# The Development of an Automated Method of Monitoring Surgeon Performance at an Academic Teaching Hospital

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**Abstract**

In this thesis, I chose to identify and evaluate different monitoring methods on surgeon specific outcomes in colorectal surgery. An initial literature search identified different methods that were applied to a cohort of colorectal patients operated on by general surgeons using an electronic hospital database. Surgeon specific complications were validated with a chart review. General surgeons at The Ottawa Hospital were surveyed on their opinions regarding monitoring outcomes. We can conclude that different methods may be needed as they are dependent heavily on specified target limits. With our derived cohort, we had adequate risk adjustment using a modified Escobar model for 30 day mortality and morbidity. These complications were derived from electronic algorithms and had excellent specificity and sensitivity. General surgeons at The Ottawa Hospital have different opinions regarding monitoring their outcomes and surgeon engagement is necessary to make monitoring fruitful for patients, public, hospital administration, and surgeons.

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# 1.0 Introduction

## 1.1 Surgical performance and public

There have been continuing controversies regarding surgeons and their performance with detrimental outcomes in certain centres resulting in the halting of surgical programs or becoming the focus of public investigations. For instance, the Bristol inquiry investigated excessive deaths post cardiac surgery in neonates between 1991 and 1995 at the Bristol Royal Infirmary in the UK and found that the events were a result of sub-standard care that was both in the structure and processes of care in the hospital as well as lack of insight in certain surgeons[1]. This inquiry shook up surgical care in Great Britain and resulted in changes within the hospital and introduction of public performance scores. In Canada, the public demanded an inquiry in pediatric cardiac results when a program was halted in Manitoba in 1995 following an external review when 12 children who had heart surgery died the year prior[2]. The inquiry revealed a number of flaws in the system that was a result of inadequate skill of the cardiac surgeon, poor teamwork, and lack of supervision. This resulted in the inquiry recommending Winnipeg to be part of the Western Canada regional program because the catchment area of Manitoba is too small and poses increased mortality and morbidity due to low volumes and not having a fully serviced program to cater to the intense needs of specialized surgeries. These events coupled with having public lives in the hands of health care providers warrant reliable performance outcome measures.

## 1.2 Trend towards improved accountability

In Canada, it is estimated that there are 185, 000 associated hospital adverse events with about 70 000 potentially preventable hospital deaths annually [3]. These preventable deaths are a result of multiple factors including structures, processes, and care that include individual physician performance. In Ontario, the Excellence Care for All Act (ECFAA) came into effect June 2010 that

requires hospitals and health care providers to put forth high standard of health care for patients and be accountable[4]. A further incentive in the act links hospital CEOs financial compensation to quality performance targets. Thus there is a trend towards improved accountability to the public in health care delivery.

### 1.3 Quantifying surgical performance

Surgeon quality is difficult to quantify. Historically, we relied on surgical outcomes to demonstrate a surgeon's capabilities. Surgeons are entrusted to perform surgeries on patients to increase their quality of life, cure disease, and perform life-saving operations. To achieve these goals, surgeons have a duty to provide quality care for their patients. To encourage self-improvement, surgeons need to continuously reflect on their previous outcomes and compare them with accepted standards. This is not only to prove their capability to themselves but to also reassure patients. Surgical procedures and their outcomes rely on the technical expertise of surgeons, and methods to ensure best practice are warranted. Thus, measuring surgeon specific outcomes are an important component of assessing surgical quality. Having good surgical outcomes are in the best interest for all parties— patient, surgeon, hospital, and society.

Surgical outcomes, such as postoperative morbidity and mortality, have become surrogate markers of surgical quality. However, crude data on mortality and morbidity rates are unable to determine whether the surgeon's patient population is "sicker" than another surgeon's. Thus, methods to discriminate patient characteristics and risk profiling are essential when attempting to report and compare surgical outcomes. Not only does a good risk model provide more accurate information about operative risk for a patient, but can

also standardize the predicted outcome for a group of patients, correcting for case-mix, and provide benchmarks for surgeons. Surgical outcome reporting is becoming more prevalent and accurate methods to monitor risk-adjusted surgical outcomes are needed. The primary purpose of accurate performance monitoring is to ensure that all surgeons perform within an acceptable standard and that there are safeguards in place.

### 1.4 Current surgical monitoring

In the United States, more and more hospitals are involved with measurement and efforts into quality improvements with the American College of Surgeons National Quality Improvement Program (NSQIP). Approximately 177 non-Veteran Affairs hospitals in the United States with over 300 beds participate in NSQIP. This program monitors hospital outcomes for surgical procedures in regards to 30 day mortality and morbidity rates. There are trained surgical clinical reviewers that collect clinical data from a random sample of 20% of all surgical cases. This is 40 successive surgical cases collected during an 8-day cycle. It costs an institution over $100,000US annually for NSQIP with an estimated savings in costs of complication such as a 5% reduction in surgical site infections, which would be estimated at $213,000 at the Ottawa Hospital.

### 1.5 Using hospital administrative data

At the Ottawa Hospital, administrative and clinical data are collected and stored in the Ottawa Hospital Data Warehouse. This database has a wealth of information and could be used to synthesize performance outcomes for surgical procedures. We could supplement

the NSQIP data by providing surgeon specific data with all the consecutive surgical procedures. The attraction is that administrative data are readily available and relatively inexpensive. However, the accuracy and reliability of the data for patient characteristics and postoperative complications have been shown to have relatively poor sensitivity due to coding problems and lack of clear definitions [5, 6]. Prospectively collected databases, such as the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP), involve dedicated research nurses to collect and enter data on patient characteristics, procedure details, and postoperative 30-day course, and are expensive costs for most hospitals. However, the quality of data collected is better in terms of sensitivity [7, 8]. There is work done by Pine et al that demonstrates that an administrative database can retain efficiency with the use of added clinical laboratory values [9-11]. Thus, using the available Ottawa Hospital Data Warehouse would be able to provide reports to individual surgeons regarding their performance in comparison to the other surgeons and use their internal competitiveness to improve their outcomes.

### 1.6 Colorectal surgery

All general surgeons are trained to do colorectal operations. All general surgeons perform colorectal surgery, whether as an elective or emergent procedure. Some reasons for colorectal surgery include malignancy, diverticulitis, inflammatory bowel disease, and ischemia. Each of these surgeries can reflect an individual's performance. At the Ottawa Hospital, some surgeons perform more colorectal surgeries than others and some do it

more on an emergent basis. As such, there is a need to monitor varying surgeons outcomes for performance and quality assurance purposes.

## 1.7 Common methods of evaluating surgeon specific outcomes

### 1.7.1 CUSUM plot

There are three general types of monitoring methods used. The first two types use observed-expected (O-E) plots: the cumulative sum chart method (CUSUM) and an extension of the CUSUM method, variable life-adjusted display (VLAD) plots.

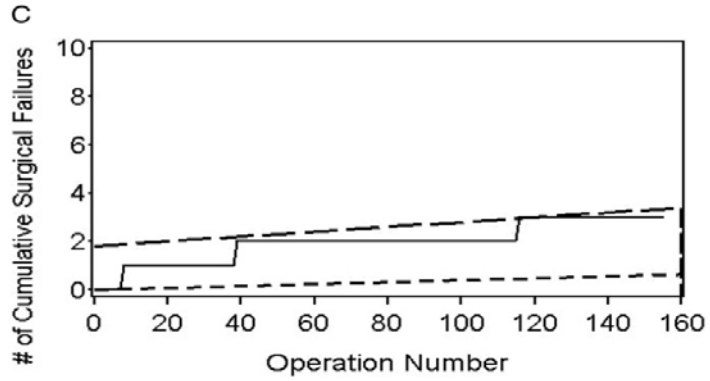


Figure 1: CUSUM example

With the CUSUM method, successive cases are plotted along the horizontal access with the plots for outcome (ie. mortality) on the vertical access. Hence, for each additional outcome such as death, the plot moves up one unit [12, 13].

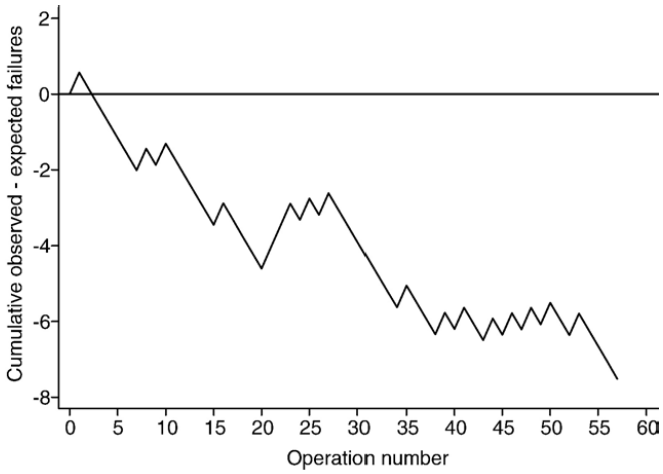


Figure 2: O-E CUSUM plot

Another plot is the O-E CUSUM plot where the vertical access is the cumulative difference of observed to expected failure for each case [13]. For expected failure rates, studies can either use an expected complication rate from literature for benchmark levels or a risk-adjusted model.

1.7.2 VLAD plot

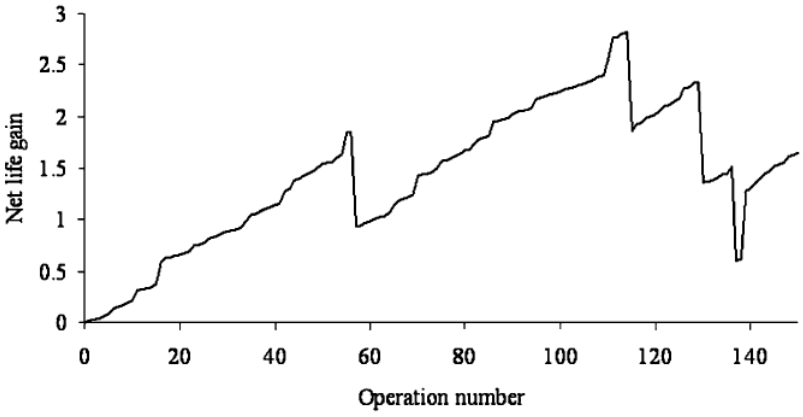


Figure 3: VLAD plot

For VLAD plots, this method takes into account total risk-adjusted mortality, normally with a validated accepted prediction model, and plots the probability against the number of operations performed. Thus both success and failure are incorporated and the plot illustrates the difference between predicted and actual outcome. For instance as the plot goes up, this represents net life gain, and when the plot drops, this represents death. This is a variation in display from the CUSUM method. The VLAD approach has been used mainly in cardiac surgeries [12].

### 1.7.3 Funnel plot

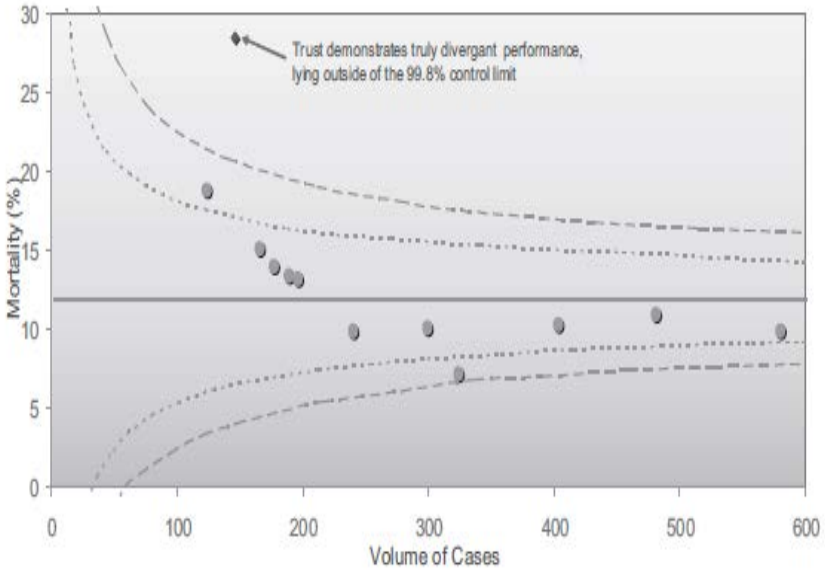


Figure 4: Funnel plot

The third type of monitoring uses funnel plots that plots data on a scatter plot and superimposes control limits around the data plots. The scatter points outside the control limits signal need for attention [14]. The control limits are normally 2 and 3 standard

deviations from the mean. Thus, the control limits are dependent on the sample size and with increasing sample sizes, the control limits converge to a funnel shape. Data points within the control limits are acceptable and likely due to natural variation, whereas data points outside the control limits need to be examined to determine the cause of variation. For example, surgical decision and error, availability of resources, and environmental factors could possibly account for these outliers. There is no ranking of hospitals or surgeons with the funnel plot method, but it can identify outliers outside the confidence limits.

### 1.7.4 Comparative benefits and drawbacks of each approach

The CUSUM plot would identify surgeons having more failures than expected and could warrant a signal to the surgeon to re-evaluate their practice. This method also illustrates learning curves for junior surgeons. However, this method does not easily exemplify surgeons performing ahead of others such as VLAD plot would demonstrate. Since the VLAD plot takes into account successes and failures, surgeons could be ranked. As surgeons may be reluctant to be ranked amongst their peers, this may not be the most popular approach. The funnel plot method does not allow for ranking and would only identify outliers with poor outcomes which may be more favourable to surgeons. However, funnel plots are dependent on adequate sample size for constructing confidence limits. Thus, different methods have varying benefits and drawbacks that may be acceptable to surgeons.

## 1.8 General formulation of the problem

The problem I chose to evaluate was to apply different monitoring methods on surgeon specific outcomes in colorectal surgery. This was to demonstrate feasibility in using a hospital administrative database and whether surgeons would "buy-in" into this type of monitoring for measuring their performance and surgical outcomes. From the outcome of my work, we would be able to determine whether this type of monitoring would be able to provide surgeons their individual outcome data in a sensible and reliable manner.

## 1.9 Surgeon specific complications

Complications discussed in surgical literature include short term 30 day postoperative outcomes. We decided the severity index scale as validated by the Clavien-Dindo classification was appropriate and would cover hard outcomes such as use of total parenteral nutrition, blood transfusions, return to operating room, interventional procedures, ICU stay, and mortality[17]. These would be measureable outcomes that would work for our intended cohort.

## 1.10 Outline of research contribution

In this study, I have conducted a literature search seeking the various methods of monitoring surgeon specific outcomes.With the identified methods, I chose the most reasonable methods to be applied to a derived cohort of patients from the Ottawa Hospital that had colorectal surgery. I chose colorectal surgery as it is a surgery that all general surgeons perform, although some may do more of this as an emergency procedure than an elective procedure. After application of the chosen methods, I described the results and contrasted the different methods. Lastly, a survey was given to the general surgeons at the Ottawa Hospital for their opinions on monitoring outcomes. From this project, I was able to demonstrate various monitoring methods for surgeon specific

outcomes in colorectal surgery at the Ottawa Hospital and get a sense from the general surgeons at the hospital in terms of what would work and what needs further investigation. This will contribute to the local milieu for monitoring outcomes as well as enhance ongoing work on quality improvements and metrics. These monitoring methods also may extend applicability to other hospitals and surgical outcomes.

## 2.0 Overall goal:

To determine the most acceptable approach for comparing surgeon specific complication rates in colorectal surgery using data derived from an electronic health record.

## 2.1 Objectives:

1) By conducting a systematic review of the published literature, identify published monitoring approaches to compare surgeon specific complication rates.
2) Define a set of surgical outcomes relevant to colorectal surgery patients and measureable using the Ottawa Hospital Data Warehouse (OHDW).
3) Validate the electronic methods used to define our cohort and outcomes compared to a gold-standard chart review.
4) Adapt a single risk adjustment model using data available in the OHDW based on an assessment of the goodness of fit and discrimination.
5) Compare surgeon specific complication rates for patients undergoing colorectal surgery at the Ottawa Hospital using the most promising monitoring approaches from our literature search (Objective 1).
6) Define the most acceptable approach for comparing complication rates through the conduct of a survey.

# 3.0 Methods

This study was approved by The Ottawa Hospital (TOH) research ethics board (Appendix A).

## 3.1 Part I: Choosing the monitoring methods to use

**Objective: Identify models and approaches that monitor surgeon performance**

### 3.2 Literature review

I conducted an electronic literature search of EMBASE (1980-2010) and Medline (1950-2010) on July 6, 2010. I developed the search strategy with the help of a librarian (Appendix B). I included the following search terms: surgical procedures, surgeons, surgeon performance, clinical competence, and task performance and analysis. Inclusion criteria included any type of surgical procedure, English studies on humans, and must have described in detail the methodology of monitoring method. I stored the articles electronically on RefWorks © and removed duplications. I screened articles by scanning titles and abstracts. I then removed remaining potential articles based on review of the full text.

### 3.3 Data extraction

I developed the data extraction sheet to capture all relevant data from the final set of included studies (Appendix C). The form captured the following items into two categories:

1) Study information: authors, country, funding source, study design, patient inclusion/exclusion criteria, intervention information, and surgical outcome measured.

2) Monitoring method: type (continuous/intermittent), coverage (hospitals), denominator data, definition of outcome variables, risk-adjustment model, data collection method, feedback format, validation, practicality, cost, and impact.

### 3.4 Data analysis

I used the Bruce et al criteria to assess the monitoring methods [15]. The need to use a set of criteria to evaluate the monitoring methods was to give some standard approach to compare the methods in an objective fashion. The Bruce et al criteria were chosen as it was specifically designed to evaluate monitoring methods and there were no other readily available criteria for this purpose.

1) Coverage of the system: national, regional, hospital, unit based
2) Denominator data: calculation of incidence rates of selected surgical outcomes
3) Definition of selected event
4) Whether risk factors were included for assessment
5) Data collection: who collected data, what methods were used, how data was collaged, validation checks
6) At what stage was the event recorded? (real-time, retrospective)
7) Output from the system: feedback to individual surgeon or group and dissemination to academic/clinical field.

### 3.5 Choosing the monitoring methods for the study

We chose three approaches used in the surgical literature that was applicable for our cohort due to practicality reasons.

### 3.6 Part II: Applying the chosen monitoring method to cohort

### 3.7 Data source

I used the Ottawa Hospital Data Warehouse (OHDW). This is a research database established for health research that includes data from 1996. It is an integration of clinical data from different sources, including laboratory data, radiology, pharmacy information systems, and administrative data from patient registration and health record systems.

### 3.8 Defining cohort

We selected our cohort as a patient encounter and defined it as a patient who had undergone a colorectal surgery at the Ottawa Hospital between April 1, 2003 and December 31, 2009. Patients could be included more than once if their subsequent colorectal surgery was greater than 30 days from the index colorectal surgery. We decided to keep encounter versus patient unit as the patients returning for a subsequent colorectal procedure was felt to be different on its own right. For example, an anterior resection is different from a colostomy reversal or a right hemicolectomy with each surgery a different experience.

Inclusions:

- Encounters in which patients underwent colorectal surgery as defined by Canadian Classification of Health Interventions (CCI) volume 4 codes (Appendix D). We modified the codes originally used in the Cancer Care Ontario (CCO) Institute of Clinical Evaluative Sciences (ICES) Atlas index [16] with minor modifications as determined by Dr. Boushey (clinical external supervisor) and myself.

- Surgeries must have been done at the Ottawa Hospital between April 1, 2003 and December 31, 2009
- Surgeries must have been done by a general surgeon
- General surgeons must have done more than one case over the study period
- Patients had to be admitted in-patients

Exclusions:

- Individuals <18 years of age at the time of their encounter
- Excluded trauma patients
- Excluded patients that had local transanal resections only (no surgery in the abdominal cavity)

### 3.10 Details of cohort selection from OHDW

To create our study cohort from the OHDW, we used the datasets "Procedures" and "Encounters." The CCI procedure codes for colorectal surgery (Appendix D) and the encrypted general surgeon identifiers (supplied by OHDW analyst) retrieved the patient encounters from the "Procedures" table that were performed in our study timeframe. We linked these identified procedures to the Encounters table to retrieve information regarding their admission and discharge dates, hospital service code, campus, gender, age, admission priority, transfer, and encounter type (inpatient). Other information from the "Procedures" table included date of procedure, and operating time (OR time).

We also included patients that had a subsequent colorectal surgery after 30 days from the initial surgery as a new encounter. We excluded patients if they were admitted to the trauma service, were less than 18 years of age, if the surgeon only had less than one case during the time period, and patients that received only a transanal excision. For confidentiality purposes, unique identifiers encrypted patients and general surgeons.

### 3.11Defining and validating outcomes

#### 3.11.1 Define outcomes:

I defined outcomes as 30 day postoperative complications using the modified Clavien-Dindo classification system (Table 1)[17]. Patients that received total parenteral nutrition (TPN) or had a blood transfusion were a grade 2 complication. Patients that returned to the operating room for a procedure, had an endoscopic intervention or had a radiologic intervention (ie. Percutaneous drain) were a grade 3 complication. Patients that had a stay postoperatively in the intensive care unit (ICU), cardiac care unit (CCU), or step-down unit were a grade 4 complication. Patients that died postoperatively were a grade 5 complication (Appendix E).

For this study, I defined mortality as grade 5 and 30 day in-hospital mortality. Morbidity was 30 day in-hospital grade 2-4 complications (TPN, blood transfusion, return to OR, interventional procedure, and ICU/CCU stay).

Other outcomes extracted were readmission within 30 days of discharge and length of stay. Readmissions were taken from the “HR Abstract” database to determine the number of readmissions within 30 days of discharge. Patients could have more than one readmission if

they were re-admitted more than once within 30 days of the initial discharge. I extracted length of stay from the "HR Abstract" database and defined it as the number of days in hospital for the index colorectal surgery from admission to discharge.

**Table 1: Modified Clavien-Dindo Outcome definitions from OHDW**

| Grades | Source of info | Rule in words |
|---|---|---|
| **Grade 2:** Total Parenteral Nutrition (TPN)<br><br>Note: two rules were derived | 1) Rule 1: Nservice, phmService<br>2) Rule 2: Nprocedures | 1) Rule 1: A patient was considered to have required TPN if: there was an order for TPN within the pharmacy information system within 30 days of index colorectal surgery (See Appendix E for TPN pharmacy codes). Note that for my cohort it includes all patients from the General but only starts after June 1, 2004 for Civic patients.<br>2) Rule 2: A patient was considered to have required TPN if there was a procedure code for TPN within the discharge abstract (CCI Procedure code: 1LZ35) and the procedure was performed within 30 days of index colorectal procedure. |
| **Grade 2:** Blood Transfusion | Nservice, NserviceReport, NserviceReportText, Nlabservice | A patient was considered to have had a blood transfusion if there was a service code (stmWID=15847) within the service table with a report text of at least one packed red blood cell transfusion within 30 days of index colorectal procedure. Please note that this is only available for patients after Oct 26, 2006. |
| **Grade 3:** Requiring surgical, endoscopic, or radiological intervention | Nprocedures | A patient was considered to have had a grade 3 complication (further surgical, endoscopic or radiological intervention within 30 days of index surgery) if there was a procedure code listed in Appendix F in the procedures table.<br><br>Comment: Note that for the surgical intervention (negative laparotomy does not count—must have had something done in that 2nd OR). Similarly for endoscopic |

| | | |
|---|---|---|
| | | intervention, it cannot only be an endoscopy (diagnostic), but must have had cautery, clips, some procedure done. |
| **Grade 4:** ICU/CCU/Step-down unit<br><br>Note: two rules were derived | 1) Rule 1: SpecialCare Unit<br>2) Rule 2: Inpatient Census History | 1) Rule 1: A patient was considered to have been in the ICU/CCU/Step-down unit if they had an entry into the special care unit table within 30 days of index colorectal surgery. (Appendix G)<br>2) Rule 2: A patient was considered to have been in the ICU/CCU/Step-down unit if they were on the nursing wards listed as ICU/CCU/Stepdown (See Appendix C) units within 30 days of index colorectal surgery. (Note this is a modification from the table in the concept definition document to exclude stays in the post-anesthetia care units (PACU) and included the B2 Trauma monitoring unit. Note this starts after April 1, 2004 only.) (Appendix G) |
| **Grade 5:** Mortality | Nencounter | A patient was considered dead if they had encDeathIndicator='D' in the patient encounter within 30 days of index colorectal surgery. |

### 3.11.2 Validating outcomes:

To validate our electronic algorithm, we conducted a chart review of encounters in whom we did or did not identify a complication. We used Hulley's nomogram to estimate the desired number of charts needed to calculate a statistically valid sample size for our study. Using the nomogram, our initial estimated cohort of 5800 encounters calculated a sample size of 288 patients assuming a 25% complication rate derived from the literature with 95% confidence intervals and margin of error of 5% [18]. We rounded up to 300 charts to be retrieved and reviewed. 150 charts with no complications derived from the electronic

algorithms and 150 charts with complications were selected. This was done with a random selection process on SAS.

Two reviewers conducted the chart review. However, for practical reasons, each chart was reviewed once. Five charts were reviewed independently and compared at the beginning to make sure the results were the same. If one reviewer had questions regarding one of the charts, the other would review that chart for clarification and come to an agreed outcome.

### 3.11.3 Statistical analysis

Using the chart review as the gold standard, we created 2 x 2 tables and calculated the appropriate sensitivities and specificities for each outcome. Weighted 2x2 kappa coefficients, positive predictive values (PPV), negative predictive values (NPV), likelihood ratios, and accuracy were calculated. All statistics for this study were done in SAS version 9.2 (SAS Institute, Cary, North Carolina).

## 3.12 Choosing appropriate risk indices for mortality and morbidity

### 3.12.1 Risk prediction models

The three risk prediction models used in this study were the Escobar model, Escobar$^{+}$ model, and the ColoRectal Biological and Hematological Outcome Model (CR-BHOM).

#### 3.12.1.1 Escobar model

Escobar model is a risk prediction model using logistic regression for in-patient mortality that has been previously validated with the OHDW [19]. The original model variables include sex, age at time of admission, admission type (emergency surgical and nonsurgical, elective

surgical and nonsurgical), admitting diagnosis, *L*aboratory-based *A*cute *P*hysiology *S*core (LAPS) and *CO*morbidity *P*oint *S*core (COPS) [20].

The admission type was taken from the admission category code and patient service code from the "HR DAD." Sex was from the gender code from the "Abstract" table. I calculated age at admission from the birth date and admission date from the "Abstract" table.

LAPS score included 14 laboratory values: serum albumin, anion gap, arterial pH, PaCO2, and PaO2, bicarbonate, total serum bilirubin, blood urea nitrogen, serum creatinine, serum glucose, serum sodium, serum troponin I, hematocrit, and total white blood cell count. These variables came from the "Laboratory Service" and "Service" tables. Our laboratory values for troponin included both troponin I and troponin T, using previous modifications for troponin T cut points [19]. I calculated LAPS score with lab values available 48 hours pre-admission and 6 hours post admission. If there were multiple lab values, the most deranged value pre-admission was used. If there were no pre-admission lab values, then the most deranged 6 hour post-admission lab value was used. Imputation was done with patients with missing values. Patients with a calculated risk of less than 6% mortality with the other variables were imputed normal lab values. Patients with greater or equal to 6% mortality were imputed a different set of lab values [20].

Since the OHDW did not have available admitting diagnosis, it was previously done on the OHDW with the most responsible diagnosis [19]. We followed this method with taking the most responsible diagnosis from the "Diagnosis" table.

The Elixhauser score substituted for COPS, as was previously done [21]. I used a one-year lookback window to determine the Elixhauser score using patient diagnosis from the "Diagnosis" table. The Elixhauser score is comprised of 31 comorbidities.

#### 3.12.1.2 Escobar$^{+}$ model

Another risk prediction model for in-hospital mortality was the Escobar$^{+}$ model [22]. In the original model, Cox regression used the Escobar variables with additional variables. For our cohort, we used the variables in Escobar$^{+}$ model as a logistic regression rather than a Cox regression because we were interested in a binary outcome at 30 days postoperative rather than a daily risk prediction for time to event. The additional variables included a daily preoperative intensive care unit (ICU) status, an alternate level of care (ALC) status, year of admission, hospital campus, and a Procedural Independent Mortality Risk score (PIMR).

The ICU status was taken from the "Special Care Unit" table and a value of 1 was inserted if the patient was in the ICU prior to the colorectal surgery during that admission. If the patient was not in the ICU prior to the surgery, then a value of zero was taken.

I determined the ALC status from the "Encounter" table if they were off active medical care prior to the colorectal surgery.

Year of admission and hospital campus code (either the General, Civic, or Heart Institute) came from the discharge abstract table.

PIMR score was an index that assigned a score based on the type and urgency of a therapeutic procedure performed in-hospital (Appendix H). This was taken from the "Procedures" table as well as the urgency status from the "HR DAD." The total score was the summation of the PIMR score for the day of the index colorectal surgery.

#### 3.12.1.3 ColoRectal Biochemical and Hematological Outcome Model (CR-BHOM)

We applied a specific risk index for colorectal cancer surgery to our cohort. This model used logistic regression with the following variables to predict 30 day mortality and morbidity: mode of admission, age on admission, urea, sodium, albumin [23]. The mode of admission was from the "HR DAD" table, age was calculated in the same manner as the ESCOBAR model, and the laboratory values (urea, sodium, albumin) were from the "Laboratory Service" table. For the laboratory values, we took the first value available from 24 hours pre-admission and up to 6 hours post-admission. For missing lab values, we imputed normal laboratory values.

### 3.12.2 Other variables to consider

Other clinically important variables we considered included whether the procedure was done for cancer or benign reason, whether the surgery was done by laparoscopic or open approach, whether it was a procedure for colon or rectal reason, or what type of resection type (segmental resection, total colectomy, bypass, stoma reversal, anterior resection (AR), or abdominoperineal resection (APR)).

We considered laparoscopic and open surgical techniques because laparoscopic surgery has been shown to have shorter length of stay and are not as invasive as open surgery [24]. We also considered resection type because the type of resection may be of differing levels of surgical technical difficulty and also reflect different severity of patient illnesses and outcomes.

### 3.12.3 Building the models with additional variables

We applied the three models, Escobar, Escobar+, and CR-BHOM, to our cohort using both the coefficients from their model and with our own calibrated coefficients. We added the additional variables into the models with a stepwise backwards elimination method excluding variables with a p-value > 0.05. These included variables such as operating for cancer or benign reason, laparoscopic or open surgery, colon or rectal resection, and resection type (segmental resection, total colectomy, bypass, stoma reversal, anterior resection or abdominoperineal resection).

### 3.12.4 Comparing models

Models were compared to each other with calculation of c-statistic for discrimination and Hosmer and Lemeshow test for goodness of fit (calibration). We considered models adequate with a c-statistic > 0.7 and H-L p-value >0.05[2526].

### 3.12.5 Determining the final model

After comparing the models using the c-statistic and Hosmer and Lemeshow goodness of fit, we decided to choose the model that had an acceptable c-statistic and H-L test as well as which model included clinically important variables. We decided to go with the same model

for both the mortality and morbidity binary outcomes at 30 days postoperatively for convenience.

### 3.13 Building control charts and funnel plots

#### 3.13.1 General considerations

In general, control charts plot successive cases along the horizontal axis versus successes/failures along the vertical axis; while the funnel plots plot the total number of cases to date along the horizontal axis versus the failure risk along the vertical axis. The control charts that were chosen to be built with the cohort from the OHDW came from the initial literature review. The three that were chosen were the cumulative sum chart method (CUSUM), variable life adjusted display (VLAD), and funnel plots.

We arbitrarily defined control limits as per convention as explained below for each method. We used the Ottawa Hospital complication rates to define parameters for the control charts. This implies that charts derived would compare individual general surgeons to others at the Ottawa Hospital. These comparisons would not compare surgeon's performance to general surgeons in other centres.

##### 3.13.1.1 Setting targets / control limits

We defined the target in this study as the overall mean for the surgeons at the Ottawa Hospital (TOH). We did not select targets from the literature because external studies did not typically adjust for the same factors as we did and we found a wide range of literature benchmarks.

We classified control limits, depending on the type of graph, into limits to indicate when the surgeon's outcome rate exceeded a threshold for excessive good or bad outcomes. If possible, we created both alert and alarm limits. An 'alert limit' is a warning signal to get the clinician's attention and is typically used to make sure that individual's outcomes are more closely monitored; an 'alarm limit' is signaling a clinician's unacceptable performance and is typically used to signal a mandatory review of their cases.

#### 3.13.1.2 Separate analyses for elective/emergent cases, crude/risk adjusted

We performed separate analyses for elective and emergent cases because we observed large variations in patient baseline characteristics and outcomes between these two subgroups in our cohort and it is easier to interpret the data separating the two cohorts.

