Costs and risks of weekend anesthesia staffing at 6 independently managed surgical suites

Franklin Dexter, MD, PhD
Iowa City, Iowa

Richard H. Epstein, MD
Philadelphia, Pennsylvania

H. Michael Marsh, MBBS
Detroit, Michigan

We previously developed a statistical method that managers can use to assure that nurse anesthetists are on call on weekends for as few hours as possible while providing a specified level of care for operating room (OR) patients. The statistically derived staffing solutions are optimal, meaning that the total number of staffed hours is guaranteed to be as low as possible to achieve the specified risk of being unable to care for patients as promptly as they had in the recent past.

We used the statistical method to review nurse anesthetist weekend staffing at 6 surgical suites that were part of a healthcare system with a cost-conscious management team. Four of the suites had already made staffing changes resulting in a greater than 6% risk of being understaffed. One suite had adequate current staffing but slightly exceeded the minimum total staffing hours. One suite had more anesthetist coverage than was needed, resulting in excess staffing costs greater than $200,000 per year.

We conclude that the principal value of the statistical method may be in helping healthcare system administrators and anesthetists quantify the impact of contemplated reductions in staffing on their risk of understaffing and prolonging patients' wait for OR care.

Key words: **Economics, organization and administration; operating room information systems; operating rooms; operations research; personnel staffing and scheduling.**

A statistical method was previously developed that anesthesia group managers can use to assure that nurse anesthetists are on call on weekends for as few hours as possible while providing a specified level of care for operating room (OR) patients.[1] The statistical method relies on 3 types of data: (1) historical data on the numbers of operating rooms running (ie, rooms in which patients were undergoing surgery) each hour during the weekend, (2) the duration and start times of the shifts that the anesthetists consider to be desirable, and (3) the level of risk that the anesthesia group is willing to accept in being understaffed for OR care. A staffing solution is a combination of shifts that anesthetists work (eg, one anesthetist Saturday from 7 AM to 7 PM and a second from Saturday 7 AM to Sunday 7 AM). The statistically derived staffing solutions are optimal in the sense that the total number of staffed hours is guaranteed to be as low as possible to achieve the specified risk of being unable to care for patients as promptly as they had in the recent past.[1,2] The statistical method was previously validated using data from an academic medical center.[1]

The current study was formulated to review Certified Registered Nurse Anesthetist (CRNA) weekend staffing at 6 surgical suites. The healthcare system's administration, responsible for these 6 surgical suites, was concerned with optimizing the delivery of anesthesia care during weekend reduced staffing periods without incurring unnecessary cost expenditures. Similar statistical analyses to help balance labor costs versus the desire to prevent understaffing have been performed successfully for obstetrical and postanesthesia care units.[2,3] We hypothesized, albeit incorrectly, that the statistical method would identify staffing solutions whereby all the cases are covered but for which anesthetist hours are lower than those obtained using the staffing plans developed independently by each surgical suite's anesthesia manager based on his or her experience and the data. Instead, our results will show that at several surgical suites the managers had underestimated their risk of being understaffed and had already reduced staffing sufficiently for the risk to exceed that chosen by the healthcare system's administration.

Methods

- *Review of the statistical method.* The mathematical

basis, equations, and validity of the statistical method, and a detailed example of the steps in using the method were published in the *AANA Journal*.[1] In this section we summarize the details relevant to using the method in practice. In the next section we describe the 6 surgical suites to which the method was applied.

The statistical method[1] is based on determining whether the managers can reduce staffed anesthetist hours while providing a specified level of prompt OR patient care. The latter is quantified by the percentage of 24-hour periods with at least 1 patient not being able to receive care during the same 1-hour period as he or she would have in the recent past. For example, if 95% coverage were deemed acceptable, then the staffing solution would allow at most 1 future day in 20 when not enough anesthetists are available for at least 1 hour during a 24-hour period to staff an OR that had been adequately staffed previously. The prescribed level of future risk that the group would be accepting in being understaffed would then be 5%. If achieving 100% coverage were required, then this would mean staffing at least as many ORs that were used each hour in the recent past. The statistical analysis makes no assumptions about how cases were or are booked or queued. Instead, the analysis considers when cases were previously performed and then matches anesthetist staffing to that historical OR workload. For example, if during the past 2 years between 7 PM and 7 AM there were never more than 3 ORs running simultaneously, then the anesthesia group would be assured to be providing better than 95% coverage by staffing for 3 ORs between 7 PM and 7 AM in the future.

