Original Research Article

Can we predict when operating lists will finish in a regional Queensland hospital?

David Liu
Fourth Year Medicine (Graduate)
University of Queensland

David was a recipient of a University of Queensland (UQ) Research Scholarship in medicine for 2008-2009. In 2009, David presented at the Asian Medical Students' Association International Conference in Taiwan and was a UQ delegate at the Australian Medical Students' Association National Leadership Development Seminar in Canberra.

Winner of the Co-Op Bookshop Prize for Best Academic Article in this issue of the AMSJ

Background: Over-running operating lists are a common cause of same-day cancellations of surgery, while under-running operating lists are a common cause of wasted health resources due to the fixed costs of operating suites. The predominant cause of operating lists running off-schedule is not known, but it is believed that if due to booking problems, it should be possible to predict when a list will over- and under-run. **Aims:** To understand the prevalence of cancellations, over- and under-running operating lists in a regional Queensland hospital, and to test whether over- and under-running lists can be predicted. **Methods:** A sample of 120 operating lists was prospectively obtained and each list timed from start to finish. A predicted duration was calculated for each list by summing the average durations for each of the operations on the list (including anaesthetic and turn-over durations), derived from past surgical records. **Results:** Twenty-eight percent of lists suffered a cancellation, of which 79% were predicted to over-run their scheduled duration. Of the lists that did not suffer a cancellation, 45% over-ran, of which 84% were predicted; and 37% under-ran, of which 84% were predicted. **Conclusion:** The large proportion of predicted over- and under-runs support the hypothesis that booking problems are the main causes of operating lists running off-schedule, as opposed to other factors affecting surgical duration that the model would not have accounted for. This suggests that operating lists running off-schedule can potentially be avoided. Further study is warranted to investigate the reasons behind over- and under-booking.

Background

A problem in the management of operating schedules for hospitals is that operations do not always run to schedule. This can cause operating lists to over- or under-run their allocated time. In this paper, Pandit's [1] definitions for these terms were used:

- an over-run occurs when the actual duration of the list exceeds its scheduled duration by more than 20 minutes;
- an under-run occurs when the actual duration of the list is less than its scheduled duration by more than 20 minutes.

Studies in the United Kingdom show that the percentage of operating lists running significantly over scheduled time is between 21-53%, while the percentages of operating lists running significantly under scheduled time is between 33-39%. [1-3] There have so far been no similar studies conducted in an Australian setting.

A study from the United States compared operation durations with the time scheduled for those respective operations. Based on data of the 20 most frequently performed surgical procedures, it was found that for 31.8% of cases the actual case length exceeded the time scheduled for the procedure by 15% or more. For 23.1% of the cases, the actual case length was shorter than the time scheduled for the procedure by 15% or more. [4]

A number of studies have shown that over-running of operating lists is associated with cancellations of procedures. A study at a major tertiary hospital in Australia found that 13.2% of scheduled elective operations were cancelled on the day of the procedure and the leading cause of cancellation (18.3%) was lack of theatre time due to over-running operating lists. [5] Similar studies in hospitals outside of Australia have had similar findings. [2,6-8]

Cancellations have a negative effect on quality of life for patients who have their operations cancelled, as well as those who are on elective surgery waiting lists. Patients who have their operations cancelled must live with a surgically treatable morbidity for a longer period of time, and have an increased risk of developing major depression within twelve weeks of their cancellation. [9] Cancellations also mean that patients who are on waiting lists for elective surgery may have their operations further delayed, meaning that they too must live with a surgically treatable morbidity for a longer period of time.

Under-running operating lists result in the under-utilisation of the total available operating theatre time. There are significant fixed daily costs of running an operating theatre, thus frequent under-running of operating lists is expensive. [10] In a health system with finite resources, cost-saving by minimising the incidence of operating list under-runs would mean that more funds would be available for use in other important areas of the health system. Avoiding under-booking of operating lists would also mean that sick patients can be treated earlier and waiting time for other patients on elective surgery waiting lists can be reduced. [11]

The aims of this project are to understand the prevalence of over- and under-running operating lists and cancellations (which are associated with operating list over-runs) in a regional Queensland hospital, and to test if over- and under-booking are the main causes of operating lists running over- and under-time, respectively. Intuitively, poor scheduling is a potential cause of operating lists running off-schedule, but the current literature has not established whether it is any more important than other demonstrated causes of prolonged or shortened surgical duration, such as patient factors, surgical techniques or skills of the anaesthetist or surgeon. [12-14] If booking behaviour does indeed represent the main reason why operating lists run off-schedule, it could potentially be modified to minimise over- and under-runs.