We also evaluated crude and risk-adjusted outcomes using the final model chosen in section 2.4.5 for both mortality and morbidity outcomes.

### 3.13.2 Basic CUSUM graphs

The basic CUSUM graph plots successive cases for each surgeon on the x-axis and the cumulative number of mortality or morbidity events on the y-axis [27]. The equation for the CUSUM value is:

$$C_n = \sum_{p=1}^{p=n} \Delta_p$$

Where n is the number of operations in the sequence, $C_n$ is the CUSUM value at operation number p, and $\Delta p$ is the observed outcome for the patient at operation number p. For CUSUM plots, p is valued at 0 or 1 based on whether an adverse outcome occurs.

We also calculated the predicted CUSUM using the following equation:

$$P_n = \text{int} \sum_{p=1}^{p=n} \delta_p$$

Where $P_n$ is the predicted CUSUM value at operation number p, $\delta_p$ is the predicted outcome rate for the patient at operation number p and we calculated the predicted outcome rate from our Escobar model with the additional cancer variable.

Figure 1 is an example of a basic CUSUM graph demonstrating one individual's consecutive case log with the number of cumulative surgical failures. As the line graph moves horizontally, this represents successive cases for each surgeon and as the line goes up, this represents failure (ie. mortality, morbidity).

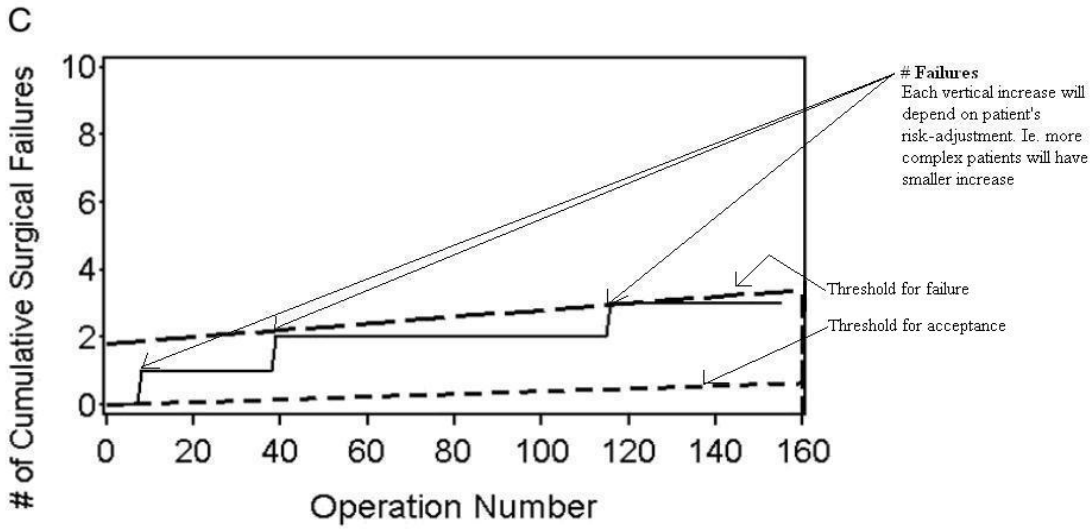

Figure 1: Example of basic CUSUM

For calculating the alert and alarm boundaries, the mean mortality and morbidity rate for the cohort was doubled at the alarm level. Alpha was kept at 0.05 and beta to 0.20. The formulas to calculate the alert and alarm boundaries are below [28]:

$a = \log [(1-â)/á]$

$P = \log [p1/p0]$

$b = \log [â/(1-á)]$

$Q = \log [(1-p0)/(1-p1)]$

$s = Q/(P+Q)$

$alert = n*s – (b/(P+Q))$

$alarm = n*s + (a/(P+Q))$

where $á = 0.05$ and $â = 0.20$

p1 = doubling or halving mortality or morbidity rate (p0) for upper and lower boundaries

p0 = overall morbidity or mortality rate

n = number of case in sequence

This formula will provide limits to determine when the number of outcomes exceeds twice the expected risk or half the expected risk.

### 3.13.3 Risk-adjusted CUSUM (RA-CUSUM) graphs

For risk-adjusted CUSUM (RA-CUSUM) graphs, we applied weights consisting of odds ratios, using the method developed by Steiner et al [29]. The odds ratio was defined as the probability of the event over the probability of an alternative event. In our study, the odds of having an adverse outcome for each case were:

$$\frac{\delta_p}{(1-\delta_p)}$$

Where $\delta_p$ is the predicted outcome risk for the patient at operation number p.

The hypothesis, $H_0$, was the outcome risk that was set to the level of current practice for the Division of General Surgery at TOH. The alternative hypothesis, $H_A$, was the deviation from $H_0$ to be detected.

The two-sided tabular CUSUM was used. We used two alternate hypotheses: one to detect a doubling rate in adverse outcome ($\delta_A$=2) and the other to look for halving in the rate for adverse outcome ($\delta_A$=0.5). $\delta_A$ is the probability of an adverse outcome under $H_A$.

For each case, a log-likelihood ratio ($W_n$) was calculated: if the patient encounter did not have an adverse outcome (ie. Mortality or morbidity), then this equation used was[30]:

$$W_n = \log\left[\frac{1-\delta_p + OR_O \cdot \delta_p}{1-\delta_p + OR_A \cdot \delta_p}\right]$$

However, if the patient encounter has an adverse outcome, then this equation used was:

$$W_n = \log\left[\frac{(1-\delta_p + OR_O \cdot \delta_p)\cdot OR_A}{(1-\delta_p + OR_A \cdot \delta_p)\cdot OR_O}\right]$$

The cumulative X-values for maximum and minimum values were calculated to detect a deterioration or improvement of an outcome rate[30]:

$$X_t^+ = \max(0, X_{t-1}^+ + w_t) \text{ and } X_t^- = \min(0, X_{t-1}^- - w_t)$$

The "max" component above sets $X_t$ to zero unless $X_{t-1}^+$ is positive, and the "min" component above sets to $X_t$ to zero unless $X_{t-1}^-$ was negative.

**Control limits**:

We decided against setting Type I and Type II errors with alpha=0.05 and beta=0.20 for determining the control limits because with cumulative control charts, the run would always cross the control limits after a series of cases even if it were false. Thus to determine the appropriate threshold, we determined the appropriate average run length (ARL) for a false positive and a true positive. We used the integrative equation approach in SAS. The equation used to obtain the ARL's of 2 1-sided states was [31]:

$1/ARL = 1/ARL^{+} + 1/ARL^{-}$

$ARL_0$ is defined as the average number of cases until CUSUM chart falsely signals a change, and $ARL_1$ means the average number of cases until CUSUM chart signals when mortality or morbidity rate increased to an unacceptable level. Ideally, we would want to have a long $ARL_0$ and a short $ARL_1$.

H is the decision interval (or control limit) where upon crossing this value, the process is considered to be out of control and K is the reference value.

To determine the appropriate H and K values, we used Lucas tabular design rules (1976) setting the target means as the overall elective mortality or morbidity rate (and also for overall emergent mortality and morbidity rate), and delta (critical deviation from the target) which we arbitrarily chose as 1 standard deviation. Sigma, the standard deviation, was obtained from the overall cohort for the respective rates (mortality or morbidity). Thus, for using the appropriate target, delta, sigma, and n=1, the integrative equation approach led us

to choose the appropriate H and K values of 3.5 and 0.5 to give an in-control $ARL_0$ at 99.79 cases and an out-of-control $ARL_1$ 7.39 of  cases (Appendix I). The same H and K values were used for elective and emergency mortality and morbidity cases.

### 3.13.4 Variable life-adjusted display (VLAD)

VLAD plots are a variation of a CUSUM plot. Here, successive cases are plotted horizontally and the vertical rise is the difference between the cumulative predicted risk and the cumulative observed outcome rate, which is called the net life gain[32]. Figure 2 is an example of VLAD graph depicting consecutive operations horizontally with the survival or net life gain going vertically.

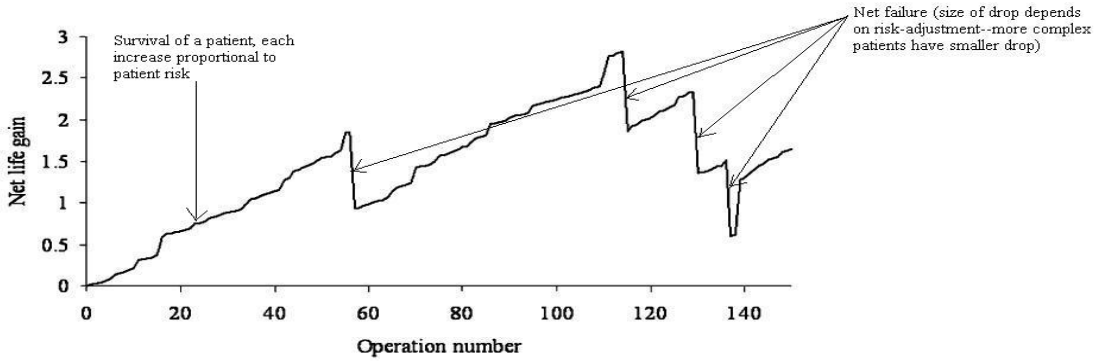


Fig. 2. VLAD chart plotting a running tally of net life gain derived from Fig. 1.

The cumulative predicted risk is:

$$\rho_n = \sum_{p=1}^{p=n} \delta_p$$

Where p is the number of operations in the sequence, $\delta_p$ is the predicted outcome rate for the patient at operation number p, and $\rho_n$ is the cumulative risk in cases, n.

The VLAD plot for net life gain is:

$$P_n = \sum_{p=1}^{p=n} \delta_p - \Delta_p$$

Where p is the number of cases in sequence, $\delta_p$ is the predicted outcome rate for the patient at operation number p, $\Delta p$ is the observed outcome rate for the patient at operation number p, and Pn is the VLAD-value (or net life gain).

Predicted limits were constructed with the assumption that the overall mortality for a sizeable sequence of cases was that if it were repeated for an identical series of patients, it would be approximately normally distributed. The standard normal variate and prediction interval was calculated:

$$\left( -z\sqrt{\sum_{1}^{n} \hat{y}_i(1-\hat{y}_i)},\ z\sqrt{\sum_{1}^{n} \hat{y}_i(1-\hat{y}_i)} \right)$$

Where z=1.96 for 95% limits and Z=2.576 for 99% limits. $\hat{y}_i$ is the estimated preoperative risk of death and n is the number of cases[32 33]. The prediction limit was computed for each successive case. This did not account for the implied multiple comparisons and is a limit with this type of prediction limit.

### 3.13.5 Unadjusted funnel plots

Funnel plots were constructed with the number of total cases done in the study period by each surgeon on the horizontal axis. The vertical axis is the mortality rate or morbidity rate. The target chosen was the overall mortality rate = sum of all mortality for the total patient encounters/sum of all cases *100. This was done similarly with the overall morbidity rate.

Figure 3 is an example of funnel plot where each surgeon is represented as a dot on the graph with the dot being a representation of a cross-sectional period of time.

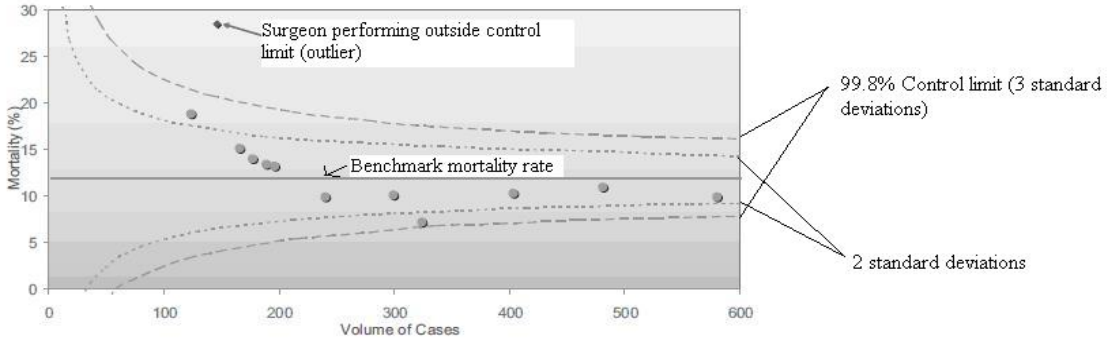


Figure 3: Funnel plot example

For the alert boundary, 2 standard errors from the target was used and for the alarm boundary, 3 standard errors from the target was used from an exact binomial method [34]:

$$SE = \sqrt{\frac{p(1-p)}{n}}$$

Where SE is the standard error, p is the overall mortality or morbidity rate, and n is the number of cases for that one surgeon.

### 3.13.6 Risk-adjusted funnel plots

For each surgeon, the risk-adjusted mortality rate and risk-adjusted morbidity rate was calculated for their set of cases.

The formula:

Risk-adjusted mortality rate for each surgeon

= (#observed deaths per surgeon/#expected deaths per surgeon)*100 which gave a rate per 100 cases.

The expected deaths were calculated using logistic regression with the Escobar model with the additional cancer variable. Similarly, the risk-adjusted morbidity was calculated in the same fashion.

The same formula for alert and alarm limits was calculated using 2 and 3 standard errors as the formula used in the unadjusted funnel plots.

The target rate was the overall mortality rate = sum of mortality/sum of cases.

### 3.14 Building individual surgeon reports

#### 3.14.1 Individual surgeon's patient demographics and outcomes

Each surgeon's cases were broken down into patient demographics and short term outcomes into tables comparing themselves to the rest of the general surgeons at TOH.

#### 3.14.2 Individual surgeon's results for elective mortality and morbidity, and emergent mortality and morbidity

I created figures for basic CUSUM, risk-adjusted CUSUM, VLAD, and risk-adjusted funnel plots for each surgeon for elective and emergency cases for 30-day in-hospital mortality, and elective and emergency cases for 30-day postoperative morbidity. I used SAS to merge these figures.

### 3.15 Comparing monitoring methods

To compare the results from the different graphs, I tallied the number of flags for each monitoring method. We compared the flags across the figures and for alert and alarms for worsening outcome as well as detection of alert and alarm for improvements in outcome.

## 3.16 Part III: What do surgeons think about monitoring and who should view the results?

### 3.1 Development of the survey

I developed the survey to capture information on surgeon demographics, opinion on their practice, which examples of monitoring methods do they find acceptable, what are appropriate outcome measures, and who should have access to their outcomes. Response choices consisted of fill in the blank, circling yes/no, ranking figures and outcomes, areas for written comments, and choosing answers amongst a list (Appendix J).

### 3.2 Distribution of the survey

I handed out the surveys individually to the 20 currently practicing general surgeons at TOH. The package consisted of a consent form, a survey, and a return envelope. After each week, I emailed individuals a reminder up to three times before I considered them as non-responders.

If surgeons had questions or concerns, they were able to contact me for one-on-one sessions, phone calls, and/or clarifications via email.

### 3.3 Collecting and analyzing the survey

I coded the survey responses into an excel spreadsheet. I tabulated and organized the results into figures on demographics, monitoring methods, and opinions on reporting outcomes. I recorded personal comments and kept them as free text to add to the discussion.

# Results

## 4.0 Part I: Literature Review

### 4.1 Flow chart of selected articles

Using EMBASE and Medline databases, the literature search was conducted on July 6, 2010. There were 4558 articles on EMBASE and 1503 articles identified on Medline. After merging and removing duplications, there were 5835 unique articles (Exhibit 1). After first pass on title and abstracts, there were 268 articles remaining to retrieve for full text review. On second pass of full text, there were 127 articles to read in detail for data abstraction. Only 88 articles met eligibility criteria and were included in the final review.

### 4.2 Data extraction results

Study characteristics of the 88 included studies are displayed in Exhibit 7. Using our search strategy, most of the included studies used CUSUM monitoring methods, followed by VLAD/CRAM charts, then with funnel plots (Exhibit 2). Out of the studies that used the CUSUM method, most types were for surveillance and/or information systems or for constructing learning curves (Exhibit 3). The number of publications on monitoring methods in surgery had increased over the past decade with most of the literature coming from the United Kingdom (Exhibit 4 and 5). The majority of studies were done in cardiac surgery (including pediatric cardiac surgery) and general surgery with 31 and 21 studies respectively (Exhibit 6).

### 4.3 Data analysis (Bruce et al)

Using the Bruce et al [15] assessment criteria for monitoring methods, the maximum total score was 7 points. The mean score was 4.64 (SD 1.21). 98% of the studies had described the type of coverage (national/ regional/ hospital/ unit-based) and also had a definition of an

outcome. Only 50% of studies explicitly reported the method of data collection information. Not many published studies included risk factors (36.4%) or had any feedback to the surgeons (22.7%) (Exhibit 8).

### 4.4 Conclusions

There are many types of monitoring methods used in surgery in relating to monitoring surgeon specific outcomes. Some methods used continuous monitoring, whereas others were static. Some studies used risk-adjustments for patients to level the case-mix between surgeons. However, many of the available tools did not demonstrate follow through with timely feedback to the individuals or departments. After reviewing the included studies, the three most popular monitoring methods were the CUSUM, VLAD/CRAM, and funnel plots. For our cohort and remainder of the study, we use these three methods.

## 5.0 Part II: Applying chosen monitoring methods to cohort

### 5.1 Cohort characteristics

There were a total of 4980 encounters (4318 unique patients) that met our inclusion criteria. Due to the differences in patient characteristics between elective and emergent cases, the groups were kept separate in the analysis (Exhibit 9). I separated out the patient characteristics for sex, age and comorbidity scores to each individual but kept the other characteristics unique to the encounter as each encounter is unique. For elective cases, the mean age was 63 years (SD 15.0), majority was male (56.8%), and median Elixhauser comorbidity score was 4 (IQR: 0, 10). Most were operated on for cancer (62.4%), were done with an open approach (72.1%), were for a colon surgery (65.2%), and had a segmental resection (43.0%). 21.4% of elective patients received a stoma. For emergent cases, mean age was 63.3 years (SD 17), 48.6% were male, and had a median Elixhauser comorbidity score of 5 (IQR: 0, 16). 91.7% of cases were done with the open approach, 37.2% were operated on for cancer, 90.8% were colon cases, 65% were segmental resections, and 50.7% of emergent patients received a stoma.

### 5.2 Outcomes-Table of overall outcomes

Results for short term outcomes are displayed in Exhibit 10. These outcomes were derived from electronic algorithms from OHDW. 83.3% of elective cases had no complications whereas 50.4% of emergent cases had no complications. Grade 5 complication (30 day in-hospital mortality) was 1.2% for elective cases and 11.3% for emergent cases. Emergent cases had a higher percentage of complications at every grade compared to elective cases. For the highest grade of complication per encounter, 11.7% emergent cases received either a blood transfusion or total parenteral nutrition (TPN), 8.3% had a grade 3 complication that

required further operation, endoscopic or radiologic intervention, and 18.2% emergent cases went to stay in the intensive care unit or step-down unit (grade 4 complication). This is in contrast to elective cases with the highest complication of grade 2 complications at 4.3%, grade 3 complications at 7.3%, and grade 4 complications at 3.8%. The median length of stay for emergent cases were double elective cases at 13 days (IQR: 8, 26) for emergent and 6 days (IQR: 5, 9) for elective. Elective cases had 5.6% 30 day readmission for one readmission and 0.4% for 2 readmissions within 30 days. Emergent cases had 7.2% 30 day readmission once and 0.6% readmission twice within 30 days.

### 5.3 Validation of Outcomes

Health records were given 300 charts to pull. However, only 292 charts were included because 8 charts were incomplete or missing. Exhibit 11 displays the 2 x 2 tables for each 30-day outcome.

For grade 2 complications with blood transfusion, the sensitivity was 0.87 (95% CI: 0.75-0.95) and specificity was 0.97 (95% CI: 0.91-0.99) with data from the service text reports from October 26, 2006. The charts that had blood transfusions but not identified in the electronic algorithm were mainly due to patients receiving blood transfusion in the operating room, and were not captured in the electronic data warehouse. During the dates chosen, anesthesia was charting on paper and had not moved to electronic form during this period.

For grade 2 complications with total parenteral nutrition (TPN), there were two sources of data—the ‘Procedures’ table and the ‘Pharmacy service’ table. The procedures table had a lower sensitivity of 0.67 (95% CI: 0.53-0.80) compared to the pharmacy table of 0.96 (95%

CI: 0.87-1.00). The specificity was excellent with either table at 1.00 (95% CI: 0.98-1.00) with the procedures table and 0.99 (95% CI: 0.97-1.00) with the pharmacy data. We decided to use the dataset from the 'Pharmacy service' table since it had a higher sensitivity than the dataset from the 'Procedures' table.

For grade 3 complications, overall sensitivity was 0.91 (95% CI: 0.81-0.97) and overall specificity was 0.94 (95% CI: 0.91-0.97). Breaking down grade 3 into the various components, the sensitivity was lower than overall. Return to operating room had a sensitivity of 0.77 (95% CI: 0.58-0.90), endoscopic intervention had a sensitivity of 0.75 (95% CI: 0.19-0.99), and interventional radiology had a sensitivity of 0.85 (95% CI: 0.68-0.95). Specificity was good with all three: 0.97 (95% CI: 0.94-0.98) for return to operating room, 0.96 (95% CI: 0.93-0.98) for endoscopic intervention, and 0.98 (95% CI: 0.95-0.99) for radiologic intervention.

There were two different datasets to derive grade 4 complications: 'special care unit' table and 'inpatient census' table. The 'inpatient census' table was only available after April 1, 2004. The sensitivity and specificity were 1.00 (95% CI: 0.94-1.00) and 0.99 (95% CI: 0.97-1.00). With the 'special care unit' table, the sensitivity was 0.98 (95% CI: 0.92-1.00) and the specificity was 0.99 (95% CI: 0.97-1.00). Since both datasets had excellent sensitivity and specificity, we decided to go with the 'special care unit' table as it would include our entire cohort.

Grade 5 complications had the best sensitivity and specificity: 1.00 (95% CI: 0.85-1.00) and 1.00 (95% CI: 0.99-1.00).

Exhibit 12 demonstrates the frequency by encounter and the sensitivity and specificity with the weighted 2x2 kappa coefficients. The kappa coefficient had perfect agreement with grade 5 complication with both k+ and k- of 1. The rest of the complications had excellent weighted kappa coefficients. Grade 2 blood transfusions had k- of 0.81 and k+ of 0.91 and grade 2 TPN had k- of 0.95 and k+ of 0.95. Grade 3 complication had a k- of 0.89 and k+ of 0.95. Grade 4 complication had k- of 0.98 and k+ of 0.96.

Exhibit 13 displays the results of accuracy, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and positive and negative likelihood ratios for short term outcomes. There was excellent accuracy of our electronic algorithms for the short term outcomes ranging from 0.93 to 1.00. PPV ranged from 0.80 to 1.00. NPV was excellent with a range of 0.93 to 1.00. Positive likelihood ratios were from 16.4 to infinite and negative likelihood ratios went from 0 to 0.13.

### 5.4 Risk prediction models

The model fitting for the risk prediction models, Escobar, Escobar$^{+}$, and CR-BHOM are in Exhibit 16 for 30 day in-hospital mortality and 30 day morbidity. The c-statistics for all three models were above 0.80 for mortality and above 0.70 for morbidity; hence all 3 models had good discrimination. The Hosmer-Lemeshow statistic had a good fit for Escobar and Escobar$^{+}$ models for both mortality and morbidity with the p-value greater than 0.05, but

the CR-BHOM model did not have a good fit with p-values of 0.0118 for mortality and 0.0416 for morbidity.

For mortality with the Escobar model, cancer had a p-value <0.0001, open/laparoscopic approach had a p-value of 0.1225, colon/rectal surgery had a p-value of 0.0403, and resection type had a p-value of 0.0175. However, when all four additional variables were in the model, only cancer had a significant p-value of 0.006 (the p-values for open/lap were 0.1827, colon/rectal was 0.2382, and resection type 0.1373).

For mortality with the Escobar$^{+}$ model, the variables that were significant as a single addition was cancer (p-value<0.0001), colon/rectal (p-value=0.0334), and resection type (p-value=0.0377). Open/laparoscopic approach was not significant at p-value 0.1418. However, when all the four variables were in the model, only cancer was significant with a p-value of 0.0001.

For the CR-BHOM model, all four additional variables were significant: cancer (p-value=0.0001), open/laparoscopic (p-value=0.0308), colon/rectal (p-value=0.0094), and resection type (p-value=0.0302). With all of the variables in the model, only resection type became insignificant (p-value=0.1773).

For morbidity with the Escobar model, cancer, open/laparoscopic, and resection were all significant with p-values all less than 0.0001 and remained significant when all the variables were in the model. Colon/rectal surgery was not significant with p-value=0.7174.

For morbidity with the Escobar$^{+}$ model, the results are similar to the original Escobar model with the variables cancer, open/laparoscopic, and resection type all significant as the one additional variable to the model and when all three variables were in the model (p-values all less than 0.0001).

For morbidity with the CR-BHOM model, cancer was significant with p-value of 0.0003, open/laparoscopic approach with p-value <0.0001, and resection type with p-value of 0.0003. Colon/rectal surgery were not significant as a single add-on to the model with p-value of 0.5025. However, with all the variables in the model, all 4 variables were significant (colon/rectal with a p-value of 0.0264 and the other three variables all had p-values<0.0001).

Exhibit 19 displays the likelihood ratio test for the other variables added to the three models for mortality and morbidity. All the p-values for the models with the additional variables were significant with values less than 0.0001.

**Final model**

After evaluating the three models with the additional variables, Drs. Forster, Fergusson, and I decided to go with the Escobar model with the addition of the variable, operating for cancer versus benign reason. We decided to keep the same variables for both mortality and morbidity models for simplicity. The final model parameters are in Exhibit 14 and Exhibit 15 for 30 day in-hospital mortality and morbidity. We decided upon this model because it

had a good c-statistic, good fit, well validated on the OHDW and other cohorts, and required fewer variables than the Escobar$^{+}$ model. Exhibit 16 demonstrates the discrimination and goodness of fit of the final model compared to the three models (Escobar, Escobar$^{+}$, and CR-BHOM). The Escobar$^{+}$ model was very good as well, but required more variables for only marginally better c-statistic. Furthermore, it had only been validated once and on not as many cohort groups as the original Escobar model. The CR-BHOM did not have a good fit to be considered as the final model. The cancer variable added a better fit to the original Escobar model and is clinically meaningful, according to Dr. Boushey (colorectal surgeon). The receiver operating characteristic (ROC) curves are displayed in Exhibits 17 and 18 for mortality and morbidity.

## 5.5 Building control charts and funnel plots

### 5.5.1 Example of basic CUSUM graph

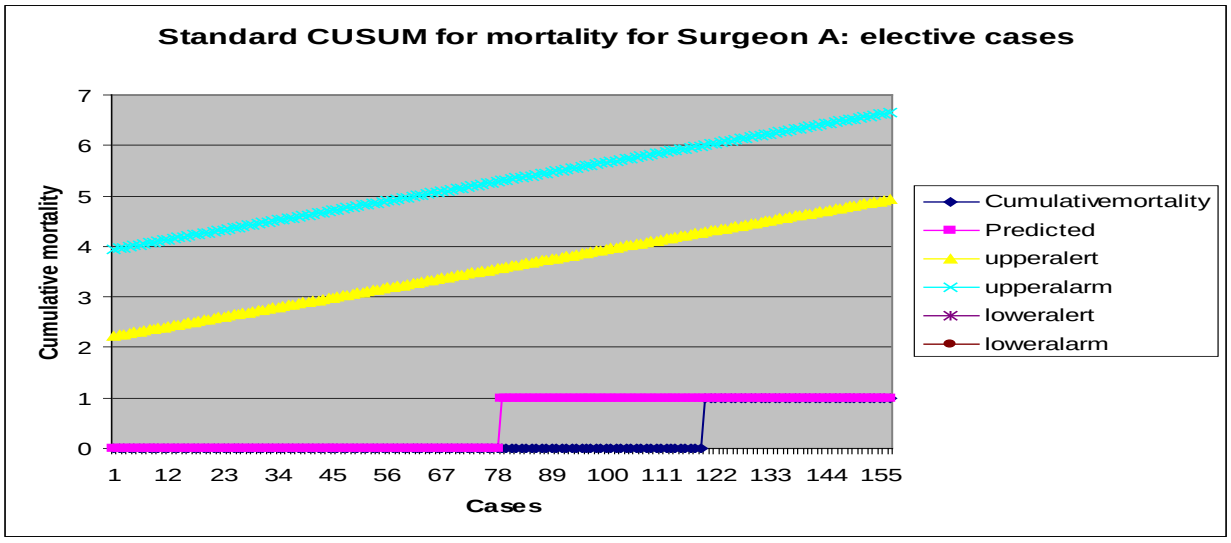


Exhibit 20 (above) is an example of a basic CUSUM graph for Surgeon A. Upper and lower alarm and alert boundaries were created for the doubling or halving of mortality rate in this

example. Graphs for all surgeons were constructed in this fashion for both mortality and morbidity for their respective elective and emergent cases (Appendix K).

### 5.5.2 Example of RA-CUSUM graph

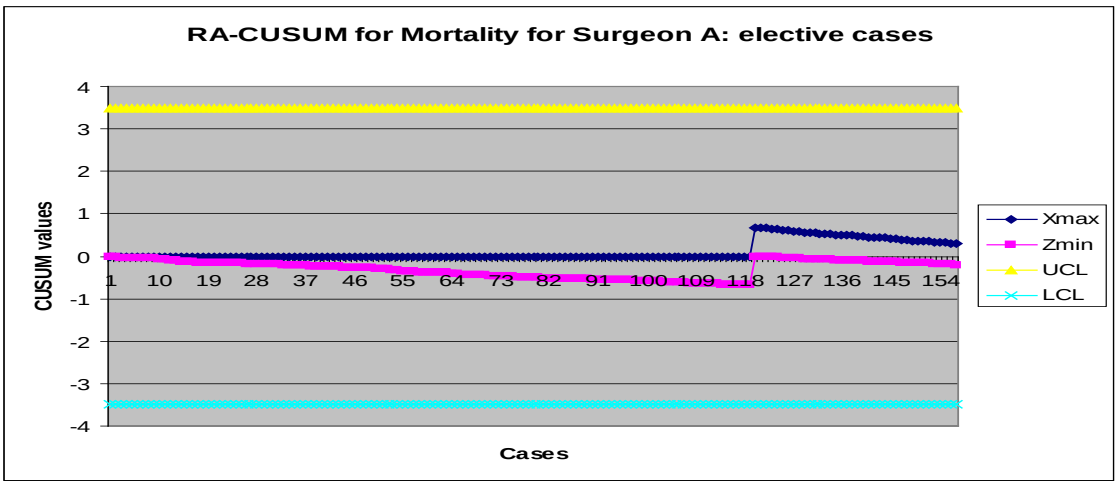


Exhibit 21(above) is an example of the risk-adjusted CUSUM graph of Surgeon A for mortality. The two-sided tabular CUSUM had upper and lower control limits of 3.5 and a weighting of odds ratio of doubling or halving mortality. These were constructed for all general surgeons for their respective elective and emergent cases for both mortality and morbidity (Appendix K).

### 5.5.3 Example of VLAD

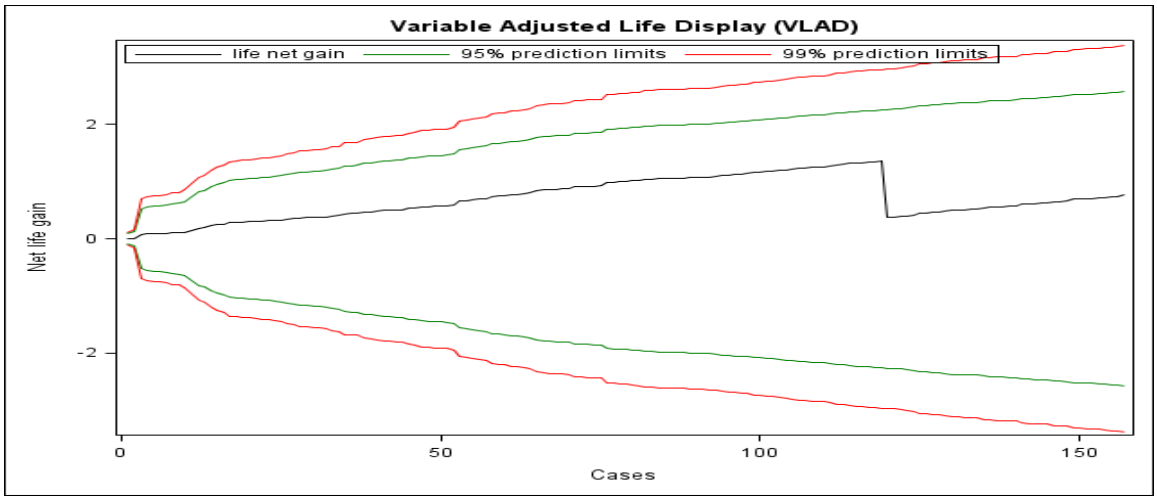


Exhibit 22 (above) is an example of VLAD graph for Surgeon A. 95% and 99% prediction

limits are shown. Graphs for the general surgeons were constructed in this fashion for elective and emergent cases for mortality and morbidity (Appendix K).