Individuals scheduled to be on call can be taking "in-house" call, call "from home," or combinations thereof. If the optimal staffing solution for OR coverage were one 24-hour shift (Table 1), then 1 anesthetist could be on-call for OR coverage for 24 hours, or equivalently 3 anesthetists could each be on call 1 at a time for 8 hours. The minimum number of anesthetists required to satisfy the call requirement each day equals the optimal number of shifts required each day. For example, if the optimal staffing for OR coverage were one 24-hour shift, then the minimum number of anesthetists for OR care would be 1.

The number of anesthetists who would be scheduled to work at each hour of the 24-hour period of interest is calculated for all possible staffing solutions from the durations and start times of the different shifts. The number of anesthetists at each hour is then compared to the number of anesthetists who were actually needed at that hour during each 24-hour period of historical data. If during any hour of the 24-hour period a proposed staffing solution would not have provided adequate staffing, then the day in question is counted as being staffed inadequately by that proposed staffing solution. If the number of understaffed days exceeds a cutoff value, then that staffing solution is discarded as unacceptable. The cutoff value is calculated by finding the lower 95% confidence bound on the number of historical 24-hour periods for which a proposed staffing solution could have provided an inadequate number of OR staff during at least 1 hour while maintaining the prescribed level of *future* risk that the group accepts in being understaffed.[1] For each staffing solution providing adequate coverage, the total number of staffed hours during the 24-hour period and the total number of shifts required for the 24-hour period are calculated. From among all the staffing solutions that satisfy the risk criterion, the recommended staffing solution is the one with the least number of staff hours during the 24-hour period and/or total number of staff required for the 24-hour period.

Table 1. Weekend anesthesia group staffing shifts considered in the analysis

Shift evaluated*	Start time	End time	Duration (h)
1	NA	NA	0†
2	7 AM	7 AM	24
3	7 AM	3 PM	8
4	7 AM	5 PM	10
5	7 AM	7 PM	12
6	7 AM	9 PM	14
7	7 AM	11 PM	16
8	9 AM	7 AM	10
9	9 AM	9 PM	12
10	9 AM	11 PM	14
11	9 AM	7 AM	22
12	3 PM	11 PM	8
13	3 PM	7 AM	16
14	7 PM	7 AM	12
15	11 PM	7 AM	8

*** All combinations of 6 of the above shifts (with duplicates allowed) were tested to find the optimal weekend staffing solution.**

† Every proposed weekend staffing solution was a combination of 6 of these 15 shifts. The "0" hour shift listed in the first row was needed to permit assignment of fewer than 6 nurse anesthetists to a proposed weekend staffing solution.

The statistical method considers differences in workload from hour to hour within the 24-hour period of interest.[1] However, the underlying statistical assumption is that there are no systematic differences among weeks in the expected workload of the surgical suite at each of the hours of the 24-hour period. Provided that this assumption is true, then the statistical method will accurately model the variability in OR workload week to week for each of the hours of the 24-hour period of interest. We tested this assumption by applying the turning points test[3] to total OR hours from each 24-hour period and the signs test[3] to the maximum number of rooms running each 24-hour period.*

• *Application of the statistical method to anesthesia staffing at 6 surgical suites.* For the current study, analyses were performed separately for 7 AM, Saturday, to 7 AM, Sunday, and 7 AM, Sunday, to 7 AM, Monday. We considered from 1 to 6 combinations of the 15 different shifts chosen by the healthcare system's administration for each of these 24-hour periods (see Table 1). Staffing for breaks and non-OR cases was excluded. The surgical suites included a mixture of academic and private facilities, some suburban and some urban.

Two years of historical OR case data were analyzed from 5 of the surgical suites and 1 year from the sixth suite because of changes in caseload between the first and second year of data collection. In that the data were available previously to the managers, our analysis focused on the value of the statistical analysis of the data, not the data itself.

