Systematic Review of General Thoracic Surgery Articles to Identify Predictors of Operating Room Case Durations

Franklin Dexter, MD, PhD*†

Elisabeth U. Dexter, MD, FACS‡

Danielle Masursky, PhD§

Nancy A. Nussmeier, MD§

BACKGROUND: Previous studies of operating room (OR) information systems data over the past two decades have shown how to predict case durations using the combination of scheduled procedure(s), individual surgeon and assistant(s), and type of anesthetic(s). We hypothesized that the accuracy of case duration prediction could be improved by the use of other electronic medical record data (e.g., patient weight or surgeon notes using standardized vocabularies).

METHODS: General thoracic surgery was used as a model specialty because much of its workload is elective (scheduled) and many of its cases are long. PubMed was searched for thoracic surgery papers reporting operative time, surgical time, etc. The systematic literature review identified 48 papers reporting statistically significant differences in perioperative times.

RESULTS: There were multiple reports of differences in OR times based on the procedure(s), perioperative team including primary surgeon, and type of anesthetic, in that sequence of importance. All such detail may not be known when the case is originally scheduled and thus may require an updated duration the day before surgery. Although the use of these categorical data from OR systems can result in few historical data for estimating each case's duration, bias and imprecision of case duration estimates are unlikely to be affected. There was a report of a difference in case duration based on additional information. However, the incidence of the procedure for the diagnosis was so uncommon as to be unlikely to affect OR management.

CONCLUSIONS: Matching findings of prior studies using OR information system data, multiple case series show that it is important to rely on the precise procedure(s), surgical team, and type of anesthetic when estimating case durations. OR information systems need to incorporate the statistical methods designed for small numbers of prior surgical cases. Future research should focus on the most effective methods to update the prediction of each case's duration as these data become available. The case series did not reveal additional data which could be cost-effectively integrated with OR information systems data to improve the accuracy of predicted durations for general thoracic surgery cases.

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Prediction of operating room (OR) case durations using historical data is most accurate when the average is taken of the durations of historical cases with the same combination of scheduled procedure(s), individual surgeon and assistant(s) who will perform the procedure(s), and type of anesthetic(s).[1–3] Still, there is residual inaccuracy in case duration estimates. There are two components to inaccuracy of the durations of multiple cases with the same predicted duration: bias and imprecision. An example of bias is all cases taking 8 min less than their predicted durations.[4] An example of imprecision is half of cases taking 30 min less than their predicted durations and the other half taking 30 min longer than their predicted durations. By far, the largest source of inaccuracy in predicted case durations is imprecision, not bias.[5]

The imprecision of the actual durations of cases with the same predicted duration can result in facilities having long patient and surgeon waiting times on the day of surgery.[3,5] To mitigate late starts, managers appropriately compensate by budgeting extra OR capacity (i) to permit scheduled buffers of time between surgeons' successive lists of cases and (ii) to facilitate the movement of cases from one OR to another.[1,3] However, the mitigation is costly and imperfect. Ideally, the imprecision itself would be reduced.

Reliance on the triad of procedure(s), surgeon, and anesthetic when estimating case duration is based

From the Departments of *Anesthesia and †Health Management and Policy, University of Iowa, Iowa City, Iowa; and Departments of ‡Surgery, and §Anesthesiology, SUNY Upstate Medical University, Syracuse, New York.

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Address correspondence and reprint requests to Franklin Dexter, MD, PhD, Division of Management Consulting, Department of Anesthesia, University of Iowa, Iowa City, IA 52242. Address e-mail to Franklin-Dexter@UIowa.edu or www.FranklinDexter.net.

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heavily on studies of OR information systems data.[1–3] In this paper, we try to discover additional predictors of case duration by systematically reviewing observational studies that included data from sources such as medical records (e.g., surgeons' notes written with standardized vocabularies), preanesthesia evaluation forms (e.g., patient weight), and radiology picture archiving and communication systems (e.g., tumor location). Integration of such clinical data with OR information systems might improve the accuracy of case duration prediction for a sufficient number of different procedures as to be cost-effective.

