Can J Anesth/J Can Anesth (2013) 60:1070–1076
DOI 10.1007/s12630-013-0025-5

REPORTS OF ORIGINAL INVESTIGATIONS

# Cohort study of cases with prolonged tracheal extubation times to examine the relationship with duration of workday

# Étude de cohorte des cas d'extubation trachéale prolongée pour étudier leur relation avec la durée des journées de travail

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Received: 30 May 2013 / Accepted: 15 August 2013 / Published online: 14 September 2013


**Abstract**

**Purpose** *The economics of the use of an anesthetic drug or device that produces benefit through reduction in operating room (OR) time depends on the day of the week and the total hours of surgical cases in the OR in which they are performed. Principally, this has to do with different durations of the regularly scheduled workday in the ORs within and among hospitals. We tested hypotheses relevant to the economic benefit of avoiding prolonged tracheal extubation times.*

**Methods** *Observational data were obtained from a multiple-specialty academic tertiary hospital that uses an anesthesia information management system. Prolonged tracheal extubation times were considered those with tracheal extubations occurring 15 min or more after the end of surgery. The assessment of prolonged tracheal extubation times was limited to cases for which the patient's trachea was intubated and extubated while physically in the OR. Percentages were calculated for each of n = 39 four-week periods. Results are reported as mean (standard error of the mean) of these percentages, and the phrases "at most/least" are used to refer to the corresponding 95% confidence limits.*

**Results** *At most, 6.1% [mean 5.5 (0.3)%] of the prolonged tracheal extubation times were attributable to cases that did not end during regular workdays from 7:00 AM-10:59 PM. At least 55.6% of prolonged tracheal extubation times occurred during cases on regular workdays and in an OR with more than eight hours of cases and turnovers [mean 57.0 (0.9)%; $P < 0.0001$]. This percentage was 23.8 (0.8)% larger than for all other cases.*

**Conclusions** *In the absence of an accurate facility-specific cost analysis, prolonged tracheal extubation times should not be treated as fixed costs but as resulting in proportionally increased OR variable costs.*

**Résumé**

**Objectif** *En anesthésie, les économies résultant de l'utilisation d'un médicament ou d'un dispositif qui entraîne des avantages en réduisant le temps en salle d'opération (SO) dépendent du jour de la semaine et du nombre total d'heures de cas chirurgicaux réalisés dans cette salle. Ces économies ont surtout à voir avec les différences de durée d'une journée de travail normale planifiée dans les SO à l'intérieur de chaque hôpital et entre les hôpitaux. Nous avons testé des hypothèses pertinentes aux avantages économiques liés à la prévention d'un délai d'extubation trachéale prolongés.*

**Méthode** *Nous avons obtenu des données observationnelles d'un hôpital tertiaire, universitaire et pluri-spécialisé qui se sert d'un système de gestion de l'information en anesthésie. Nous avons défini qu'il y avait*

**Author contributions** *Richard H. Epstein* and *Franklin Dexter* helped design the study. *Richard H. Epstein* helped conduct the study. He has access to the original data with protected health information. *Franklin Dexter* helped analyze the de-identified data. *Richard H. Epstein, Franklin Dexter,* and *Sorin J. Brull* helped write the paper.

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*délai d'extubation trachéale lorsqu'il se passait 15 min ou plus entre la fin de la chirurgie et l'extubation. Nous nous sommes limités aux cas pour lesquels la trachée du patient a été intubée et extubée alors qu'il était physiquement en SO. Des pourcentages ont été calculés pour chacune de n = 39 périodes de quatre semaines. Les résultats sont rapportés comme moyenne ± écart type de la moyenne de ces pourcentages, et les expressions « au plus / au moins » sont utilisées pour décrire les limites de confiance de 95 % correspondantes.*

**Résultats** *Au plus, 6,1 % des délais d'extubation étaient attribuables à des cas qui ne se sont pas terminés pendant les journées de travail normales, soit de 7 h à 22 h 59 (5,5 % ± 0,3 %). Au moins 55,6 % des délais d'extubation sont survenus pendant des cas lors des journées de travail normales et dans une SO avec plus de huit heures de cas et de roulements (57,0 % ± 0,9 %, P < 0,0001). Ce pourcentage était de 23,8 % ± 0,8 % plus élevé que pour tous les autres cas.*

**Conclusion** *En l'absence d'une analyse des coûts précise spécifique à l'institution, les délais d'extubation trachéale ne devraient pas être traités comme des coûts fixes mais comme résultant en des coûts variables de SO augmentant proportionnellement.*

The economics of use of an intervention that produces benefit through reduction in operating room (OR) time depends on the day of the week and the hours of cases in the OR in which the intervention is applied.[1-5] Analyses can be performed when targeting specific ORs for reductions in turnover times, surgical times, and first-case of the day starts.[2,3,5] A screening process can be used to decide whether a comprehensive analysis is warranted.[4] The screening process identifies ORs where focused efforts to ensure on-time first case of the day starts may have value.[4] In the current paper, we evaluate *screening criteria*, not for specific ORs but for events associated with tracheal extubations.

