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# Standardized Monitoring of Post-Operative Morbidity and Mortality for the Evaluation of Thoracic Surgical Quality

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## 1. Introduction

Reliable and reproducible evaluation of quality of surgical care is of utmost importance for governments, hospitals, clinicians, and patients. Given the elective nature of the majority of surgical care, and the immediacy of its impact, surgeons have long built a strong culture and tradition of quality assessment and peer review. Building upon this foundation, there is increasing focus on standardization of means to evaluate surgical quality, developed by associations, institutions, and individual centers.

The overall aim of this chapter is to review these initiatives, focusing on an individual division of thoracic surgery, and its efforts to standardize the evaluation of surgical quality and develop a means to monitor it over time. While the tools developed may or may not be immediately relevant, it is hoped that the reasources and principles outlined are useful in the development of surgical quality assessment programs.

## 2. Framework for the evaluation of surgical quality

According to Donabedian, assessment about the quality of care can be made from three interrelated components: structure, process, and outcomes. Structure refers to organizational characteristics of the particular health care setting (Donabedian, 1988). Relative to surgery, structural measures include the following: the physical plant, the equipment and supplies, the members of the surgical team and their qualifications, and provider volume (Daley, Henderson, & Khuri, 2001). It is important to note that many structural measures are not readily actionable, which limit their ultimate effectiveness as a means toward quality improvement (Birkmeyer et al., 2004).

Process refers to the perioperative care received by the patient (Donabedian, 1988). In surgery, important process measures include: informed consent, the preoperative preparation of the patient, the choice of the surgical intervention and its execution, use of preoperative checklists, routine postoperative care and efficient clinical handover (Khuri, Daley, & Henderson, 1999). Although process measures are actionable, they are difficult to measure reliably on a routine basis (Birkmeyer et al., 2004).

Finally, outcomes refer to the effects of care on the health status of the patient (Donabedian, 1988). Outcomes measurement, which are inherently patient-centered, have been the most measured, and indeed fundamental to evaluating the quality of surgical care.

In this chapter, emphasis is placed on the evaluation of surgical outcomes, as surgical outcomes are frequently used in many ongoing efforts as measures of the quality of surgical care (Dimick et al., 2003). Specifically, postoperative morbidity and mortality (M&M) rates remain the most frequently measured and reported outcomes (Martin et al., 2002). M&M rates are often the only data provided as a means of comparing surgical techniques or peri-operative management decisions (Martin et al., 2002).

Postoperative mortality is defined either as in hospital mortality, 30-day mortality, or a combination of both (Khuri et al., 1999). Postoperative morbidity, on the other hand, refers to adverse events and complications following surgery (Khuri et al., 1999). Surgical adverse events contribute significantly to postoperative morbidity, yet the measurement and monitoring of these events is often imprecise and of uncertain validity (Bruce et al., 2001).

The use of standardized, valid and reliable definitions is fundamental for the accurate measurement and monitoring of surgical complications (Bruce et al., 2001). In 1992, Clavien and colleagues were to first to introduce an innovative system to grade complications by severity proportional to the effort required to treat the complications (Clavien et al., 1992). This methodology was recently revised and a novel five-tiered classification system was developed with the intent of presenting an objective and reproducible method for reporting complications (Dindo et al., 2004). This system, now known as the Clavien-Dindo classification system, has been used in several surgical specialties and has widespread applicability (DeOliveira et al., 2006; Feldman et al., 1997; Grobmyer et al., 2007; Guillonneau et al., 2002; Kocak et al., 2006; Liu et al., 2009; Mazeh et al., 2009; Stolzenburg et al., 2006; Tamura et al., 2006; Targarona et al., 2000).