### 5.5.4 Example of unadjusted funnel plot

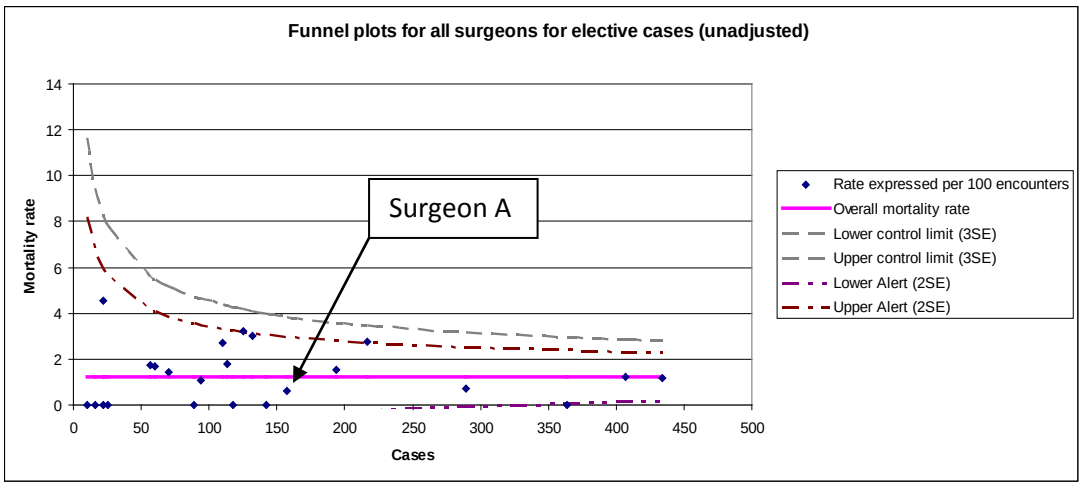


Exhibit 23 (above) is an example of an unadjusted funnel plot for elective mortality for the general surgeons over the study period. Alert and alarm boundaries were constructed using two and three times the standard error. Surgeon A is indicated in Exhibit 23. Similar figures were constructed for elective morbidity and emergent mortality and morbidity (Appendix K).

### 5.5.5 Example of risk-adjusted funnel plot

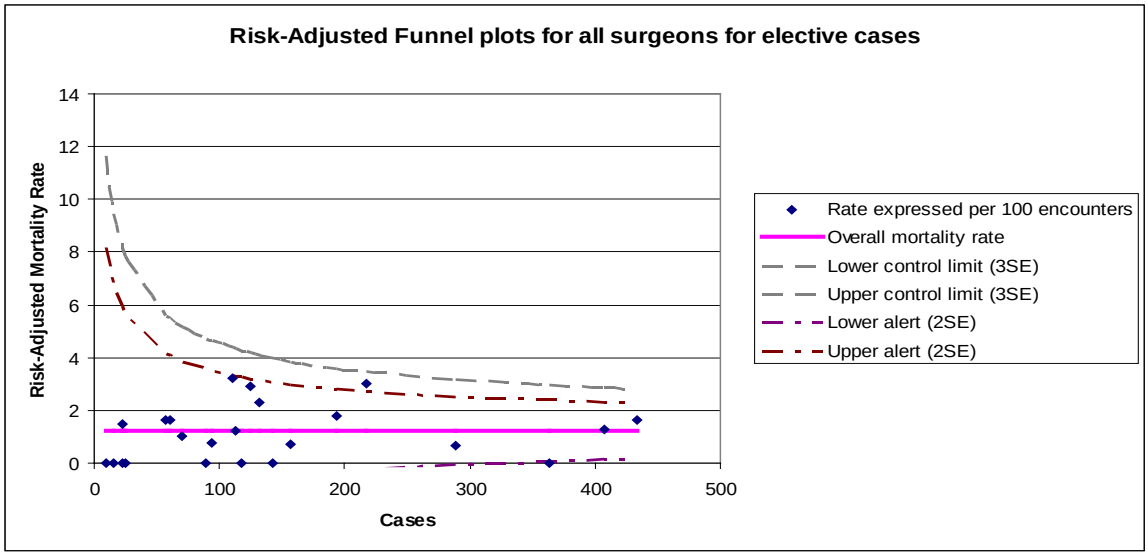


Exhibit 24a (above) is the risk-adjusted funnel plot for elective mortality over the study

period. Alert and alarm boundaries were two and three times standard error. Graphs for elective morbidity and emergent mortality and morbidity were constructed (Appendix K).

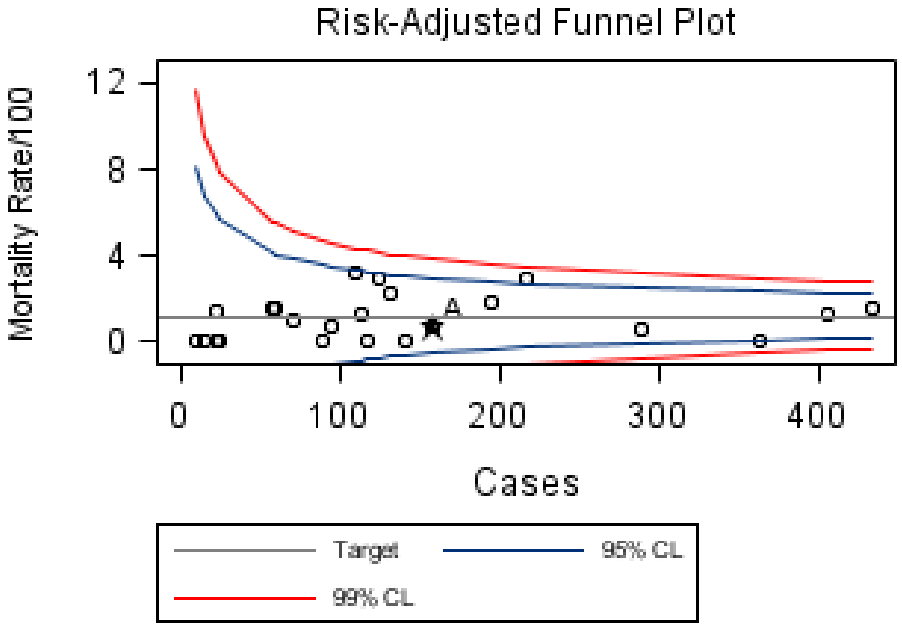


Exhibit 24b (above) indicates where Surgeon A lies amongst his peers.

### 5.6 Building individual surgeon reports

#### 5.6.1 PDF reports for individual surgeons

Appendix K displays the constructed report cards for each individual surgeon. The first two tables of the report list patient characteristics and surgery outcomes. The graphs are sub-grouped into elective mortality, elective morbidity, emergent mortality and emergent morbidity. For the funnel plots, each surgeon can see where they stand amongst others, but other surgeons remain unidentifiable to that surgeon.

#### 5.6.2 Comparing results—Table of flags

The summary of flags for bad outcomes was tabulated in Exhibit 25. The number of flags varied for the different graphs depending on the alert and alarm limits. For instance, for

elective mortality, there were 4 alerts with basic CUSUM graph (Surgeons C, G, I and P), 4 surgeons that exceeded the 99% lower prediction limit for VLAD (Surgeons B, C, G, and I), 7 surgeons that exceeded the 95% lower prediction limit for VLAD (Surgeons B, C, D, F, G, I and P), 2 surgeons that exceeded the upper alert in the unadjusted funnel plot (Surgeons C and P), and one surgeon that exceeded the upper alert for the risk-adjusted funnel plot (Surgeon C). There were more flags in the elective morbidity for bad outcomes than elective mortality and it varied depending which type of monitoring method was used. Emergent mortality and morbidity also had varying flags depending on the plot.

The summary of flags for good outcomes is displayed in Exhibit 26. The highest number of flags for elective mortality was the only one using the varying methods. For elective morbidity, the most flags were in basic CUSUM in crossing the alarm indicating improvement (10 flags). However, the rest of the plots for elective morbidity for detecting an improvement in morbidity ranged from 0 to 8 surgeons depending on the monitoring method. For emergent mortality, only the VLAD graph and basic CUSUM plots demonstrated flags for improvement. For emergent morbidity, there was quite a range of flags depending on the monitoring method (0 to 9 flags), with the most number of flags using basic CUSUM method.

Exhibit 27 displays a summary of proportion of outcomes out of the varying monitoring methods. Each individual surgeon's proportion out of the methods is tallied for bad outcomes. Bad outcomes were anytime the surgeon had crossed an alert or alarm boundaries using the monitoring methods: basic CUSUM, risk-adjusted CUSUM, VLAD, and funnel

plots. Morbidity and mortality results are combined and separated into elective and emergent results. The average proportions of bad outcomes with the cumulative monitoring methods for all surgeons are 17.4% and 8.2% for elective and emergent cases respectively. The ranges for elective mortality and morbidity are from 0 to 62.5% and the emergent ranges from 0 to 25%. Seven surgeons had 0% elective and emergent mortality and morbidity flags. Two surgeons (Surgeons C and G) have results over 50% for elective mortality and morbidity with the combined monitoring methods.

## 6.0 Part III: What do surgeons think about monitoring and who should view the results?

### 6.1 Survey response

The survey was distributed to the twenty general surgeons currently practicing at the Ottawa Hospital in March and April 2011. There was a response rate of 80% (16/20). Surgeons who did not return the questionnaire after three follow-ups of email reminders were considered non-responders. Some surgeons contacted me for more information regarding the survey. One surgeon asked questions over the phone and two surgeons met up with myself in person to ask questions for clarification and some of their concerns regarding the survey.

### 6.2 Surgeon demographics

Exhibit 28 displays the demographics of the respondents. There is one female general surgeon, 37.5% (6/16) are between 50-59 years of age, and majority (75%) has been practicing for over 20 years. Only three surgeons have not had any type of fellowship training and the rest of the surgeons had fellowship training, including trauma, critical care, hepato-pancreato-biliary (HPB), transplant, minimally-invasive surgery, colorectal, thoracic, vascular, surgical oncology, and gastro-intestinal fellowships. 50% of the surgeons said they performed some form of self-audit. Examples included database, mortality and morbidity rounds, and comparing their span of results to benchmark literature rates.

When asked about their own practice on colon and rectal surgery, most surgeons felt that they performed more than 10 cases colon surgery/year (68.8%) whereas for rectal surgery, most felt they performed less than 10 cases/year (68.8%) (Exhibit 29a). 25% of surgeons felt they did more than 75% of their colorectal cases emergently and 50% felt that it consisted of

less than 25% of their practice (Exhibit 29b). 50% of surgeons felt that less than 25% of their colorectal practice is done laparoscopically and 31.3% felt that more than 50% of their colorectal practice is performed laparoscopically (Exhibit 29c).

### 6.3 Surgeon opinion on figures

In Exhibit 30, majority of surgeons (87.5%) found the cumulative failure graph acceptable, followed by the funnel plot (62.5%) and then the VLAD graph (31.3%). Surgeons found the cumulative failure graph easy to interpret (75%), allowed for patient risk-adjustment (50%) and permitted surgeons see their consecutive cases (50%). However, the disadvantage they felt with the cumulative failure graph was that it did not allow for the complexity of each case to be accounted (69%) and that low volume surgeons may appear to have worse outcomes than high volume surgeons (56.3%).Other comments were that there is potential to see improvements to changes in practice but it may be difficult to define thresholds and risk-adjustments.

With the funnel plot example, surgeons felt this type of graph was easy to interpret (81.3%) and easy to spot outliers (68.8%). However, surgeons felt that it did not tell how complex each case is (87.5%). Other comments included that it is a static picture, hence not illustrating change, and may be better for assessing institutional performance.

For the VLAD graph, surgeons found it too complex and not easy to understand. Yet, one surgeon felt it intuitive where “success goes up, and failure goes down.” Others were unsure about the acceptability of this type of graph and did not see the advantage of this method.

Other comments regarding monitoring were that “better outcomes monitoring per surgeon and per procedure is a welcomed thing” and “very much needed.” Others felt that they would not trust these graphs if they felt they did not understand it.

### 6.4 Surgeon opinion on outcomes

The order of performance indicators that were felt important by the general surgeons were mortality, postoperative complication, and breakdown of surgical procedures performed. Less important performance indicators for the surgeons were resident satisfaction surveys and teaching at academic half days. Comments included that surgeon performance is different than academic or teacher performance whereas one surgeon wrote that the number of medical legal actions should be included, as well as number of publications and administrative responsibilities. Other indicators surgeons noted were that for cancer cases, margins and lymph nodes should be a performance indicator.

87.5% felt that a return to the operating room after index surgery is considered a postoperative complication. Other complications were felt to be postoperative interventional radiology (75%), unplanned ICU stay (68.8%), blood transfusion (56.3%), cardiac care unit stay (37.5%), postoperative endoscopic intervention (31.3%), and total parenteral nutrition (25%). Others suggested wound infection, anastomotic leak rates, hernia rates, and the 22 complication of National Surgical Quality Improvement Program (NSQIP) should be included as a postoperative complication [35, 36].

### 6.5 Surgeon opinion on transparency

Exhibit 31 displays the response of surgeons on "who should be able to view surgeons' outcomes." Surgeons were allowed to check more than one response. 62.5% felt that the Department chair, Division head, and Cancer Assessment Centre colorectal steering committee should be able to view surgeons' outcomes, 56.3% felt surgeons only should see the results, and 50% felt hospital administration should know the results. Within the division on general surgery, 43.8% surgeons felt the other surgeons should know their results. Most surgeons felt that the public and patients should not know the outcomes with 31.3% comfortable with them knowing the results.

### 6.6 Other comments shared by surgeons

There are differing opinions on monitoring outcomes and how to go about it. One surgeon felt that all hospitals should have a mechanism to identify poor outcomes or poor surgical performance amongst the staff but it should be through a medical committee and not through administration. Other surgeons were a bit more wary saying that public has room for misuse with outcome data, and that administrative data can be dangerous. One surgeon felt that this type of reporting may be in part due to an apparent agenda and should be discouraged, "for example, leading to only colorectal surgeons being allowed to do procedure A in this hospital."

# 7.0 Discussion

## 7.1 Summary of results

From the literature search, there were several monitoring methods employed in the surgical realm. Most common methods included CUSUM, VLAD, and funnel plots. From the OHDW, we extracted our colorectal cohort of 3267 elective and 1713 emergent encounters from the time period between April 1, 2003 and December 31, 2009. Risk adjustment to the cohort was acceptable and in good discrimination with our final chosen model, which was the Escobar model with the additional cancer variable. We validated short term outcomes with a chart review with excellent specificity and sensitivity. We applied CUSUM, VLAD, and funnel plots to our risk adjusted cohort and alert and alarm flags varied depending on the monitoring method and assumptions. A summative proportion of the individual surgeons outcomes from the different monitoring methods were tabulated and were illustrated. We surveyed the general surgeons at the Ottawa Hospital and found that the basic CUSUM was the most acceptable method. Most surgeons felt that the public and their patients should not be able to view their outcome data.

## 7.2 Overall Conclusion: Not one "optimal" monitoring method

From this study, we can conclude there was not one ideal method for monitoring surgeon specific outcomes and several monitoring methods are likely needed. This depends on the sensitive target and control limits applied to each model. First, we found evidence of this by the literature review demonstrating that there are several monitoring methods in surgery (Exhibit 2). Continuous monitoring methods included CUSUM, VLAD/CRAM, simple moving average, and Shewhart statistical process control. Intermittent monitoring methods

included funnel plot, intermittent comparison, mortality and morbidity rounds, intraoperative assessment, human reliability assessment, sequential probability ratio test, surgeon performance index, checklist model, and caterpillar plots. These various methods have varying advantages and disadvantages and there are several studies remonstrating that different methods are needed [37]. However the table of summarizing the table of flags for each individual surgeon (Exhibit 27) does suggest that certain surgeons have a higher proportion of flags than others and should warrant a more thorough review of that particular surgeon's case log.

Secondly, the application of CUSUM, VLAD, and funnel plots on our derived cohort from the OHDW gave varying alerts and alarm flags thus making it difficult to determine the better method (Exhibit 25, Exhibit 26). Granted, there were assumptions made to calculate the alert and alarm boundaries from one method to the other which would easily alter the number of flags raised. Due to the assumptions and various boundaries created, this would entail judicious use of multiple methods. To better elucidate which flags were deemed "serious" and "necessary" would require a review of all the cases prior to the raised flag. This was not part of my thesis but should be done in a prospective study.

Although results of the survey indicated that the basic CUSUM method was the most acceptable to general surgeons at the Ottawa Hospital, there were differing opinions regarding the different monitoring methods (Exhibit 30). For instance, one surgeon felt that the VLAD plot was easy to interpret where "success goes up, and failure goes down." On the other hand, other surgeons made comments that they did not understand VLAD graphs

and would not particularly feel comfortable with something "complex." Thus with the differing opinions from the surgeons, it would be better to have different monitoring methods used so that surgeons can use the graph they understand the easiest or prefer. Alternatively, surgeons can become more educated on monitoring methods with training and choose one method with a given period of adjustment.

7.3 Risk prediction modeling for mortality and morbidity

Considering the OHDW, a hybrid of administrative and clinical data, the risk prediction modeling chosen for the colorectal cohort (Escobar model with the additional cancer variable) was good for mortality and adequate for morbidity. The c-statistic was 0.8796 for mortality and 0.7415 for morbidity and Hosmer-Lemeshow p-values were 0.5381 and 0.6076 respectively. In comparison to other published prediction models, such as the ACS NSQIP colorectal risk calculator that has c-statistic of 0.910 for mortality and 0.683 for overall morbidity [38]. Other models, such as the CR-POSSUM had a c-statistic ranging from 0.59 to 0.898 for mortality and had not been done for morbidity [39-49]. Most of the models had been developed for mortality and not morbidity. Thus, our chosen model suited well for both mortality and morbidity.

The three models that we tested on our cohort also had good discrimination. When we used the CR-BHOM model for our cohort, the c-statistic was 0.8539 for mortality and 0.7255 for morbidity in comparison to the author's original cohort that had a c-statistic of 0.810 for mortality and 0.697 for morbidity [23]. Compared to the original Escobar model published with the derivation set (c-statistic for 30 day mortality was 0.86) and Escobar$^{+}$ model (c-

statistic 0.870 for mortality), the final model chosen was a good fit. However, the Escobar[+] was originally a time-dependent Cox regression whereas in this study, it was done as a logistic regression for 30 day in-hospital mortality to compare to the other models being tested.

Thus, we were reassured with the risk-adjustment models that our chosen final model would provide an adequate risk adjustment for the cohort for monitoring purposes.

7.4 Electronically derived algorithms for outcomes using OHDW

For the first time, we applied the modified Clavien-Dindo classification for postoperative outcomes to the OHDW. The electronic algorithms used to extract these outcomes had excellent results. The kappa coefficient, the chance-corrected index, with a value of 0 means it would occur by chance and 1 when the agreement is perfect [50]. The cited guidelines say that kappa values above 0.80 are "almost perfect" and judging from Exhibit 12, most of the sensitivities and specificities for the complications have kappa coefficients above 0.80 [51]. The one with a lower kappa coefficient was for specificity of grade 3 complications (return to operating room, endoscopic or radiologic intervention). This lower specificity could be attributed to coding misclassification.

The highest sensitivity and specificity was with mortality, a hard outcome, which had kappa scores of 1 and 1 (Exhibit 12). The other outcomes, from Grade 2 to 4 complications had high sensitivities and specificities above 0.90 except for blood transfusion, which had a sensitivity of 0.87 and specificity of 0.97. This lower sensitivity was due to the fact that the

electronic data repository did not capture all the blood transfusions given intraoperatively. Thus, we can conclude that with the high sensitivity, specificity and kappa scores, the electronic algorithms used to derive the modified Clavien-Dindo postoperative complications from the OHDW were successful in this cohort.

### 7.5 Construction of monitoring methods

We constructed the different monitoring methods with their respective equations and their own assumptions. We used these assumptions to construct the prediction limits for alert and alarm boundaries. For instance, for the construction of the limits, I used the overall mean rate for mortality or morbidity for elective or emergent colorectal procedures at the Ottawa Hospital during the study period. For weights on alert and alarm, I used a doubling of the mean mortality or morbidity rate or a halving of the mean rates for construction for flags for bad or good events. With these assumptions, it would allow for comparison amongst surgeons at TOH but not with other hospitals. For it to be compared with other hospitals, benchmarking would need to be done with standardized mortality and morbidity rates for elective and emergent colorectal procedures. However, since these rates varied so greatly in the literature, we decided to use within hospital rates for in-group comparison.

### 7.6 Surgeon involvement in publishing outcome data

From our survey response and examples of monitoring methods used, any work to publish outcomes should involve surgeons, especially if looking at surgeon specific measures and outcome data. We need surgeons involved with the process as they are very hesitant about published outcomes and who should know these results. At the Ottawa Hospital, some

surgeons felt quite reluctant to allow others to view their outcomes (Exhibit 31). Surprisingly, not all surgeons would want the department chair or even surgeons within their division to know their outcomes. Especially, with a publicly funded health care system, patients should have a right to know their surgeon outcomes and only 31% of surgeons felt their patients should know their outcomes. Perhaps the big hesitancy with regarding others to know of their outcomes, surgeons are suspicious of the data and whether it was properly collected, if it was validated, was it adjusted properly, and was the data manipulated for some other purpose (i.e. policy driven). To our knowledge, this is the first study looking at surgeon opinion on who should view their individual outcomes.

### 7.7 Surgeon outcomes and performance indicators

Surgeons had varying responses as to which they felt were adequate outcome measures and performance indicators. The survey results indicated that postoperative complications consist of many outcomes and that surgeon performance indicators include various clinical, academic, and administrative components. These components vary depending on individual surgeon opinion and would need a group consensus that would be better facilitated with focus groups and meetings.

### 7.8 Public opinion on outcome data

Although having the outcomes publicly available, there is some evidence that consumers may not be aware or even utilize the information (Schneider et al, 1998). According to a recent Cochrane review, there have been no studies that looked on the impact of providing patients a surgeon's performance data to patients considering elective surgery (Henderson,

2010). Furthermore, consumer comprehension of the displayed data may lead to misinterpretation (Donelan et al, 2011). However, in a publicly funded healthcare system, it makes logical sense that the public should be able to view the results of surgeons and that surgeons should be able to tell their patients their results. Furthermore, hospital administrators should be able to know their institution and individual surgeon performances.

## 7.9 Study strengths

There are a number of strengths in this study. We were able to employ several monitoring methods that we found used in the literature to the colorectal cohort derived from OHDW. All the general surgeons at the Ottawa Hospital were analyzed using the different monitoring methods. There was excellent validation of the electronic algorithms for modified Clavien-Dindo postoperative complications. To our knowledge, this is the first survey to examine the attitudes of general surgeons on monitoring and who should view their outcomes.

## 7.10 Study limitations

Study limitations included the retrospective nature of this study in employing monitoring methods. This entails that we can make observations with the retrospective data, but a prospective study would be needed to determine the reliability of these monitoring methods as a method done in real time.

Another limitation is that the database included administrative information that relies on coding accuracy and I used data driven parameters for the chosen risk adjustment model.

I limited the study to general surgeons and their patient at The Ottawa Hospital and the results may not be applicable to other centres. However, my thesis is a good example of

demonstrating different monitoring techniques and perhaps at one centre, a different method may work out better than others.

The risk-adjustment model may miss certain variables that are not captured by the database; however, the c-statistic and Hosmer-Lemeshow values demonstrated that the model had good discrimination and calibration.

The outcomes chosen may not have included certain outcomes such as tumor margins. However, outcomes can be easily added to the composite outcome in the future.

## 8.0 Recommendations

### 8.1 Surgeon education on monitoring methods and outcomes

From this study, it is evident that surgeons require education in the area of learning about the different approaches of monitoring and outcomes. Whatever monitoring method is employed, surgeons need to be taught about the graphs, what they mean and are used for and how to correctly interpret the data. As well, they should also know the limitations of this type of data and monitoring.

### 8.2 Surgeon engagement into transparency of results

Surgeons should be involved and engaged in monitoring their own outcomes and as a group be able to present the information to hospital administration, to their patients, and to the public. This way, there is ownership to what is being presented and that surgeons do not feel singled out and feel a part of the process. Further research into how surgeons can be engaged will need to be done in terms of surveys and focus groups.

### 8.3 Several monitoring methods are needed for surgeon specific outcomes.

From our study, it can be concluded that several monitoring methods are needed for surgeon specific outcomes. This is because of the varying opinions of individual surgeons and also that the different way data is presented with static and continuous monitoring imparts different information. Furthermore, the cumulative number of flags raised with the different methods should signal a further inquiry within a particular surgeon's case log. The

presentation of the methods to the surgeons will need to be trialed using quantitative and qualitative research methods.

## 9.0 Conclusions

We can conclude from this study that there are many different ways to monitor surgeon specific complications and that several methods may be needed to adequately characterize them. With the Ottawa Hospital Data Warehouse, we derived electronic algorithms to pick out postoperative complications for colorectal surgery with excellent specificity and sensitivity. With our derived cohort, we had adequate risk adjustment using a modified Escobar model that added a cancer variable for 30 day mortality and morbidity. Within the Ottawa Hospital, general surgeons have different opinions and education and surgeon engagement is necessary to make monitoring fruitful in terms of leading quality improvement initiatives and making results more transparent to the public and hospital administration.

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# Appendix

**Appendix A**: REB Approval letter


**Ottawa Hospital Research Ethics Boards / Conseils d'éthique en recherches**

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http://www.ohri.ca/ohreb


September 24, 2010

**Re: Protocol # 2010650-01H** **Evaluating Different Approaches in Monitoring Surgeon Specific Complication Rates in Patients Undergoing Colorectal Surgery**

**Protocol approval valid until - September 23, 2011**

Thank you for the documentation received September 17, 2010. I am pleased to inform you that this protocol, English Draft Questionnaire, and English Consent Form dated September 15, 2010 underwent expedited review by the Ottawa Hospital Research Ethics Board (OHREB) and are approved. No changes, amendments or addenda may be made to the protocol or the consent form without the OHREB's review and approval.

The validation date should be indicated on the bottom of all consent forms and information sheets (see copy attached). If the study is to continue beyond the expiry date noted above, a Renewal Form should be submitted to the OHREB approximately six weeks prior to the current expiry date. If the study has been completed by this date, a Termination Report should be submitted.

The Ottawa Hospital Research Ethics Board is constituted in accordance with, and operates in compliance with the requirements of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans; Health Canada Good Clinical Practice: Consolidated Guideline; Part C Division 5 of the Food and Drug Regulations of Health Canada; and the provisions of the Ontario Health Information Protection Act 2004 and its applicable Regulations.

Yours sincerely,

Chairman
Ottawa Hospital Research Ethics Board

Encl.

/cb

**Appendix B**
Search strategy:

Database: Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) <1950 to Present>
Search Strategy:
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1 exp specialties, surgical/ (135369)
2 exp surgical procedures, operative/ (1940333)
3 "Task Performance and Analysis"/ (18252)
4 Clinical Competence/ (49390)
5 Credentialing/ (2997)
6 ("surgical performance" or "surgeon performance").ab,ti. (374)
7 ("cumulative sum analysis" or cusum).ab,ti. (299)
8 ("variable life adjusted display" or "vlad").ab,ti. (45)
9 "funnel plot".ab,ti. (255)
10 3 or 4 or 5 or 6 or 7 or 8 or 9 (70296)
11 1 and 2 and 10 (1616)
12 limit 11 to english language (1503)

Database: EMBASE <1980 to 2010 Week 26>
Search Strategy:
---
1 exp specialties, surgical/ (1670306)
2 exp surgical procedures, operative/ (1670306)
3 Clinical competence/ (4689)
4 credentialing/ (8544)
5 ("surgical performance" or "surgeon performance").ab,ti. (300)
6 ("cumulative sum analysis" or cusum).ab,ti. (264)
7 ("variable life adjusted display" or "vlad").ab,ti. (35)
8 "funnel plot".ab,ti. (209)
9 "Task Performance and Analysis"/ (64096)
10 3 or 4 or 5 or 6 or 7 or 8 or 9 (77700)
11 1 and 2 and 10 (4800)
12 limit 11 to english language (4558)

**Appendix C**

**Reviewer:** BC

**Study ID:** 00000

**Report ID:** 00000

Monitoring Methods in Surgery

# DATA ABSTRACTION FORM

**Author:**

**Year:**

| **1. Paper Data** | | | |
|---|---|---|---|
| **Authors** | | | |
| **Journal** | | | |
| **Volume** | | **Publication year** | |
| **Chapter** | | **Page Numbers** | |
| **Article title** | | | |
| **Aim** | | | |
| **Country** | | **Language** | English |
| **Funding** | | | |
| **Search details** | ☐ Medline | ☐ EMBASE | ☐ Other: |
| **Eligibility for review:** ☐Yes ☐No | | | |
| **Inclusion/Exclusion Criteria:**<br><br>**Study is any type of surgical procedure** ☐Yes ☐No<br>**Must describe methodology of approach** ☐Yes ☐No<br>**Reported in English** ☐Yes ☐No<br>**Study on humans** ☐Yes ☐No | | | |

| **Notes:** |
|---|

| **2. Study Design** | |
|---|---|
| ☐ Prospective | ☐ Measurement/validation study |
| ☐ Surveillance/information system | ☐ Unclear |
| ☐ Systematic Review | ☐ RCT |
| ☐Other | |
| **Sample Size:** | |
| **Study Duration:** | |
| **Notes** | |

| **3. Surgical Specialty** | |
|---|---|
| ☐ General | ☐ Gynecological |
| ☐ Ear, nose, and throat | ☐ Cardiac |
| ☐ Orthopedic | ☐ Vascular |
| ☐ Pediatric | ☐ Eye |
| ☐ Neurosurgery | ☐ Urological |
| ☐ Plastic surgery | ☐ Other: _____ |
| **Notes** | |

| **4. Procedure** | |
|---|---|
| ☐ Open surgery | ☐ Laparoscopic |
| ☐ Endoscopic | ☐ Other: |

| |
|---|
| **Specify procedure (s):** |
| **Notes:** |

| **5. Surgical adverse event** | |
|---|---|
| ☐ Mortality | ☐ Other: |

| | |
|---|---|
| **Definitions:**<br><br>**(Include references)** | |
| **Validity** | **How is adverse event measured?**<br><br>☐Subjective ☐ Objective ☐ Both |
| **Face Validity** | **Measure/test/grading system**<br><br>☐Relevant ☐ Reasonable ☐Unambiguous ☐ Clear |
| **Objective Assessment** | **List test used to assess adverse event:** |
| **Accuracy** | ☐**Compared to gold standard** ☐ **Report of agreement of standard**<br><br>**Describe standard:** |
| **Sensitivity** | ☐Reported<br><br>What is it? |
| **Specificity** | ☐Reported ☐Level of agreement<br><br>What is it? |
| **Reliability** | Did more than one person assess event? ☐Yes ☐No<br><br>Describe: |

| | |
|---|---|
| | Was there agreement between assessors? ☐Yes ☐No<br>Describe:<br><br>If so, how were discrepancies resolved?<br>Describe: |
| | Did the same person assess the event at 2 or more points in time?<br>☐Yes ☐No |
| **Practicality** | Do the authors refer to the practicality or feasibility of the measure?<br>☐Yes ☐No |
| | Is the instrument easy to administer and process? ☐ Yes ☐No |
| | Consider time and resources? ☐Yes ☐No |
| **Notes:** | |

| **6. Surveillance/monitoring studies** | | | | |
|---|---|---|---|---|
| **Type of surveillance** | ☐ Continuous | | ☐ Intermittent | |
| | ☐ All surgical procedures | | ☐ Selected procedures | |
| **Coverage** | ☐ National | ☐ Regional | ☐ Hospital | ☐ Unit |
| | **Hospitals** | | | |
| | **Departments** | | | |
| **Extent of coverage** | ☐ Denominator data collected | | ☐Denominator data available | |
| **Notes** | | | | |

| **7. Data collection** |
|---|

| | | |
|---|---|---|
| **Who collected data?** | ☐ Nurse | ☐ Research assistant |
| | ☐ Physician | ☐ Other: |
| **Process** | ☐Manual ☐Automated ☐Other: | |
| **Methods** | When the event was first recorded and entered into monitoring system:<br><br>At what stage in the 'natural history' of the event it was recorded on the monitoring system?<br>☐At time of event ☐After event and prior discharge ☐Discharge<br>☐Other:<br><br>Details of follow-up postdischarge (postdischarge surveillance and monitoring): ☐Present ☐Absent<br>☐Direct observation ☐Postal questionnaire ☐Telephone ☐ Other<br>Describe: | |
| **Data collection forms** | Describe: | |
| **Validation** | Case Ascertainment against gold standard? ☐Yes ☐No<br>Describe:<br><br>Self diagnose? ☐Yes ☐No<br><br>Data entry methods: ☐Manual ☐Automated<br>Accuracy rates of data input: | |

| | |
|---|---|
| | System-level validation studies: ☐Yes ☐No<br>Describe: |
| **Notes** | |

| **8. Risk analysis** | | |
|---|---|---|
| **Risk stratification used?** | ☐ Yes | ☐ No |
| **Risk index used** | List: | |
| | **Risk factors:**<br>☐Age ☐Comorbidity:<br>☐Sex ☐Other:<br>☐ASA | |
| **Notes** | | |

| **9. Feedback** | |
|---|---|
| **Feedback to users** | ☐Yes ☐No ☐Timely?<br>Describe: |
| **Format of output** | Describe: |
| **Dissemination** | ☐Confidential ☐Public |

| | |
|---|---|
| | ☐Individual ☐Groups of surgeons |
| **Notes** | |

| **10. Others** | |
|---|---|
| **Cost of system** | |
| **Description of impact** | |
| **Notes** | |

| **11. Additional information** | |
|---|---|
| **Comments** | |
| **Contact with authors** | |