One method of testing this hypothesis is to investigate if it can be predicted when an operating list will run over- or under-time by adding the average durations of procedures on that operating list (taking into account estimated time used for anaesthetics and turn-over between cases). Lists that predictably run off-schedule would likely to be due to scheduling errors (or intentional over- and under-bookings), while those that run off-schedule and cannot be predicted to do so through this model are likely to be caused by other factors that affect surgical duration.

Hypothesis

More than one quarter of the operating lists at the hospital will have a cancellation, and of those the majority would have been prospectively predicted to over-run. Around half of all operating lists will either over- or under-run, and that the majority of these would have been prospectively predicted to do so.

Methods

Using the regional Queensland hospital's Operating Room Management Information System (ORMIS), mean durations and turn-over times for all elective surgical procedures performed at the hospital from 1 March 2008 to 1 March 2009 were collected.

One hundred and twenty consecutive operating lists from the regional Queensland hospital between 1 April 2009 and 1 August 2009 were prospectively obtained. Only operating lists that contained operations or combinations of operations performed between 1 March 2008 and 1 March 2009 were included in this sample. A predicted duration was generated for each operating list by adding the estimated durations and turn-over times for the individual operations on that list. The possibility of using a regression model to increase the accuracy of list duration predictions was considered. However, a study by Wright *et al.* [15] compared the predictive accuracy on operating list duration of a model using only average durations of past operations with a regression model that included a number of patient and clinician factors known to affect surgical duration. This study found no significant difference in the predictive accuracy between the two models. [15] For the purposes of this study, it was decided that it would not be worth the significant investment in time to collect the additional data necessary to construct a regression model, considering that it is likely to offer no improvement in predictive accuracy over the model eventually used in this study.

The durations of each of the 120 operating lists were obtained by subtracting the actual starting time of the first procedure from the actual finishing time of the last procedure on each list. The allocated amount of time for operating lists at the regional Queensland hospital was 240 minutes. List durations equal to or longer than 260 minutes were classified as over-runs, and list durations that were equal to or shorter than 220 minutes were classified as under-runs. Those that were between 220 and 260 minutes were classified as on time. Although there is no widely accepted definition for on-time, over- and under-runs, the preliminary data collected for this project showed that a 20 minute margin was representative of the duration of some short surgical procedures, and thus would have some utility in demonstrating that over- and under-running lists could benefit from the omission or addition of a short procedure respectively.

Table 1. *Breakdown of lists without a cancellation, and the sensitivity and specificity of the model to predict which of these lists over-ran, under-ran, or ran on-time.*

	Operating lists without a cancellation (95% confidence intervals)		
Timing	**As a percentage of all lists that did not have a cancellation**	**Sensitivity of prediction**	**Specificity of prediction**
Over-run	45% (36-54%)	84% (65-94%)	82% (71-89%)
Under-run	37% (28-46%)	84% (62-94%)	85% (75-91%)
On-time	18% (11-25%)	73% (58-84%)	85% (73-93%)

The numbers of true on-time, over- and under-running lists were compared with the number of predicted on-time, over- and under-running lists to perform a sensitivity and specificity analysis.

Results

Twenty-eight percent (95% CI 19-37%) of the 120 operating lists suffered a cancellation, of which 79% (95% CI 75-83%) were predicted to over-run their scheduled duration. An analysis of all lists that did not suffer any cancellations is shown in Table 1. The sensitivities and specificities of the model to predict whether these lists over-ran, under-ran or ran on-time is also given. This gives an indication of the predictive power of the model – for example, a sensitivity of 84% for over-runs means 84% of lists predicted to over-run actually over-ran, and a specificity of 82% for over-runs means 82% of lists predicted not to over-run did not act actually over-run.