We used general thoracic surgery as a model specialty to discover what additional data could improve the accuracy of predictions of case durations for many cases. Because general thoracic cases are typically long and elective (scheduled), the imprecision in predicted durations influences how many hours of cases are scheduled in each OR each day. Thus, we expected the general thoracic surgical literature to be stocked with case series that used operative duration and other components of case durations as reported end-points.

METHODS

PubMed was searched on July 6, 2007, for general thoracic surgery articles that included data on one or more components of case duration. The following search protocol was used:

- (pulmonary surgical procedures[MeSH Terms] OR mediastinoscopy[MeSH Terms] OR thoracoscopy[MeSH Terms] OR thoracotomy[MeSH Terms] OR esophagectomy[MeSH Terms] OR esophagectomy[Text Word] OR oesophagectomy[Text Word] OR pneumonectomy[Text Word] OR ((“lung”[MeSH Terms] OR lung[Text Word]) AND lobectomy[All Fields])) AND
- (case duration* OR procedure duration* OR surgical duration* OR operating room time* OR operative time* OR surgical time* OR anesthesia time* OR theater time* OR anesthesia time*).

The search yielded 347 abstracts, which were screened according to the following criteria:

- A numeric result was reported for any end point in the abstract (e.g., qualitative reviews were excluded),
- A procedure was performed on humans in operating rooms (e.g., not veterinary surgery or human femurs *in situ*),
- Surgery was not limited to the heart (i.e., appeared just from MeSH term “thoracoscopy” or “thoracotomy”), and
- Statement was made of a difference between groups in at least one of the preceding end-points.

No restrictions were placed on the language, year, or quality of the article. Studies were excluded that presented before/after groups as assessing trends over time (e.g., last decade to this decade). Studies were included that presented before/after groups as assessing historical control versus new intervention (e.g., older data for an older procedure to newer data for a new procedure).

The search yielded 71 abstracts, whose full papers were read and further screened according to the following criterion:

- The estimated mean or median difference between groups was reported for any of the above end points and was said to be significantly different from zero ($P < 0.05$), according to whatever statistical method the authors picked.

For articles that included two means and standard deviations, and stated that the difference was statistically significant, but did not report a P value, we performed Student's t-test ourselves. However, articles were excluded in which group comparisons included differences in the numbers of procedures performed (e.g., mediastinoscopy followed by lung resection as two sequential surgical cases versus one surgical case). We already know that performing multiple procedures will take at least as long as the longest of the individual procedures, and numbers of procedures do not represent additional data obtainable from electronic medical records.[6]

RESULTS

There are differences in case duration based on the type of procedure(s), surgeon and assistant(s) performing the procedure, and the type of anesthetic used. For type of procedure(s), multiple studies report differences in components of case duration based on different anatomic procedures used for the same medical condition (Table 1)[7–15] and based on different methods or approaches used to achieve the same anatomic result (Table 2)[16–38]. For surgeon, day-to-day differences in case duration result from varying composition of the surgical team (Table 3),[39–42] but not from surgical technique (Table 4)[43–48] since each surgeon tends to select one technique over another. For type of anesthetic, differences are also reported (Table 5).[49–53]

Tables 1–5 are ordered in declining sequence of the median differences in case duration. The sequence matches the relative impact expected from prior analyses of OR information system data.[2] Different anatomic results have the largest impact (Table 1), surgical approach the second largest (Table 2), and so forth.

The information shown in Tables 1–5 are not all used when cases are originally booked at some facilities (e.g., those of the authors). For example, Table 2 includes the surgical approach, which may be decided only once all imaging is available. Table 3 includes the complete surgical team, most of who may not be known until the working day before surgery. Table 5

Table 1. Impact of Anatomic Differences in the Surgical Procedure on Average Operative Times

Procedure	Difference	Difference in mean time (min)	Reference
Esophagectomy	Transthoracic versus transhiatal	168	7
Repair of pectus excavatum	Open versus minimally invasive	128	8
Esophagectomy	Transthoracic versus transhiatal	114	9
Esophagectomy	Transthoracic versus transhiatal	114	15
Esophagectomy	Transthoracic versus transhiatal	108	14
Mediastinoscopy	Transcervical extended mediastinal lymphadenectomy versus cervical mediastinoscopy	93	13
Esophagectomy	Colonic conduit versus gastric pull-up	80	12
Splanchnicectomy	Bilateral versus unilateral left	36	11
Lung resection	Mediastinal lymph node dissection versus lymph node sampling	15	10

The differences in time studied were operative times,[7,10–11,12,14,15] procedure times,[13] or unspecified.[8] The first procedure of each pair in the difference column was the procedure with the longer average mean time.

includes the specific type of anesthetic, which may not be known until after completion of the preanesthesia evaluation and assignment of the anesthesiologist. Thus, routine usage of the information listed in Tables 1–5 would generally involve changes to the prediction of case duration as data are updated.