In this chapter, the Clavien-Dindo classification system is adapted to the thoracic surgical setting (Dindo et al., 2004). Therefore, the objectives are to describe the development of a classification system to grade presence and severity of thoracic morbidity and mortality (TM&M), which would enable us to compare surgical procedures and subgroups of patients, and simultaneously allow us to evaluate the feasibility of the system over the first two years of its implementation at the Ottawa Hospital, a high-volume, single academic thoracic surgery center. Second, the reliability and reproducibility of the TM&M classification is explored. Lastly, the impact of a standardized classification of post-operative complications on quality assessment in thoracic surgery is discussed.

The objective evaluation of both the presence and severity of thoracic morbidity and mortality and the prospective monitoring of thoracic surgical volume represents an important means of standardizing surgical outcomes, enabling comparisons between centers and surgeons, and represents a crucial component to ensuring continuous quality improvement and the best practice of care.

## 3. Large-scale quality initiatives

There are several ongoing, large-scale initiatives aimed specifically at measuring and improving surgical outcomes. For example, the National Surgical Quality Improvement Program (NSQIP) (Khuri et al., 1998) and the Society for Thoracic Surgeons (STS) database (Caceres et al., 2010), provide hospitals and cardiothoracic surgeons with information on their risk-adjusted M&M rates.

The NSQIP was created as a program that originated in the Veteran's Administration Hospitals in the United States as a quality improvement tool for surgical care (Khuri et al., 1998). The NSQIP uses clinical information from medical records to risk-adjust hospital

mortality rates. One of the advantages of this type of system includes extensive clinical information on over one million patients for risk-adjusted analyses on 30-day outcomes of surgical care. Since the NSQIP has been implemented, marked improvement in surgical quality has been documented – M&M rates have declined, patient satisfaction has improved, and lengths of stay have decreased (Hall et al., 2009).

Similarly, the STS database was developed as an initiative to standardize nationwide outcomes in adult cardiac surgery, and it has currently expanded into general thoracic and congenital cardiac surgery databases (Caceres et al., 2010). Since its inception, the STS database has grown as a powerful source of risk-adjusted outcomes, large scale scientific contributions, and invaluable information for healthcare policy making (Caceres et al., 2010).

The NSQIP and STS database offer inter-institutional benchmarking, however, they are less applicable as a continuous quality improvement measure for an individual surgical program, as understanding and improving the delivery of a particular operation may require measures tailored to that operation (Birkmeyer et al., 2004), such as proper evaluation of the burden of illness of individual complications and subsequent patient impact. Moreover, the tracking of postoperative morbidity is less successful than of mortality due to the lack uniform definitions within the NSQIP and STS database (Grover et al., 1996).

## 4. Systematic classification of morbidity and mortality following thoracic surgery

Objective analysis and discussion of surgical M&M is the foundation of quality assurance. However, defining and measuring quality is a particularly difficult undertaking (Donabedian, 1988). Mortality is well defined in the literature and is a comparable surgical outcome, whereas morbidity rates have been poorly reported; thus, limiting comparisons among surgeons, procedures, and centers, and within the same center over time (Clavien et al., 1992; Clavien et al., 1994). To enable such comparisons, data on surgical outcomes must be acquired in a standardized and transparent format (Clavien et al., 1992).

Most surgeons depend on regular review of complications at M&M conferences to evaluate experience, analyze complications and receive feedback regarding quality improvement measures undertaken to minimize risk (Murayama et al., 2002). However, data from M&M conferences are neither systematically collected, nor stored in a standardized and reproducible fashion (Antonacci et al., 2008). These shortcomings of traditional methods for quality assurance have partly encouraged a movement toward a new paradigm for improving surgical care quality (Feldman et al., 1997), involving the continuous surveillance and evaluation of surgical adverse events.

Continuous monitoring of surgical M&M: i) allows for benchmarking; 2) identifies areas in need of improvement; 3) improves knowledge transfer; 4) facilitates staff and resident education; 5) enables prospective research; and 6) evaluates effectives of interventions. Clavien and colleagues were the first to introduce an innovative system to grade complications by severity proportional to the effort required to treat the complications (Clavien et al., 1992). This system of reporting serves as a means of judging the completeness of M&M reporting (Martin et al., 2002). Moreover, the Clavien-Dindo classification schema of surgical adverse events is precise, simple, reproducible and can be used to provide information that can assist in the continuous monitoring of surgical quality.