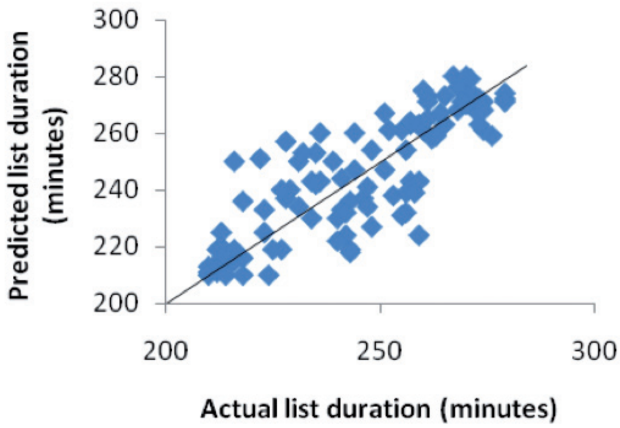

Figure 1. *Predicted duration of list plotted against actual duration of list (lists with cancellations are excluded). The diagonal line is the line of identity (predicted duration equals actual duration).*

This reasonably good ability of the computer estimates to predict operating list duration is shown graphically in Figure 1: the overall correlation coefficient, r is 0.83 ($r^2 = 0.68$; $p < 0.001$).

Tables 3 to 11 contain summary descriptive results for the types of procedures that were included in the 120 operating lists analysed in this study.

The procedures with the smallest coefficients of variation were haemorrhoidectomy (17%), excision of lesion of skin and subcutaneous tissue of foot (19%), incision of pilonidal sinus or cyst (10%), interruption of sapheno-femoral junction varicose veins (18%), hemithyroidectomy (17%), carpal tunnel release (18%), release of tendon sheath of hand (13%), total knee replacement (15%) and total hip replacement (17%).

The procedures with the largest coefficients of variation were arthroscopic repair of meniscus of knee (41%), closed reduction of fracture of distal radius with internal fixation (41%), decompression of subacromial space (37%), primary repair of nerve (39%), excision of lesion of skin and subcutaneous tissue of lip (44%), excision of lesion of skin and subcutaneous tissue of ear (42%).

Discussion

Data analysis

Consistent with expectations, more than one quarter (28%) of the operating lists in this study suffered a cancellation, and the vast majority of these (79%) were lists that were predicted by the model to over-run their scheduled time. This supports the notion that over-bookings leading to over-running operating lists are a significant cause of same-day surgery cancellations.

When the operating lists without cancellations were analysed, it was found that 45% over-ran and 37% under-ran their scheduled time. Only 18% of lists actually ran on-schedule. Although there is only limited published data on the prevalence of over- and under-running operating

Table 2. *Comparison of the prevalence of over-run, on-time and under-run operating lists.*

Timing	This study	Pandit *et al.* [1]	Widdison *et al.* [2]	Barr *et al.* [3]
Over-run	45%	53%	42%	21%
On-time	18%	10%	19%	47%
Under-run	37%	37%	39%	33%

lists in hospitals, the proportion of operating lists running off-schedule in this study can be compared to that of three United Kingdom (UK) hospitals as shown in Table 2. Side-by-side comparison shows that the regional Queensland hospital in this study had a greater proportion of over-runs and a lower proportion of on-time lists than all but the study by Pandit *et al.* [1] The proportions of under-runs were similar between all studies, which ranged from 33 to 39%. These findings show that over- and under-running of operating lists is at least as prevalent, if not more-so at the regional Queensland hospital in comparison to UK hospitals that have been previously studied.

Of the operating lists without cancellations that over- or under-ran scheduled time, the vast majority were prospectively predicted to over-run (84%) and under-run (84%), respectively. As the predictive calculations of the model in this project were based on the sum of estimated operation durations and their anaesthetic and turn-over times, these findings support the hypothesis that over-booking and under-booking are the main causes of operating lists running off-schedule, as opposed to other demonstrated causes of prolonged or shortened surgical duration (such as patient factors, surgical techniques, or skills of the anaesthetist or surgeon) affecting surgical duration that the model would not have accounted for. [12-14]

If booking errors occur because the people booking the operating lists do not know (or falsely believe that they know) the duration of the individual operations on those lists, a strategy that could be used to reduce these booking errors would be to use the similar methods of data collection employed in this study. Data about the average durations and variation in duration of all of the operations that a surgical team has performed in the past year can be presented to surgical teams to assist them in scheduling their operating lists. One study has shown that surgical teams that use predicted durations to schedule cases have fewer under-runs, over-runs and cancellations than teams that did not use predicted durations to schedule cases. [16]