The use of all of the data from Tables 1 to 5 to select historical cases from the OR information system to use to predict a future case's duration can result in there being few historical case durations for each future case. Depending on each facility's relationship between how a case is scheduled and the selection of the surgeon preference card(s), the consequence can be a reduction in how often each preference card is used. Having many preference cards can contribute to inaccuracies and infrequent updates, even for components such as medications for which inaccuracy can harm patients.[54] Table 6 shows that small sample sizes themselves are unlikely to contribute paradoxically to increased bias and imprecision in predictions of case durations (e.g., from intraoperative delays).

By analyzing OR information system data, it is not possible to judge whether a predictor of case duration (e.g., anesthetic) is causing the difference or is just a marker for an underlying patient characteristic, disease characteristic, etc., that is an actual cause of the difference in case duration and would itself be a more accurate predictor. The preceding 45 studies had many such characteristics that were known preoperatively and that were compared statistically between the groups for which there were large differences in case duration (Tables 1–5). Table 7 shows that almost all of the characteristics did not differ significantly between groups. Thus, the previously identified predictors of case duration (Tables 1–5) were, in fact, directly causing the differences, not serving simply as markers for individual data in Table 7. If one or more of the characteristics in Table 7 were used for case duration prediction, their use would need to be in addition to the data in Tables 1–5, not in lieu of one or more of those data.

Our original goal had been to identify other types of electronic data such as those in Table 7 that could be used for cost-effective improvement in the accuracy of case duration prediction. Table 8 summarizes the only three studies that reported statistically significant differences in components of case duration based on criterion other than those in Tables 1–5.[9,55,56] Two of these studies[55,56] dealt with an urgent procedure, making the imprecision of the estimate of case duration typically irrelevant to OR management decision making. The other study[9] used data that would be in physician notes and/or picture archiving and communication systems: transhiatal esophagectomy for resection of laryngocervical tumors took an hour longer than for lower thoracic tumors. However, the incidence of the procedure for laryngocervical tumors is likely only around two cases per year per 1 million population (Table 8),[57,58] making the finding of limited relevance to OR management.

DISCUSSION

Four Implications of Our Findings

First, although we used an entirely different approach to evaluating differences in case duration than the statistical analysis of OR information system data for all cases at a facility,[1–6] the results were strikingly similar.

Second, the data stored in OR information systems are the principal ones needed for the prediction of durations for most cases (Tables 1–5). The cost of adding data from other information systems such as electronic medical records would be fixed regardless of the few cases for which benefits may accrue. Thus, to improve the accuracy of estimates, initial efforts should focus on the most effective methods and computer–human interfaces to determine and use the data already[1–6] known to be important (Tables 1–5),