### 4.1 Development of the Thoracic Morbidity and Mortality (TM&M)

The TM&M system was developed according to the Clavien-Dindo classification schema of surgical adverse events (Dindo et al., 2004) (Table 1). Definitions of surgical adverse events were modified according to complications in patients following thoracic surgery through peer review and questionnaire, and adjusted based on surgeons' experience. A complication was defined as any deviation from the normal postoperative course. For each of the following systems: pulmonary, pleural, cardiac, renal, gastrointestinal, neurological, wound, and other, complications were defined and classified according to their specific gradation. The Common Terminology Criteria for Adverse Events (version 3.0) (Trotti et al., 2003) was also used to refine some definitions.

| Grade | Definition |
|---|---|
| **Minor** | |
| Grade I | Any complication without need for pharmacologic treatment or other intervention. |
| Grade II | Any complication that requires pharmacological treatment or minor intervention only. |
| **Major** | |
| Grade III | Any complication that requires surgical, radiological, endoscopic intervention, or multi-therapy. |
| Grade IIIa | Intervention does not require general anaesthesia. |
| Grade IIIb | Intervention requires general anaesthesia. |
| Grade IV | Any complication requiring ICU management and life support. |
| Grade IVa | Single organ dysfunction. |
| Grade IVb | Multi-organ dysfunction. |
| **Mortality** | |
| Grade V | Any complication leading to the death of the patient. |

Table 1. Classification of complications following thoracic surgery

### 4.2 Data collection

Daily data collection of M&M was carried out by a senior thoracic surgical resident and the thoracic surgery research coordinator using the TM&M form. Weekly lists of operative procedures along with related complications were compiled and further validated by attending staff. These complications were then discussed at monthly departmental M&M conferences. A database for complication reporting was developed; data entered included gender, age and preoperative diagnosis. Surgical details entered were type of operation, including whether it was a video assisted or open operation. The grading of complications was prospectively applied to each patient according to severity and effort required to treat the complication.

Descriptive statistical analyses were performed to analyze surgical volume and M&M rates after thoracic surgery. Incidence of complications in different subgroups was analyzed using the Chi-square test or Fisher's exact test. Correlations between complication grade and hospital length of stay was analyzed using analysis of variance (ANOVA). A $p$ value of less than 0.05 was considered significant. Data were analyzed using SAS version 9.2 software.

### 4.3 Patients

The TM&M classification system was applied to a cohort of 953 consecutive patients undergoing non-cardiac thoracic surgery at the Ottawa Hospital from January 1, 2008 to December 31, 2009. There were 520 male (54.5%) and 433 female (45.5%) patients with a mean age of 61 years (range, 14–95 years). While 592 patients (62.1%) had a malignant disease, the remaining 361 patients (37.9%) had a range of benign lung, esophageal and other thoracic-related diseases.

### 4.4 Overall grade and severity of thoracic surgical complications

During the study period, a total of 953 patients (mean age 61, range 14-95) underwent a thoracic surgical procedure, of which 369 (29.3%) patients had at least one complication. Grades I and II complications accounted for 4.9% and 63.9% of all complications, respectively. Grade III and IV complications and comprised 21.1% and 7.8% of all complications, respectively. Overall mortality rate (Grade V) was 2.2%.

### 4.5 Burden of illness of individual complications

The TM&M classification system offers a comprehensive and objective evaluation of the impact of individual complications on patients. Atrial fibrillation (18.8%) and prolonged air leak (18.2%) compromised the majority of grade II complications following pulomonary resection, and thus, require more careful attention. The majority of prolonged air leak complications following pulmonary resection were grade I or II (87%), grade IIIa and IIIb were 9% and 2%, respectively, and Grade IV was 2%. Upon evaluation of all complications secondary to air leak after pulmonary resection, 97% of all atrial fibrillation was Grade II, with 1 patient (3%) experiencing a Grade IVa complication. In addition, since we began evaluating if complications led to prolonged hospital stay or re-admission, we found air leak led to 17% rate of re-admission, and 29% prolonged hospital stay, compared to 2% and 7% for atrial fibrillation. Thus, despite similar incidence after pulmonary resection, we identified air leak as having a significantly greater burden of illness than atrial fibrillation as defined by more severe complications, re-admissions and longer stay.