**Appendix D**: Canadian Classification of Health Interventions (CCI) Volume 4

Codes for colorectal surgeries

| CCI Code | Categorize | Open/lap | Category | Resection | Surgery |
|---|---|---|---|---|---|
| 1NK87DN | Resection of colon without stoma, with anastomosis | lap | A | segmental | colon |
| 1NM87DE | Resection of colon without stoma, with anastomosis | lap | A | segmental | colon |
| 1NM87DF | Resection of colon without stoma, with anastomosis | lap | A | segmental | colon |
| 1NM87DN | Resection of colon without stoma, with anastomosis | lap | A | segmental | colon |
| 1NM89DF | Resection of colon without stoma, with anastomosis | lap | A | total | colon |
| 1NM91DF | Resection of colon without stoma, with anastomosis | lap | A | total | colon |
| 1NQ87DF | Resection of colon without stoma, with anastomosis | lap | A | AR | rectal |
| 1NQ89GV | Resection of colon without stoma, with anastomosis | lap | A | AR | rectal |
| 1NK87RE | Resection of colon without stoma, with anastomosis | open | A | segmental | colon |
| 1NM87RD | Resection of colon without stoma, with anastomosis | open | A | segmental | colon |
| 1NM87RE | Resection of colon without stoma, with anastomosis | open | A | segmental | colon |
| 1NM87RN | Resection of colon without stoma, with anastomosis | open | A | segmental | colon |
| 1NM89RN | Resection of colon without stoma, with anastomosis | open | A | total | colon |
| 1NM91RD | Resection of colon without stoma, with anastomosis | open | A | total | colon |
| 1NM91RE | Resection of colon without stoma, with anastomosis | open | A | total | colon |
| 1NM91RN | Resection of colon without stoma, with anastomosis | open | A | total | colon |
| 1NQ87PB | Resection of colon without stoma, with anastomosis | lap | A | AR | rectal |
| 1NQ87RD | Resection of colon without stoma, with anastomosis | open | A | AR | rectal |
| 1NQ89KZ | Resection of colon without stoma, with anastomosis | open | A | AR | rectal |
| 1NQ89KZXXG | Resection of colon without stoma, with anastomosis | open | A | AR | rectal |
| 1NQ89SF | Resection of colon without stoma, with anastomosis | open | A | AR | rectal |
| 1NQ89SFXXG | Resection of colon without stoma, with anastomosis | open | A | AR | rectal |
| 1NQ90LAXXG | Resection of colon without stoma, with anastomosis | open | A | AR | rectal |
| 1NQ87DE | Resection of colon without stoma, with anastomosis | lap | A | AR | rectal |
| 1NM91DE | Resection of colon without stoma, with anastomosis | open | A | total | colon |
| 1NM87DA | Resection of colon without stoma, without anastomosis | lap | B | segmental | colon |
| 1NM87LA | Resection of colon without stoma, without anastomosis | open | B | segmental | colon |
| 1NQ89LH | Resection with permanent stoma | open | E | APR | rectal |
| 1NQ89LHXXG | Resection with permanent stoma | open | E | APR | rectal |
| 1NQ89RS | Resection with permanent stoma | open | E | AR | rectal |
| 1NQ89RSXXG | Resection with permanent stoma | open | E | AR | rectal |
| 1NQ89AB | Resection with permanent stoma | lap | E | APR | rectal |
| 1NM87DX | Resection with potentially reversible stoma | lap | F | segmental | colon |
| 1NM87DY | Resection with potentially reversible stoma | lap | F | segmental | colon |
| 1NM91DX | Resection with potentially reversible stoma | lap | F | segmental | colon |
| 1NQ87DX | Resection with potentially reversible stoma | lap | F | AR | rectal |
| 1NM87TF | Resection with potentially reversible stoma | open | F | segmental | colon |
| 1NM87TG | Resection with potentially reversible stoma | open | F | segmental | colon |
| 1NM89TF | Resection with potentially reversible stoma | open | F | total | colon |
| 1NQ87TF | Resection with potentially reversible stoma | open | F | AR | rectal |
| 1NM91TF | Resection with potentially reversible stoma | open | F | total | colon |
| 1NM89DX | Resection with potentially reversible stoma | lap | F | total | colon |
| 1NK87TF | Resection with potentially reversible stoma | open | F | segmental | colon |

| | | | | | |
|---|---|---|---|---|---|
| 1NK87TG | Resection with potentially reversible stoma | open | F | segmental | colon |
| 1NK76DN | Bypass | lap | G | bypass | colon |
| 1NM76DN | Bypass | lap | G | bypass | colon |
| 1NK76RE | Bypass | open | G | bypass | colon |
| 1NM76RE | Bypass | open | G | bypass | colon |
| 1NM76RN | Bypass | open | G | bypass | colon |
| 1NK77EN | Stoma | lap | H | bypass | colon |
| 1NK77RR | Stoma | open | H | bypass | colon |
| 1NM77EP | Stoma | lap | H | bypass | colon |
| 1NM77RS | Stoma | open | H | bypass | colon |
| 1NM77RSXXG | Stoma | open | H | bypass | colon |
| 1NK77RRXXG | Stoma | open | H | bypass | colon |
| 1NM76RN | Stoma | open | H | bypass | colon |
| 1NK82EN | Stoma reversal | lap | I | reversal | |
| 1NK82RE | Stoma reversal | open | I | reversal | |
| 1NK82RR | Stoma reversal | open | I | reversal | |
| 1NK82DP | Stoma reversal | lap | I | reversal | |
| 1NK82RF | Stoma reversal | open | I | reversal | |
| 1NM82EP | Stoma reversal | lap | I | reversal | |
| 1NM82RN | Stoma reversal | open | I | reversal | |
| 1NM82RS | Stoma reversal | open | I | reversal | |
| 1NM82DF | Stoma reversal | lap | I | reversal | |
| | | | | | |
| | What CSO used for colorectal cancer procedures | Category | | | |
| | Resection with permanent stoma | E | | | |
| | Resection with potentially reversible stoma | F or A+H or I within 12 months | | | |
| | Resection without stoma | A where no H or I within 12 months | | | |
| | Bypass, stoma, local excision or other abdominal procedure | G, H, B, C, or D | | | |

## Appendix E

Grade 2 Outcome, TPN Pharmacy Codes

| stmWID | Description |
|---|---|
| 3779 | 1TPN MONITORING |
| 3780 | TPN MONITORING - FOLLOW-UP PT |
| 11201 | TPN AA 7% DEXT 20% WITH LYTES |
| 11202 | TPN AA 2.5%-DEXTROSE 20% |
| 11203 | TPN AA 3.5% DEXTROSE 10% |
| 11204 | TPN AA 3.5% DEXTROSE 12.5% |
| 11205 | TPN AA 5% & DEXTROSE 20% |
| 11206 | TPN AA 5% & DEXTROSE 20% |
| 11207 | TPN AA 4% & DEXTROSE 20% NL |
| 11208 | TPN AA 4.25% DEXT 20% NO LYTES |
| 11209 | TPN AA 4.25% DEXT 20% w LYTES |
| 11210 | TPN AA 4.25% DEXT 5% NO LYTES |
| 11211 | TPN AA 4.25% DEXT 5% w LYTES |
| 11212 | TPN AA 4.25% DEXT 15% w LYTES |
| 11213 | TPN AA 5% & DEXTROSE 5% w LYTE |
| 11214 | TPN AA 5% DEXTROSE 5% NO LYTES |
| 11215 | TPN AA 7% DEXT 5% NO LYTES |
| 11216 | TPN AA 7% DEXT 5% WITH LYTES |
| 11217 | TPN AA 7% DEXT 20% NO LYTES |
| 11218 | TPN STANDING ORDER |
| 14937 | TPN DEXTROSE 20% NO AMINO ACID |
| 14943 | TPN DEXT 20% NO AA WITH LYTES |
| 458 | A TPN - |
| 459 | TPN - |
| 2235 | TPN |
| 2236 | HOME TPN (OUTPATIENT) |
| 8254 | HOME TPN (OUTPATIENT) |
| 8255 | TPN |
| 14790 | TPN 5/20 (IP) |
| 14791 | HOME TPN (OUTPATIENT) |
| 14792 | TPN 7/20 (IP) |
| 14793 | TPN 5/5 (IP) |
| 2241 | ALT TPN |
| 8256 | ALT TPN |
| 14794 | ALTERNATING TPN 5/20 (IP) |
| 14795 | ALTERNATING TPN 7/20 (IP) |
| 14796 | ALTERNATING TPN 5/5 (IP) |
| 2326 | PNU TPN |
| 20781 | Acetate (TPN) vial TPN lyte |
| 20827 | Calcium (TPN) vial TPN lyte |
| 23283 | Calcium (TPN) vial TPN Peripheral |
| 22319 | CIVA-Dextrose 20% in water IV |
| 22828 | Insulin Regular (Novolin Toronto) vial 100 unit/mL *TPN* |

| | |
|---|---|
| 20843 | Potassium (TPN) vial TPN lyte |
| 23287 | Potassium (TPN) vial TPN peripheral |
| 22826 | Ranitidine (for TPN) vial 25 mg/mL (2 mL) |
| 22317 | CIVA-AA and Dextrose (Neonatal TPN) IV 250 mL |
| 21659 | Zinc for TPN - Civic vial 75 mcmol/mL (10 mL) |
| 1036 | AMINO ACID (PNU TPN) |
| 1037 | POTASSIUM (PNU TPN) |
| 1038 | SODIUM (PNU TPN) |
| 1039 | MAGNESIUM (PNU TPN) |
| 1040 | CALCIUM (PNU TPN) |
| 1041 | MULTIVITAMINS (PNU TPN) |
| 1042 | TRACE ELEMENTS (PNU TPN) |
| 1044 | ZINC (PNU TPN) |
| 1045 | POTASSIUM ACETATE (PNU TPN) |
| 1046 | SODIUM ACETATE (PNU TPN) |
| 1047 | RANITIDINE (PNU TPN) |
| 1054 | PNU TPN INGREDIENT |
| 8333 | IRON DEXTRAN (TPN) |
| 22912 | NEONATAL TPN |
| 3510 | AMINO ACIDS/ELECTROLYTE-TPN |
| 3631 | AMINO AC/D50W/ELECTROLYTE-TPN |
| 3632 | AMINO AC/D50W/ELECTROLYTE-TPN |
| 20780 | Acetate (TPN) vial TPN lyte |
| 20826 | Calcium (TPN) vial TPN lyte |
| 23282 | Calcium (TPN) vial TPN Peripheral |
| 22318 | CIVA-Dextrose 20% in water IV |
| 22827 | Insulin Regular (Novolin Toronto) vial 100 unit/mL *TPN* |
| 20842 | Potassium (TPN) vial TPN lyte |
| 23286 | Potassium (TPN) vial TPN peripheral |
| 20840 | Magnesium (TPN) vial TPN lyte |
| 21660 | CIVA-Multivitamin (MVI-12) vial 50 mL (2 x 25 mL) |
| 20846 | Sodium (TPN) vial TPN lytes |
| 20844 | Phosphate (TPN) vial TPN lyte |
| 23284 | Phosphate (TPN) vial TPN peripheral |
| 22825 | Ranitidine (for TPN) vial 25 mg/mL (2 mL) |
| 22316 | CIVA-AA and Dextrose (Neonatal TPN) IV 250 mL |
| 21658 | Zinc for TPN - Civic vial 75 mcmol/mL (10 mL) |
| 25690 | TPN Record-MAR |
| 26599 | TOH-Total Parenteral Nutrition Order |
| 12873 | /AMINO ACIDS 3.5% IN DEXT 10% |
| 12874 | /AMINO ACIDS 3.5 % - DEXT 12.5 |
| 12875 | AMIN0 ACIDS 4.25%-DEXTROSE 15% |
| 12876 | AMINO ACIDS 4.25% IN DEXT 20% |
| 12877 | AMINO ACID 4.25%-DEXT 20-NO LY |
| 12878 | AMINO ACIDS 4.25%-DEXTROSE 5% |

| | |
|---|---|
| 12879 | AMINO ACIDS 4.25%-DEXTROSE 5% |
| 12880 | AMINO ACIDS 4% IN DEXT 20% |
| 12881 | AMINO ACIDS 5% IN DEXTROSE 20% |
| 12882 | AMINO ACID 5% DEXT 20% NO LYTE |
| 12883 | AMINO ACIDS 5% DEXTROSE 5% |
| 12884 | AMINO ACIDS 5% - DEXTROSE 5% |
| 12885 | AA 7%-DEXT 20% NO LYTES |
| 12886 | AA 7%-DEXT 5% WITH LYTES |
| 12887 | AA 7%-DEXT 5% NO LYTES |
| 12888 | AMINO ACID 10 G/L DEXTROSE 50G |
| 12889 | AMINO ACID 10 G/L DEXTROSE 75G |
| 12890 | AMINO ACID 10 G/L DEXTROSE100G |
| 12891 | AMINO ACID 15 G/L DEXTROSE 50G |
| 12892 | AMINO ACID 15 G/L DEXTROSE 75G |
| 12893 | AMINO ACID 15 G/L DEXTROSE 100 |
| 12894 | AMINO ACID 15 G/L DEXTROSE 125 |
| 12895 | AMINO ACID 20 G/L DEXTROSE 100 |
| 12896 | AMINO ACID 20 G/L DEXTROSE 50 |
| 12897 | AMINO ACID 20 G/L DEXTROSE 75G |
| 12898 | AMINO ACID 25 G/L DEXTROSE 100 |
| 12899 | AMINO ACID 25 G/L DEXTROSE 50G |
| 12900 | AMINO ACID 25 G/L DEXTROSE 75G |
| 12901 | AMINO ACID 30 G/L DEXTROSE 100 |
| 12902 | AMINO ACID 30 G/L DEXTROSE 50G |
| 12903 | AMINO ACID 30 G/L DEXTROSE 75G |
| 12904 | AMINO ACID 34 G/L DEXTROSE 100 |
| 12905 | AMINO ACID 5 G/L DEXTROSE 100G |
| 12906 | AMINO ACID 5 G/L DEXTROSE 75G |
| 12907 | AMINO ACID 5G/L DEXTROSE 50 |
| 13780 | AMINO ACID 2.5% DEXTROSE20 NL |
| 14352 | AMINO ACID 5 G/L DEXTROSE 150G |
| 14353 | AMINO ACIDS 10G DEXTROSE 150G/ |
| 14354 | AMINO ACIDS 15G DEXTROSE 150G/ |
| 14355 | AMINO ACIDS 20G DEXTROSE 150G/ |
| 14356 | AMINO ACIDS 25G DEXTROSE 150G/ |
| 14357 | AMINO ACIDS 30G DEXTROSE 150G/ |
| 19037 | Amino Acid 10% IV 250 mL |
| 20881 | Amino Acids 10% with electrolytes IV |
| 23009 | Amino Acids 10% with electrolytes IV |
| 20785 | Amino Acid 10% IV 10% no lytes 1,000mL |
| 20883 | Amino Acid 10% IV 10% no lytes 3,000mL |
| 20849 | Amino Acids 5% and Dextrose 20 % with electrolytes IV 5%/20% |
| 20851 | Amino Acids 5% and Dextrose 20% without electrolytes IV 5%/20% |
| 20853 | Amino Acids 5% and Dextrose 5% with electrolytes IV 5%/5% |
| 20859 | Amino Acids 5% and Dextrose 5% without electrolytes IV 5%/5% |

| | |
|---|---|
| 20857 | Amino Acids 7% and Dextrose 20% with electrolytes IV 7%/20% |
| 20861 | Amino Acids 7% and Dextrose 20% without electrolytes IV 7%/20% |
| 20855 | Amino Acids 7% and Dextrose 5% with electrolytes IV 7%/5% |
| 20863 | Amino Acids 7% and Dextrose 5% without electrolytes IV 7%/5% |
| 24910 | CIVA-Amino Acids and Dextrose (Adult) IV 1 bag |
| 14786 | AMINO ACIDS |
| 19036 | Amino Acid 10% IV 250 mL |
| 20880 | Amino Acids 10% with electrolytes IV |
| 23008 | Amino Acids 10% with electrolytes IV |
| 20784 | Amino Acid 10% IV 10% no lytes 1,000mL |
| 20882 | Amino Acid 10% IV 10% no lytes 3,000mL |
| 20848 | Amino Acids 5% and Dextrose 20 % with electrolytes IV 5%/20% |
| 20850 | Amino Acids 5% and Dextrose 20% without electrolytes IV 5%/20% |
| 20852 | Amino Acids 5% and Dextrose 5% with electrolytes IV 5%/5% |
| 20858 | Amino Acids 5% and Dextrose 5% without electrolytes IV 5%/5% |
| 20856 | Amino Acids 7% and Dextrose 20% with electrolytes IV 7%/20% |
| 20860 | Amino Acids 7% and Dextrose 20% without electrolytes IV 7%/20% |
| 20854 | Amino Acids 7% and Dextrose 5% with electrolytes IV 7%/5% |
| 20862 | Amino Acids 7% and Dextrose 5% without electrolytes IV 7%/5% |
| 2409 | LIPIDS 10% - |
| 2410 | LIPIDS 20% - |
| 19233 | CIVA-Lipid Emulsion 20% emulsion 20 % (250 mL) |
| 22616 | CIVA-Lipid Emulsion 20% emulsion 20 % (50 mL) |
| 22635 | CIVA-Lipid Emulsion 20% emulsion 20 % (1 mL) |
| 19232 | CIVA-Lipid Emulsion 20% emulsion 20 % (250 mL) |
| 22615 | CIVA-Lipid Emulsion 20% emulsion 20 % (50 mL) |
| 22634 | CIVA-Lipid Emulsion 20% emulsion 20 % (1 mL) |

**Appendix F**: Grade 3 CCI codes

| Grade 3 Complications | hprcCd | Description |
|---|---|---|
| Return to OR | 1GJ77LA | tracheostomy, open approach |
| Return to OR | 1GJ77LALJ | tracheostomy, open approach, multiple position changes |
| Return to OR | 1GJ54JANG | tracheostomy, external approach |
| Return to OR | 1GJ54JATS | tracheostomy, external approach |
| Return to OR | 1GY53LA | thoracotomy |
| Return to OR | 1GY13LA | thoracotomy |
| Return to OR | 2GY70LA | thoracotomy |
| Return to OR | 1EA72LA | craniotomy |
| Return to OR | 1OT72LA | adbo compartment release |
| Return to OR | 1KA76LA | aortic bypass |
| Return to OR | 1IA76LA | aortic bypass |
| Return to OR | 1ID76MUXXA | aortic bypass |
| Return to OR | 1IC76MU | aortic bypass |
| Return to OR | 1NK76RE | small intestine bypass, open approach |
| Return to OR | 1NK76RF | small intestine bypass, open approach |
| Return to OR | 1NK76RJ | small intestine bypass, open approach |
| Return to OR | 1NK76DN | small intestine bypass, laparoscopic |
| Return to OR | 1NK76DP | small intestine bypass, laparoscopic |
| Return to OR | 1NK77RQ | ileostomy, open approach with j-tube |
| Return to OR | 1NK77EN | ileostomy, laparoscopic |
| Return to OR | 1NK77RR | ileostomy, open approach |
| Return to OR | 1NK77RRXG | ileostomy, open approach |
| Return to OR | 1NK80DA | small intestine repair, laparoscopic |
| Return to OR | 1NK80DAXXE | small intestine repair, laparoscopic |
| Return to OR | 1NK80LA | small intestine repair, open approach |
| Return to OR | 1NK80LAXXE | small intestine repair, open approach |
| Return to OR | 1NK82EN | closure of stoma, laparoscopic approach |
| Return to OR | 1NK82RE | closure of stoma, open approach with another stoma |
| Return to OR | 1NK82RF | closure of stoma, open approach with another stoma |
| Return to OR | 1NK82LA | small intestine reattachment, open approach |
| Return to OR | 1NK82RQ | small intestine reattachment, open approach with J-tube |
| Return to OR | 1NK82RR | small intestine reattachment |
| Return to OR | 1NK84RRXG | continent ileostomy, open approach |
| Return to OR | 1NK87TG | small intestine excisional, open with stoma |
| Return to OR | 1NK87TF | small intestine excisional, open with stoma |
| Return to OR | 1NK87RF | small intestine excisional, open no stoma |
| Return to OR | 1NK87RE | small intestine excisional, open no stoma |
| Return to OR | 1NK87DX | small intestine excisional, laparoscopic with stoma |
| Return to OR | 1NK87LA | small intestine excisional, open approach |
| Return to OR | 1NM74LA | cecocoloplicopexy, open approach |
| Return to OR | 1NM76RE | diversionary stoma, open approach |
| Return to OR | 1NM76RN | diversionary stoma, open approach |
| Return to OR | 1NM77EP | large intestine bypass with stoma, laparoscopic |
| Return to OR | 1NM77RS | large intestine bypass with stoma, open |
| Return to OR | 1NM77RSXX | large intestine bypass with stoma, open |

| | G | |
|---|---|---|
| Return to OR | 1NM80LA | large intestine repair, open approach |
| Return to OR | 1NM80LAXXE | large intestine repair, open approach |
| Return to OR | 1NM87DY | large intestine excision, laparoscopic with stoma and mucus fistula |
| Return to OR | 1NM87DX | large intestine excision, laparoscopic with stoma |
| Return to OR | 1NM87DF | large intestine excision, laparoscopic |
| Return to OR | 1NM87DN | large intestine excision, laparoscopic |
| Return to OR | 1NM87DA | large intestine excision, laparoscopic |
| Return to OR | 1NM87DE | large intestine excision, laparoscopic |
| Return to OR | 1NM87LA | large intestine excision, open approach |
| Return to OR | 1NM87RD | large intestine excision, open approach |
| Return to OR | 1NM87RE | large intestine excision, open approach with stoma |
| Return to OR | 1NM87RN | large intestine excision, open with stoma |
| Return to OR | 1NM87TF | large intestine excision, open with stoma |
| Return to OR | 1NM87TG | large intestine excision, open with stoma |
| Return to OR | 1NP72LA | small/large intestine release, open approach |
| Return to OR | 1NQ52LA | Rectal drainage, open approach |
| Return to OR | 1NQ52LATS | Rectal drainage, open approach |
| Return to OR | 1NQ80LA | Repair rectum, open approach |
| Return to OR | 1NQ80PB | Repair rectum, open perineal approach |
| Return to OR | 1NQ86MB | Repair of anorectal, open approach |
| Return to OR | 1NQ86MBXXE | Repair of anorectal, open approach |
| Return to OR | 1NQ86ME | Repair of anorectal, open approach |
| Return to OR | 1NQ86MH | Repair of anorectal, open approach |
| Return to OR | 1NQ86MHXXE | Repair of anorectal, open approach |
| Return to OR | 1NQ86MR | Repair of anorectal, open approach |
| Return to OR | 1NQ87TF | Rectum, partial excision, open with stoma |
| Return to OR | 1NQ89LH | Rectum, total excision, abdominoperineal approach |
| Return to OR | 1NQ89GV | Total rectal excision, open approach |
| Return to OR | 1NQ89RS | Total rectal excision, open approach, with colostomy |
| Return to OR | 1OB13LA | Control of bleeding, spleen |
| Return to OR | 1OB13LAGX | Control of bleeding, spleen |
| Return to OR | 1OB89LA | Remove spleen, open approach |
| Return to OR | 1OD89LA | Cholecystectomy, open approach |
| Return to OR | 1OT13LA | Control of bleeding, abdomen, open approach |
| Return to OR | 1OT13LANP | Control of bleeding, abdomen, open approach |
| Return to OR | 1OT52LA | Drainage, abdominal cavity, open approach |
| Return to OR | 1OT52LATS | Drainage, abdominal cavity, open approach |
| Return to OR | 1OT55LANP | Removal of device, abdominal cavity, open approach |
| Return to OR | 1OT56LA | Removal of FB, abdominal cavity |
| Return to OR | 1OT80LA | Repair abdominal cavity, open approach |
| Return to OR | 1OT80LAXXE | Repair abdominal cavity, open approach |
| Return to OR | 1OT80LAXXN | Repair abdominal cavity, open approach |
| Return to OR | 1OT87LA | Excision, partial, abdominal cavity, open approach |
| Return to OR | 1OW80LA | Repair surgically constructed sites in the digestive tract, open approach |
| Return to OR | 1OZ94LA | Therapeutic intervention, abdominal cavity, open |

| | | |
|---|---|---|
| | | approach |
| Return to OR | 1QG87LA | Excision, partial, scrotum, open approach |
| Return to OR | 1QM89LA | Excision, total, testes, open approach |
| Return to OR | 1QM91LA | Excision, radical, testes, open approach |
| Return to OR | 1RY87LA | Excision, partial perineum, open approach |
| Return to OR | 1SY80DA | Repair, muscles of the chest and abdomen, laparoscopic |
| Return to OR | 1SY80DAXXN | Repair, muscles of the chest and abdomen, laparoscopic |
| Return to OR | 1SY80LA | Repair, muscles of the chest and abdomen, open approach |
| Return to OR | 1SY80LAXXG | Repair, muscles of the chest and abdomen, open approach |
| Return to OR | 1SY80LAXXA | Repair, muscles of the chest and abdomen, open approach |
| Return to OR | 1SY80LATZ | Repair, muscles of the chest and abdomen, open approach |
| Return to OR | 1SY80LAXXN | Repair, muscles of the chest and abdomen, open approach |
| Return to OR | 1SY80LAXXQ | Repair, muscles of the chest and abdomen, open approach |
| Return to OR | 1SY87LA | Excision, partial, muscles of the chest and abdomen, open approach |
| Return to OR | 1SZ52LA | Drainage, soft tissue of the chest and abdomen, open approach |
| Return to OR | 1SZ59LA | Destruction, soft tissue of the chest and abdomen, open approach |
| Return to OR | 1SZ87LA | Excision, partial soft tissue of the chest and abdomen, open approach |
| Return to OR | 1SZ87LAXXN | Excision, partial soft tissue of the chest and abdomen, open approach |
| Return to OR | 1SZ87DA | Excision, partial soft tissue of the chest and abdomen, laparoscopic |
| Return to OR | 1YS14JAFN | Skin excision, abdomen, external approach |
| Return to OR | 1YS14JANCN | Skin excision, abdomen, external approach |
| Return to OR | 1YS14JANP | Skin excision, abdomen, external approach |
| Return to OR | 1YS14JAXXN | Skin excision, abdomen, external approach |
| Return to OR | 1YS59JAGX | Skin destruction, abdomen and trunk |
| Return to OR | 1YS80JAFF | Excision, pilonidal |
| Return to OR | 1YS80LA | Excision, pilonidal |
| Return to OR | 1YS80LAXXB | Excision, pilonidal |
| Return to OR | 1YS80LAXXE | Excision, pilonidal |
| Return to OR | 1VC74LA | Fixation, femur, open approach |
| Return to OR | 1VC74LAKD | Fixation, femur, open approach |
| Return to OR | 1VC74LALQ | Fixation, femur, open approach |
| Return to OR | 1VC74LANW | Fixation, femur, open approach |
| Return to OR | 1VG87DA | Knee joint, excision, laparoscopic |
| Return to OR | 1VQ93LA | Amputation, tibula/fibula |
| Return to OR | 1VQ93LAXXE | Amputation, tibula/fibula |
| Return to OR | 1VX59LAGX | Destruction, soft tissue of leg |
| Return to OR | 1AW72LAGX | Release, spinal cord, open approach |
| Return to OR | 1AX53LAFT | Implantation of device, spinal canal and meninges |
| Return to OR | 1GV52LA | pleural drain, open approach |

| | | |
|---|---|---|
| Return to OR | 1GV52LATS | pleural drain, open approach |
| Return to OR | 1HA52QB | pericardial drainage, via sternotomy/thoracotomy |
| Return to OR | 1KA80LA | Repair, abdominal aorta, open approach |
| Return to OR | 1KA80LAXXN | Repair, abdominal aorta, open approach |
| Return to OR | 1KE51LA | Occlusion, abdominal arteries |
| Return to OR | 1KE51LAFF | Occlusion, abdominal arteries |
| Return to OR | 1KG87LAXXN | partial excision, leg arteries, open approach |
| Return to OR | 1KT80LA | Repair vessels in pelvis, perineal, gluteal region, open approach |
| Return to OR | 1KT80LAXXN | Repair vessels in pelvis, perineal, gluteal region, open approach |
| Return to OR | 1KZ51LA | Occlusion of vessels, open approach |
| Return to OR | 1NF53LATS | G-tube, open approach |
| Return to OR | 1NF87LA | Excision, stomach, open approach |
| Return to OR | 1NK53LAQB | J-tube, open approach |
| Return to OR | 1NK53LATS | J-tube, open approach |
| Return to OR | 1NP86MB | abdomino uterine fistula repair, open approach |
| Return to OR | 1NP86ME | abdomino uterine fistula repair, open approach |
| Return to OR | 1NP86MEXXE | abdomino uterine fistula repair, open approach |
| Return to OR | 1NP86MH | abdomino uterine fistula repair, open approach |
| Return to OR | 1NP86MHXXA | abdomino uterine fistula repair, open approach |
| Return to OR | 1NP86MHXXE | abdomino uterine fistula repair, open approach |
| Return to OR | 1NP86MHXXG | abdomino uterine fistula repair, open approach |
| Return to OR | 1NP86MR | abdomino uterine fistula repair, open approach |
| Return to OR | 1NP86MRXXE | abdomino uterine fistula repair, open approach |
| Return to OR | 1NQ87LA | partial excision, rectum, open approach |
| Return to OR | 1NQ87PB | partial excision, rectum, open approach |
| Return to OR | 1YS52LA | Drainage, skin of abdomen and trunk, open approach |
| Return to OR | 1OT52DA | abdominal drain, laparoscopic |
| Return to OR | 1OT52DATS | abdominal drain, laparoscopic |
| Return to OR | 1OT52DB | Drainage, abdominal cavity, laparoscopic approach |
| Return to OR | 1NQ52DA | Rectal drainage, laparoscopic approach |
| Return to OR | 1NQ52DB | Rectal drainage, laparoscopic approach, via abdomen |
| Return to OR | 1OB52LA | Drainage, splenic area, open approach |
| Return to OR | 1OB52DA | Drainage, splenic area, laparoscopic approach |
| Return to OR | 1OB52DB | Drainage, splenic area, laparoscopic approach |
| Return to OR | 1OA52LA | Drainage, subphrenic space, open approach |
| Return to OR | 1OA52DA | Drainage, subphrenic area, laparoscopic approach |
| Return to OR | 1OA52DB | Drainage, subphrenic area, laparoscopic approach |
| Return to OR | 1NT87LA | Anal diverticulectomy |
| Return to OR | 1IS53LALF | Open permanent IVC devic implantation |
| Return to OR | 1NP73LA | Derotation of large intestine, open approach |
| | | |
| Endoscopic Intervention | 1GM35BAD2 | bronchoscopy therapeutic |
| Endoscopic Intervention | 1GM52BATJ | bronchoscopy, drainage |
| Endoscopic Intervention | 1GM56BATJ | bronchoscopy, removal of foreign body |