Prolonged tracheal extubation times are considered those in which tracheal extubations occur 15 min or more after the time of the end of surgery.[6-8] Approximately 15% of tracheal,extubations take 15 min or longer.[6,8] We tested whether a hospital choosing not to perform a full economic analysis,[2,3] should treat the cost of prolonged tracheal extubations as fixed or variable.

Suppose that most prolonged tracheal extubations occur during urgent cases. For example, a patient is seen in the emergency room for post-tonsillectomy bleeding on Saturday at 8 AM. The patient is promptly brought to the surgical suite, undergoes rapid sequence tracheal intubation, and the surgery is completed 20 min later. On emergence, the patient takes 15 min to awaken. Hospitals appropriately plan extra capacity for urgent cases.[9-15] Reducing the incidence of prolonged tracheal extubations in this setting will not reduce labour costs because those costs are fixed at a high level, as hospitals must have the ability to treat the number of urgent patients present on the busiest of days.[10,13,14] The costs are said to be fixed because they are not dependent on the actual number of cases.

> Hypothesis #1: Few (e.g., ≤ 10%) prolonged tracheal extubation times are attributable to cases that end late nights, early mornings, weekends, or holidays (i.e., not regular workdays 7:00 AM to 10:59 PM).

If Hypothesis #1 were rejected, there would be little value to full economic analysis quantifying the effect of a drug, device, or intervention on the incidence of prolonged tracheal extubation times.

On workdays, the cost of a change in OR time depends on the total hours in the ORs for which the drug or device reducing OR time is used.[8] This has to do with different durations of the regularly scheduled workday in the ORs within and among hospitals. The total hours of cases and turnovers in each OR differ more than twofold, not only among hospitals within the same country but also among ORs within hospitals.[16-18] The full cost analysis can be performed using data from randomized trials and the hospital's OR information system.[3,4,8,19-21]

Suppose that essentially all (e.g., > 90%) ORs at a hospital have more than 8 hours of cases each workday. Then, OR time is a variable cost.[3,4,22] Furthermore, hospitals with long workdays typically have surgeons who fill an OR for the day in which they operate.[18] Thus, there is a rationale for anesthesia providers caring for these patients to reduce the chance that tracheal extubation times will be prolonged.

> Hypothesis #2: Most (e.g., > 50%) prolonged tracheal extubation times occur during cases on regular workdays and in an OR with more than eight hours of cases and turnovers.

If Hypothesis #2 were accepted, then reducing the incidence of prolonged tracheal extubation times could reduce costs. There would be value to performing a full economic analysis quantifying the extent to which a drug or device reduces (or not) the incidence of prolonged tracheal extubation times, because such reductions in incidence could be reducing variable costs.

Suppose that, in contrast, many of a hospital's ORs have fewer than eight hours of cases every workday (i.e., Hypothesis #2 was rejected).[23,24] It follows that OR time can reasonably be treated as a fixed cost.[1-8] In addition, completing more cases should be unexpected because

small (e.g., five minutes) reductions in time are insufficient for reliably scheduling additional cases.[25,26] Overall revenue far exceeds variable costs because of the large fixed costs of surgical care,[27-29] and not performing a scheduled case increases net societal costs.[30,31] Consequently, the small reductions in OR time achieved by reducing the incidence of prolonged tracheal extubation times would reasonably be treated as having no economic benefit.

## Methods

The Thomas Jefferson University Institutional Review Board approved this observational study at its affiliated academic hospital without a requirement for informed consent. The hospital is a multiple-specialty academic hospital that uses an anesthesia information management system (Innovian®, Dräger, Telford, PA, USA).[32,33] Patients receiving care in the hospital's freestanding outpatient surgery centre and in non-OR locations (e.g., endoscopy suites) were excluded because few of those patients received general anesthesia with tracheal intubation.

The data were collected from a period of three years, November 2009 through December 2012 (i.e., 39 four-week periods) (Table 1). The data elements in the SQL Server database (Microsoft, Redmond, WA, USA) included the dates and times of patient entry into the OR, tracheal intubation, end of surgery, tracheal extubation, and exit from the OR. They were processed using Structured Query Language (Transact-SQL, Microsoft, Redmond, WA, USA).

