed at a sufficiently low level that hospital occupancy is nearly 100% (*i.e.*, virtually every hospital bed is filled every day). To maintain nursing costs, hospitals thus need to ensure that no new nursing staff are hired. Hospitals should monitor nursing workload to ensure that acuity levels do not increase beyond its staffing guidelines. For example, mechanisms should be in place to ensure that patients needing an intensive care unit bed are not simply assigned a hospital ward bed. If focusing surgical services on priority areas changes the average acuity of patients, then the number of physical beds might have to be reduced to retain the same total nursing hours.

In addition, our results show that hospitals must either receive supplemental funds from their health care systems for implants or they must purchase prespecified numbers of each type of implant and use no more than that number. The former is the case in the Province of Ontario, where the Ministry of Health provides supple-

mental funding to designated hospitals for hip and knee implantation cases that generally covers the costs of the hip and knee implants. The latter choice is a common method of controlling hospital costs in other systems (*i.e.*, rationing). When the purchased implants run out, no additional elective cases using such implants are performed until the next fiscal year. This strategy can be implemented as part of a supplier-negotiated consignment program. Our analysis shows that proactive efforts to contain implant costs for elective cases must be in place.

Implications for Managerial Accounting

For purposes of OR time allocation, detailed enterprise-wide cost data need not necessarily be collected, and the resulting voluminous, hierarchical accounting reports need not be reviewed. The collection and interpretation of patients' OR, hospital ward, and intensive care unit length of stay and implant costs is sufficient. For example, consider two hypothetical surgeons who perform cases without implants. Each surgeon's hospital ward and intensive care unit days per OR hour are similar. Then, when applied to these two surgeons, the result of this article would be that, if OR time were exchanged from one surgeon to the other, on a long-term (*e.g.*, annual) basis⁴ hospital perioperative variable costs would be expected to increase little. This is not only because the staffing itself accounts for approximately 62% of the costs, but also because much of the remaining costs are predicted or caused by the surgeons' patients' OR, hospital ward, and intensive care unit lengths of stays.

This does not mean that enterprise-wide cost data are not useful for other perioperative applications. They are important when individual surgical procedures are considered, whether as part of clinical pathways,⁷ incentive programs,⁸ or contracts.⁹

Implications for Operating Room Management

Hospitals with a fixed annual budget are able to provide a finite amount of care. It is not possible to schedule elective cases at such facilities based on the assumption that care will be provided for all of the surgeons' patients, whether on whatever future workday the surgeon chooses¹⁰⁻¹² or within a reasonable length of time.^{13,14} In general, such institutions must either ration care explicitly through predetermined volumes or implicitly by controlling access to scarce resources, such as OR time. Frequently, OR time allocations are based, in part, on each surgeon's use of his or her allocated OR time, and to a large extent on political deal-making. Rarely are the full financial considerations of a particular allocation taken into account. The implication of our findings is that if intensive care unit time, ward time, or implant costs are not considered when OR time is allocated, depending on the vagaries of the allocation process, the

hospital perioperative budget could increase unexpectedly by as much as 34%. If hospital costs are to be held in check, then not just OR use but also intensive care unit time, ward time, and implant time per hour of OR time must be considered in the process of allocating OR time.

This approach has not traditionally been necessary, because patients previously were admitted preoperatively for surgery, and so control of access to hospital resources could be maintained *via* hospital admission. Large public hospitals have traditionally focused on the number of beds planned for each surgical service and surgeon. Outpatient and same-day admit surgery has fundamentally changed this equation, although it can take several years for this to be appreciated by large bureaucracies. The OR manager now controls this process through OR allocation.

Methodologic Limitations

We analyzed detailed cost data from one hospital to provide guidance to other hospitals with limited data. Because the hospital studied had a wide mix of specialties (table 1, fig. 1), ranging in resource use from hospital dentistry to cardiac surgery, and we made deliberately extreme assumptions, the results are likely to give the worst-case increase in costs. Accordingly, the results described here will be of most value to hospital administrators without their own detailed cost data and less value to administrators at hospitals with their own detailed cost data. The latter may benefit from performing the analysis described here on their own data.

Our work is limited by the fact that the cost data come from only one large multiple-specialty hospital. By using the resampling methodology, we created a couple of thousand different mixes of surgeons, and therefore probably simulated almost every type of hospital. However, we cannot say this for sure, because we do not know of equivalent data from a facility with a fixed annual budget and no incremental revenue; this was the reason that we performed our study in the first place. Nevertheless, hospital executives frequently make major strategic management decisions based on imperfect information. The results presented here provide hospital executives with the best information to date to make those decisions.

Summary

We analyzed data from a hospital with a uniquely detailed hospital financial management database to provide guidance to other hospitals. Although our primary application area was hospitals with a fixed annual bud-

get that seek to position their surgical services to priority areas, our results can be used by administrators at other hospitals with a lack of accurate or detailed managerial accounting data.

We showed that changing OR allocations among surgeons without changing total OR hours allocated can increase hospital perioperative variable costs by up to one third. Thus, at hospitals with fixed or nearly fixed annual budgets, allocating OR time based on an OR-based statistic such as utilization can adversely affect the hospital financially. The OR manager can reduce the potential increase in costs by considering not just OR time, but also the resulting use of hospital beds and implants.

We also showed that, when linking OR scheduling and hospital financial management information systems for cost control, data collection can focus on patients' OR, hospital ward, and intensive care unit length of stay and implants.

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