| | | |
|---|---|---|
| Endoscopic Intervention | 1NM56BA | Removal of FB large intestine, endoscopic |
| Endoscopic Intervention | 1NM87BA | Colonoscopy with excision large intestine |
| Endoscopic Intervention | 1NP13BAC2 | Endoscopic and control of bleeding |
| Endoscopic Intervention | 1NP13BAGX | Endoscopic and control of bleeding |
| Endoscopic Intervention | 1NP13BAKK | Endoscopic and control of bleeding |
| Endoscopic Intervention | 1NQ13CAGN | Rectal control of bleeding via scope |
| Endoscopic Intervention | 1NQ52BA | Rectal scope with drainage of rectum |
| Endoscopic Intervention | 1NQ52BATS | Rectal scope with drainage of rectum |
| Endoscopic Intervention | 1NQ53CATS | Implant device in rectum |
| Endoscopic Intervention | 1OE52BA | ERCP |
| Endoscopic Intervention | 1OE52BATS | ERCP |
| Endoscopic Intervention | 1OE57BABD | ERCP with stone extraction |
| Endoscopic Intervention | 1PE50BABJ | Dilation of the renal pelvis, cystoscope |
| Endoscopic Intervention | 1PE50DABD | Dilation of the renal pelvis, cystoscope |
| Endoscopic Intervention | 1PE50DABJ | Dilation of the renal pelvis, cystoscope, with flexible dilatotor |
| Endoscopic Intervention | 1PG50BABJ | Dilation, ureter using flexible dilator |
| Endoscopic Intervention | 1PG50DABJ | Dilation, ureter |
| Endoscopic Intervention | 1PG59BAAG | Destruction, ureter with laser |
| Endoscopic Intervention | 1PQ50BA | Dilation, urethra |
| Endoscopic Intervention | 1PQ50BABJ | Dilation, urethra |
| Endoscopic Intervention | 1PQ50BABP | Dilation, urethra |
| Endoscopic Intervention | 1PQ50CABJ | Dilation, urethra |
| Endoscopic Intervention | 1RS13CANP | Control vaginal bleed |
| Endoscopic Intervention | 1GV52DATS | pleural drainage via VATS/endoscopic approach |
| Endoscopic Intervention | 1NA13BAGX | control of bleeding, esophagues, OGD |
| Endoscopic Intervention | 1NF13BAC2 | control of bleeding, stomach, OGD |
| Endoscopic Intervention | 1NF13BAGX | control of bleeding, stomach, OGD |

| | | |
|---|---|---|
| Endoscopic Intervention | 1NF13BAKK | control of bleeding, stomach, OGD |
| Endoscopic Intervention | 1NF13BAX7 | control of bleeding, stomach, OGD |
| Endoscopic Intervention | 1NF53BTQB | Implantation of internal device, stomach (G-tube?), endoscopic |
| Endoscopic Intervention | 1NF53BTTS | Implantation of internal device, stomach (G-tube?), endoscopic |
| Endoscopic Intervention | 1NF53CATS | Implantation of internal device, stomach (G-tube?), endoscopic |
| Endoscopic Intervention | 1NF53HATS | Implantation of internal device, stomach (G-tube?), endoscopic |
| Endoscopic Intervention | 1NK50BABD | Dilation, small intestine |
| Endoscopic Intervention | 1NK50BANR | Dilation, small intestine |
| Endoscopic Intervention | 1GJ77HA | tracheostomy, perc approach |
| Endoscopic Intervention | 1QT87BA | TURP, endoscopic approach |
| Endoscopic Intervention | 1RN87BAGX | Excision, cervix, endoscopic approach |
| Endoscopic Intervention | 1GJ50CANG | Trachea dilation |
| Endoscopic Intervention | 1NM50BABD | Dilation of large intestine using c-scope and balloon dilator |
| Endoscopic Intervention | 1NM50BANR | Dilation of large intestine using c-scope and balloon dilator |
| Endoscopic Intervention | 1NP72DA | decompress GI tract, endoscopic |
| Endoscopic Intervention | 1NQ50BABD | Rectal dilation, endoscopically |
| Endoscopic Intervention | 1NQ50CABP | Rectal dilation, endoscopically |
| Endoscopic Intervention | 1OE50BANR | Choledocotomy for dilation |
| Endoscopic Intervention | 1PM52CATS | Bladder catheterization, endoscopically |
| Endoscopic Intervention | 1PM52BATS | Bladder catheterization, endoscopically |
| | | |
| Radiologic Intervention | 1OT52HA | abdominal drain, perc |
| Radiologic Intervention | 1OT52HATS | abdominal drain, perc |
| Radiologic Intervention | 1OT52HHD1 | abdominal drain, perc |
| Radiologic Intervention | 1OT52HHD3 | abdominal drain, perc |
| Radiologic Intervention | 1OT56HA | Removal of FB from abdo/pelvis, perc approach |
| Radiologic Intervention | 1NP13GQC2 | control of bleeding using perc approach |
| Radiologic | 1NP13GQGE | control of bleeding using perc approach |

| | | |
|---|---|---|
| Intervention | | |
| Radiologic Intervention | 1OA52HA | Drainage, liver, perc |
| Radiologic Intervention | 1OA52HATS | Drainage, liver, perc |
| Radiologic Intervention | 1OD52HA | Gallbladder drainage, perc |
| Radiologic Intervention | 1OD52HATS | Gallbladder drainage, perc |
| Radiologic Intervention | 1OE52GPTS | Bile duct drainage, PTC |
| Radiologic Intervention | 1OZ94HA | Therapeutic intervention, abdominal cavity, perc |
| Radiologic Intervention | 1PE52HH | Drainage, renal pelvis, perc |
| Radiologic Intervention | 1SQ52HA | Pelvic Drain, perc |
| Radiologic Intervention | 1SZ52HA | Drainage, soft tissue of chest and abdomen |
| Radiologic Intervention | 1SZ52HATS | Drainage, soft tissue of chest and abdomen |
| Radiologic Intervention | 1UB52HA | Drainage, wrist joint, perc |
| Radiologic Intervention | 1VC52HA | Drainage, femur, perc |
| Radiologic Intervention | 1VG52HA | Drainage, neck, perc |
| Radiologic Intervention | 1WA52HA | Drainage, ankle joint |
| Radiologic Intervention | 1WM52HA | Drainage, other joints in the toe, perc |
| Radiologic Intervention | 1YS52HA | Drainage, skin of abdomen and trunk, perc |
| Radiologic Intervention | 3IP10VX | Xray, heart and coronary arteries, with intra-arterial contrast |
| Radiologic Intervention | 1AC52GKSJ | Drainage, brain ventricles, perc |
| Radiologic Intervention | 1AX80HAU9 | Repair spinal canal and meninges |
| Radiologic Intervention | 1GV35HHC1 | Chest tube with pharmacotherapy |
| Radiologic Intervention | 1GV52HA | chest, perc drain |
| Radiologic Intervention | 1GV52HATS | chest, perc drain |
| Radiologic Intervention | 1GV52HAHE | chest, perc drain |
| Radiologic Intervention | 1GV52HATK | chest, perc drain |
| Radiologic Intervention | 1IJ50GQOA | Dilation of the coronary arteries |
| Radiologic Intervention | 1IL35HHT9 | pharmacotherapy, vessels of the heart, perc |
| Radiologic | 1IS50GRBD | dilation, vena cava |

| | | |
|---|---|---|
| Intervention | | |
| Radiologic Intervention | 1IS51GRKA | occlusion, vena cava |
| Radiologic Intervention | 1IS56GR | removal of FB from vena cava, perc |
| Radiologic Intervention | 1KE51GQ | Occlusion, abdominal arteries perc |
| Radiologic Intervention | 1KE51GQGE | Occlusion, abdominal arteries perc |
| Radiologic Intervention | 1KG50GQOA | Dilation, leg arteries |
| Radiologic Intervention | 1KV13HAC2 | control of bleeding using perc approach |
| Radiologic Intervention | 1KV53HACH | Implantation of device, artery |
| Radiologic Intervention | 1KX53HA | Implantation of device, vein |
| Radiologic Intervention | 1KX53HACH | Implantation of device, vein |
| Radiologic Intervention | 1KX53HAFT | Implantation of device, vein |
| Radiologic Intervention | 1KY50GPBD | Dilation of artery |
| Radiologic Intervention | 1NK52HATS | Drainage small intestine, perc |
| Radiologic Intervention | 1NQ52HA | Rectal drainage of rectum, perc |
| Radiologic Intervention | 1NQ52HH | Rectal drainage of rectum, perc |
| Radiologic Intervention | 1NQ52HB | Rectal drainage of rectum, perc aspiration |
| Radiologic Intervention | 1OT52HB | Drainage, abdominal cavity, perc aspiration |
| Radiologic Intervention | 1OB52HA | Drainage, splenic area, perc |
| Radiologic Intervention | 1OB52HB | Drainage, splenic area, perc aspiration |
| Radiologic Intervention | 1OB52HH | Drainage, splenic area, perc |
| Radiologic Intervention | 1OA52HB | Drainage, subphrenic space, perc aspiration |
| Radiologic Intervention | 1OA52HH | Drainage, subphrenic space, perc |
| Radiologic Intervention | 1NT52HA | Drainage, arm, perc |
| Radiologic Intervention | 1OA59HAAW | Liver ablation, perc |

**Appendix G**: Grade 4 ICU codes

Grade 4: ICU Special Care Unit codes

| Special Care Unit Code | Description |
|---|---|
| 25 | Trauma intensive care nursing unit |
| 30 | Combined medical/surgical intensive care nursing unit |
| 40 | Cardiac intensive care nursing unit |
| 45 | Coronary intensive care nursing unit |
| 50 | Neonatal intensive care nursing unit |
| 90 | Step-down medical unit |
| 95 | Step-down surgical unit |

Grade 4: ICU inpatient census

| Campus | Functional Center | Functional Center Description | Nursing station | Nursing station description |
|---|---|---|---|---|
| C | OH.CH.712302300 | Acute Monitor Unit | B5AM | B5AM |
| C | OH.CH.712302300 | Acute Monitor Unit | F2AM | F2AM ACUTE MONITORIN |
| C | OH.CH.712302300 | Acute Monitor Unit | G3SU | ICU |
| C | OH.CH.712403000 | ICU-Comb Med/Surgical | F2IC | ICU |
| C | OH.CH.712403000 | ICU-Comb Med/Surgical | G2IC | ICU |
| C | OH.CH.712403000 | ICU-Comb Med/Surgical | G2IX | ICU |
| C | OH.CH.712403000 | ICU-Comb Med/Surgical | G3SU | ICU |
| C | OH.CH.712403000 | ICU-Comb Med/Surgical | J2IC | ICU |
| C | | Trauma Monitoring Unit | B2TR | B2 Trauma Unit |
| G | OH.CO.712405000 | ICU-Neonatal | NICU | ICU NURSERY |
| G | OH.GH.712302350 | GH Acute Monitoring Area (6 Beds) | 5AMA | FIVE ACUTE MONITORIN |
| G | OH.GH.712403000 | ICU-Comb Med/Surgical | ICM | ICU MEDICINE |
| G | OH.GH.712403000 | ICU-Comb Med/Surgical | ICS | ICU SURGICAL |
| G | OH.GH.712403000 | ICU-Comb Med/Surgical | ICUN | ICU NORTH |
| G | OH.GH.712403000 | ICU-Comb Med/Surgical | ICUS | ICU SOUTH |
| G | OH.GH.712403000 | ICU-Comb Med/Surgical | ICX | ICU MEDICAL & SURGIC |
| G | OH.GH.712404500 | ICU-Coronary Care (Med) | 7NCC | 7 NORTH CARDIOLOGY C |
| G | OH.GH.712404500 | ICU-Coronary Care (Med) | CCU | CORONARY CARE UNIT |

| | | | | |
|---|---|---|---|---|
| G | OH.GH.712405000 | ICU-Neonatal | N2IC | NURSERY LEVEL 2 |
| G | OH.GH.712405000 | ICU-Neonatal | N2OV | NURSERY LEVEL 2 OV |
| G | OH.GH.712405000 | ICU-Neonatal | NIOV | NURSERY ICU OVERFLOW |
| H | HI.HI.712404000 | CSU-Cardiac Surgical Unit | HCSA | HCSA |
| H | HI.HI.712404000 | CSU-Cardiac Surgical Unit | HCSB | HCSB |
| H | HI.HI.712404000 | CSU-Cardiac Surgical Unit | HCSC | HCSC |
| H | HI.HI.712404000 | CSU-Cardiac Surgical Unit | HCSI | HCSI |
| H | HI.HI.712404000 | CSU-Cardiac Surgical Unit | HSCR | HSCR |
| H | HI.HI.712404000 | CSU-Cardiac Surgical Unit | HSCS | HSCS |
| H | HI.HI.712404500 | ICU-Coronary Care (Med) | H1CA | H1CA |
| H | HI.HI.712404500 | ICU-Coronary Care (Med) | H1CB | H1CB |
| H | HI.HI.712404500 | ICU-Coronary Care (Med) | H1CC | H1CC |
| H | HI.HI.712404500 | ICU-Coronary Care (Med) | HSCC | HSCC |

## Appendix H

PIMR Score CCI codes:

| procedure | description | urgency | score |
|---|---|---|---|
| 1HZ30 | Resuscitation, heart NEC | E | 11 |
| 1HP87 | Excision partial, ventricle | E | 10 |
| 1HA52 | Drainage, pericardium | L | 9 |
| 1SQ27 | Radiation, pelvis | L | 9 |
| 1HV80 | Repair, aortic valve | E | 8 |
| 1TA03 | Immobilization, shoulder joint | E | 8 |
| 1VP80 | Repair, patella | E | 7 |
| 1YS59 | Destruction, skin of abdomen and trunk | L | 7 |
| 1HS80 | Repair, tricuspid valve | E | 6 |
| 1IC53 | Implantation of internal device, thoracic [descending] aorta | E | 6 |
| 1KE51 | Occlusion, abdominal arteries NEC | E | 6 |
| 1OT53 | Implantation of internal device, abdominal cavity | E | 6 |
| 1SZ87 | Excision partial, soft tissue of the chest and abdomen | E | 6 |
| 1AJ87 | Excision partial, cerebellum | L | 6 |
| 1LZ35 | Pharmacotherapy (local), circulatory system NEC | L | 6 |
| 1AC52 | Drainage, ventricles of brain | E | 5 |
| 1GM52 | Drainage, bronchus NEC | E | 5 |
| 1GZ31 | Ventilation, respiratory system NEC | E | 5 |
| 1HZ37 | Installation of external appliance, heart NEC | E | 5 |
| 1KE80 | Repair,  abdominal arteries NEC | L | 5 |
| 1VC93 | Amputation, femur | L | 5 |
| 1HZ09 | Stimulation, heart NEC | E | 4 |
| 1KG57 | Extraction, arteries of leg NEC | E | 4 |
| 1NK76 | Bypass, small intestine | E | 4 |
| 1NK80 | Repair, small intestine | E | 4 |
| 1AA52 | Drainage, meninges and dura mater of brain | E | 3 |
| 1AN87 | Excision partial, brain | E | 3 |
| 1GY13 | Control of bleeding, thoracic cavity NEC | E | 3 |
| 1HA52 | Drainage, pericardium | E | 3 |
| 1IS51 | Occlusion, vena cava (superior and inferior) | E | 3 |
| 1NA13 | Control of bleeding, esophagus | E | 3 |
| 1NA50 | Dilation, esophagus | E | 3 |
| 1NP13 | Control of bleeding, small and large intestine | E | 3 |
| 1VQ93 | Amputation, tibia and fibula | E | 3 |
| 1GJ77 | Bypass with exteriorization, trachea | E | 2 |
| 1NF53 | Implantation of internal device, stomach | E | 2 |
| 1NK87 | Excision partial, small intestine | E | 2 |
| 1NM87 | Excision partial, large intestine | E | 2 |
| 1OT52 | Drainage, abdominal cavity | E | 2 |
| 1VA53 | Implantation of internal device, hip joint | E | 2 |
| 1VC74 | Fixation, femur | E | 2 |
| 1VC93 | Amputation, femur | E | 2 |
| 1GZ31 | Ventilation, respiratory system NEC | L | 2 |
| 1GV52 | Drainage, pleura | E | 1 |

| | | | |
|---|---|---|---|
| 1IS53 | Implantation of internal device, vena cava (superior and inferior) | E | 1 |
| 1IL35 | Pharmacotherapy (local), vessels of heart | E | -2 |
| 1NV89 | Excision total, appendix | E | -3 |
| 1LZ37 | Installation of external appliance, circulatory system NEC | E | -4 |
| 1IJ50 | Dilation, coronary arteries | L | -4 |
| 1VA53 | Implantation of internal device, hip joint | L | -4 |
| 1VG53 | Implantation of internal device, knee joint | L | -4 |
| 1RD89 | Excision total,  ovary with fallopian tube | L | -5 |
| 1SY80 | Repair, muscles of the chest and abdomen | L | -5 |
| 1OT87 | Excision partial, abdominal cavity | E | -6 |
| 1QT87 | Excision partial, prostate | L | -6 |
| 1RM89 | Excision total, uterus and surrounding structures | L | -7 |

## Appendix I

Determining H, K, ARLs for Risk-adjusted CUSUMs

```
/*****************************************************************
Copying macro from page 85 of textbook (King, 1995) for ARL
*****************************************************************/

%macro cuarltab (type=, delta=, sigma=, n=, hs=);
      %if &hs= %then %let hs=0;

      data cuarltab;
            n=&n; sigma=&sigma; k=&delta/2;
litdelta=&delta/(sigma/sqrt(n));
            do hstar=1 to 12 by .1;
            kstar=k/(sigma/sqrt(n));
            arl0=cusumarl("&type", 0, hstar, kstar, &hs);
            arls=cusumarl("&type", litdelta, hstar, kstar, &hs);
            h=hstar*(sigma/sqrt(n));
            output;
            if arl0>2000 then go to endarl;
            end;
      endarl:
      run;

      title 'CUSUM ARL and Parameters Table';

      proc print;
      run;
%mend cuarltab;

/****
Elective Mortality:
Using Lucas (1976) tabular CUSUM design rules:
Target mean=0.012
Delta (the critical deviation from the target)=  sigma = 0.11
Standard deviation=0.11
*****************************************************************/
```

| Obs | n | sigma | k | litdelta | hstar | kstar | arl0 | arls | h |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.11 | 0.055 | 1 | 1.0 | 0.5 | 5.60 | 2.5841 | 0.110 |
| 2 | 1 | 0.11 | 0.055 | 1 | 1.1 | 0.5 | 6.37 | 2.7536 | 0.121 |
| 3 | 1 | 0.11 | 0.055 | 1 | 1.2 | 0.5 | 7.23 | 2.9286 | 0.132 |
| 4 | 1 | 0.11 | 0.055 | 1 | 1.3 | 0.5 | 8.21 | 3.1083 | 0.143 |
| 5 | 1 | 0.11 | 0.055 | 1 | 1.4 | 0.5 | 9.31 | 3.2919 | 0.154 |
| 6 | 1 | 0.11 | 0.055 | 1 | 1.5 | 0.5 | 10.54 | 3.4788 | 0.165 |
| 7 | 1 | 0.11 | 0.055 | 1 | 1.6 | 0.5 | 11.93 | 3.6682 | 0.176 |
| 8 | 1 | 0.11 | 0.055 | 1 | 1.7 | 0.5 | 13.48 | 3.8595 | 0.187 |
| 9 | 1 | 0.11 | 0.055 | 1 | 1.8 | 0.5 | 15.20 | 4.0524 | 0.198 |
| 10 | 1 | 0.11 | 0.055 | 1 | 1.9 | 0.5 | 17.13 | 4.2464 | 0.209 |
| 11 | 1 | 0.11 | 0.055 | 1 | 2.0 | 0.5 | 19.27 | 4.4411 | 0.220 |
| 12 | 1 | 0.11 | 0.055 | 1 | 2.1 | 0.5 | 21.66 | 4.6363 | 0.231 |
| 13 | 1 | 0.11 | 0.055 | 1 | 2.2 | 0.5 | 24.30 | 4.8320 | 0.242 |
| 14 | 1 | 0.11 | 0.055 | 1 | 2.3 | 0.5 | 27.24 | 5.0278 | 0.253 |
| 15 | 1 | 0.11 | 0.055 | 1 | 2.4 | 0.5 | 30.49 | 5.2239 | 0.264 |
| 16 | 1 | 0.11 | 0.055 | 1 | 2.5 | 0.5 | 34.09 | 5.4201 | 0.275 |
| 17 | 1 | 0.11 | 0.055 | 1 | 2.6 | 0.5 | 38.08 | 5.6164 | 0.286 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 18 | 1 | 0.11 | 0.055 | 1 | 2.7 | 0.5 | 42.50 | 5.8128 | 0.297 |
| 19 | 1 | 0.11 | 0.055 | 1 | 2.8 | 0.5 | 47.39 | 6.0094 | 0.308 |
| 20 | 1 | 0.11 | 0.055 | 1 | 2.9 | 0.5 | 52.81 | 6.2062 | 0.319 |
| 21 | 1 | 0.11 | 0.055 | 1 | 3.0 | 0.5 | 58.80 | 6.4031 | 0.330 |
| 22 | 1 | 0.11 | 0.055 | 1 | 3.1 | 0.5 | 65.43 | 6.6002 | 0.341 |
| 23 | 1 | 0.11 | 0.055 | 1 | 3.2 | 0.5 | 72.76 | 6.7975 | 0.352 |
| 24 | 1 | 0.11 | 0.055 | 1 | 3.3 | 0.5 | 80.88 | 6.9951 | 0.363 |
| 25 | 1 | 0.11 | 0.055 | 1 | 3.4 | 0.5 | 89.85 | 7.1928 | 0.374 |
| 26 | 1 | 0.11 | 0.055 | 1 | 3.5 | 0.5 | 99.79 | 7.3908 | 0.385 |
| 27 | 1 | 0.11 | 0.055 | 1 | 3.6 | 0.5 | 110.77 | 7.5889 | 0.396 |
| 28 | 1 | 0.11 | 0.055 | 1 | 3.7 | 0.5 | 122.93 | 7.7872 | 0.407 |
| 29 | 1 | 0.11 | 0.055 | 1 | 3.8 | 0.5 | 136.37 | 7.9857 | 0.418 |
| 30 | 1 | 0.11 | 0.055 | 1 | 3.9 | 0.5 | 151.24 | 8.1844 | 0.429 |
| 31 | 1 | 0.11 | 0.055 | 1 | 4.0 | 0.5 | 167.68 | 8.3831 | 0.440 |
| 32 | 1 | 0.11 | 0.055 | 1 | 4.1 | 0.5 | 185.87 | 8.5820 | 0.451 |
| 33 | 1 | 0.11 | 0.055 | 1 | 4.2 | 0.5 | 205.98 | 8.7811 | 0.462 |
| 34 | 1 | 0.11 | 0.055 | 1 | 4.3 | 0.5 | 228.21 | 8.9802 | 0.473 |
| 35 | 1 | 0.11 | 0.055 | 1 | 4.4 | 0.5 | 252.79 | 9.1794 | 0.484 |
| 36 | 1 | 0.11 | 0.055 | 1 | 4.5 | 0.5 | 279.97 | 9.3787 | 0.495 |
| 37 | 1 | 0.11 | 0.055 | 1 | 4.6 | 0.5 | 310.02 | 9.5780 | 0.506 |
| 38 | 1 | 0.11 | 0.055 | 1 | 4.7 | 0.5 | 343.24 | 9.7774 | 0.517 |
| 39 | 1 | 0.11 | 0.055 | 1 | 4.8 | 0.5 | 379.97 | 9.9769 | 0.528 |
| 40 | 1 | 0.11 | 0.055 | 1 | 4.9 | 0.5 | 420.57 | 10.1764 | 0.539 |
| 41 | 1 | 0.11 | 0.055 | 1 | 5.0 | 0.5 | 465.44 | 10.3760 | 0.550 |
| 42 | 1 | 0.11 | 0.055 | 1 | 5.1 | 0.5 | 515.05 | 10.5756 | 0.561 |
| 43 | 1 | 0.11 | 0.055 | 1 | 5.2 | 0.5 | 569.89 | 10.7752 | 0.572 |
| 44 | 1 | 0.11 | 0.055 | 1 | 5.3 | 0.5 | 630.50 | 10.9749 | 0.583 |
| 45 | 1 | 0.11 | 0.055 | 1 | 5.4 | 0.5 | 697.50 | 11.1746 | 0.594 |
| 46 | 1 | 0.11 | 0.055 | 1 | 5.5 | 0.5 | 771.55 | 11.3743 | 0.605 |
| 47 | 1 | 0.11 | 0.055 | 1 | 5.6 | 0.5 | 853.41 | 11.5741 | 0.616 |
| 48 | 1 | 0.11 | 0.055 | 1 | 5.7 | 0.5 | 943.88 | 11.7739 | 0.627 |
| 49 | 1 | 0.11 | 0.055 | 1 | 5.8 | 0.5 | 1043.87 | 11.9737 | 0.638 |
| 50 | 1 | 0.11 | 0.055 | 1 | 5.9 | 0.5 | 1154.40 | 12.1735 | 0.649 |
| 51 | 1 | 0.11 | 0.055 | 1 | 6.0 | 0.5 | 1276.55 | 12.3733 | 0.660 |

```
/*****************************************************************
Elective cases, morbidity
*****************************************************************/
%cuarltab(type=twosided, delta=0.37 , sigma=0.37 , n=1);
```

| Obs | n | sigma | k | litdelta | hstar | kstar | arl0 | arls | h |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.37 | 0.185 | 1 | 1.0 | 0.5 | 5.60 | 2.5841 | 0.370 |
| 2 | 1 | 0.37 | 0.185 | 1 | 1.1 | 0.5 | 6.37 | 2.7536 | 0.407 |
| 3 | 1 | 0.37 | 0.185 | 1 | 1.2 | 0.5 | 7.23 | 2.9286 | 0.444 |
| 4 | 1 | 0.37 | 0.185 | 1 | 1.3 | 0.5 | 8.21 | 3.1083 | 0.481 |
| 5 | 1 | 0.37 | 0.185 | 1 | 1.4 | 0.5 | 9.31 | 3.2919 | 0.518 |
| 6 | 1 | 0.37 | 0.185 | 1 | 1.5 | 0.5 | 10.54 | 3.4788 | 0.555 |
| 7 | 1 | 0.37 | 0.185 | 1 | 1.6 | 0.5 | 11.93 | 3.6682 | 0.592 |
| 8 | 1 | 0.37 | 0.185 | 1 | 1.7 | 0.5 | 13.48 | 3.8595 | 0.629 |
| 9 | 1 | 0.37 | 0.185 | 1 | 1.8 | 0.5 | 15.20 | 4.0524 | 0.666 |
| 10 | 1 | 0.37 | 0.185 | 1 | 1.9 | 0.5 | 17.13 | 4.2464 | 0.703 |
| 11 | 1 | 0.37 | 0.185 | 1 | 2.0 | 0.5 | 19.27 | 4.4411 | 0.740 |
| 12 | 1 | 0.37 | 0.185 | 1 | 2.1 | 0.5 | 21.66 | 4.6363 | 0.777 |
| 13 | 1 | 0.37 | 0.185 | 1 | 2.2 | 0.5 | 24.30 | 4.8320 | 0.814 |
| 14 | 1 | 0.37 | 0.185 | 1 | 2.3 | 0.5 | 27.24 | 5.0278 | 0.851 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 1 | 0.37 | 0.185 | 1 | 2.4 | 0.5 | 30.49 | 5.2239 | 0.888 |
| 16 | 1 | 0.37 | 0.185 | 1 | 2.5 | 0.5 | 34.09 | 5.4201 | 0.925 |
| 17 | 1 | 0.37 | 0.185 | 1 | 2.6 | 0.5 | 38.08 | 5.6164 | 0.962 |
| 18 | 1 | 0.37 | 0.185 | 1 | 2.7 | 0.5 | 42.50 | 5.8128 | 0.999 |
| 19 | 1 | 0.37 | 0.185 | 1 | 2.8 | 0.5 | 47.39 | 6.0094 | 1.036 |
| 20 | 1 | 0.37 | 0.185 | 1 | 2.9 | 0.5 | 52.81 | 6.2062 | 1.073 |
| 21 | 1 | 0.37 | 0.185 | 1 | 3.0 | 0.5 | 58.80 | 6.4031 | 1.110 |
| 22 | 1 | 0.37 | 0.185 | 1 | 3.1 | 0.5 | 65.43 | 6.6002 | 1.147 |
| 23 | 1 | 0.37 | 0.185 | 1 | 3.2 | 0.5 | 72.76 | 6.7975 | 1.184 |
| 24 | 1 | 0.37 | 0.185 | 1 | 3.3 | 0.5 | 80.88 | 6.9951 | 1.221 |
| 25 | 1 | 0.37 | 0.185 | 1 | 3.4 | 0.5 | 89.85 | 7.1928 | 1.258 |
| 26 | 1 | 0.37 | 0.185 | 1 | 3.5 | 0.5 | 99.79 | 7.3908 | 1.295 |
| 27 | 1 | 0.37 | 0.185 | 1 | 3.6 | 0.5 | 110.77 | 7.5889 | 1.332 |
| 28 | 1 | 0.37 | 0.185 | 1 | 3.7 | 0.5 | 122.93 | 7.7872 | 1.369 |
| 29 | 1 | 0.37 | 0.185 | 1 | 3.8 | 0.5 | 136.37 | 7.9857 | 1.406 |
| 30 | 1 | 0.37 | 0.185 | 1 | 3.9 | 0.5 | 151.24 | 8.1844 | 1.443 |
| 31 | 1 | 0.37 | 0.185 | 1 | 4.0 | 0.5 | 167.68 | 8.3831 | 1.480 |
| 32 | 1 | 0.37 | 0.185 | 1 | 4.1 | 0.5 | 185.87 | 8.5820 | 1.517 |
| 33 | 1 | 0.37 | 0.185 | 1 | 4.2 | 0.5 | 205.98 | 8.7811 | 1.554 |
| 34 | 1 | 0.37 | 0.185 | 1 | 4.3 | 0.5 | 228.21 | 8.9802 | 1.591 |
| 35 | 1 | 0.37 | 0.185 | 1 | 4.4 | 0.5 | 252.79 | 9.1794 | 1.628 |
| 36 | 1 | 0.37 | 0.185 | 1 | 4.5 | 0.5 | 279.97 | 9.3787 | 1.665 |
| 37 | 1 | 0.37 | 0.185 | 1 | 4.6 | 0.5 | 310.02 | 9.5780 | 1.702 |
| 38 | 1 | 0.37 | 0.185 | 1 | 4.7 | 0.5 | 343.24 | 9.7774 | 1.739 |
| 39 | 1 | 0.37 | 0.185 | 1 | 4.8 | 0.5 | 379.97 | 9.9769 | 1.776 |
| 40 | 1 | 0.37 | 0.185 | 1 | 4.9 | 0.5 | 420.57 | 10.1764 | 1.813 |
| 41 | 1 | 0.37 | 0.185 | 1 | 5.0 | 0.5 | 465.44 | 10.3760 | 1.850 |
| 42 | 1 | 0.37 | 0.185 | 1 | 5.1 | 0.5 | 515.05 | 10.5756 | 1.887 |
| 43 | 1 | 0.37 | 0.185 | 1 | 5.2 | 0.5 | 569.89 | 10.7752 | 1.924 |
| 44 | 1 | 0.37 | 0.185 | 1 | 5.3 | 0.5 | 630.50 | 10.9749 | 1.961 |
| 45 | 1 | 0.37 | 0.185 | 1 | 5.4 | 0.5 | 697.50 | 11.1746 | 1.998 |
| 46 | 1 | 0.37 | 0.185 | 1 | 5.5 | 0.5 | 771.55 | 11.3743 | 2.035 |
| 47 | 1 | 0.37 | 0.185 | 1 | 5.6 | 0.5 | 853.41 | 11.5741 | 2.072 |
| 48 | 1 | 0.37 | 0.185 | 1 | 5.7 | 0.5 | 943.88 | 11.7739 | 2.109 |
| 49 | 1 | 0.37 | 0.185 | 1 | 5.8 | 0.5 | 1043.87 | 11.9737 | 2.146 |
| 50 | 1 | 0.37 | 0.185 | 1 | 5.9 | 0.5 | 1154.40 | 12.1735 | 2.183 |
| 51 | 1 | 0.37 | 0.185 | 1 | 6.0 | 0.5 | 1276.55 | 12.3733 | 2.220 |