Whether the patient had a prolonged time to tracheal extubation was determined using the times of tracheal intubation, end of surgery, and tracheal extubation. Cases were excluded in which the patient's trachea was not intubated and extubated while the patient was physically in the OR. For example, we determined whether the patient underwent tracheal intubation prior to arrival from the time of patient entry into the OR and the time of tracheal intubation. We expected that small inaccuracies in documented times (e.g., a one- or two-minute difference between the time when tracheal extubation occurred *vs* the time documented in the patient record) would not affect results since they affect neither the day of the week on which the patient entered the OR nor the hour of the day at which tracheal extubation occurred. To assess the potential impact of such inaccuracy, we performed a sensitivity analysis using 8:59 PM as the end of workday rather than 10:59 PM (Table 2).

For evaluating Hypothesis #2 from the dates and times of all patients' entries and exits from ORs, we calculated

**Table 1** Characteristics of the cases studied [mean (standard error of the mean) among 39 four-week periods]

| | All cases[a] | Prolonged tracheal extubation | |
|---|---|---|---|
| | | No | Yes |
| Intubated and extubated in operating room[a] | 44.6 (0.2)% | 100% | 100% |
| Cases per week[a] | 702 (6) | 222 (2) | 42 (1) |
| Cases per workday | 137 (1) | 43.8 (0.4) | 8.1 (0.2) |
| Rooms used an average of at least once per workday | 45.3 (0.2) | 24.2 (0.4) | 1.0 (0.0) |
| Surgeons averaging $\geq$ 1 case per workday | 54.0 (0.7) | 9.5 (0.3) | 1.0 (0.0) |
| Surgeons averaging $\geq$ 1 case per week | 122.7 (0.9) | 74.0 (0.7) | 15.7 (0.6) |
| Procedures with an average $\geq$ 1 case per week | 138.1 (1.3) | 64.1 (1.1) | 7.0 (0.5) |
| Operating room time (case duration) in hours % longer duration than cases without prolonged extubation | 1.88 (0.01) | 2.76 (0.01) | 3.61 (0.04) |
| Age (yr) | 55.0 (0.1) | 52.3 (0.2) | 52.1 (0.3) |
| Weight (kg) | 81.1 (0.1) | 81.8 (0.1) | 80.8 (0.3) |
| Body mass index ($kg \cdot m^{-2}$) | 28.3 (0.1) | 28.5 (0.1) | 28.1 (0.1) |
| General surgery (% of operating room hours) | 18.7 (0.2)% | 21.4 (0.3)% | 17.4 (0.7)% |
| Orthopedics (% of operating room hours) | 14.9 (0.2)% | 17.8 (0.3)% | 17.8 (0.7)% |
| Otolaryngology (% of operating room hours) | 21.1 (0.2)% | 18.8 (0.3)% | 18.7 (0.6)% |
| Scheduled cases (% of operating room hours) | 95.0 (0.1)% | 96.2 (0.1)% | 94.4 (0.3)% |
| Performed on workday (% of operating room hours) | 97.6 (0.1)% | 98.1(0.1)% | 96.8 (0.2)% |
| Prone | 9.1 (0.1)% | 14.0 (0.2)% | 25.8 (0.7)% |
| Male | 46.3 (0.2)% | 46.1(0.3)% | 53.1(0.6)% |
| American Society of Anesthesiologists' Physical Status III-IV | 43.1 (0.3)% | 45.5(0.5)% | 53.1(0.8)% |

The statistics were calculated using batch means (i.e., means of means) and thus follow normal distributions[33-36]

[a] The "All Cases" column includes all cases at the surgical suite, including the patients without tracheal intubation and extubation

the total hours of cases and turnovers in each OR on each workday.[2-4] Evaluating whether the total exceeds eight hours applies regardless of whether staffing is planned for eight hours, ten hours, or longer (e.g., use of a second shift of staff).[3,4] A full economic analysis is related to the calculation that each five minutes of reduced OR time results in saving of approximately six minutes of (expensive) OR time.[3,4,22] The reduction is $> 5$ min because some of the time reduction is overutilized OR time; however, the reduction is $< 7.5$ min (i.e., a typical "time and a half" rate) because most of the cost reduction is accrued by reducing staffed hours (e.g., fewer 12-hr shifts in lieu of ten-hour shifts).[3,4]