It is important to recognise that booking errors may not be 'errors' at all, and that operating lists may be intentionally over- or under-booked. The possibility of intentional over- and under-bookings was raised by the findings of one study that showed surgeons who over-booked operating lists had very accurate estimates of the duration of individual operations (inclusive of anaesthetic durations) on their operating lists. [1] It has been suggested that lists may be intentionally over-booked in the face of pressures to reduce surgical waiting lists or meet hospital budgets. One study indicated that some surgeons over-book lists because there is a perception from their colleagues that booking fewer cases means they are 'not working hard'. [17] It has been suggested that lists may be intentionally under-booked for teaching purposes, low bed availabilities for post-operative care or to accommodate planned staff absences for meetings and other activities. [1,2] It is important to investigate in a follow-up study whether or not intentional over- and under-booking occurs, and if so, the reasons behind why it occurs must be identified as strategies may need to be tailored to address the specific underlying cause.

Other uses of surgical duration data

Data on durations of surgical procedures can be useful for costing services for the purposes of Medicare rebates. If the Medicare rebate for a given procedure is to reflect the cost of delivering the procedure, then procedure duration must be taken into account as it has been shown in many studies that staff hourly wages represent the greatest proportion of hospital costs. [10,18,19]

The collection of surgical duration data could be useful in allowing surgical teams to compare the present rate at which they complete their procedures with past performances. Analysis of these trends could help clinicians to identify patterns of change in their performances and identify the relationship of this to other key factors (such as changes in staff, use of equipment, surgical technique or patient load) so that changes can be made and clinical and economic outcomes improved.

Limitations

This study was performed in a regional hospital in Queensland, Australia. As a regional hospital, the scope of the operations performed at the hospital are narrower than that provided at a major metropolitan centre. Intuitively, with a narrower scope of operations, surgeons at a regional centre would be more accurate at estimating the duration of their operating lists compared with their metropolitan counterparts. The implications mean that generalisations based on the results in this study to a non-regional hospital may be limited. In addition, it should be noted that hospitals outside of Queensland may follow different protocols with respect to operating list scheduling (for example, in some hospitals the surgeon is not solely responsible for planning each operating list).

At the regional Queensland hospital in this study, only 240 minute (half-day) operating lists are used. This differs from some other hospitals, where 480 minute (full-day) operating lists are also utilised. According to the theatre administration, this is due to the limited number of operating rooms at the hospital and the need to accommodate the operating lists of all surgeons. The implication of not being able to analyse full-day lists in this study is that the differences in over- and under-running between half and full-day lists cannot be explored. This could be an area of interest for a follow-up study, as it is plausible that the surgeons may find it easier to estimate the duration of their half-day lists compared to longer full-day lists when scheduling their operations. [1]

At the hospital in this study, the start and finish time for each operation (from which the mean durations of operations are derived) are entered into the ORMIS computer system by a theatre staff member at the conclusion of each operation. Errors may have occurred where clock times are misread, finish times are estimated (i.e. the staff member enters the times into the computer before the operation is finished), or the data is entered incorrectly or not entered at all. However, errors of this kind were probably small in this study as a large database was used, where all data was checked to remove any obviously invalid entries such as those containing missing data, negative operation durations and impossibly short or long operation durations.

Conclusion

This study has shown that over- and under-booking are the most likely cause of operating lists running off-schedule. It is important to be aware that although over- and under-booking may not be the only causes of operating lists running off-schedule, they are significant and modifiable factors that if addressed correctly, could improve outcomes for patients (by reducing cancellations), doctors (by utilising their time more efficiently), and the health system (by reducing costs).

It is hoped that this study will be the catalyst for further research investigating the aetiology of booking errors, so that practical steps can be taken to avoid booking errors and minimise the negative consequences associated with them.

Conflicts of interest

None declared.

Acknowledgements

Dr. Diann Eley and Dr. Iliesa Beci for their support of this project, and Sylvia Johnson for her invaluable help with data collection.

Table 3. Orthopaedic hand operations.

	Carpal tunnel release (unilateral)	Palmar fasciectomy for Dupuytren's contracture involving 1 digit	Release of interphalangeal joint capsule for Dupuytren's contracture	Release of tendon sheath of hand	Open reduction of fracture of distal phalanx of hand with internal fixation
Mean duration in minutes	47	70	56	47	94.6
Median duration minutes	45	70	49	46	94
Standard deviation	8.4	22.7	19.9	6.3	25.4
Coefficient of variation	0.18	0.32	0.35	0.13	0.27
Sample size	181	14	6	5	7

Table 4. Orthopaedic arm and shoulder operations.