/* Emergency mortality*/

| Obs | n | sigma | k | litdelta | hstar | kstar | arl0 | arls | h |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.32 | 0.16 | 1 | 1.0 | 0.5 | 5.60 | 2.5841 | 0.320 |
| 2 | 1 | 0.32 | 0.16 | 1 | 1.1 | 0.5 | 6.37 | 2.7536 | 0.352 |
| 3 | 1 | 0.32 | 0.16 | 1 | 1.2 | 0.5 | 7.23 | 2.9286 | 0.384 |
| 4 | 1 | 0.32 | 0.16 | 1 | 1.3 | 0.5 | 8.21 | 3.1083 | 0.416 |
| 5 | 1 | 0.32 | 0.16 | 1 | 1.4 | 0.5 | 9.31 | 3.2919 | 0.448 |
| 6 | 1 | 0.32 | 0.16 | 1 | 1.5 | 0.5 | 10.54 | 3.4788 | 0.480 |
| 7 | 1 | 0.32 | 0.16 | 1 | 1.6 | 0.5 | 11.93 | 3.6682 | 0.512 |
| 8 | 1 | 0.32 | 0.16 | 1 | 1.7 | 0.5 | 13.48 | 3.8595 | 0.544 |
| 9 | 1 | 0.32 | 0.16 | 1 | 1.8 | 0.5 | 15.20 | 4.0524 | 0.576 |
| 10 | 1 | 0.32 | 0.16 | 1 | 1.9 | 0.5 | 17.13 | 4.2464 | 0.608 |
| 11 | 1 | 0.32 | 0.16 | 1 | 2.0 | 0.5 | 19.27 | 4.4411 | 0.640 |
| 12 | 1 | 0.32 | 0.16 | 1 | 2.1 | 0.5 | 21.66 | 4.6363 | 0.672 |
| 13 | 1 | 0.32 | 0.16 | 1 | 2.2 | 0.5 | 24.30 | 4.8320 | 0.704 |
| 14 | 1 | 0.32 | 0.16 | 1 | 2.3 | 0.5 | 27.24 | 5.0278 | 0.736 |
| 15 | 1 | 0.32 | 0.16 | 1 | 2.4 | 0.5 | 30.49 | 5.2239 | 0.768 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 16 | 1 | 0.32 | 0.16 | 1 | 2.5 | 0.5 | 34.09 | 5.4201 | 0.800 |
| 17 | 1 | 0.32 | 0.16 | 1 | 2.6 | 0.5 | 38.08 | 5.6164 | 0.832 |
| 18 | 1 | 0.32 | 0.16 | 1 | 2.7 | 0.5 | 42.50 | 5.8128 | 0.864 |
| 19 | 1 | 0.32 | 0.16 | 1 | 2.8 | 0.5 | 47.39 | 6.0094 | 0.896 |
| 20 | 1 | 0.32 | 0.16 | 1 | 2.9 | 0.5 | 52.81 | 6.2062 | 0.928 |
| 21 | 1 | 0.32 | 0.16 | 1 | 3.0 | 0.5 | 58.80 | 6.4031 | 0.960 |
| 22 | 1 | 0.32 | 0.16 | 1 | 3.1 | 0.5 | 65.43 | 6.6002 | 0.992 |
| 23 | 1 | 0.32 | 0.16 | 1 | 3.2 | 0.5 | 72.76 | 6.7975 | 1.024 |
| 24 | 1 | 0.32 | 0.16 | 1 | 3.3 | 0.5 | 80.88 | 6.9951 | 1.056 |
| 25 | 1 | 0.32 | 0.16 | 1 | 3.4 | 0.5 | 89.85 | 7.1928 | 1.088 |
| 26 | 1 | 0.32 | 0.16 | 1 | 3.5 | 0.5 | 99.79 | 7.3908 | 1.120 |
| 27 | 1 | 0.32 | 0.16 | 1 | 3.6 | 0.5 | 110.77 | 7.5889 | 1.152 |
| 28 | 1 | 0.32 | 0.16 | 1 | 3.7 | 0.5 | 122.93 | 7.7872 | 1.184 |
| 29 | 1 | 0.32 | 0.16 | 1 | 3.8 | 0.5 | 136.37 | 7.9857 | 1.216 |
| 30 | 1 | 0.32 | 0.16 | 1 | 3.9 | 0.5 | 151.24 | 8.1844 | 1.248 |
| 31 | 1 | 0.32 | 0.16 | 1 | 4.0 | 0.5 | 167.68 | 8.3831 | 1.280 |
| 32 | 1 | 0.32 | 0.16 | 1 | 4.1 | 0.5 | 185.87 | 8.5820 | 1.312 |
| 33 | 1 | 0.32 | 0.16 | 1 | 4.2 | 0.5 | 205.98 | 8.7811 | 1.344 |
| 34 | 1 | 0.32 | 0.16 | 1 | 4.3 | 0.5 | 228.21 | 8.9802 | 1.376 |
| 35 | 1 | 0.32 | 0.16 | 1 | 4.4 | 0.5 | 252.79 | 9.1794 | 1.408 |
| 36 | 1 | 0.32 | 0.16 | 1 | 4.5 | 0.5 | 279.97 | 9.3787 | 1.440 |
| 37 | 1 | 0.32 | 0.16 | 1 | 4.6 | 0.5 | 310.02 | 9.5780 | 1.472 |
| 38 | 1 | 0.32 | 0.16 | 1 | 4.7 | 0.5 | 343.24 | 9.7774 | 1.504 |
| 39 | 1 | 0.32 | 0.16 | 1 | 4.8 | 0.5 | 379.97 | 9.9769 | 1.536 |
| 40 | 1 | 0.32 | 0.16 | 1 | 4.9 | 0.5 | 420.57 | 10.1764 | 1.568 |
| 41 | 1 | 0.32 | 0.16 | 1 | 5.0 | 0.5 | 465.44 | 10.3760 | 1.600 |
| 42 | 1 | 0.32 | 0.16 | 1 | 5.1 | 0.5 | 515.05 | 10.5756 | 1.632 |
| 43 | 1 | 0.32 | 0.16 | 1 | 5.2 | 0.5 | 569.89 | 10.7752 | 1.664 |
| 44 | 1 | 0.32 | 0.16 | 1 | 5.3 | 0.5 | 630.50 | 10.9749 | 1.696 |
| 45 | 1 | 0.32 | 0.16 | 1 | 5.4 | 0.5 | 697.50 | 11.1746 | 1.728 |
| 46 | 1 | 0.32 | 0.16 | 1 | 5.5 | 0.5 | 771.55 | 11.3743 | 1.760 |
| 47 | 1 | 0.32 | 0.16 | 1 | 5.6 | 0.5 | 853.41 | 11.5741 | 1.792 |
| 48 | 1 | 0.32 | 0.16 | 1 | 5.7 | 0.5 | 943.88 | 11.7739 | 1.824 |
| 49 | 1 | 0.32 | 0.16 | 1 | 5.8 | 0.5 | 1043.87 | 11.9737 | 1.856 |
| 50 | 1 | 0.32 | 0.16 | 1 | 5.9 | 0.5 | 1154.40 | 12.1735 | 1.888 |
| 51 | 1 | 0.32 | 0.16 | 1 | 6.0 | 0.5 | 1276.55 | 12.3733 | 1.920 |

/*Emergency morbidity*/

| Obs | n | sigma | k | litdelta | hstar | kstar | arl0 | arls | h |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.48 | 0.24 | 1 | 1.0 | 0.5 | 5.60 | 2.5841 | 0.480 |
| 2 | 1 | 0.48 | 0.24 | 1 | 1.1 | 0.5 | 6.37 | 2.7536 | 0.528 |
| 3 | 1 | 0.48 | 0.24 | 1 | 1.2 | 0.5 | 7.23 | 2.9286 | 0.576 |
| 4 | 1 | 0.48 | 0.24 | 1 | 1.3 | 0.5 | 8.21 | 3.1083 | 0.624 |
| 5 | 1 | 0.48 | 0.24 | 1 | 1.4 | 0.5 | 9.31 | 3.2919 | 0.672 |
| 6 | 1 | 0.48 | 0.24 | 1 | 1.5 | 0.5 | 10.54 | 3.4788 | 0.720 |
| 7 | 1 | 0.48 | 0.24 | 1 | 1.6 | 0.5 | 11.93 | 3.6682 | 0.768 |
| 8 | 1 | 0.48 | 0.24 | 1 | 1.7 | 0.5 | 13.48 | 3.8595 | 0.816 |
| 9 | 1 | 0.48 | 0.24 | 1 | 1.8 | 0.5 | 15.20 | 4.0524 | 0.864 |
| 10 | 1 | 0.48 | 0.24 | 1 | 1.9 | 0.5 | 17.13 | 4.2464 | 0.912 |
| 11 | 1 | 0.48 | 0.24 | 1 | 2.0 | 0.5 | 19.27 | 4.4411 | 0.960 |
| 12 | 1 | 0.48 | 0.24 | 1 | 2.1 | 0.5 | 21.66 | 4.6363 | 1.008 |
| 13 | 1 | 0.48 | 0.24 | 1 | 2.2 | 0.5 | 24.30 | 4.8320 | 1.056 |
| 14 | 1 | 0.48 | 0.24 | 1 | 2.3 | 0.5 | 27.24 | 5.0278 | 1.104 |
| 15 | 1 | 0.48 | 0.24 | 1 | 2.4 | 0.5 | 30.49 | 5.2239 | 1.152 |
| 16 | 1 | 0.48 | 0.24 | 1 | 2.5 | 0.5 | 34.09 | 5.4201 | 1.200 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 17 | 1 | 0.48 | 0.24 | 1 | 2.6 | 0.5 | 38.08 | 5.6164 | 1.248 |
| 18 | 1 | 0.48 | 0.24 | 1 | 2.7 | 0.5 | 42.50 | 5.8128 | 1.296 |
| 19 | 1 | 0.48 | 0.24 | 1 | 2.8 | 0.5 | 47.39 | 6.0094 | 1.344 |
| 20 | 1 | 0.48 | 0.24 | 1 | 2.9 | 0.5 | 52.81 | 6.2062 | 1.392 |
| 21 | 1 | 0.48 | 0.24 | 1 | 3.0 | 0.5 | 58.80 | 6.4031 | 1.440 |
| 22 | 1 | 0.48 | 0.24 | 1 | 3.1 | 0.5 | 65.43 | 6.6002 | 1.488 |
| 23 | 1 | 0.48 | 0.24 | 1 | 3.2 | 0.5 | 72.76 | 6.7975 | 1.536 |
| 24 | 1 | 0.48 | 0.24 | 1 | 3.3 | 0.5 | 80.88 | 6.9951 | 1.584 |
| 25 | 1 | 0.48 | 0.24 | 1 | 3.4 | 0.5 | 89.85 | 7.1928 | 1.632 |
| 26 | 1 | 0.48 | 0.24 | 1 | 3.5 | 0.5 | 99.79 | 7.3908 | 1.680 |
| 27 | 1 | 0.48 | 0.24 | 1 | 3.6 | 0.5 | 110.77 | 7.5889 | 1.728 |
| 28 | 1 | 0.48 | 0.24 | 1 | 3.7 | 0.5 | 122.93 | 7.7872 | 1.776 |
| 29 | 1 | 0.48 | 0.24 | 1 | 3.8 | 0.5 | 136.37 | 7.9857 | 1.824 |
| 30 | 1 | 0.48 | 0.24 | 1 | 3.9 | 0.5 | 151.24 | 8.1844 | 1.872 |
| 31 | 1 | 0.48 | 0.24 | 1 | 4.0 | 0.5 | 167.68 | 8.3831 | 1.920 |
| 32 | 1 | 0.48 | 0.24 | 1 | 4.1 | 0.5 | 185.87 | 8.5820 | 1.968 |
| 33 | 1 | 0.48 | 0.24 | 1 | 4.2 | 0.5 | 205.98 | 8.7811 | 2.016 |
| 34 | 1 | 0.48 | 0.24 | 1 | 4.3 | 0.5 | 228.21 | 8.9802 | 2.064 |
| 35 | 1 | 0.48 | 0.24 | 1 | 4.4 | 0.5 | 252.79 | 9.1794 | 2.112 |
| 36 | 1 | 0.48 | 0.24 | 1 | 4.5 | 0.5 | 279.97 | 9.3787 | 2.160 |
| 37 | 1 | 0.48 | 0.24 | 1 | 4.6 | 0.5 | 310.02 | 9.5780 | 2.208 |
| 38 | 1 | 0.48 | 0.24 | 1 | 4.7 | 0.5 | 343.24 | 9.7774 | 2.256 |
| 39 | 1 | 0.48 | 0.24 | 1 | 4.8 | 0.5 | 379.97 | 9.9769 | 2.304 |
| 40 | 1 | 0.48 | 0.24 | 1 | 4.9 | 0.5 | 420.57 | 10.1764 | 2.352 |
| 41 | 1 | 0.48 | 0.24 | 1 | 5.0 | 0.5 | 465.44 | 10.3760 | 2.400 |
| 42 | 1 | 0.48 | 0.24 | 1 | 5.1 | 0.5 | 515.05 | 10.5756 | 2.448 |
| 43 | 1 | 0.48 | 0.24 | 1 | 5.2 | 0.5 | 569.89 | 10.7752 | 2.496 |
| 44 | 1 | 0.48 | 0.24 | 1 | 5.3 | 0.5 | 630.50 | 10.9749 | 2.544 |
| 45 | 1 | 0.48 | 0.24 | 1 | 5.4 | 0.5 | 697.50 | 11.1746 | 2.592 |
| 46 | 1 | 0.48 | 0.24 | 1 | 5.5 | 0.5 | 771.55 | 11.3743 | 2.640 |
| 47 | 1 | 0.48 | 0.24 | 1 | 5.6 | 0.5 | 853.41 | 11.5741 | 2.688 |
| 48 | 1 | 0.48 | 0.24 | 1 | 5.7 | 0.5 | 943.88 | 11.7739 | 2.736 |
| 49 | 1 | 0.48 | 0.24 | 1 | 5.8 | 0.5 | 1043.87 | 11.9737 | 2.784 |
| 50 | 1 | 0.48 | 0.24 | 1 | 5.9 | 0.5 | 1154.40 | 12.1735 | 2.832 |
| 51 | 1 | 0.48 | 0.24 | 1 | 6.0 | 0.5 | 1276.55 | 12.3733 | 2.880 |

## Appendix J Survey of General Surgeons at the Ottawa Hospital Regarding Monitoring Approaches in Colorectal Surgery

Instructions: Please answer all questions within this survey to the best of your abilities.

Section A: Personal Demographics

1. Age**:** ☐ 30-39 ☐ 40-49 ☐ 50-59 ☐ 60-69 ☐ ≥70
2. Gender: ☐ Male ☐ Female
3. How many years have you been practicing as a surgeon? _____
4. What formal fellowship training do you have (**check all that apply**)?

| | | |
|---|---|---|
| ☐ Bariatric | ☐ Pediatric | ☐ Trauma/critical care |
| ☐ Colorectal | ☐ Surgical oncology | ☐ Vascular |
| ☐ Hepatobiliary | ☐ Thoracic | ☐ Minimally invasive surgery (MIS) |
| ☐ Transplant | ☐ Other: _____ | ☐ None |

Section B: Current Practice

5. How many colon resections do you do a year?

   ☐ 0-10 ☐ 11-20 ☐ 21-30 ☐ 31-50 ☐ >50

6. How many rectal resections do you do a year?

   ☐ 0-10 ☐ 11-20 ☐ 21-30 ☐ 31-50 ☐ >50

7. What percentage of your colorectal cases is done **emergently**? _____%
8. What percentage of your colorectal cases is done **laparoscopically**? _____%

Section C: Opinion on monitoring approaches

Please look at the three graphs presented below. Each is a graphical representation of a different monitoring method for surgical outcome.

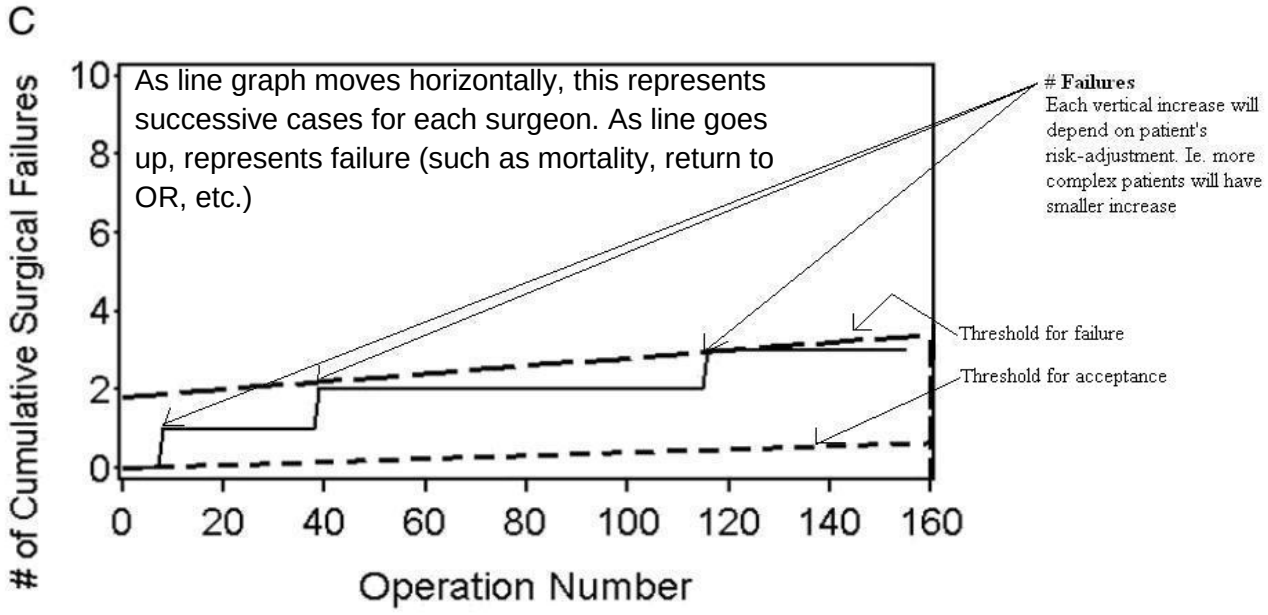



**Figure 1:** This is an example of cumulative sum chart method (CUSUM) showing successive cases plotted along the horizontal access with plots for outcome (i.e. mortality, postoperative complications) on the vertical access. For each additional outcome (in this case, surgical failure) the plot moves up one unit. This method would identify surgeons having more failures than expected and can illustrate learning curves for new techniques and junior surgeons. This method can either use an expected complication rate from literature for benchmark levels or a risk-adjusted model.

**9. Is figure 1 an acceptable approach for monitoring outcomes?**

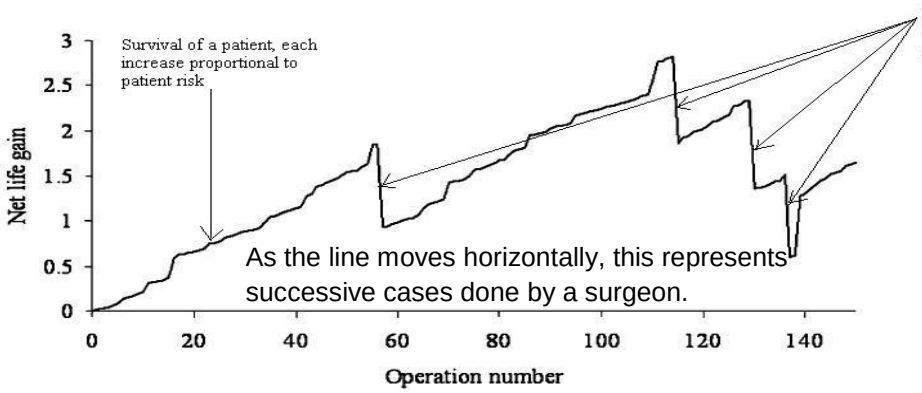
Yes_____ No_____ Unsure_____

**10.** What are the advantages of Figure 1?

☐ Easy to interpret
☐ Allows for patient risk-adjustment
☐ Can see consecutive cases
☐ Can spot outliers
☐ Other_____

**11.** What are the disadvantages of Figure 1?

☐ Does not tell how complex each case is
☐ Slow to respond to large changes
☐ Difficult to see patterns
☐ Static picture
☐ Low volume surgeons may appear to have worse outcomes than high-volume surgeons
☐ Dependent on number of cases done per surgeon
☐ Other _____




As line moves up, represents survival of a patient. If line moves down, then represents bad outcome (mortality, complication).

Fig. 2. VLAD chart plotting a running tally of net life gain derived from Fig. 1.

**Figure 2**: An example of variable life-adjusted display plots. This method takes into account total risk-adjusted mortality and plots the probability against the number of operations performed. Both success and failure are incorporated and the plot illustrates the difference between predicted and actual outcome. For instance as the plot goes up, this represents net life gain, and when the plot drops, this represents death. This is a variation of the CUSUM method.

**12. Is figure 2 an acceptable approach for monitoring outcomes?**

Yes_____ No_____ Unsure_____

**13.** What are the advantages of Figure 2?

☐ Easy to interpret
☐ Allows for patient risk-adjustment

☐ Can see consecutive cases
☐ Can spot outliers
☐ Other_____

**14.** What are the disadvantages of Figure 2?

☐ Does not tell how complex each case is
☐ Slow to respond to large changes
☐ Difficult to see patterns
☐ Static picture
☐ Low volume surgeons may appear to have worse outcomes than high-volume surgeons
☐ Dependent on number of cases done per surgeon
☐ Other _____

This graph will plot all surgeons and will identify outliers outside control limit.

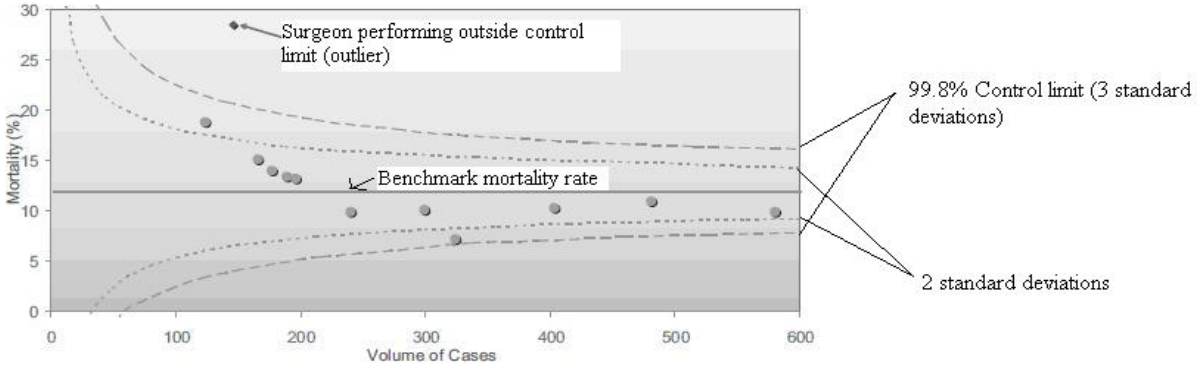



**Figure 3:** Funnel plot comparing performances of different surgeons (bullets). The boundaries are the 95% limits. Control limits are superimposed on the scatter plot that is normally 2 and 3 standard deviations from the mean. Data points within the control limits are acceptable and likely due to natural variation, whereas data points outside the control limits need to be examined to determine the cause of variation. This method identifies outliers. This method depends on adequate sample size.

**15. Is figure 3 an acceptable approach for monitoring outcomes?**

Yes_____ No_____ Unsure_____

16. What are the advantages of Figure 3?

☐ Easy to interpret
☐ Can spot outliers

☐ Can see consecutive cases
☐ Allows for patient risk-adjustment
☐ Other _____

17. What are the disadvantages of Figure 3?

☐ Does not tell how complex each case is
☐ Slow to respond to large changes
☐ Difficult to see patterns
☐ Static picture
☐ Low volume surgeons may appear to have worse outcomes than high-volume surgeons
☐ Dependent on number of cases done per surgeon
☐ Other _____

18. Please rank the order of which figure you feel is more appropriate for reporting surgical outcomes for surgeons (**1 most appropriate** and **3 most inappropriate**):

Figure 1 ____ Figure 2 ____ Figure 3 ____

19. Comments on which figure you find the easiest to interpret:

_____
_____
_____

20. Comments on disadvantages and concerns about the figures (and which one):

_____
_____
_____

21. Do you currently audit your own practice? Yes_____ No_____

22. If you audit your practice, how do you do it?

_____
_____
_____

23. Have you used any of these monitoring methods described in this survey?

Yes____ No____

24. If yes, which ones?

_____
___

25. Did other institutions that you previously worked at use any monitoring method?

Yes_____ No_____

26. If yes, which ones did they use? _____-
_____

27. Additional comments on monitoring approaches:

_____
_____
_____

Section D: Opinion on Surgical Performance Indicators:

Surgical performance indicators are a tool for assessment of individual performance and to enhance the performance of the entire group by means of optimization of an individual's quality. This is meant for individual feedback.

28. Please rank which components that you feel are most important as surgeon performance indicators: (**1 is most important** and **11 is least important**)

_____ Mortality rates
_____Postoperative complication rates
_____Risk-adjustment for patients
_____Breakdown of surgical procedures performed
_____Percentage of emergency procedures
_____Comparison to colleagues
_____Average patient demographics
_____Patient satisfaction surveys
_____Teaching at Academic Days
_____Resident satisfaction surveys
_____Other:_____

29. What postoperative complication rates would you want included? (Please check all that apply)

☐Patients on total parenteral nutrition (TPN)
☐Patients who received blood transfusions
☐Patients who return to operating room after index surgery

☐Patients who had postoperative interventional radiology

☐Patients who had postoperative endoscopic interventions

☐Patients with unplanned ICU stay

☐Patients with CCU stay postoperatively

☐

Other:_____

__

30. Who should be able to view a surgeon's outcomes? (Please check all that apply)

☐Patients

☐Surgeon Only

☐Surgeons within division

☐Department Chair/Division Head /CAC Colorectal Steering Committee

☐ Hospital administration

☐Public

31. Other comments/concerns that you wish to share:

_____

_____

_____

32. Would you consent to further contact if clarification of answers is needed?

Yes_____ No_____

*Please return the questionnaire in the provided envelope.*

**Thank you for participating in this study! Your comments are valuable to us.**

**Exhibits:**

**Exhibit 1: Flow chart of literature search**

Search ran July 6, 2010

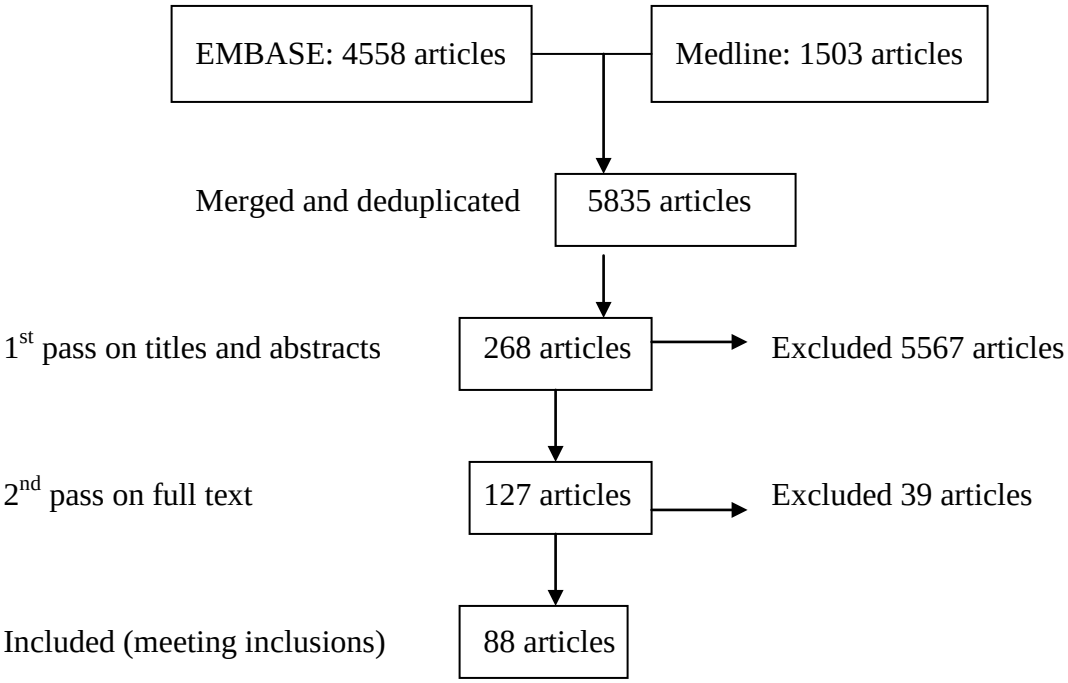
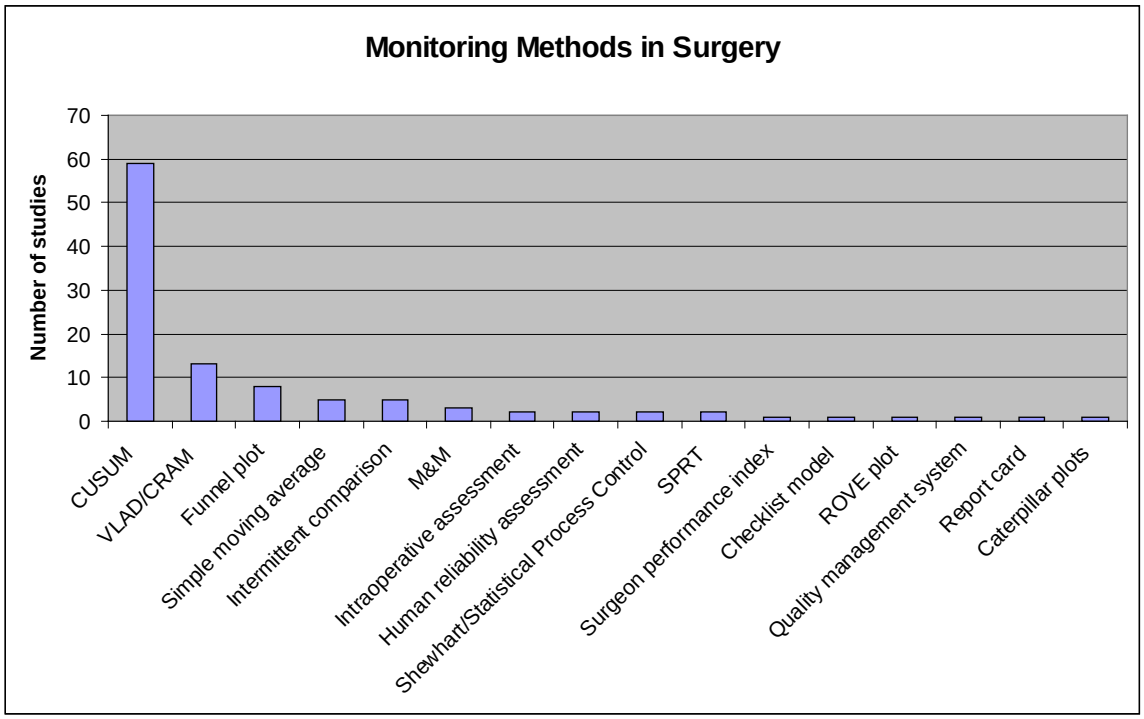


Exhibit 2: The different monitoring methods included in the literature review.