## 5. Testing the reliability and reproducibility of the TM&M classification system

Any system that is developed to provide an objective evaluation of the quality of surgical care must be simple, reproducible, and applicable to any surgical specialty at any medical institution. The next section describes how the reproducibility and reliability of the TM&M classification system was evaluated.

### 5.1 Methods

The Canadian Association of Thoracic Surgeons (CATS) was approached for a multi-center evaluation of the TM&M classification system (n = 95 members). The membership of CATS includes full-time practitioners of general (non-cardiac) thoracic surgery, along with qualified general and cardiovascular surgeons whose practice includes more than 50% thoracic surgery (Darling et al., 2004).

To assess the reproducibility and reliability of the modified classification, an electronic questionnaire was designed with 31-items. The Ottawa Hospital Research Ethics Board

approved this study. The questionnaire consisted of three parts including: i) an information sheet with the TM&M classification system along with definitions of the severity grades; ii) 20 case-based questions asking respondents to classify postoperative adverse events in accordance to the proposed classification system; and iii) questions regarding personal judgments about the classification system.

The 20 case-based scenarios were placed randomly with regards to their complication grade. The 20 case-based scenarios were chosen to have an even representation of minor (Grades I – II) and major case examples (Grades IIIa – V). Respondents were asked to choose the most severe grade of complication for each case.

Weighted kappa statistics were calculated to assess the inter-rater reliability among the survey respondents. The level of agreement among the raters was evaluated using the system put forth by Landis and Koch, 1977, in which a kappa value of 0.21 to 0.4 reflects fair agreement, a value of 0.41 to 0.60 reflects moderate agreement, a value of 0.61 to 0.80 reflects substantial agreement, and a value of 0.81 or more reflects almost perfect agreement (Landis & Koch, 1977). Data were analyzed using R statistical software.

### 5.2 Results

From the 95 members, 52 surveys were completed (54.7%). The majority of respondents were affiliated with a university teaching hospital (78.8%, $n$ = 41) and practiced in Ontario (32.7%, $n$ = 17) or Quebec (15.4%, $n$ = 8). Ontario and Quebec are the most densely populated provinces in Canada with populations of approximately 12.2 million and 7.6 million, respectively. Of the 52 completed surveys, 8 (15.4%) were completed by members practicing outside of Canada. Most surgeons had been in practice for less than 10 years (51.0%, $n$ = 26).

The weighted Kappa statistic assesses agreement between two raters on an ordered scale (Landis & Koch, 1977). With 52 raters, a total of 1326 individual weighted Kappa statistics were calculated for all distinct pairs of raters. Of those 1326 weighted Kappa statistics, 1152 (87.0%) were greater than 0.81, a range which is interpreted as "almost perfect agreement." Furthermore, 173 (13.0%) were in the range between 0.61 and 0.8, interpreted as "substantial agreement." Thus, all of the statistics indicated at least substantial agreement. All results were statistically significant ($p < .0001$).

Respondents were asked to agree or disagree with several statements regarding their personal judgments of the TM&M classification system. Of the 52 respondents, 49 (98.0%) considered the TM&M classification system as straightforward to understand. A total of 48 respondents (94.1%) considered the TM&M classification system as reproducible; that is, different surgeons would tend to agree on the classification of individual patient events. A total 47 respondents (92.2%) considered the TM&M classification system as logical; that is, it accurately reflects the level of severity of adverse events. Lastly, 50 respondents (98.0%) consider the TM&M classification system useful in their patients; that is, it will be helpful to evaluate both presence and severity of surgical adverse events.