We made two decisions designed for deliberately underestimating the duration of the workday and thereby reducing the chance that Hypothesis #2 would be satisfied. First, if the to-follow case was non-elective and the turnover time exceeded 90 min, neither the turnover time nor the to-follow case was included. Second, if the turnover time between elective cases was longer than 90 min, it was set equal to 90 min.[2,3] These 1.8 (0.1)% of turnovers that were very prolonged (i.e., > 90 min) were likely caused by cancelled or rescheduled cases causing non-sequential scheduling [mean (standard error of the mean) of the percentages].[34]

Each hypothesis has one end point based on a proportion (e.g., percentage of prolonged tracheal extubation times that occurred during cases on regular workdays and in an OR with more than eight hours of cases and turnovers). The master surgical schedule influences which surgeons work on which days and thereby results in the presence of prolonged tracheal extubation times to be clustered by time of day and day of the week.[35] Consequently, the statistics were calculated using the method of batch means,[34-37] specifically, by pooling the proportions among four-week periods. For each of the two proportions (i.e., one per hypothesis), Visual Basic for Applications in Excel 2010 was used to perform the Freeman-Tukey transformation for every four-week period (Microsoft, Redmond, WA, USA). The denominator was sufficiently large (108 cases for each of the 39 periods) for the transformation to be appropriate. The mean and the lower confidence limit were calculated using Student's one-sample $t$ test, and then the inverse of the Freeman-Tukey transformation was performed analytically.[37,38] The upper (Hypothesis #1) and lower (Hypothesis #2) 95% confidence limits for the corresponding percentages were calculated using the $n = 39$ four-week periods and are described by the phrases, "at least/most". The $P$ values testing the hypotheses were Bonferroni adjusted for the two comparisons.

## Results

The characteristics of the surgical suite studied, surgeons' scheduling patterns, and patients are summarized in Table 1.

At most, 6.1% of prolonged tracheal extubations were attributable to cases that did not end during regular workdays from 7:00 AM to 10:59 PM. In other words, only 5.5 (0.3)% of prolonged tracheal extubations occurred late nights, early mornings, weekends, or holidays (Table 2). Hypothesis #1 is supported ($P < 0.0001$).

At least 55.6% of prolonged tracheal extubations occurred during cases on regular workdays and in an OR with more than eight hours of cases and turnovers [57.0 (0.9)%]. Hypothesis #2 is supported ($P < 0.0001$). This percentage was 23.8 (0.8)% larger than for all other cases (i.e., the hospital's impressions based on the overall percentage of ORs with more than eight hours of cases and turnovers should not be applied to cases with prolonged tracheal extubation times).

## Discussion

For a financial decision that involves small reductions in OR time only for a subset of cases, many hospitals would need to perform a full analysis if seeking accurate cost

**Table 2** Study end points [mean (standard error of the mean) among 39 four-week periods]

| | All cases[b] | Prolonged tracheal extubation | |
|---|---|---|---|
| | | No | Yes |
| Case ended during regular workday from 7:00 AM to 10:59 PM[a] | 97.5(0.1)% | 96.5(0.1)% | 94.5(0.3)% |
| Case ended during regular workday from 7:00 AM to 8:59 PM[a] | 96.8(0.1)% | 95.4(0.2)% | 92.9(0.4)% |
| Case occurred during regular workday and in an operating room with more than 8 hr of cases and turnovers[a] | 34.6(0.4)% | 52.0(0.6)% | 57.0(0.9)% |

[a] Percentages are reported after transformation as described in the last paragraph of the Methods. We used 10:59 PM as our base analysis considering that an anesthesiologist working that late might do cases the next workday. The 8:59 PM is included as a sensitivity analysis

[b] The "All Cases" column includes all cases at the surgical suite, including the patients without tracheal intubation and extubation. This column is used in the last sentence of the Results

identification.[2-4,8,19] The cost of performing a full analysis should be balanced against the potential cost of making an incorrect decision without such an analysis. In the absence of a full analysis for the economics of prolonged tracheal extubation times, our results show that hospitals in which most ORs schedule more than eight hours of cases and turnovers should treat OR time as a variable cost, not a fixed cost (see Introduction). For the many ambulatory surgery centres in which all ORs have less than eight hours of cases per day, time can be treated as a fixed cost. Even for most of the cases at the studied hospital's tertiary ORs (65%), OR time should be treated as a fixed cost, but not for cases with prolonged tracheal extubation times (Table 2). From Reference[3], each five-minute reduction in intraoperative time should be treated as reducing costs, and the reduction is approximately 20% larger than the cost per five minutes of OR time (see Introduction). Our results are important because tracheal extubation times differ significantly among anesthetic drugs (e.g., from meta-analysis of randomized trials, $\geq$ 95% reduction in the incidence of prolonged tracheal extubation times with desflurane *vs* isoflurane).[8,20,21] Nevertheless, our results are limited in being heterogeneous among hospitals (i.e., they are *screening criteria* to be used by facilities to choose whether or not to perform a full facility-specific analysis).[2,4,19]