Abbreviations:

CUSUM = cumulative sum chart method

VLAD/CRAM = variable life-adjusted display/cumulative risk adjusted mortality chart

M&M = Mortality and Morbidity rounds

SPRT = Sequential probability ratio test

ROVE = Risk-adjusted observed versus expected plot

Exhibit 3: CUSUM types

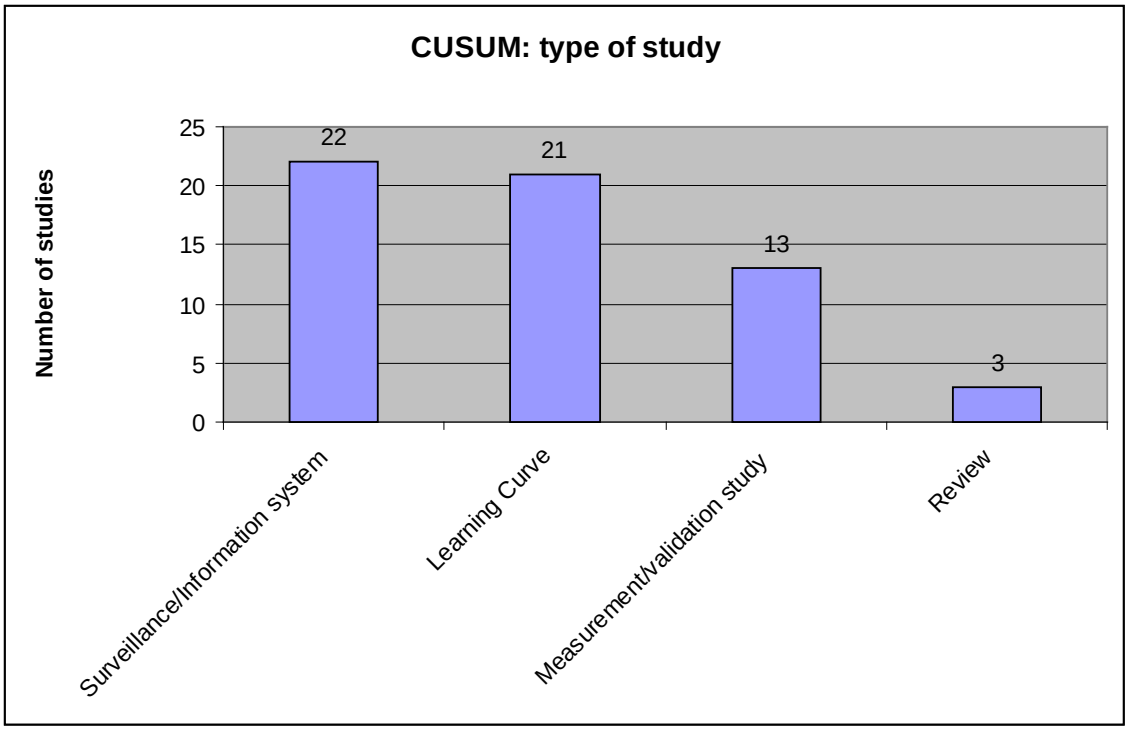



Exhibit 4: Year study was published

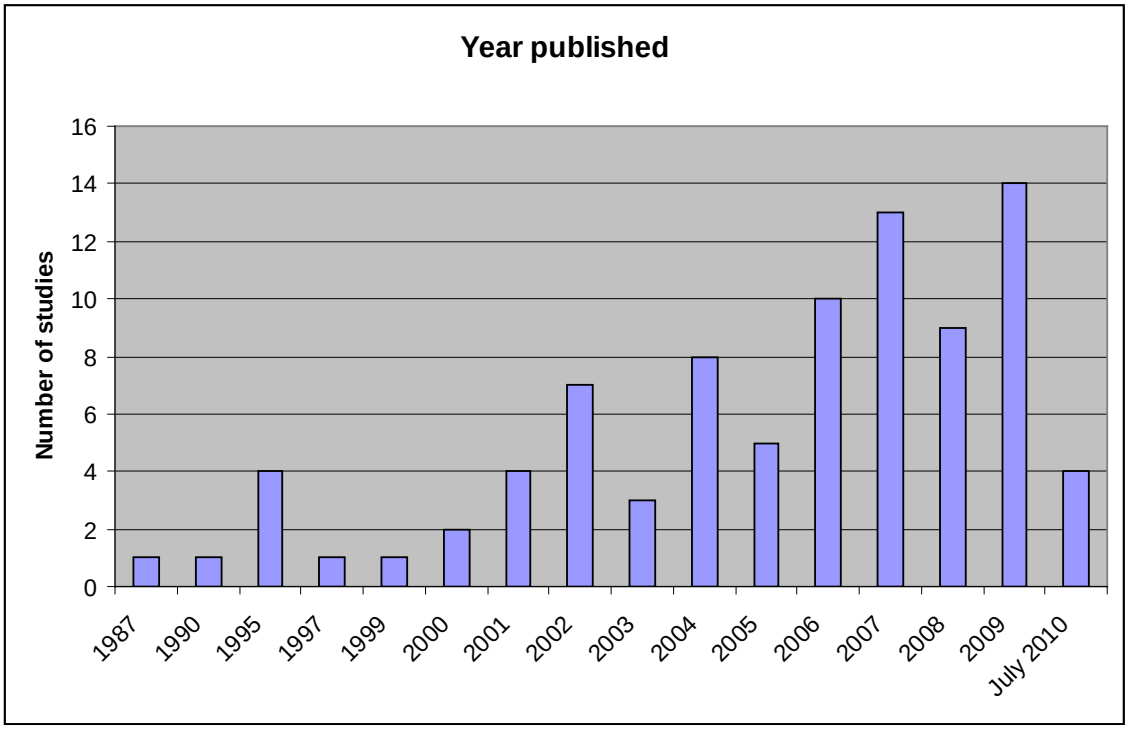


Exhibit 5: Country of study origin of included literature

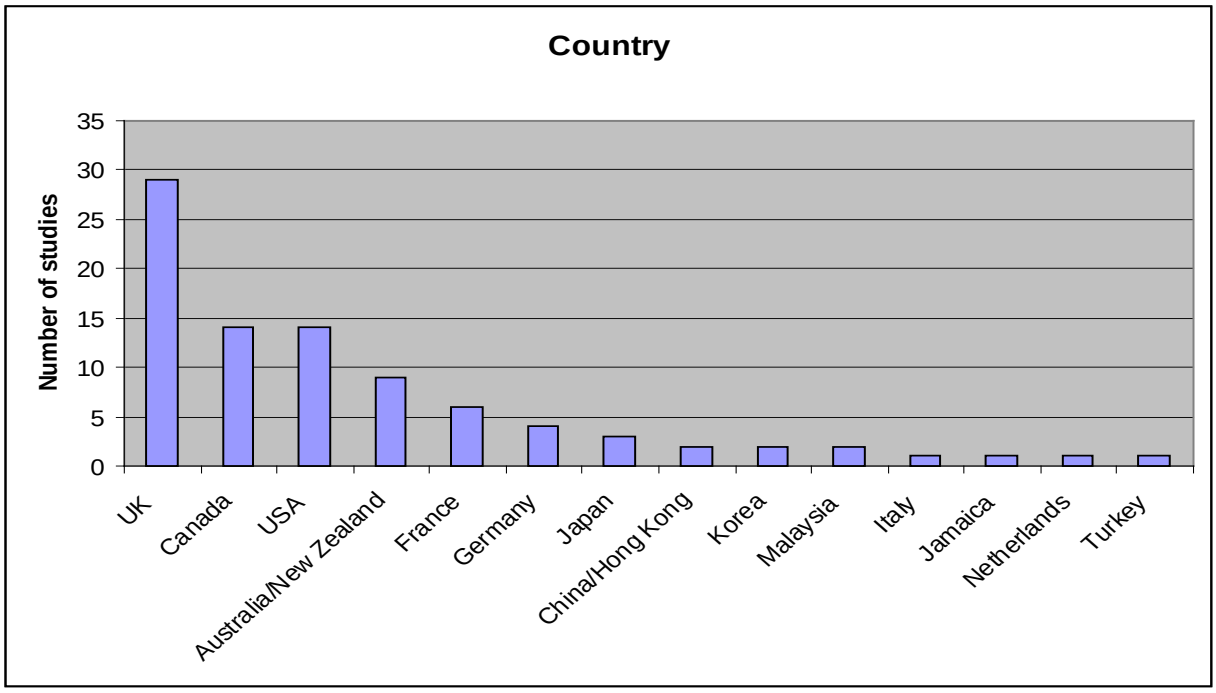
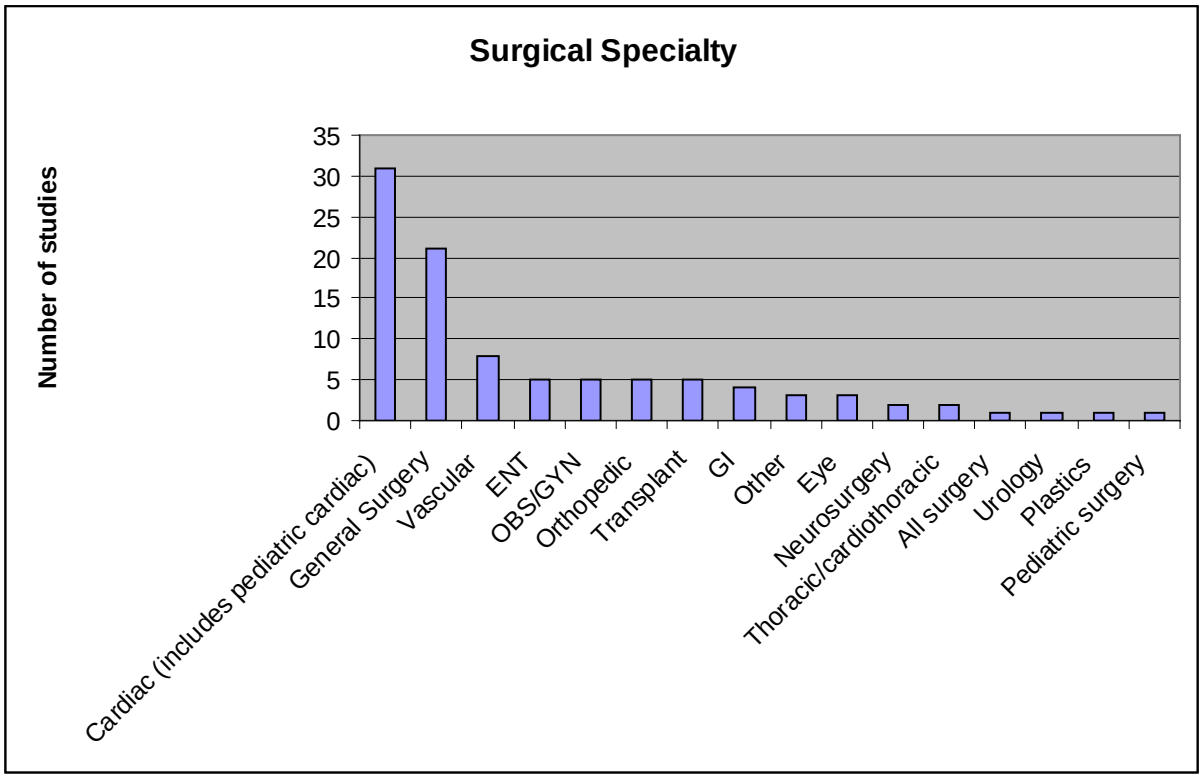



Exhibit 6: Surgical specialties studied in included literature



## Exhibit 7: Study characteristics of included studies

| Author | Year | Country | Study Design | Coverage | Patient Sample | # surgeon | Surgical Specialty | Study dates | Procedure | Monitoring method | Primary Outcome | Target and failure rates |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Piccoli et al | 1987 | Italy | Measurement/ validation study | 1 hospital unit | 38 | u/c | Transplant | 1978-1984 | Kidney transplant | CUSUM | Serum creatinine | w=2 (defined as length taken for one observation horizontally) d=5.0 (lead distance), φ=14 degrees (the half-amplitude of V-mask); ARL=5.5 (average run length) |
| Maurice-Williams et al | 1990 | UK | Surveillance/ information system | 1 hospital unit | 648 | 7 | Neurosurgery | 1988-1989 | Major' or 'complex major' neurosurgical procedures. | M&M | Complications as determined by the surgeon | N/A |
| Copeland et al | 1995 | UK | Measurement/ validation study | 1 hospital, 2 units | 3004 | 5 | General and urology | August 1, 1992- Aug 1, 1993 | Non day-case surgery: hernia repair, surgery of the external genitalia and soft tissues | O/E q 4-6 months | Mortality | O/E=1, if <1 better, if >1 than worse, also calculated 95% Confidence intervals. |
| D'Amico et al | 1995 | USA | Measurement/ validation study | 1 hospital unit | 75 | u/c | ENT | u/c | Surgical therapy for squamous cell carcinoma on head and neck | CUSUM | Serum SCCAg levels | V-mask: 1 SD |
| Murray et al | 1995 | UK | Audit data | National | 136,203 | 160 | General | 1991 | Day-case admission, elective or emergency admission | Caterpillar plots with confidence intervals | Mortality | Relative mortality rate compared to overall, with 95% CI |
| Van Rij et al | 1995 | New Zealand | Measurement/ validation study | 1 hospital unit | On average per each trainee: 62 cases | 17 trainees | General | 1988-1993 | Open appendectomy, inguinal hernia repair, open cholecystectomy | CUSUM | skin-to-skin' OR time | Physicians picked failure rates: appendectomy 50 minutes, X0=0.9. Herniorrhaphies 50 min, X0=0.8. Open cholecystectomy 60 min, X0=0.8. |
| Lovegrove et al | 1997 | UK | Surveillance/ information system | 1 hospital unit | 547 | 1 | Cardiac | 1992-1996 | Cardiac surgery, cardiopulmonary bypass | VLAD | In hospital mortality | None |
| Novick et al | 1999 | Canada | learning curve | 1 hospital unit | 1347 | 1 | Cardiac | Oct 1988-Sep 30, 1998 | Cardiac surgical procedures | CUSUM | 30-day mortality | Xo=0.1 (10% target failure rate). 80% Alert and 95% alarm boundary lines. |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Steiner et al | 1999 | Canada | Surveillance/ information system | 1 hospital unit | 104 | u/c | Pediatric Cardiac | 6 years | Neonatal arterial switch operations for transposition of the great arteries | CUSUM | Mortality | Failure rate based on previous surgical literature |
| Cuschieri | 2000 | UK | Measurement/validation study | 1 hospital unit | 20 | u/c | General | u/c | laparoscopic cholecystectomy | Human reliability assessment (HRA) | Errors: skill-based, rule-based, knowledge-based | Errors decided by a group of experts |
| Sherlaw-Johnson et al | 2000 | UK | Methods | 1 hospital unit | 393 | 1 | Cardiac | Jan 1992-Dec 31, 1995 | Isolated CABG and isolated valve operations | VLAD | Mortality | Probabilities calculated for group assuming normal distribution (mean mortality and SD) |
| Bartlett et al | 2001 | New Zealand | Learning curve | 1 hospital unit | 614 | 4 | General | Feb 1992-August 1994 | laparoscopic cholecystectomy | CUSUM | Conversion to open cholecystectomy | Used target rate of 10% as was the accepted rate in literature for conversion. The groups' overall intention to treat laparoscopically was 85% |
| Cox et al | 2001 | USA | Learning curve | Regional | 2255 | 16 | General | April 1994-April 1998 | Sentinel lymph node mapping | CUSUM, funnel plot | Mapping failure of sentinel lymph node | Failure rate for each surgeon with their own data. Surgical Volume Index (SVI) defined as average # cases in 30 day period. |
| Novick et al | 2001 | Canada | Learning curve | 1 hospital unit | 110 | 1 | Cardiac | March 2000 (4 months before and 4 months after policy change) | On-pump CABG and Off-pump CABG (OPCAB) | CUSUM | Mortality | Xo=0.1 ("acceptable failure rate" of 10%) Boundary lines: 80% alert and 90% alarm |
| Steiner et al | 2001 | Canada | Surveillance/information system | Regional | 230 | | Pediatric Cardiac | 3 year | Neonatal arterial switch operations for transposition of the great arteries | CUSUM | Mortality | Example: arbitrarily chose odds ratio=2 for CUSUM to detect increases in odds of failure |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cheung et al | 2002 | Hong Kong | Measurement/validation study | 1 hospital unit | 638 | 37 | General | 1994-1997 | Appendectomy | Intermittent adjusted outcomes (training assessment) | Complications: pneumonia, MI, wound infection, intra-abdominal collection, intestinal obstruction | Used GLMM to adjust for random surgeons' effect |
| Findlay et al | 2002 | Canada | Audit data | Regional (3 hospitals) | 946 CEAs in 894 patients | 10 | Neurosurgery, general surgery, vascular surgery | 6 years ( April 1994-Sep 1995, Sep 1996-Sep 1997, Oct 1997-Oct 1998, Oct 1999-Oct 2000) | Carotid endarterectomy (CEA) | 4 audits | Postop stroke or 30 day mortality | Audit criteria for comparison: Used over 70% symptomatic carotid stenosis were appropriate. Uncertain were for 50-69% symptomatic and >60% asymptomatic stenosis. Inappropriate were medically or neurologically unstable patients or did not meet the above criteria. |
| Forbes et al | 2002 | Canada | Learning curve | 1 hospital unit | 32 | 1 | vascular | 2.5 years u/c | Open ruptured abdominal aortic aneurysm repair | CUSUM | 30-day mortality | Set Xo=0.4 (40% mortality--set arbirtarily). 80% and 95% alarm boundary lines calculated using a target mortality rate of 30%. |
| Lim et al | 2002 | Malaysia | Measurement/ validation study | 1 hospital | 397 | 11 | GI, nephrology, radiology, obstetrics, ENT | u/c | Renal biopsy, ERCP, stereotaxic core needle breast biopsy, thyroidectomy, instrument delivery | CUSUM | Renal biopsy: failure <10 glomeruli/ ERCP: unsuccessful canulation/ thyrodectomy: OR time, pain on POD2/ Delivery: failure to deliver as intended | ERCP: 10% acceptable failure rate, 20% unacceptable failure rate (literature). Renal biopsy: consensus among local nephrologists suggest acceptable and unacceptable failure rates at 10 and 20%. Breast biopsy: experience from specialist centres suggest that acceptable failure rate is 2% and 5% is unacceptable. Instrument delivery: consensus among local obstetricians suggest that acceptable and unacceptable failre rates are 6 and 12%. Thyroidectomy: used consultant surgeon's performance as standard |
| Novick et al | 2002 | Canada | Learning curve | 1 hospital unit | 248 | 1 | Cardiac | July 1999-March 2001 | On-pump CABG and Off-pump CABG (OPCAB) | CUSUM | Mortality | Xo=0.1 (10% 'maximum acceptable failure rate') with 80% alert and 95% alarm boundary lines |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Novick et al | 2002 | Canada | Measurement/validation study | 1 hospital unit | 322 | 1 | Cardiac | July 1, 1999-Oct 9, 2001 | On-pump CABG and Off-pump CABG (OPCAB) | CUSUM | Mortality | Xo=0.1 (10% 'maximum acceptable failure rate' |
| Rombout et al | 2002 | Netherlands | Surveillance/ information system | 1 hospital unit | 1009 | initially 6, then restricted to 3 senior surgeons | ENT | July 1, 1992-June 30, 1999 | all ear surgeries, including small-hole stepedectomy, stapedectomies, and revision stapes surgery | Comparison of 2 periods of time | Adverse events and complications | Compare 2 periods of time |
| Behol z et al | 2003 | Germany | Surveillance/ information system | 1 hospital unit | 2500 inpatients/year, 1800 open heart procedures | u/c | Cardiac | 18 months | All open heart procedures | Quality Management System | Patient satisfaction questionnaire and questionnaire for satisfaction of referring physicians and hospitals | Revised international standard EN ISO 9001:2000 model chosen |
| Sharp et al | 2003 | UK | Learning curve | 1 hospital unit | 92 | 1 | ENT | Sep 1994-June 2002 | Superficial, partial superficial, and total/near total parotidectomies | CUSUM | Post-surgical facial nerve weakness (immediately postop and 6 months postop) | Used Xo=0.1, 0.15 and 0.2 (these are below the quoted value of 25%) |
| Tekkis et al | 2003 | UK | Measurement/validation study | ASCOT: 31 hospitals/ RISC: 5 hospitals | ASCOT database: 1036 / RISC database: 601 | u/c | General | ASCOT: Jan 1999-Dec 2000/ RISC: Jan 1999-Jan 2001 | Gastro-esophageal cancer surgery, oesophageal and gastric surgery | Continous running means, intermittent for funnel plots | In-hospital mortality | Used non-parametric bootstrap resampling technique with 10,000 iterations to calculate standard errors and to correct parameter estimation bias. Constructed control limits 90%, 95%, and 99% CI around mean operative mortality for the group. |
| Albert et al | 2004 | Germany | Surveillance/ information system | 1 hospital unit | 14 487 cases | u/c | Cardiac | Jan 1996-2003 | All heart operations | VLAD | Mortality within 30 days | No target or boundaries set |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Butler et al | 2004 | UK | Surveillance/ information system | n/a | hypothetical | n/a | Gynecological | n/a | Gynecological procedures | CUSUM, VLAD | Mortality | O/E=1 |
| Forbes et al | 2004 | Canada | Learning curve | 1 hospital unit | 96 | 2 | Vascular/interventional radiology | 1998-2002 | Elective endovascular repair of asymptomoatic infrarenal abdominal aortic aneurysm | CUSUM | 30-day mortality | Xo=0.1 as "acceptable initial clinical failure rate" from literature. 80% alert and 95% alarm boundary lines with target failure rate of 10% and alternative failure rate of 20% |
| Nizard et al | 2004 | France | Learning curve | 1 hospital unit | 78 | u/c | Orthopedic | u/c | CT-based computer-assisted surgery for Total knee arthroplasties | CUSUM | Alignment of lower limb, implant positioning and operative time | Target was 180 degrees for femortibial axis with 3 degrees deviation. Femoral and tibial components, targe value 90 degrees and 2 degrees deviation. For OR time, target mean and deviation to be detected twice standard deviation. Type I error rate of 0.01. |
| Polonieckiet al | 2004 | UK | Surveillance/ information system | Regional | 371 | u/c | Cardiac | 1986-2000 | Heart transplant | CUSUM, CRAM(VLAD), moving average, run of deaths, sequential probability ratio test | 30-day mortality | Used benchmark literature rate of 15% mortality and excess mortality to be 20%. CRAM used internal control. Table 3 has summary of test results. |
| Rogers et al | 2004 | UK | Surveillance/ information system | National | Cardiac Surgery Database: 1372 CT database: 1341 | u/c | Cardiac | Cardiac Surgery Database: April 1996-Sep 2002/ CT Transplantation Database: July 1995-Sep 2002 | Cardiac surgery database: adult elective and urgent CABG/ Cardiothoracic transplantation database: orthotopic heart transplantation | CUSUM (in all forms), VLAD | 30 day postop mortality | Depends which charting method. With VLAD/CRAM and SPRT. Patient-specific expected failure rates from empirically derived risk models. Boundary lines detect increase in failure rate of 50% increase in risk. False positive and false-negative 5%. |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sherlaw-Johnson et al | 2004 | UK | Methods | 1 hospital unit | 381 | 5 | Cardiac | u/c | CABG | VLAD | Mortality | Calculate each individual surgeons expected mortality rate with risk model. 95% prediction intervals. |
| Tang et al | 2004 | UK | Measurement/ validation study | 3 hospitals | 200 | 26 | General | u/c | laparoscopic cholecystectomy | Observational clinical human reliability assessment (OCHRA) | Error identification | Expert panel checked accuracy |
| Harris et al | 2005 | Canada | Measurement/ validation study | 1 hospital unit | 136 | u/c | Vascular | 1999-2003 | Open tranperitoneal repair of ruptured infrarenal abdominal aortic aneurysms | CUSUM | Mortality during hospitalization or <=30 days postop | Control limit set at +/- 2.5 |
| Leandro et al | 2005 | UK | Surveillance/ information system | 1 hospital unit | 674 | u/c | Transplant | Oct 1, 1988-Aug 31, 2002 | liver transplant | Bernoulli CUSUM | 1 year mortality | Benchmark unacceptable mortality rate of 0.2. Average probability of mortality of 0.15 or 0.17 based on cohort. |
| Rogers et al | 2005 | UK | Surveillance/ information system | National | 1634 heart, 1162 lung | u/c | Cardiothoracic | July 1995-March 2004 | 1st time isolated adult orthotopic heart, lung, or heart-lung transplants | CUSUM, VLAD, SPRT | 30 day postop mortality | Charts designed to detect 50% increase in mortality risk (OR 1.5). Two settings for alpha and beta were chosen. Alpha=beta=0.1 (10% for signal alert) and Alpha=beta=0.05(5%) for alarm. Patient-specific expected mortality rates were estimated from risk model. |
| Song et al | 2005 | Japan | Learning curve | 1 hospital unit | 50 | 1 | Cardiac | April 2000-March 2004 | CABG | CUSUM | 30 day mortality postop | Assumed X0=0.05 (5%) for mortality and 0.1 (10%) for operation time, crossclamp time, and LIMA harvesting time and injuring time and 0.8 alert line and 0.95 alarm line |
| Tekkis et al | 2005 | UK and USA | Learning curve | 1 hospital unit | 1965 | 12 | General | Feb 1983-Dec 2001 | ileal pouch anal anastomosis (IPAA) | CUSUM | Ileoanal pouch failure | No target or boundaries set |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Axelrod et al | 2006 | USA | Surveillance/ information system | National: 114 liver centers, 258 kidney centers | 18,277 liver transplant; 59,650 kidney transplant | u/c | Transplant | Jan 1997-Dec 2001 | Liver and kidney transplant | CUSUM | 1 year mortality for liver; 1-year graft survival for kidney | Control limit L and V-mask were defined based on the center's volume and it was determined whether the CUSUMs produced a signal (flag). Benchmark was based on PSRs (time to flag was taken as 3 or 3.5 years). Designed to provide a signal approximately 8% of time in a 3.5 year period. Used simulation study modeled on survival outcomes for liver transplant programs. Control limit for 1-year death rate of 13.09% (which corresponds to national average). |
| Catchpole et al | 2006 | UK | Measurement/validation study | 1 hospital unit | 24 | u/c | Pediatric Cardiac | Oct 2003-July 2004 | Pediatric cardiac cases that utilized midline sternotomy and cardiopulmonary bypass | Intraoperative assessment with modules | Minor and Major failures | From preliminary work--checklist produced |
| Chang et al | 2006 | UK | Surveillance/ information system | 1 hospital unit | 20 | 1 | Orthopedic | u/c | Total hip or knee replacement | CUSUM | Postop wound blistering | h=5 standard deviations and k=0.5 of a standard deviation of the datapoints. ARL was 465. (h--the control limit-- is the rise distance and k is the slope of both arms). Previous audit on their unit showed 10% incidence of wound blisters. Thus, adopted acceptable rate of wound blisters as Xo=0.9. |
| Hardoon et al | 2006 | UK | Surveillance/ information system | National | 3268 | u/c | Orthopedic | 1990-1997 | Hip replacement with 3M Capital Hip System prostheses (cemented) | CUSUM | Failure of hip prostheses | Used benchmark literature rate of 10%. Unacceptable revision rate of 1.5 times target rate. An alert boundary level of 3 was used (this corresbonded to a probability of 0.17 'false alert' and probability of 0.99 of a 'true alert') |
| Hutter et al | 2006 | USA | Measurement/ validation study | 1 hospital unit | 1439 NSQIP, 5905 M&M | u/c | General | July 1, 2002-June 30, 2003 | Major general surgery procedures | M&M rounds vs NSQIP | Mortality | Compare M&M to NSQIP data |
| Jha et al | 2006 | USA | Unclear | 31 hospitals | u/c | 168 | Cardiac | 1989-2002 | CABG | Report card system | Mortality | Divided into deciles. Compared to subsequent year. |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kang et al | 2006 | UK | Measurement/ validation study | 1 hospital unit | 460 | u/c | Pediatric Cardiac | March 2003-May 2004 | Open heart pediatric surgery | VLAD | In-hospital mortality | Expected mortality for individual operation derived from regression equation. Boundary lines 95-99%. |
| Lee et al | 2006 | South Korea | Learning curve | 1 hospital unit | 198 | 2 | General | April 1, 2001-March 2005 | Total gastrectomy with D2 lymph node dissection. Roux-en-Y esophagojejunostomy | CUSUM | Inadequate lymph node harvest | Xo=0.05 (5% acceptable failure rate)---arbitarily set by authors. Then the authors showed target success rates of 98%, 95%, 90%, 92.5%, and 85%. |
| Novick et al | 2006 | Canada | Measurement/validation study | 1 hospital unit | 793 | 1 | Cardiac | July 1999-Dec 2004 | Coronary bypass grafting | CUSUM, VLAD | Mortality | For risk adjusted CUSUM, used detection of 50% increase of 33% decrease in odds ratio (authors chose this because they deemed it was clinically significant). Pres-set control limits +/-2. |
| Pullatt et al | 2006 | USA | Measurement/validation study | 1 hospital unit | 324 | 1 | Vascular | May 1995-May 2005 | Endoscopic great saphenous vein harvest and minimal incision approach without endoscope | CUSUM | Primary and secondary graft patency failure, unable to limb salvage, perioperative wound complications | Xo=20% was derived from authors published experience. Upper 95% alarm and 80% alert boundary lines and lower 80% reassurance lines using alternative failure rate defined as twice the acceptable clinical failure rate. |
| Biau et al | 2007 | France (9 Canada, 8 UK, 4 NZ, 3 USA, 2 France, 1 other 5 countries) | Systematic Review | 77 studies where 31 relevant | varies | varies | All surgical and interventional | 1991-2005 | 14 cardiac, 7 anesthesia, 4 general surgery, 3 endoscopy, 2 otolaryngology, 1 orthopedics | CUSUM | Mortality | 5 studies: consensus from dept, 9 studies used reported rates in literature, 4 from expert society requirements, 5 studies from observation during monitoring of procedures |
| Bowles et al | 2007 | Australia | Surveillance/ information system | 1 hospital unit | 506 | 13 | General | u/c | Colorectal surgeries | CUSUM | Any inpatient mortality | End points agreed upon by group of general surgeons |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forbes et al | 2007 | Canada | Learning curve | 1 hospital unit | 166 | 2 | Vascular | 1998-2002 Surgeon A, 2000-2004 Surgeon B | Endovascular aortic aneurysm repair | CUSUM | 30-day mortality | Xo=10% as "acceptable initial clinical failure rate". 80% alert and 95% alarm boundary lines and 80% reassuruance lines calculated using target initial clinical failure rate of 10% and alternative failure rate of 20%. |
| Hardoon et al | 2007 | UK | Surveillance/ information system | national | 3688 hip prosthesis, 3494 patients | u/c | Orthopedic | 1990-1997 | Hip replacement with 3M Capital Hip System prostheses (cemented) | Poisson CUSUM | Failure of hip prostheses | Ran simulated data sets and ended up choosing upper bound 3 so that false detection rate is close to 5%. |
| Holzhey et al | 2007 | Germany | Surveillance/ information system | 1 hospital unit | 1441 | 8 | Cardiac | August 1996-Jan 2006 | Minimally invasive direct coronary artery bypass | CUSUM | 30 day mortality or death in hospital | Xo=0.1 as "acceptable failure rate" based on previous publications. Alert at 80% and upper 95% alarm. Lower than 95% when surgeon equal to or below accepted rate. |
| Lane et al | 2007 | UK | Surveillance/ information system | 1 hospital unit | Amnio: 1176 Ventouse: 278 | Amnio: 7 Ventouse: 16 | Obstetrics | Amnio: 2001-2005 Ventouse: 2004 | Amniocentesis and Ventouse delivery | Funnel plot, CUSUM | Amnio: multiple needle insertion rate / Ventouse: final delivery by forceps or by C-section | Complication rates from literature. Ventouse delivery at 22% and amniocentesis multiple needle insertions of 3%. |
| Lerch et al | 2007 | Canada | Measurement/ validation study | 1 hospital unit | 765 | 13 | General | June 29, 1999-April 21, 2005 | Sentinel Lymph node biopsy | CUSUM | False negative rate: the SLN is negative, but the full ALND are positive nodes | Set acceptable and unacceptable failure rates as 2% and 10%. Alpha-0.05 and beta-0.2. Upper boundary=1.3. Lower boundary=0. |
| Moore et al | 2007 | Canada | Measurement/ validation study | u/c | 126 | u/c | Vascular | March 10, 2001 to Feb 10, 2006 | Endovascular aortic aneurysm repair and open aneurysm repair for ruptured AAA | CUSUM | 30-day mortality | "Alert" line if outcome performance worse than expected and superior line is crossed if outcome performance better than expected according to the risk-adjustment model. This line would be crossed every 100 surgeries by surgeons operating at the level of pre-EVAR protocol surgeons. |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sibanda et al | 2007 | UK | Measurement/ validation study | Regional (1 hospital unit) | 57 | 1 | Pediatric Surgery | June 1994-June 2006 | Kasai portoenterostomy | CUSUM | Clearance of jaundice (plasma bilirubin level <20 umol/L within 6 months postop) | Xo=0.43 (based on data found for England and Wales). Alert threshold (type I error probability 95%) and alarm threshold (probability 99%). For SPRT chart used OR=1.5 and .67 |
| Song et al | 2007 | Japan | Learning curve | 1 hospital unit | 10 | 1 | Cardiac | April 2002-Oct 2005 | Elective arch-first operations for unruptured aortic arch aneurysms >6 cm in maximal diameter | CUSUM | 30 day postop mortality and mortality within the same hospitalization | Xo=0.07 because authors state 30 day mortality and morbidity to be 8.4% and 2% for average failure rate for operative skill according to the Japanese Association of Thoracic Surgery database. For operative and other times, it was definied as a time that did not exceed the originator's averages plus 1 standard deviation. 80% alert line and 95% alarm boundary line. |
| Wiegmann et al | 2007 | USA | Measurement/validation study | 1 hospital unit | 31 | u/c | Cardiac | 3 weeks | CABG, valve repair/replacement, CABG and valve repair, aortic root replacement and other procedures | intraoperative assessment | Events: any occurrence that seemed to disrupt the natural progression of the operation. Classified into errors and surgical flow disruptions. | Interdisciplinary team of experts reviewed errors |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wolfe et al | 2007 | Australia | Surveillance/ information system | 1 hospital unit | 2148 | 3 | Cardiac | 1997-2003 | Cardiac surgery on cardiopulmonary bypass | Shewhart and moving average charts, CUSUM | Return to the operating theatre for reexploration for excessive bleeding | An important improvement was defined as a shift in re-exploration rate of 4% and a important deterioration was defined as a shift to 6%. Assumed from published literature that the normal re-exploration rate was 5%. Control limits at +/- 6.9 for accepting nulll hypothesis of 4% and for accepting alternative hypothesis of 6% rate. Type 1 error rate of 0.05 and 95% power. |
| Yap et al | 2007 | Australia | Review | 1 hospital unit | 1000 | u/c | Cardiac | 4 year period | Heart valve surgery | CUSUM | In-hospital mortality | Acceptable mortality of 5% and unacceptable mortality of 7.5% from literature. Alpha and beta set at 0.10. Another example shows 3 % acceptable failure and 10% unacceptable. |
| Biau et al | 2008 | France | Learning curve | 1 hospital unit | 532 | 1 | GI/Endoscopic | 8 years | Endoscopic retrograde cholangiopancreatography (ERCP) | CUSUM | Unsuccessful cannulation of duct selected before the exam | For learning curve, Po=0.175 (failure rate 17.5%; process out of control) and H1 with P1=0.1 (failure rate 10%; process of control). Control limit of h=1.25 chosen to yield ARL values of 74 and 32. For standard CUSUM, Po=0.1 and failure rate above P1=0.25 as suboptimal performance and contorl limit of h=2.25 chosen to yield ARL values of 119 and 24. |
| Biswas et al | 2008 | USA | Surveillance/ information system | 258 transplant centres | 59,650 | u/c | Transplant | Jan 1997-Dec 2001 | Kidney transplant | CUSUM | Graft failure | Simulation study to see accuracy of theoretical approximations increases with u and h. h ranges from 3 to 6 based on u=0. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bridgewater et al | 2008 | UK | Review | National | u/c | u/c | Cardiac | 3 year period (unclear what years) | Cardiac surgery registry (CABG, AVR) | CUSUM, VLAD, Funnel plots | Hospital mortality for 1 year | Wide confidence intervals of 99.99% of the mean--justified since data neither validated nor risk-adjusted. Also notified surgeons outside 95% confidence intervals. |
| Cox et al | 2008 | UK | Measurement/ validation study | 1 hospital unit | 16 | 1 | Ophthalmology | u/c | Phacoemulsification | Checklist prevention model | Errors: following task analysis (step not performed, partially completed, repeated) | Experienced surgeons analyzed errors. |
| Kunadian et al | 2008 | UK | Surveillance/ information system | 1 hospital unit | 5198 | 5 | Cardiology | Jan 2003-Dec 2006 | Percutaneous coronary intervention | Funnel plot | In-hospital mortality | Used 3 sigma (99.8% confidence intervals) around mean and warning at 2 sigma (95% confidence intervals around predicted mean) |
| Mosquera et al | 2008 | New Zealand | Measurement/ validation study | 2 hospital units | 454 | 1 | Vascular | Sep 1995-April 2006 | Elective aortic procedures, emergency or acute aortic procedures, carotid procedures, infrainguinal arterial bypasses, miscellaneous revascularization procedures | VLAD | 30 day mortality | No limits set |
| Ng et al | 2008 | Australia | Surveillance/ information system | Regional | 117, 083 | u/c | Ophthalmology | 1980-2000 | all cataract and lens-related operations | Poisson funnel plot, ROVE plot, CUSUM | Postop endophtalmitis | Used similation to determine average run length (ARL) for different risk-adjusted CUSUM decision levels of h. Example used here was h=2.5 |
| Song et al | 2008 | Japan | Surveillance/ information system | 1 hospital unit | 274 | u/c | Cardiac | April 2002-Dec 2006 | Open-heart surgery | CUSUM | 30 day postop mortality | Xo=10% for overall mortality and morbidity. Xo=5% for valve surgery, 2% for coronary surgery and 15% for aortic surgery. 80% alert and 95% alarm boundary lines. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Toker et al | 2008 | Turkey | Learning curve | 1 hospital unit | 90 | 1 | Thoracic | June 2002-Sep 2006 | Videothoracoscopic thymic surgery | CUSUM | OR time, conversions, readmissions, postop complications | no boundaries set |
| Antonacci et al | 2009 | USA | Surveillance/ information system | 3 hospitals and 1 ambulatory care | 29,237 | 63 | General | Sep 2000-April 2005 | All surgical procedures | M&M weekly rounds | Mortality: death within 30 days or admission to surgical service | Expert review |
| Asch et al | 2009 | USA | Measurement/ validation study | Regional: all Florida and New York hospitals that are non-federal acute care hospitals | 4,909,169 deliveries | 4124 | Obstetrics/ Gynecological | 1992-2007 | Vaginal and C-section | Intermittent adjusted outcomes comparing physicians trained at different residency programs | Vaginal: laceration, hemorrhage, others Cesarean: hemorrhage, infection, all others | Hierarchical generalized linear models with logit link function to assess independent association between residency program and complication measures. |
| Axelrod et al | 2009 | USA | Surveillance/ information system | National: 67 liver centers, 113 kidney centers | 11, 957 liver transplant; 31, 666 kidney transplant | u/c | Transplant | July 1, 2004-Dec 31, 2007 | Liver and kidney transplant | CUSUM | 1 year mortality for liver; 1-year graft survival for kidney | Control limit L and V-mask were defined based on the center's volume and it was determined whether the CUSUMs produced a signal (flag). Benchmark was based on PSRs (time to flag was taken as 3 or 3.5 years). Designed to provide a signal approximately 8% of time in a 3.5 year period. Used simulation study modeled on survival outcomes for liver transplant programs. Control limit for 1-year death rate of 13.09% (which corresponds to national average). |
| Biau et al | 2009 | France | Surveillance/ information system | 1 hospital unit | 83 | u/c | Orthopedic | Nov 2006-June 2007 | Primary total hip replacement | CUSUM | 10 points as markers of inadequate surgical performance | Target 90% success rate. Limit h set at 1.75 |
| Carty et al | 2009 | USA | Measurement/ validation study | 1 hospital | 1068 | 8 | Plastic Surgery | Jan 18, 1995- Dec 31, 2007 | Bilateral reduction mammaplasty | Learning curve-Statistical process control | Mortality | Compared to survey of expert plastic surgeons. For graph, used standard deviations (3SD, 2SD, 1SD) around expected mean. |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chen et al | 2009 | China | Learning curve | 1 hospital unit | 200 | 2 | Cardiac | u/c | Off-pump CABG | CUSUM | Mortality | X=0.1 based on another publication. Used 80% alert and 95% alarm boundaries |
| Choi et al | 2009 | Korea | Learning curve | 1 hospital unit | 199 | 3 | General | May 2001-Nov 2006 | Laparoscopic sigmoid resection | Moving average method, CUSUM | Failure: conversion to open surgery, perioperative major complications, inadequate number of lymph nodes harvested (<12) | Xo=0.1 (acceptable failure rate) |
| East et al | 2009 | Jamaica | Learning curve | 1 hospital unit | 24 | 2 | General | u/c | Sentinel lymph node biosy with methylene blue dye | CUSUM | False negative rate: the SLN is negative, but the full ALND are positive nodes | Po=0.15 (acceptable failure rate), p1=0.3 (unacceptable failure rate), Type I error=0.05, Type 2 error=0.2. Based on recommendations. |
| Hartrumpf et al | 2009 | Germany | Measurement/ validation study | 1 hospital unit | 3703 | 11 | Cardiac | 3 consecutive annual periods | isolated CABG, isolated AVR, isolated MVR, AVR+CABG, MVR+CABG, other | Intermittent Surgeon Performance Index (SPI) | 30 day mortality or never left the hospital | Developed algorithm for SPI |
| Kunadian et al | 2009 | UK | Measurement/ validation study | 48 hospitals | 149,888 | u/c | Cardiology | Jan 1, 2002-Dec 31, 2004 | Percutaneous coronary intervention | Funnel plot | Mortality | 3 sigma (3 DS from mean) for upper and lower control limits (99% CI) and 2 sigma from mean for 95% warning limits. |
| Mayer et al | 2009 | UK | Surveillance/ information system | varies depending on example | various examples | n/a | General, Pediatric cardiac, Cardiac, GI | varies | Colonoscopy, breast cancer, pediatric cardiac surgery, CABG | Funnel plots | Mortality | 2 and 3 SD from the mean. |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sego et al | 2009 | USA | Measurement/ validation study | 1 hospital unit | 6994 | u/c | Cardiac | 1992-1998 | Cardiac procedures | RA CUSUM, RA Bernoulli CUSUM, RAST CUSUM | 30 day mortality | Used 73% reduction which corresponds to doubling in odds of 30-day mortality. Used AFT model from training data, and used Markov chain approach to identify control limit of h=4.8327 which results in ARL around 10,000. An average of 1 false alarm every 10 years. |
| Tsang et al | 2009 | UK | Measurement/ validation study | 1 hospital unit | 1986 | u/c | Cardiac | 2000-2003, 2004-2006 | All open heart procedures | VLAD | In-hospital mortality | Risk adjusted predictions. 2-sided prediction limits (95% and 99%). |
| Waller et al | 2009 | New Zealand | Measurement/ validation study | 1 hospital unit | 290 | 1 | Gastroenterology | June 2006-May 2008 | Endoscopic retrograde cholangiopancreatography (ERCP) | CUSUM | Unsuccessful cannulation of duct selected before the exam | Used literature benchmark data. Acceptable and unacceptable cannulation failure rates set at 0.2 and 0.35. Type I and Type II error rates set at 0.10. |
| Bege et al | 2010 | France | Learning curve | 1 hospital unit | 127 | 1 | General | Jan 2002-June 2005 | laparoscopic conservative mesorectal excision | CUSUM, 30-patient simple moving average | 30 day mortality | Did not choose an arbitrary success level. The cut-off point on the curve was deemed the end of the learning period. |
| Connolly et al | 2010 | Australia | Surveillance/ information system | 1 hospital, 2 units | 216 | u/c | ENT and general | Jan 2003-Dec 2006 | Thyroidectomy | CUSUM | Hematoma, hypocalcemia, vocal cord palsy | Wanted to use literature rates, but heterogeneity of definitions mean that had to have a consesnsus of the trend observed in the literature. |
| Dessolle et al | 2010 | France | Learning curve | 1 hospital unit | 846 | 6 | Gynecological | 6 months | Embryo transfer | CUSUM | Negative pregnancy | Pregnancy rate of 20% considered inadequate and 40% was considered adequate. From consensus among care providers. LC-CUSUM limit h=1.86 to yield Type I error to 1.7% in 100 procedures. For CUSUM, limit h=4.71 to yield Type I and II errors to 4.4% and 2.5% in 200 procedures |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Salowi et al | 2010 | Malaysia | Surveillance/ information system | 1 hospital unit | 80 | 3 trainees, 1 consultant | Ophthalmology | u/c | Phacoemulsification | CUSUM | Posterior capsular rupture and postop refracted vision of worse than 6/12 | Acceptable and unacceptable rates (5% and 10%) derived from surgeries reported to National Cataract Surgery Registry. |