## 6. Impact of a systematic classification of post-operative complications on quality assessment in thoracic surgery

By using the TM&M system as a continuous measure of quality, we have now embarked on several initiatives to further improve complication rates related to thoracic procedures.

### 6.1 Example of value: Most common complications

#### 6.1.1 Atrial fibrillation

Non-cardiac thoracic surgeries are often complicated by supra-ventricular arrhythmias, with atrial fibrillation representing the most common type of rhythm disturbance. Despite prevention efforts, atrial fibrillation remains one of the primary reasons for prolonged hospital stay, re-admission and additional complications post-pulmonary resection (Ramzan et al., 2011). The use of the TM&M classification system allows for the determination of the severity and burden of illness of a complication, which can lead to initiatives to improve the quality of care.

Using univariate analysis, several prognostic variables were identified for atrial fibrillation through a retrospective chart review of pulmonary resection cases. Logistic regression was used to identify risk factors with the strongest prognostic value for the outcome of atrial fibrillation. Significant variables in the multivariate analysis included age, left ventricular dysfunction, angina pectoris and open or converted surgery. These risk factors are specific to our individual institution over this two year period and may alter over time. However, identification of risk factors will allow for appropriate and targeted management of individuals with increased risk of developing post-operative atrial fibrillation (Ramzan et al., 2011).

#### 6.1.2 Prolonged alveolar air leak

Another frequent complication after pulmonary resection for pulmonary diseases is prolonged alveolar air leak (Bardell & Petsikas, 2003; Irshad et al., 2002). Like atrial fibrillation, prolonged alveolar air leak has a significant clinical impact on patients and resources. Moreover, prolonged alveolar air leak can lead to additional morbidities, such as respiratory infections, empyema, and prolonged need for chest tubes (Brunelli et al., 2004; Brega et al., 2003).

Using the same methodology as outlined above, risk factors for prolonged alveolar air leak were identified and include obstructive pattern on PFT (FEV1<80%, FEV1/FVC<70%), higher pack-year of smoking, self-reported diagnosis of bronchitis, lobectomy (especially right upper lobectomy) and extended lobectomy (Liang et al., 2011). Risk factors can be used to identify patients who would benefit from prevenetive interventions, such as the use of buttressed stapled lines with bovine pericardium (Cerfolio et al., 2001) (Bio-Vascular Dry Peri-Strips, Mineapolis, MN), pleural tents for upper lobectomy, pneumoperitoneum after lower lobectomy, focal seal (genzyme, biosurgery, Cambridge MA), fibrin glue (Stolz et al., 2005) and collagen patch (Malapert et al., 2010). Practice changes could be monitored for efficacy using the TM&M classification system.

### 6.2 Example of value: Comparison between surgical procedures

Video-assisted thoracic surgery (VATS) is a relatively new technology that has rapidly become the standard of care for uncomplicated pulmonary resection. However, concerns have been expressed regarding the safety and oncologic efficacy of VATS lobectomy (Nicastri et al., 2008). The TM&M tool was utilized for reporting presence and severity of complications during the initiation of a VATS lobectomy learning curve, and compared to open lobectomy controls. The patterns of postoperative morbidity in patients undergoing VATS lobectomy, was analyzed, in order to deduce if there existed an altered number or pattern of adverse events.

A retrospective review of all patients undergoing thoracic surgery for lung cancer at the Ottawa Hospital was conducted to identify those patients who underwent elective pulmonary lobectomy for clinical stage I and II non-small cell lung cancer. All consecutive VATS lobectomies performed in the Ottawa Hospital since January 2006 until August 2010 were age-matched (±5 years) and stage-matched with a control cohort of open lobectomy cases. Data on patient demographics, co-morbidities, pulmonary function, pathological stage, operative procedure and time, blood loss, type and grade of postoperative complications, and hospital length of stay were recorded and analyzed.