Table 2. Impact of Surgical Approach on Average Operative Times

Procedure	Difference in surgical approach	Difference in mean time (min)	Reference
Thymectomy for the treatment of myasthenia gravis	Bilateral thoracoscopy versus extended transsternal approach	145	21
Anterior instrumented fusion for idiopathic thoracic scoliosis in	Thoracoscopy versus thoracotomy	125	23
Anterior instrumented correction for idiopathic thoracic scoliosis	Thoracoscopy versus mini-open thoracotomy	114	24
Thymectomy for myasthenia gravis	Thoracoscopy with sternal lifting versus median sternotomy	91	19
Lobectomy for lung cancer	Thoracoscopy versus thoracotomy	79	31
Heller myotomy for esophageal achalasia	Thoracoscopy versus laparoscopy	74	26,27
Lobectomy for lung cancer	Thoracoscopy versus thoracotomy	73	25
Thymectomy for myasthenia gravis	Sternotomy versus thoracoscopy	68	22
Bilateral sequential lung transplantation	Clamshell incision versus bilateral anterolateral thoracotomy without sternal division	65	28
Excision of benign neurogenic mediastinal tumors	Thoracoscopy versus thoracotomy	59	32
Debridement of complex empyema	Thoracotomy versus thoracoscopy	49	29
Lung wedge resection for nodules	Thoracotomy versus thoracoscopy	46	31
Anterior spinal surgery for scoliosis	Thoracotomy versus thoracoscopy	38	16
Pericardial window	Thoracoscopy versus subxiphoid approach	36	20
Repair of foramen of Morgagni congenital diaphragmatic hernia	Thoracotomy versus hand-assisted thoracoscopy	25	17
Lung wedge biopsy for diffuse lung disease	Thoracoscopy versus thoracotomy	24	35
Repair of persistent ductus arteriosus	Thoracotomy versus thoracoscopy	22	18
Lobectomy for lung cancer	Thoracoscopy versus thoracotomy	22	36
Lung wedge biopsy diffuse lung disease	Thoracotomy versus thoracoscopy	20	33
Lung resection & pleurectomy for spontaneous pneumothorax	Thoracotomy versus mini-thoracotomy	16	37
Pleurectomy for treatment of recurrent spontaneous pneumothorax	Thoracoscopy versus thoracotomy	16	34
Lung wedge biopsy for diffuse lung disease	Thoracotomy versus thoracoscopy	15	30
Lung wedge biopsy for diffuse lung disease	Thoracotomy versus thoracoscopy	10	38

The differences in time studied were operative times,[16–17,18,21–22-38] anesthesia time[20] or unlisted.[19] Refs. 16, 23, and 24 were included because the average numbers of discs excised did not differ between groups. The first surgical approach of each pair in the difference column was the approach with the longer average mean time.

not searching for more data. We speculate that many facilities are using the information in Tables 1, 2, and 4, but need to add use of their knowledge of staff assignment (Table 3) and type of anesthetic (Table 5).

Third, because case durations have marked uncertainty, there is no singular "*the duration*." Because the decision whether to perform a case in a specific OR at a specific facility on a specific day tends to be affected little by inaccuracy in predicted case duration,[2–5] obtaining all of the information at the time the case is scheduled is unnecessary. In contrast, close to the day of surgery, decisions (e.g., case sequencing)[2,3] depend on the longest and shortest times that cases may take and are sensitive to inaccuracy in case duration prediction. We recommend that for decisions made the working day before surgery, the original prediction of case duration not be used, but a more accurate prediction including the additional data then available, such as the expected perioperative team (Table 3) and anesthetic (Table 5).

Table 3. Impact of Surgical Team on Average Operative Times

Procedure	Difference	Difference in mean time (min)	Reference
Transcervical-subxiphoid thoracoscopic "maximal" thymectomy without sternotomy	One surgeon versus two surgical teams working simultaneously	40	39
Thoracoscopic lobectomy	Trainees' performing their 1st to 46th cases versus experienced surgeon	39	40
Thoracoscopic lobectomy	"Consultant" (attending) surgeon's first 46 cases versus 185th to 230th cases	37	40
Cervical mediastinoscopy	Trainees reduction in operative time	20	41
Bilateral thoracoscopic T2–T3 sympathetic ganglionectomy	Anesthesia providers' first 58 cases versus second set of 58 cases	14	42

The differences in time studied were operative times[39–41] and anesthesia times.[42] In the study reported in Ref. 41, two trainees' operative times decreased with experience ($R^2 = 0.83$ and 0.77), with the magnitudes of the decline from the first five to the final five being approximately 20 min. The first surgical team of each pair in the difference column was the surgical team with the longer average mean time.