	Decompression of subacromial space	Closed reduction of fracture of distal radius	Closed reduction of fracture of distal radius with internal fixation	Repair of rotator cuff	Repair of rotator cuff with decompression of subacromial space
Mean duration in minutes	85	51	63	93	87
Median duration minutes	47	19	26	70	59
Standard deviation	31.3	10.7	25.9	24.2	20.5
Coefficient of variation	0.37	0.21	0.41	0.26	0.24
Sample size	5	53	17	14	20

Table 5. Arthroscopic knee procedures.

	Arthroscopy of knee	Arthroscopic debridement of knee	Arthroscopic meniscectomy of knee	Arthroscopic meniscectomy of knee with debridement, osteoplasty or chondroplasty	Arthroscopic repair of meniscus of knee	Arthroscopic reconstruction of cruciate ligament of knee with repair of meniscus
Mean duration in minutes	62.4	63.8	57.8	60.5	64.5	113.4
Median duration minutes	60	57.5	58	61	57.5	112
Standard deviation	17.1	19.0	12.6	12.8	26.6	34.2
Coefficient of variation	0.27	0.30	0.22	0.21	0.41	0.30
Sample size	132	20	16	14	6	13

Table 6. Joint replacements, ankle procedures, and primary repair of nerve.

	Total knee replacement	Total hip replacement	Revision of total arthroplasty of hip	Open reduction of dislocation of ankle with internal fixation	Open reduction of fracture of ankle	Open reduction of fracture of ankle with internal fixation of diastasis, fibula or malleolus	Primary Repair of nerve
Mean duration in minutes	123.4	113.5	169.8	97.2	102.8	103.2	70.0
Median duration minutes	122.5	116	172.5	106.5	105	102	65
Standard deviation	18.5	19.2	55.9	29.4	25.7	30.8	27.0
Coefficient of variation	0.15	0.17	0.33	0.30	0.25	0.30	0.39
Sample size	174	74	12	10	9	78	19

Table 7. General surgery of hernias.

	Laparoscopic repair of inguinal hernia, unilateral	Open repair of inguinal hernia, unilateral	Repair of umbilical hernia	Repair of incisional hernia	Repair of incisional hernia with prosthesis
Mean duration in minutes	89.4	80.7	69.4	101.1	125.3
Median duration minutes	90	78	68	94	122
Standard deviation	22.7	20.5	17.4	36.8	27.9
Coefficient of variation	0.25	0.25	0.25	0.36	0.22
Sample size	25	103	76	24	7

Table 8. *Appendicectomies and cholecystectomies.*

	Open appendicectomy	Laparoscopic appendicectomy	Laparoscopic cholecystectomy	Laparoscopic cholecystectomy proceeding to open cholecystectomy	Open cholecystectomy
Mean duration in minutes	79.4	94.6	103.1	116.8	111.7
Median duration minutes	76	90	99.5	117	101
Standard deviation	28.9	23.9	27.7	34.1	41.3
Coefficient of variation	0.36	0.25	0.27	0.29	0.37
Sample size	36	213	264	9	23

Table 9. *General surgery of breasts, thyroids, and varicose veins.*

	Mastectomy (including axillary node dissection)	Excision of lesion of breast	Total thyroidectomy	Hemithyroidectomy	Interruption of sapheno-femoral junction varicose veins
Mean duration in minutes	116.6	76.6	166.4	114.5	90.8
Median duration minutes	115	73	147	116	92.5
Standard deviation	24.0	25.3	57.4	20.0	16.4
Coefficient of variation	0.21	0.33	0.35	0.17	0.18
Sample size	39	75	26	23	10

Table 10. *Anterior resections, haemorrhoidectomies, and pilonidal sinus surgery.*

	Anterior resection	Haemorrhoidectomy	Excision of pilonidal sinus or cyst	Incision of pilonidal sinus or cyst
Mean duration in minutes	248.8	57.6	63.4	46.9
Median duration minutes	282	59	62	47
Standard deviation	62.6	9.5	14.1	4.6
Coefficient of variation	0.25	0.17	0.22	0.10
Sample size	5	17	15	19