We focused on prolonged tracheal extubation times because their incidence is increased by large mean tracheal extubation times, large standard deviation of tracheal extubation times, or both.[8,21] The incidence of prolonged tracheal extubation times contains the same statistical information as the mean and standard deviations of tracheal extubation times.[A] Prolonged tracheal extubation times can be assessed retrospectively from data in the anesthesia information management system or prospectively from observation in ORs.[6,8] Prolonged tracheal extubation times are particularly common (> 20%) among long cases (e.g., four to six hours) performed in the prone position (e.g., spine surgery).[35] The mean times from end of surgery to OR exit are at least (95% lower confidence limit) 11.3 min longer when the tracheal extubation time is prolonged, whether stratified by duration of surgery and positioning (prone or not), procedure, or surgeon.[35]

[A] For example, Fig. 3 of Reference[8] shows a surgeon's extubation times, mean 9.27 min and standard deviation 5.68 min. All extubation times combined followed a Weibull distribution ($P = 0.58$), but extubation times longer than the mean of 9.27 min followed a folded normal distribution ($P = 0.45$). To calculate the percentage of extubation times that were prolonged, the Z-score = (15-9.27)/5.68 = 1.01. Taking 100% minus the inverse of the cumulative normal distribution for that Z score gives 15.7% prolonged extubation times. This model was accurate for that surgeon (actual 15.3%) and all surgeons [bias 0.7 (0.2)%].

Our study was limited to the valuation of the time associated with prolonged tracheal extubation. Prolonged tracheal extubation times have other economic values depending on the perspective of the analysis (e.g., hospital *vs* physician). Cases with prolonged tracheal extubation times have a greater chance of members of the OR team waiting for tracheal extubation (i.e., slowing workflow).[6] Cases with prolonged tracheal extubation times also have longer times from OR exit to the start of the surgeon's next case in the OR.[8] When surgeons score anesthesiologists' attributes on a scale from 0 = "no importance" to 4 = "a factor that would make me switch groups/ hospitals", their average score is 3.9 for "patient quick to awaken".[39] Cases with prolonged tracheal extubation times are rated by anesthesiologists as having poor recovery from anesthesia.[7]

Our reported *P* values were limited to two cut points, 10% for Hypothesis #1 and 50% for Hypothesis #2. Readers may choose any other value. We found that 5.5 (0.3)% of prolonged tracheal extubation times occur late nights, early mornings, weekends, and holidays. Readers from a hospital that would consider even 80% of prolonged tracheal extubation times during the workdays to be worth examining would then also conclude that local incidences of prolonged tracheal extubation times should be measured. We found that 57.0 (0.9)% of prolonged tracheal extubation times occurred during cases on regular workdays and in an OR with more than eight hours of cases and turnovers. Readers from a hospital that can implement changes targeted to specific ORs (e.g., use displays in specific ORs) may accept a test of Hypothesis #2 with a lower threshold that, under those circumstances, would result in stronger conclusions.

Finally, although in the current article we limited consideration to the economics of prolonged tracheal extubation times, the same concepts and analysis can be applied to evaluate other variables that may result in prolongation of surgical cases (e.g., pharmacokinetic model-driven control of total intravenous anesthesia or reversal of neuromuscular blockade).

**Acknowledgements** We appreciate discussions with Eric M. Maiese Ph.D., Merck Global Health Outcomes during study design and value his recommendations on the paper.

**Funding** This study was funded in part by Merck Sharp & Dohme Corp., a subsidiary of Merck & Co., Inc., Whitehouse Station, NJ.

**Conflicts** Richard H. Epstein is President of Medical Data Applications, Ltd., which developed software licensed by the University of Iowa when it performed the analyses mentioned in the Discussion. The University of Iowa performs the analyses described in the Discussion for hospitals and companies. Income from the Division's consulting work is used to fund Division research. Franklin Dexter has tenure and receives no funds personally, including honoraria, other than his salary and allowable expense reimbursements from the University of Iowa. Dr. Dexter and his

family have no financial holdings in any company related to his work other than indirectly through mutual funds for retirement. Sorin J. Brull serves as a member of the Global Advisory Board for Merck, Inc. He and his family have no financial holdings in any company related to this work other than indirectly through mutual funds for retirement.

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