Table 4. Impact of Surgical Method on Average Operative Times

Procedure	Difference	Difference in mean time (min)	Reference
Esophagectomy	Partial handsewn versus mechanical stapled cervical technique for esophagogastric anastomosis	88	44
Interruption of patent ductus arteriosus	Robotically assisted versus thoracoscopy	78	45
Thoracoscopy for primary spontaneous pneumothorax	Endosuturing versus endostapling	46	46
Esophagectomy	Handsewn versus mechanical stapled technique for esophagogastric anastomosis	19	43
Rigid bronchoscopy for bronchial foreign body removal in children	Hopkins telescope versus standard forceps	7	47
Cervical esophagogastric anastomosis	Single layer of interrupted Polyglactin sutures (Vicryl) versus continuous absorbable monofilament (Maxon)	6	48

The differences in time studied were operative times,[43–46] anastomosis time,[48] and unspecified.[47] The differences in results[43,44] for the two esophagectomy studies may be attributable[43] to the fact that the study with the larger difference included the study not just of differences in time taken to make the anastomosis, but the more liberal use of the endostapler for ligation and division of the short gastric, left gastric, and omental vascular continuity with the stomach. The first method of each pair in the difference column was the method with the longer average mean time.

Fourth, OR information systems need to incorporate the statistical methods designed for small numbers of prior surgical cases. Tables 1–5 show the importance of obtaining information on the procedure(s) to be performed (e.g., "thoracoscopic wedge resection of lung" versus "video assisted thoracoscopic surgery" and/or "wedge resection"), surgical team (e.g., "Dr. Smith and 1st year cardiothoracic resident who has not previously performed the procedure" versus "Dr. Smith"), and type of anesthetic (e.g., "general anesthesia" versus "anesthesia"). This use of so much detailed information results in small sample sizes. More than 75% of procedure(s) scheduled may be scheduled fewer than three times per year.[59,60] Additionally, more than 25% of cases may involve procedure(s) likely scheduled by the case's surgeon less than twice per year.[60,61] Pooling data among facilities generally does not suffice to compensate for the small sample sizes when estimating case durations, because procedure(s) that are rare at one facility tend to be rare elsewhere.[59,62] Table 6 provides new information showing that if all of the information

Table 5. Impact of Anesthetic on Average Operative Times

Procedure	Difference	Difference in mean time (min)	Reference
Thoracoscopic resection of peripheral solitary lung metastasis	General anesthesia with one-lung ventilation versus sole thoracic epidural anesthesia	50	49
Nonresectional lung volume reduction surgery	General anesthesia with one-lung ventilation versus sole thoracic epidural	28	50
Bilateral thoracoscopic sympathectomyfor palmar hyperhidrosis	General anesthesia with one-lung ventilation versus percutaneous intercostal nerve blocks	23	51
Thoracoscopic resection of solitary pulmonary nodules	General anesthesia with one-lung ventilation versus sole thoracic epidural anesthesia	19	52
Thoracoscopic bullectomy and pleural abrasion for spontaneous pneumothorax	General anesthesia with one-lung ventilation versus sole thoracic epidural anesthesia	14	53

The differences in times studied were the sum of the differences in anesthesia and operative times,[49,52,53] the sum of the differences in anesthesia and surgical times,[50] or operating room times.[51] For each study, the group receiving regional anesthesia did not have general anesthesia for the surgery (i.e., the blocks were used for surgery). The first anesthetic of each pair in the difference column was the anesthetic with the longer average mean time.

Table 6. Association Between Frequency of Use of Preference Cards and the Accuracy (Bias and Imprecision) of Scheduled Operating Room (OR) Times at an Academic Facility in the United States

No. times used 2004–2006[a]	No. preference cards[a]	Percentage of cases[a]	Percentage of OR time[a]	Bias measured as total over-estimation (min) of the scheduled OR time per 8 h of used OR time[b]	Imprecision measured as mean absolute percentage error of the scheduled OR time[c]
1–4	1663	10	11	0	31
5–9	373	9	11	0	30
10–14	167	7	8	0	30
15–24	144	10	12	0	29
25–34	78	8	9	0	28
35–49	56	8	9	0	26
50–74	57	13	12	1	29
75–124	38	13	13	1	28
125–174	18	9	6	2	33
175–325	14	12	11	1	24
Overall				0	29

[a] Categories refer to the numbers of times each preference card was used during the 3-yr period studied. Categories were chosen to have 10 categories with close to the same percentage of cases. There were 2608 surgeon-specific preference cards used for scheduled cases, 27,392 such cases, and 73,530 h of OR time at the studied facility.