In terms of results, there were no fundamental differences in complication rates between the two groups (47.5% for open vs. 43.3 for VATS; $p = 0.52$). There was also no difference in operative mortality between the two groups (3.3% for open vs. 1.7% for VATS; $p = 0.68$). Compared with open lobectomy, VATSlobectomy was associated with shorter mean length of stay (8.2 days for open vs. 7.8 days for VATS; $p < 0.05$). Mean operative time was higher for VATS lobectomy (239.1 minutes for open vs. 273.2 minutes for VATS; $p<0.05$). Moreover, mean surgical time was also longer for VATS lobectomy (178.2 minutes for open vs. 220.0 minutes for VATS; $p<0.05$). The amount of blood loss was significantly less following VATS lobectomy (230.6 cc for open vs. 170.3 cc for VATS; $p<0.05$).

VATS lobectomy may be a safer procedure in particular patients. Also, the efficacy of VATS lobectomy is further amplified considering that VATS lobectomy is associated with a shorter hospital length of stay. However, more research is needed to identify specific complications that have been recognized to have an important impact on outcomes, such as atrial fibrillation. Several studies have demonstrated the frequency of postoperative atrial arrhythmias to be significantly lower after thoracoscopic surgery (Whitson et al., 2008).

### 6.3 Morbidity & Mortality (M&M) conference

The most widespread strategy for quality assessment in surgery has been the departmental M&M conference. This approach to quality assessment uses peer-review of cases resulting in adverse outcomes to identify inadequate care (Feldman et al., 1997). M&M rounds are an important educational tool for residents in regards to the causes of the most severe complications. M&M conferences also play a role in teaching surgeons how to present and how to take responsibility for issues (Feldman et al., 1997).

Although the historical and educational roles of the M&M conference are unquestionable, case-finding strategies for quality assessment have several limitations including emphasis on outliers and fault-finding, focus on individual performance rather than organizational processes, and focus on individual events rather than patterns of outcomes (Feldman et al., 1997).

Our departmental M&M conference has greatly been enhanced by the improved quality of statistical reporting of all complications, as collecting TM&M data has inherently been a collegial activity. Collecting TM&M requires participation of the senior residents on a daily basis, weekly confirmation by attending staff, and monthly discussion at M&M conferences. The presence and grade of a complication is not always clear; however, frank collegial discussion enhances the validity of the data. The TM&M classification system does not replace the M&M conference; rather it provides additional information, while maintaining individual patient case presentations.

## 7. Future directions

### 7.1 Needs assessment

Assessing the degree of involvement and participation in thoracic surgical research as well as surgical quality improvement conducted across Canadian institutions is difficult as there exists no common data collection system and no prior studies. As a pilot investigation, we designed and conducted a membership survey of the Canadian Association of Thoracic Surgeons (CATS) to evaluate the extent of participation in research and quality improvement processes among thoracic surgeons (Ivanovic et al., 2011).

The survey revealed that a high level of interest and participation exists in thoracic surgery research. However, more robust quality improvement processes are needed for thoracic surgical oncology services locally and nationally (Ivanovic et al., 2011). Moreover, the development of a national database is progressively being recognized as fundamental to the practice, review and quality assessment of thoracic oncology services across Canada (Ivanovic et al., 2011). A national thoracic surgery quality improvement database offers a potential means to improve practice effectiveness, standardize surgical outcomes, enhance multidisciplinary communication, promote thoracic research, and allow for the design and implementation of programs to improve surgical quality (Ivanovic et al., 2011). The results of this pilot project have provided a strong foundation of knowledge upon which we can, with time, enhance the monitoring of quality of care, both locally and nationally. The proceeding section describes the first steps of this process.