We used a 6% future risk of the anesthesia group being understaffed for each of the surgical suites, as agreed to by the surgical suites' healthcare system's administrators. To guarantee that the future risk does not exceed 6%, a staffing solution could have understaffed the surgical suite at most twice during a 2-year historical data interval (ie, with 2 of 52 × 2 periods being understaffed for at least 1 hour, the 95% upper confidence bound for the true risk was 6%). The reason why we selected a future risk of 6% rather than a typical value such as 5% was because the choice of 6% for the future risk permitted 2 understaffed days in the historical data, whereas 5% permitted only one.

Results

The assumptions of the statistical method were previously shown to be satisfied by data from an academic medical center, as described in reference 1.[1] The assumptions were also satisfied by both statistical tests* for all 12 of the combinations of surgical suite and 24-hour period from this study.

Four of the 6 surgical suites had already made staffing changes that resulted in a greater than 6% risk of being understaffed (Table 2). For example, surgical suite #3 on Saturdays had 2 ORs staffed from 7 AM to 3 PM and 1 from 3 PM to Sunday, 7 AM. However, based on past workload, the future risk exceeded 6% of running 2 ORs between 3 PM and 5 PM. Surgical suite #6 on Sundays had 2 ORs staffed from 7 AM to Monday, 7 AM. However, past workload showed a greater than 6% risk of there being 4 or more cases needing to be done between 3 PM and 5 PM.

One of the 6 surgical suites had adequate current staffing but slightly exceeded the minimum total staffing hours for Saturday but not Sunday. This means that there were more nurse anesthetists scheduled to care for patients in operating rooms than there were patients to take care of, even on the unusually busy days.

One of the 6 surgical suites had more than 24 hours of anesthetist OR coverage than was needed for both Saturday and Sunday; the corresponding financial value exceeding US $200,000 per year (Table 3). This Table 3 provides an example of the use of the different durations and starting times of the shifts in Table 1.

Discussion

The statistical method identified a staffing solution with a significantly lower cost at 1 of the 6 surgical suites. This confirms that the statistical method can identify a staffing solution with lower costs than those identified by a practicing anesthesia group manager based on his or her experience and the data alone. However, this finding in only 1 of the 6 surgical suites suggests that cost reduction may not be the principal benefit of the statistical method in practice.

Because the statistical method considered millions of different staffing solutions[1] to find the optimal one, we had expected[2] it would find less expensive staffing solutions for all of the surgical suites. Instead, at 4 of the suites, the anesthesia managers had already decreased weekend coverage so that the future risk of being unable to care for patients who previously would have received care exceeded 6% per day. We

* The turning point test is performed by taking the difference between each 24-hour period's total OR hours and the total OR hours from the preceding 24-hour period. If the difference is positive or negative, a plus or minus sign, respectively, is ascribed to the current 24-hour period. A turning point is a 24-hour period whose sign is different from the next period. If there were a trend or positive autocorrelation in total OR hours (eg, from seasonal variation in weekend workload), then the number of turning points would be more than expected based on random chance.[3] The sign test is performed by taking the difference between the maximum number of rooms running during a 24-hour period and the preceding 24-hour period. The number of non-zero positive and negative differences would be expected, based on random chance, to be nearly equal. The sign test checks whether there is a significant difference (eg, as would occur if there were a trend toward increasing or decreasing workload over time).

Table 2. Weekend nurse anesthetist staffing at 6 surgical suites

Surgical suite	Day of the wk	Findings of our study: Current staffing risk (%)*	Findings of our study: Decrease in costs (h/d, $/y†)	Characteristics of optimal staffing solution: Minimum no. of anesthetists	Characteristics of optimal staffing solution: Minimum anesthesia staffed h	Current staffing: Anesthesia staffed h
1	Saturday	≤ 6	4 h, $11,122	4	52	56
	Sunday	≤ 6	None	2	48	48
2	Saturday	≤ 6	28 h, $77,852	4	68	96
	Sunday	≤ 6	50 h, $139,022	3	46	106
3	Saturday	> 6	None	2	32	32
	Sunday	> 6	None	3	38	24
4	Saturday	> 6	None	4	50	48
	Sunday	> 6	10 h, $27,804	2	30	40
5	Saturday	> 6	None	4	74	56
	Sunday	> 6	None	4	66	48
6	Saturday	> 6	None	5	70	48
	Sunday	> 6	None	4	58	48