[b] The bias equals 0 min when the overall amount of over-estimation equals the overall under-estimation. The numerator is the sum of all scheduled OR times minus the sum of all actual OR times.[4,5] Persistent under/over-estimation of OR time affects OR staffing costs and the frequency of release of allocated OR time, respectively.[4] Thus, the denominator is the sum of all actual times divided by 8 h, a typical workday.[4]

[c] For each case, the difference between the actual and scheduled OR times was divided by the actual time. The absolute value was taken. The mean of the absolute values for all cases in the category is given. Standard errors were 0.1% for "Overall" and 0.3% to 0.6% for the categories. The Spearman correlation coefficient between each case's imprecision and number of times the preference card was used equaled −0.02 (95% confidence interval −0.03 to −0.01).

of Tables 1–5 were used for case duration prediction, there is a low chance of an indirect reduction in the accuracy of case duration estimates caused by the reduction in sample sizes. Previous studies[3] showed the benefit of predicting the longest and shortest times that a case may take using the statistical methods designed for small numbers of prior surgical cases. The surgeon's estimate and the information of Tables 1–5 are used to estimate the center (median) of the statistical distribution of case durations, just as done currently by most OR information systems. Then, the proportional uncertainty is estimated using data from many cases,[3] not just those classified as in Tables 1–5. These so-called Bayesian statistical methods are both nonproprietary and accurate,[3] making their inclusion into commercial systems appropriate.

Limitations

Wright et al. showed that once historical case duration data have been used to provide a prediction of a new case's duration, permitting the surgeon to adjust the estimate up or down by a reasonable percentage (e.g., 10%) can decrease the imprecision.[63] At the time of case scheduling, often there is limited knowledge of who will

Table 7. Preoperative Patient Characteristics with Versus Without Significant ($P < 0.05$) Difference between the Groups That Were Studied and Reported in Tables 1–5

	Not different	Different ($P < 0.05$)	References with superscript † for different
Demographics			
Age	31	2	7†, 8, 10, 12, 13, 14, 16, 18, 19, 20, 21, 22, 23, 25, 26, 27, 28, 30, 31†, 32, 33, 34, 35, 36, 38, 40, 44, 46, 49, 50, 51, 52, 53
Gender	25	1	7†, 10, 12, 13, 14, 20, 21, 22, 25, 26, 27, 28, 29, 30, 31, 34, 35, 36, 38, 44, 48, 49, 50, 51, 52, 53
Weight	3		12, 18, 23
Disease characteristics			
Diagnosis	2		28, 44
Clinical pathologic stage	4		14, 26, 27, 31
Histology	2		13, 49
Location of lesion	8	1	10, 12†, 13, 14, 38, 44, 48, 49, 53
Laterality of diaphragmatic hernia	1		17
Size of lung lesion by imaging	1		49
Disease-free interval	1		49
Asymmetric ratio of emphysema	2		50, 53
Pleural adhesions	1		53
Malignant effusion	1		20
Preoperative major thoracic curve	2		16, 23
Side-bending correction	1		16
Duration of symptoms of myasthenia gravis	1		21
Osserman classification of myasthenia gravis	3		19, 21, 22
Procedure characteristics			
Extent of lung resection	1		10
Mediastinoscopy	1		25
Initial pleural drainage	1		53
Physiological characteristics			
Albumin level	1		12
Hemoglobin level	1		12
Forced expiratory volume in the first 1 sec: value and/or % of predicted	8	1	7†, 13, 25, 28, 30, 38, 50, 51, 52
Forced vital capacity: value and/or % of predicted	3		38, 50, 52
Diffusing capacity of the lung: % of predicted	2		30, 50
Residual volume: value and/or % of predicted	1		50
Exercise tests	2		13, 50
Performance score	2		10, 50
Arterial oxygen tension	3		38, 50, 52
Arterial carbon dioxide tension		1	50†
Maximum diameter of ductus arteriosus		1	18†
Aortopulmonary gradient		1	18†
Pulmonary hypertension		1	18†
Mean LES basal pressure	2		26, 27
Mean LES residual pressure	2		26, 27
Mean esophageal diameter	2		26, 27
Dyspnea index	1		50
Comorbidities			
"Any"	1		18
American Society of Anesthesiologists' physical status score	1		52
Hypertension	1		13
Coronary artery disease	1		13
Cardiomyopathy	1		52
Congenital heart disease	1		18
Vascular insufficiency	2		13, 52
Cardiac tamponade	1		20
Prior pericardial effusion	1		20
Respiratory disease	1		51
Chronic obstructive pulmonary disease	2		13, 52
Corticosteroid use	1		52