### 7.2 Thoracic Surgery Quality Monitoring, Information Management, and Clinical Documentation (TSQIC) System

Handheld computers are increasingly replacing paper methods for collecting patient-reported information. Studies have shown significant advances in the quality of patient care, in terms of legibility, availability, and data quality (Roukema et al., 2006) with the use of handheld computers for data collection. Moreover, extensive research has demonstrated that point-of-care clinical documentation improves communication amongst health care professionals, augments efficiency of care, and enables monitoring of quality of care. It is well known that new-generation handheld computers offer increasing support to surgeons in their daily clinical activity and an increasing potential for future use (Fischer et al., 2003).

In the Ottawa Hospital's Cancer Assessment Clinic, a paper-based documentation system is currently used to document thoracic oncology care. Numerous problems are reported with respect to the length of time spent on documenting, delay in transcription (requiring days to weeks) and the significant costs of transcription, and the low quality of the documentation. These shortcomings lead to inefficient use of clinic time, delays in communication from surgeon to oncologists, and impaired quality of care relating to poor communication. Documentation may be further compromised if it is not immediately carried out.

Building upon research studies demonstrating the value of electronic documentation to address these problems, we introduce the Thoracic Surgery Quality Monitoring, Information Management, and Clinical Documentation (TSQIC) System, a web-based software application accessed on a portable device (i.e. iPad) to perform point-of-care recording and reporting of standardized essential bedside patient information. The TSQIC has already gone through two years of iterative development by the the Ottawa Hospital's division of

thoracic surgery, and comprises standardized electronic templates facilitating recording and reporting of essential patient data for all time points throughout the continuum of thoracic surgical oncology care. The time points include referral, initial investigation, past medical history, physician orders and physical exam, pulmonary report, cardiac evaluation, staging, clinical assessment and plan, operation form, peri-operative surgical adverse events, and a minimum of two years follow up post surgery. The TSQIC is a natural extension of the TM&M. In addition to recording peri-operative adverse events, the TSQIC will automatically record essential clinical data relating to quality of care, including wait times. Optimized for an iPad, but accessible through any web-enabled computer, the TSQIC is designed to augment efficiency of clinic time and decrease costs by eliminating the need for transcription. Our eventual goal is to implement the TSQIC system within the Ottawa Hospital's Thoracic Cancer Assessment Clinic and to evaluate its accuracy, completeness, efficiency, rapidity, usability, and overall quality, compared to traditional paper-based documentation.

The TSQIC not only has the capacity to transform clinical documentation, improve efficiency and augment monitoring of quality at a single center, but has potential to be expanded to other disciplines within the Ottawa Hospital, and to other centers across Canada.

## 8. Conclusion

Quality assurance has been at the forefront for surgeons in all specialties and to this day it remains a primary objective of their professional careers (Gumpert, 1988). Surgeons have advanced a highly refined system of sustaining and improving the quality of their practice through the measurement and evaluation of structure, process, and outcomes of care. The three areas clearly overlap to some degree, as quality assurance is only possible because good structure increases the likelihood of good process, and good process increases the likelihood of good outcome (Donabedian, 1988). To date, most quality improvement initiatives in surgery have focused on measures of morbidity and mortality (Birkmeyer et al., 2004). Therefore, an objective system for monitoring and accurately reporting postoperative morbidity and mortality is fundamental in order to advance performance in thoracic surgery and collect reliable data for benchmarking. Moreover, an objective and standardized system permits comparison of outcomes between surgical procedures, between different institutions, and allows for knowledge transfer for improvement in one's own institution. The implications are wide-ranging, as all disciplines would be empowered to work towards the same goal of improving surgical in-patient outcomes.

The development of the TM&M classification system and the accompanying TM&M database has facilitated systematic monitoring, reporting and evaluation of postoperative complications across all thoracic surgical procedures performed at The Ottawa Hospital.

To test the reproducibility of the TM&M classification system, clinical case examples were created by the thoracic surgical team at the Ottawa Hospital and sent to all members of the Canadian Association of Thoracic Surgeons. The consistency of a surgeons' rating is an important consideration in outcome assessment. These ratings often fall on an ordinal scale, making the kappa coefficient an appropriate measure of reliability for such data (Brenner & Kliebsch, 1996). A high level of agreement was calculated among the 52 survey respondents for the 20 case scenarios, indicating that the TM&M classification system is consistent

among surgeons' opinion and can be applied to multifaceted case examples. Through the application of severity grades, the TM&M classification system has provided standardized measures for discriminating what may represent a minor as opposed to major adverse event following thoracic surgery.