*** A 6% risk means, practically, that there is a 6% chance that some time during a 24-hour call period there will be a need to run more operating rooms than there are anesthetists available either in-house or at home "on pager."**

† The potential decrease in costs were calculated assuming an hourly wage of US $53.47 per hour, the mean regular wage per hour for permanent Certified Registered Nurse Anesthetists at all of the surgical suites in the year 2000.

speculate that similar reductions in weekday staffing would not be tolerated due to the obvious organizational and political ramifications of not being able to care for elective patients in a timely fashion. In contrast, the impact of a decreased service level on weekends would be harder to detect. Quantifying and judging risk accurately without statistical methods can be very difficult.[4] When pressured to decrease costs, medical groups may decrease staffing sufficiently to increase the risk of being temporarily understaffed to a level that the group perceives as high.[4] Our findings suggest that the statistical method may have value in helping healthcare system administrators and anesthetists quantify the impact of reductions in staffing on the level of OR care being provided to patients. In that we excluded any extra staff who might be needed for breaks or non-OR cases, the staffing recommendations provided by the analysis can be considered to be conservative.

The statistical method determines the optimal combination of shifts specified as being appropriate for providing OR care. This issue of how many nurse anesthetists should be available at each hour of the 24-hour period of interest is a so-called "staffing problem." Once it is determined which OR shifts should be staffed, the anesthesia group then needs to decide how to schedule specific nurse anesthetists to cover those shifts: a so-called "scheduling problem." Different methods of scheduling can result in different direct and indirect costs. For example, if the optimal

Table 3. Difference between proposed and current staffing* for the second surgical suite listed in Table 2

	Current staffing	Proposed staffing
Saturday	7 AM to 7 AM	7 AM to 7 AM
	7 AM to 7 AM	7 AM to 7 AM
	7 AM to 7 AM	7 AM to 5 PM
	7 AM to 7 AM	9 AM to 7 PM
Sunday	7 AM to 7 AM	7 AM to 7 AM
	7 AM to 7 AM	7 AM to 3 PM
	7 AM to 7 AM	9 AM to 11 PM
	7 AM to 7 AM	

*** A shift can be staffed by more than 1 anesthetist. For example, a 24 hour shift from 7 AM to 7 AM could be worked by 1 person working 24 hours or 3 people working consecutively for 8 hours.**

staffing solution included a 24-hour shift, then 1 anesthetist could be on-call for 24-hours, or equivalently 3 anesthetists could each be on call 1 at a time for 8 hours. Depending on how anesthetists are paid, the direct costs of these 2 schedules may be either the same or different. Indirect costs also may differ, in that the former may be associated with more fatigue for the anesthetist on call, but the latter may encourage retention if anesthetists prefer to have more weekends without any call responsibilities. Finally, the scheduling problem should consider the issue as to whether nurse anesthetists are on call "in-house," "from home," or combinations thereof. Questions relating to which type of call is best depends on issues including patient acuity (eg, penetrating thoracic trauma versus appendectomies), the time required to arrive at the hospital from home, employment contracts, individuals' preferences, and relative staffing costs.

The statistical method considered in this paper applies only to weekend staffing. The quantity being optimized is a level of service. Optimal staffing algorithms for regularly scheduled work hours (eg, 7 AM to 3 PM) have been developed for surgical suites that care for all elective cases on whatever workday the surgeon and patient choose[5-7] for suites that care for all elective cases within a "reasonable" (not decided by the surgeon) number of days[8-10] or suites that have a limited number of hours of OR time for elective cases.[11-13] A graphical method that minimizes the costs associated with staffing during evening shifts (eg, 3 PM to 11 PM) has also been published.[6,7]

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AUTHORS

Franklin Dexter, MD, PhD, is associate professor and director, Division of Management Consulting, Department of Anesthesia, University of Iowa, Iowa City, Iowa.

Richard H. Epstein, MD, is associate professor, Department of Anesthesiology, Jefferson Medical College, Philadelphia, Pa, and president of Medical Data Applications, Ltd, Jenkintown, Pa.

H. Michael Marsh, MBBS, is professor and chair, Department of Anesthesiology, Wayne State University, Detroit, Mich.

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