Table 11. *Excision of lesion of skin and subcutaneous tissue.*

	Ear	Eyelid	Foot	Hand	Leg	Lip	Neck	Nose
Mean duration in minutes	70.9	60.5	51.8	64.4	57.2	63.9	65.3	72.6
Median duration minutes	66	58	52.5	56.5	56	52	62	71
Standard deviation	29.6	18.2	9.6	23.4	13.9	28.0	19.6	25.0
Coefficient of variation	0.42	0.30	0.19	0.36	0.24	0.44	0.30	0.34
Sample size	27	6	8	8	33	17	23	58

Correspondence

D Liu: david.liu@uqconnect.edu.au

References

[1] Pandit JJ, Carey A. Estimating the duration of common elective operations: Implications for operating list management. Anaesthesia 2006;61(8):768-76.
[2] Widdison AL. Can we predict when an operating list will finish? Ann R Coll Surg Engl 1995;77(6 Suppl):304-6.
[3] Barr A, McNeilly RH, Rogers S. Use of operating theatres. Br Med J (Clin Res Ed) 1982;285(6347):1059-61.
[4] Gordon T, Paul S, Lyles A, Fountain J. Surgical unit time utilization review: resource utilization and management implications. J Med Syst 1988;12(3):169-79.
[5] Schofield WN, Rubin GL, Piza M, Lai YY, Sindhusake D, Fearnside MR, *et al.* Cancellation of operations on the day of intended surgery at a major Australian referral hospital. Med J Aust 2005;182(12):612-5.
[6] Zafar A, Mufti TS, Griffin S, Ahmed S, Ansari JA. Cancelled elective general surgical operations in Ayub Teaching Hospital. J Ayub Med Coll Abbottabad 2007;19(3):64-6.
[7] Sanjay P, Dodds A, Miller E, Arumugam PJ, Woodward A. Cancelled elective operations: an observational study from a district general hospital. J Health Organ Manag 2007;21(1):54-8.
[8] Koppada B, Pena M, Joshi A. Cancellation in elective orthopaedic surgery. Health Trends 1991;23(3):114-5.
[9] Ivarsson B, Kimblad PI, Sjöberg T, Larsson S. Patient reactions to cancelled or postponed heart operations. J Nurs Manag 2002;10(2):75-81.
[10] Strum DP, Vargas LG, May JH, Bashein G. Surgical suite utilization and capacity planning: a minimal cost analysis model. J Med Syst 1997;21(5):309-22.
[11] Dexter F, Macario A. Applications of information systems to operating room scheduling. Anesthesiology 1996;85(6):1232-4.
[12] Hanss R, Roemer T, Hedderich J, Roesler L, Steinfath M, Bein B, *et al.* Influence of anaesthesia resident training on the duration of three common surgical operations. Anaesthesia 2009;64(6):632-7.
[13] Huber-Wagner S, Lefering R, Kay MV, Stegmaier J, Khalil PN, Paul AO, *et al.* Duration and predictors of emergency surgical operations - basis for medical management of mass casualty incidents. Eur J Med Res 2009;14(12):532-40.
[14] Howell SM, Deutsch ML. Comparison of endoscopic and two-incision techniques for reconstructing a torn anterior cruciate ligament using hamstring tendons. Arthroscopy 1999;15(6):594-606.
[15] Wright IH, Kooperberg C, Bonar BA, Bashein G. Statistical modeling to predict elective surgery time. Comparison with a computer scheduling system and surgeon-provided estimates. Anesthesiology 1996;85(6):1235-45.
[16] Pandit JJ, Westbury S, Pandit M. The concept of surgical operating list 'efficiency': a formula to describe the term. Anaesthesia 2007;62(9):895-903.
[17] Abouleish AE. Responding to 'You're inefficient – work faster!' American Society of Anesthesiologists' Newsletter 2003;67:9-10.
[18] Kendell J, Wildsmith JA, Gray IG. Costing anaesthetic practice: An economic comparison of regional and general anaesthesia for varicose vein and inguinal hernia surgery. Anaesthesia 2000;55(11):1106-13.
[19] Dexter F, Abouleish AE, Epstein RH, Whitten CW, Lubarsky DA. Use of operating room information system data to predict the impact of reducing turnover times on staffing costs. Anesth Analg 2003;97(4):1119-26.