The TM&M classification system is also complementary to several ongoing, large-scale programs designed specifically to measure and improve surgical outcomes (Birkmeyer et al., 2004), such as the National Surgical Quality Improvement Program (NSQIP) (Khuri et al., 1998) and the Society for Thoracic Surgeons (STS) database (Caceres et al., 2010). Incorporation of a standardized complication grading system, such as the TM&M, into large organizational databases would allow identification of areas for improvement for surgeons and institutions. It would provide a common denominator for the implementation of quality improvement programs to reduce the incidence of complications following thoracic surgery.

We further plan to utilize this continuous TM&M classification and reporting system as a backbone for prospective monitoring of essential surgical information, upon which to add additional clinical data collection tools. The TM&M classification system provides a strong base with which we can build a system (that is, the TSQIC system) to continuously monitor and improve the overall quality of thoracic surgical care. Expanding the TM&M classification system to include clinical data on all time points on the continuum of care, starting with patient referral to at least a two year follow-up post surgery, would certainly help improve continuous assurance of care.

A prospectively collected, standardized classification system for accurately identifying and grading thoracic surgical complications in all cases is feasible to implement, facilitates objective comparison between surgical procedures, surgeons and centers, and identifies burden of illness of individual complications. Furthermore, the TM&M classification system advocates for a practice of continuous quality improvement, advances the development of quality improvement programs, and facilitates an open forum for ongoing medical education on surgical quality assurance and evaluation.

## 9. Acknowledgments

The authors would like to gratefully acknowledge the entire division of thoracic surgery at the Ottawa Hospital including: Dr. Sudhir Sundaresan, Dr. Donna Maziak, Dr. Farid Shamji, Dr. Sebastian Gilbert, Dr. James Villeneuve, Dr. Ahmed Alhussaini, Dr. Derar Alshahab, Zeb Khan and Jennifer Threader. The authors would also like to gratefully acknowledge funding from the Department of Surgery at the Ottawa Hospital, Dr. Lorenzo Ferri (McGill University) for his suggestion to initially explore the Clavien-Dindo classification system, and to Dr. Jack Kitts, president and CEO of The Ottawa Hospital for his encouragement of this project. Lastly, the authors would like to thank the entire membership of the Canadian Association of Thoracic Surgeons for their participation in the questionnaire, in addition to their feedback.

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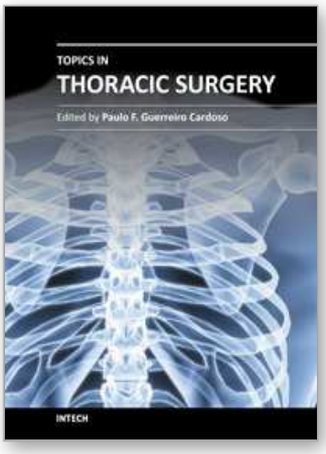


**Topics in Thoracic Surgery**

Edited by Prof. Paulo Cardoso

ISBN 978-953-51-0010-2
Hard cover, 486 pages
**Publisher** InTech
**Published online** 15, February, 2012
**Published in print edition** February, 2012

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Jelena Ivanovic, Tim Ramsay and Andrew J. E. Seely (2012). Standardized Monitoring of Post-Operative Morbidity and Mortality for the Evaluation of Thoracic Surgical Quality, Topics in Thoracic Surgery, Prof. Paulo Cardoso (Ed.), ISBN: 978-953-51-0010-2, InTech, Available from: http://www.intechopen.com/books/topics-in-thoracic-surgery/standardized-monitoring-of-post-operative-morbidity-and-mortality-for-the-evaluation-of-thoracic-sur

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