(*Continued*)

Table 7. Continued

	Not different	Different ($P < 0.05$)	References with superscript † for different
Tobacco abuse	3		12, 52, 53
Home oxygen use	1		52
Previous chest surgery		1	28†
Previous number of pneumothorax	1		34
Previous abdominal surgery	2		26, 27
Weight loss	1		12
Chromosomal abnormalities	1		18
Cancer	1		20
Diabetes	2		13, 52
Previous treatment for hyperhidrosis	1		51
Immunosuppression	1		35
Renal insufficiency	1		13
Drug abuse	1		53

When the data were provided to calculate the *P*-value (e.g., counts of a 2 × 2 table for gender in Ref. 30), and the results of the statistical analysis were reported without the *P*-value, then we calculated the *P*-value and included the finding in the table.

Table 8. Impact of Patient Characteristics on Average Operative Times

Procedure acuity	Procedure	Difference	Difference in mean time (min)	Reference
Elective (i.e., imprecision in case duration likely important)				
	Transhiatal esophagectomy	Laryngocervical versus lower thoracic malignancy	66	9
Urgent (i.e., included here only for completeness, because irrelevant to elective case scheduling)				
	Thoracoscopy for pleural empyema in children	Surgery 4 d or more versus 3 d or less after diagnosis	26	56
	Thoracoscopy for parapneumonic pleural empyema in children	Surgery 5 d or more vs. 4 d or less after diagnosis	24	55

The differences in times studied were operative times.[9,55,56] The incidence of transhiatal esophagectomy for laryngocervical cancer can be estimated as two cases per year per 1 million population using Italian data. The esophageal cancer incidence was 12.6 per 100,000 person years.[57] Of 374 patients with esophageal cancer, six had disease and presentation appropriate for the procedure (e.g., not metastasis or adenocarcinoma caused by gastroesophageal reflux). The two cases per 1 million is the product of the two ratios. The first patient characteristic of each pair in the difference column was the characteristic with the longer average mean time.

assist the surgeon.[63,64] On the basis of our findings, we speculate that the information in Tables 1–5 were the data about each case being used by the surgeon[63] to adjust his estimate. However, from our study we cannot discern more.

Our limited focus on case duration prediction resulted in our consideration of the detail with which procedures are scheduled (Table 1) but not the process. Other ways that anesthesia providers use the scheduled procedure(s) depend on those procedures being specified using a standardized vocabulary (e.g., Current Procedural Terminology), for six reasons.[1–6,63,65–68] (i) When procedures are classified using physician billing codes, the physiological complexity of the case can be quantified automatically from the corresponding anesthesia basic (startup) units. This information permits automatic and prompt evaluation of the appropriateness of a case for a facility.[65–67] (ii) When a patient is scheduled for physiologically complex surgery, the schedulers can be prompted to arrange a preanesthesia clinic appointment. (iii) Appropriate patient instructions can be selected automatically. (iv) Preapproval of insurance can be automated. (v) Automatic assignment of the case to the anesthesia providers can be based on the computer knowing the physiological complexity and rareness of each procedure. (vi) Expected postoperative bed requirements can be checked automatically.[68]

Our study was limited to procedures performed by general thoracic surgeons. However, our results matched those of a previous study of total hip replacement and knee replacement.[69]

Finally, our objective was not to average differences in operative times as part of a meta-analysis, but rather to organize and review the pertinent scientific literature. We limit our conclusions to saying that many general thoracic surgeons were sufficiently interested in the time that they take to complete their procedures that they included such end points in their clinical trials and case series. They found many factors to be important, almost all of which (Tables 1–5) matched those found to be relevant using the entirely different approach of statistically analyzing OR information system records for all specialties simultaneously.[1–6]

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