## Exhibit 8: Critical appraisal of studies using Bruce et al criteria

| Author | Coverage: National/Regional/ hospital/unit | Denominator data | Definition of outcome | Risk factors included | Data collection information | Event recorded: Real time/ Retrospective | Output: Feedback | **Total Score (max 7)** |
|---|---|---|---|---|---|---|---|---|
| Piccoli et al (1987) | X | X | X | | X | X | | **5** |
| Maurice-Williams et al (1990) | X | X | X | | X | X | X | **6** |
| Copeland et al (1995) | X | X | X | X | | | | **4** |
| D'Amico et al (1995) | X | X | X | | | X | | **4** |
| Van Rij et al (1995) | X | X | X | | | X | X | **5** |
| Murray et al (1995) | X | | X | X | X | X | | **5** |
| Lovegrove et al (1997) | X | X | X | X | X | X | X | **7** |
| Novick et al (1999) | X | X | X | | X | X | | **5** |
| Steiner et al (1999) | X | X | X | | | | | **3** |
| Cuschieri (2000) | | | X | | X | X | | **3** |
| Sherlaw-Johnson et al (2000) | X | X | X | X | | | | **4** |
| Bartlett et al (2001) | X | X | X | | | X | | **4** |
| Cox et al (2001) | X | X | X | | X | X | X | **6** |
| Novick et al (2001) | X | X | X | | X | X | | **5** |
| Steiner et al (2001) | X | X | | X | | | | **3** |
| Cheung et al (2002) | X | X | X | X | | X | | **5** |
| Findlay et al (2002) | X | X | X | | | X | X | **5** |
| Forbes et al (2002) | X | X | X | | X | X | | **5** |
| Lim et al (2002) | X | | X | | | | | **2** |
| Novick et al (2002) | X | X | X | | X | X | | **5** |
| Novick et al (2002) | X | X | X | | X | X | | **5** |
| Rombout et al (2002) | X | X | X | | X | X | X | **6** |
| Beholz et al (2003) | X | | X | | | | X | **3** |
| Sharp et al (2003) | X | X | X | | X | X | | **5** |
| Tekkis et al (2003) | X | X | X | X | | X | | **5** |
| Albert et al (2004) | X | X | X | X | X | X | X | **7** |
| Butler et al (2004) | | X | X | X | | | | **3** |
| Forbes et al (2004) | X | | X | | X | X | | **4** |
| Nizard et al (2004) | X | X | X | | | X | | **4** |
| Poloniecki et al (2004) | X | | X | X | | X | | **4** |
| Rogers et al (2004) | X | X | X | X | | X | | **5** |
| Sherlaw-Johnson et al (2004) | X | | X | X | | | | **3** |
| Tang et al (2004) | X | X | X | | X | X | | **5** |
| Harris et al (2005) | X | X | X | X | X | X | | **6** |
| Leandro et al (2005) | X | X | X | | | X | | **4** |
| Rogers et al (2005) | X | X | X | X | | | | **4** |
| Song et al (2005) | X | X | X | | | | | **3** |
| Tekkis et al (2005) | X | X | X | X | | | | **4** |
| Axelrod et al (2006) | X | X | X | X | | | | **4** |
| Catchpole et al | X | X | X | | X | X | X | **6** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| (2006) | | | | | | | | |
| Chang et al (2006) | X | X | X | | X | X | | **5** |
| Hardoon et al (2006) | X | X | X | | | | | **3** |
| Hutter et al (2006) | X | X | X | | X | X | X | **6** |
| Jha et al (2006) | X | X | X | X | X | X | X | **7** |
| Kang et al (2006) | X | X | X | X | | X | | **5** |
| Lee et al (2006) | X | X | X | | | | | **3** |
| Novick et al (2006) | X | X | X | X | | X | | **5** |
| Pullatt et al (2006) | X | X | X | | X | X | | **5** |
| Biau et al (2007) | X | X | X | | | | | **3** |
| Bowles et al (2007) | X | X | X | X | X | X | X | **7** |
| Forbes et al (2007) | X | X | X | | X | X | | **5** |
| Hardoon et al (2007) | X | X | X | | | | | **3** |
| Holzhey et al (2007) | X | X | X | | X | X | X | **6** |
| Lane et al (2007) | X | X | X | | | | | **3** |
| Lerch et al (2007) | X | X | X | | X | X | | **5** |
| Moore et al (2007) | X | X | X | X | X | | | **5** |
| Sibanda et al (2007) | X | X | X | | X | X | | **5** |
| Song et al (2007) | X | X | X | | | X | | **4** |
| Wiegmann et al (2007) | X | | X | | X | X | | **4** |
| Wolfe et al (2007) | X | X | X | | | X | X | **5** |
| Yap et al (2007) | X | X | X | | | X | | **4** |
| Biau et al (2008) | X | X | X | | X | X | | **5** |
| Biswas et al (2008) | X | X | X | X | | | | **4** |
| Bridgewater et al (2008) | X | | X | X | | | X | **4** |
| Cox et al (2008) | X | X | X | | X | X | | **5** |
| Kunadian et al (2008) | X | X | X | | X | X | | **5** |
| Mosquera et al (2008) | X | X | X | X | X | X | | **6** |
| Ng et al (2008) | X | X | X | X | X | X | | **6** |
| Song et al (2008) | X | X | X | | | X | | **4** |
| Toker et al (2008) | X | X | X | | X | X | | **5** |
| Antonacci et al (2009) | X | X | X | X | X | X | X | **7** |
| Asch et al (2009) | X | X | X | X | X | X | | **6** |
| Axelrod et al (2009) | X | X | X | X | X | X | X | **7** |
| Biau et al (2009) | X | X | X | | X | X | X | **6** |
| Carty et al (2009) | X | X | X | | | | | **3** |
| Chen et al (2009) | X | X | X | | | | | **3** |
| Choi et al (2009) | X | X | X | | | X | | **4** |
| East et al (2009) | X | X | X | | X | X | | **5** |
| Hartrumpf et al (2009) | X | X | X | X | X | X | X | **7** |
| Kunadian et al (2009) | X | X | | X | | | | **3** |
| Mayer et al (2009) | X | | X | | | | | **2** |
| Sego et al (2009) | X | X | X | X | | | | **4** |
| Tsang et al (2009) | X | X | X | X | | | | **4** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Waller et al (2009) | X | X | X | | X | X | | **5** |
| Bege et al (2010) | X | X | X | | | X | | **4** |
| Connolly et al (2010) | X | X | X | | | X | | **4** |
| Dessolle et al (2010) | X | X | X | | X | X | | **5** |
| Salowi et al (2010) | X | X | X | | X | X | X | **6** |
| **TOTAL** | **86** | **78** | **86** | **32** | **44** | **62** | **20** | |

Exhibit 9: Patient demographics for the cohort (note: unique patients for age, sex, comorbidity)

| VARIABLE | VALUE | Elective | Emergent | Overall | P-VALUE |
|---|---|---|---|---|---|
| | | N=3267 | N=1713 | N=4980 | |
| Age | Mean ± SD | 63 ± 15 | 63.35 ± 17 | 63± 16 | 0.201 |
| | Median (IQR) | 65 (53-74) | 65 (53-75) | 65 (53-75) | 0.015 |
| SEX | Female | 1156 (43.6%) | 845 (51.4%) | 2001 (46.3%) | <.001 |
| | Male | 1518 (56.8%) | 799 (48.6%) | 2317 (53.7%) | |
| Comorbidity Score* | Mean ± SD | 6.4 ± 6.7 | 7.7 ± 7.9 | 6.91 ± 7.19 | <.001 |
| | Median (IQR) | 4 (0-10) | 5 (0-16) | 4 (0-13) | <.001 |
| PIMR Score** | Mean ± SD | -0.14 ± 1.37 | 0.91 ± 2.20 | 0.22 ± 1.77 | <.001 |
| | Median (IQR) | 0 (0-0) | 0 (0-0) | 0 (0-0) | <.001 |
| LAPS Score*** | Mean ± SD | 1.51 ± 6.00 | 31.61 ± 29.97 | 11.86 ± 23.17 | <.001 |
| | Median (IQR) | 0 (0-0) | 25 (6-44) | 0 (0-15) | <.001 |
| Transfer | | 10 (0.3%) | 185 (10.8%) | 195 (3.9%) | <.001 |
| Open/ laparoscopic | Laparoscopic | 912 (27.9%) | 143 (8.3%) | 1055 (21.2%) | <.001 |
| | Open | 2355 (72.1%) | 1570 (91.7%) | 3925 (78.8%) | |
| Diagnosis | Cancer | 2038 (62.4%) | 638 (37.2%) | 2676 (53.7%) | <.001 |
| | Diverticular disease | 182 (5.6%) | 241 (14.1%) | 423 (8.5%) | |
| | Ulcerative colitis | 151 (4.6%) | 82 (4.8%) | 233 (4.7%) | |
| | Crohn's | 175 (5.4%) | 98 (5.7%) | 273 (5.5%) | |
| | Ischemic colitis | <=5 (0.1%) | 122 (7.1%) | 124 (2.5%) | |
| | Infectious colitis | <=5 (0.1%) | 45 (2.6%) | 49 (1.0%) | |
| | Other colitis | <=5 (0.1%) | <=5 (0.2%) | 6 (0.1%) | |
| | Stoma related | 522 (16.0%) | 29 (1.7%) | 551 (11.1%) | |
| | Volvulus/bowel obstruction | 19 (0.6%) | 137 (8.0%) | 156 (3.1%) | |
| | Bleeding | 0 (0.0%) | 16 (0.9%) | 16 (0.3%) | |
| | Hernia | <=5 (0.1%) | 10 (0.6%) | 13 (0.3%) | |
| | Polyp | 8 (0.2%) | 0 (0.0%) | 8 (0.2%) | |
| | Other | 160 (4.9%) | 292 (17.0%) | 452 (9.1%) | |
| Surgery | Colon | 2131 (65.2%) | 1555 (90.8%) | 3686 (74.0%) | <.001 |
| | Rectal | 1136 (34.8%) | 158 (9.2%) | 1294 (26.0%) | |
| Type of surgery | Segmental resection | 1404 (43.0%) | 1113 (65.0%) | 2517 (50.5%) | <.001 |
| | Anterior resection (AR) | 845 (25.9%) | 141 (8.2%) | 986 (19.8%) | |
| | Reversal | 495 (15.2%) | 20 (1.2%) | 515 (10.3%) | |
| | Bypass | 162 (5.0%) | 321 (18.7%) | 483 (9.7%) | |
| | Abdominoperineal resection (APR) | 291 (8.9%) | 17 (1.0%) | 308 (6.2%) | |
| | Total colectomy | 70 (2.1%) | 101 (5.9%) | 171 (3.4%) | |
| OR time, in minutes | Mean ± SD | 226.37 ± 96.11 | 172.77 ± 72.97 | 207.94 ± 92.40 | <.001 |
| | Median (IQR) | 213 (160-277) | 160 (125-205) | 191 (143-255) | <.001 |
| Stoma | | 698 (21.4%) | 869 (50.7%) | 1567 (31.5%) | <.001 |

* Based on the Elixhauser comorbidity index

** Procedural independent mortality risk score

*** Laboratory-based acute physiology score

Exhibit 10: Short term outcomes for cohort

| VARIABLE | VALUE | Elective N=3267 | Emergent N=1713 | Overall N=4980 | P-VALUE |
|---|---|---|---|---|---|
| 30 day postoperative complication index* | 0 | 2722 (83.3%) | 864 (50.4%) | 3586 (72.0%) | <.001 |
| | 2 | 140 (4.3%) | 201 (11.7%) | 341 (6.8%) | |
| | 3 | 240 (7.3%) | 142 (8.3%) | 382 (7.7%) | |
| | 4 | 125 (3.8%) | 312 (18.2%) | 437 (8.8%) | |
| | 5 | 40 (1.2%) | 194 (11.3%) | 234 (4.7%) | |
| Grade 2 TPN | 1 | 167 (5.1%) | 286 (16.7%) | 453 (9.1%) | <.001 |
| Grade 2 blood transfusion | 1 | 158 (4.8%) | 355 (20.7%) | 513 (10.3%) | <.001 |
| Grade 3 | 1 | 320 (9.8%) | 334 (19.5%) | 654 (13.1%) | <.001 |
| Grade 4 | 1 | 157 (4.8%) | 462 (27.0%) | 619 (12.4%) | <.001 |
| Grade 5 | 1 | 40 (1.2%) | 194 (11.3%) | 234 (4.7%) | <.001 |
| Length of stay, days | Mean ± SD | 9.06 ± 11.67 | 22.88 ± 28.95 | 13.81 ± 20.51 | <.001 |
| | Median (IQR) | 6 (5-9) | 13 (8-26) | 8 (5-14) | <.001 |
| 30 day readmission | 0-None | 3072 (94.0%) | 1579 (92.2%) | 4651 (93.4%) | 0.011 |
| | 1 | 183 (5.6%) | 124 (7.2%) | 307 (6.2%) | |
| | 2 | 12 (0.4%) | 10 (0.6%) | 22 (0.4%) | |

* Highest complication based on the modified Clavien-Dindo Classification system

0 No complication
2 TPN or blood transfusion
3 Return to OR/Endoscopic/Radiologic intervention
4 Stepdown/ICU stay
5 In-hospital mortality

**Exhibit 11: 2x2 tables**

Exhibit 11a: Grade 2 blood transfusion (after Oct 26, 2006)

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 47 | 3 | 50 |
| OHDW - | 7 | 96 | 103 |
| Total | 54 | 99 | 153 |

Exhibit 11b: Grade 2 TPN with pharmacy data (Note: Civic data only after June 1, 2004)

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 49 | 2 | 51 |
| OHDW - | 2 | 225 | 227 |
| Total | 51 | 227 | 278 |

Exhibit 11c: Grade 2 TPN with CCI codes

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 35 | 0 | 35 |
| OHDW - | 17 | 240 | 257 |
| Total | 52 | 240 | 292 |

Exhibit 11d: Grade 3 Interventional radiology:

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 28 | 6 | 34 |
| OHDW - | 5 | 253 | 258 |
| Total | 33 | 259 | 292 |

Exhibit 11e: Grade 3 Endoscopic intervention

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 3 | 11 | 14 |
| OHDW - | 1 | 277 | 278 |
| Total | 4 | 288 | 292 |

Exhibit 11f: Grade 3 Return to operating room

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 23 | 9 | 32 |
| OHDW - | 7 | 252 | 260 |
| Total | 30 | 262 | 292 |

Exhibit 11g: Grade 3: all return to OR, endoscopic and radiologic intervention

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 53 | 13 | 66 |
| OHDW - | 5 | 221 | 226 |
| Total | 58 | 234 | 292 |

Exhibit 11h: Grade 4 ICU/Stepdown (with inpatient census table—only available after April 1, 2004)

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 58 | 2 | 60 |
| OHDW - | 0 | 203 | 203 |
| Total | 58 | 205 | 263 |

Exhibit 11i: Grade 4 ICU/Stepdown (with special care table)

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 64 | 2 | 66 |
| OHDW - | 1 | 225 | 226 |
| Total | 65 | 227 | 292 |

Exhibit 11j: Grade 5 In-hospital mortality

| | Chart Review + | Chart Review - | Total |
|---|---|---|---|
| OHDW + | 23 | 0 | 23 |
| OHDW - | 0 | 269 | 269 |
| Total | 23 | 269 | 292 |

Exhibit 12: Electronic algorithm compared to gold standard chart review: sensitivity and specificity with weighted 2x2 kappa coefficients

| Electronic algorithm | Gold standard chart review | Frequency by encounter (%) | TPs | FPs | FNs | TNs | Sensitivity (95% CI)<br><br>k- = negative kappa coefficient | Specificity (95% CI)<br><br>k+ = positive kappa coefficient |
|---|---|---|---|---|---|---|---|---|
| Grade 2 complication: Blood transfusion | Had blood transfusion during operation or within 30 days postoperatively | 54 (35.3%) | 47 | 3 | 7 | 96 | 0.87 (0.75-0.95)<br><br>k- = 0.81 | 0.97 (0.91-0.99)<br><br>k+ = 0.91 |
| Grade 2 complication: total parenteral nutrition (TPN)* | Had TPN within 30 days postoperatively | 51 (18.3%) | 49 | 2 | 2 | 225 | 0.96 (0.87-0.99)<br><br>k- = 0.95 | 0.99 (0.97-1.00)<br><br>k+ = 0.95 |
| Grade 3: Return to operating room/ endoscopic or radiologic intervention | Had a return to operating for a procedure, endoscopic intervention, or radiologic intervention within 30 days postoperatively | 58 (19.9%) | 53 | 13 | 5 | 221 | 0.91 (0.81-0.97)<br><br>k- = 0.89 | 0.94 (0.91-0.97)<br><br>k+ = 0.75 |
| Grade 4: Intensive-care unit or stepdown stay** | Had a stay in ICU or stepdown unit within 30 days postoperatively | 65 (22.3%) | 64 | 2 | 1 | 225 | 0.98 (0.92-1.00)<br><br>k- = 0.98 | 0.99 (0.97-1.00)<br><br>k+ = 0.96 |
| Grade 5: in-hospital mortality | Had in-hospital mortality within 30 days postoperatively from index colorectal surgery | 23 (7.9%) | 23 | 0 | 0 | 269 | 1.00 (0.85-1.00)<br><br>k- = 1 | 1.00 (0.99-1.00)<br><br>k+ = 1 |

*using pharmacy data

** using special care table

Exhibit 13: Results of accuracy for electronic algorithms for short term outcomes compared to chart review

| Electronic algorithm | Accuracy (95% CI) | Sensitivity (95% CI) | Specificity (95% CI) | PPV (95% CI) | NPV (95% CI) | LR+ (95% CI) | LR- (95% CI) |
|---|---|---|---|---|---|---|---|
| Grade 2 complication: Blood transfusion | 0.93 (0.88, 0.97) | 0.87 (0.75-0.95) | 0.97 (0.91-0.99) | 0.94 (0.83-0.99) | 0.93 (0.86- 0.97) | 28.7 (9.4-88.0) | 0.13 (0.07- 0.27) |
| Grade 2 complication: total parenteral nutrition (TPN)* | 0.99 (0.96, 1.00) | 0.87 (0.75-0.95) | 0.97 (0.91-0.99) | 0.94 (0.83-0.99) | 0.99 (0.97-1.00) | 109.0 (27.4-433.9) | 0.04 (0.01, 0.15) |
| Grade 3: Return to operating room/ endoscopic or radiologic intervention | 0.94 (0.90-0.96) | 0.91 (0.81-0.97) | 0.94 (0.91-0.97) | 0.80 (0.69-0.89) | 0.98 (0.95-0.99) | 16.4 (9.64-28.1) | 0.09 (0.04-0.21) |
| Grade 4: Intensive-care unit or stepdown stay** | 0.99 (0.97-1.00) | 0.98 (0.92-1.00) | 0.99 (0.97-1.00) | 0.97 (0.89-1.00) | 1.00 (0.98-1.00) | 111.8 (28.1-444.3) | 0.02 (0.002-0.11) |
| Grade 5: in-hospital mortality | 1.00 (0.99-1.00) | 1.00 (0.85-1.00) | 1.00 (0.99-1.00) | 1.00 (0.85-1.00) | 1.00 (0.99-1.00) | infinite | 0 |

*Using pharmacy data

**Using special care unit table

Exhibit 14: Final model parameters for 30 day in-hospital mortality

| Covariate | Parameter Estimate | Standard Error | p-value |
|---|---|---|---|
| Main effects: | | | |
| Sex | -0.0290 | 0.1512 | 0.8478 |
| Agesq | 0.000503 | 0.000504 | 0.3184 |
| Agesq1 | -0.00021 | 0.00112 | 0.8514 |
| Agesq2 | 0.000653 | 0.00362 | 0.8568 |
| Elective non-surgical | 1.8352 | 0.5479 | 0.0008 |
| Emergent surgical | 1.1147 | 0.2282 | <.0001 |
| Emergent non-surgical | 2.1558 | 0.2959 | <.0001 |
| LAPS | 0.0249 | 0.0235 | 0.2896 |
| Elixhauser | 0.1116 | 0.1039 | 0.2827 |
| Cancer | -0.7435 | 0.1865 | <.0001 |
| Interaction: | | | |
| Agesq*LAPS | 1.325E-6 | 9.549E-6 | 0.8896 |
| Agesq1*LAPS | -2.22E-6 | 0.000019 | 0.9067 |
| Agesq2*LAPS | 1.271E-6 | 0.000058 | 0.9826 |
| Agesq*Elixhauser | -8.06E-6 | 0.000043 | 0.8496 |
| Agesq1*Elixhauser | 0.000011 | 0.000085 | 0.8989 |
| Agesq2*Elixhauser | -0.00004 | 0.000262 | 0.8747 |
| LAPS*Elixhauser | -0.00079 | 0.000259 | 0.0023 |

Exhibit 15: Final model parameters for 30 day morbidity

| Covariate | Parameter Estimate | Standard Error | p-value |
|---|---|---|---|
| Main effects: | | | |
| Sex | -0.1644 | 0.0725 | 0.0234 |
| Agesq | -0.00006 | 0.000112 | 0.5636 |
| Agesq1 | 0.000246 | 0.000314 | 0.4319 |
| Agesq2 | -0.00054 | 0.00115 | 0.6366 |
| Elective non-surgical | 1.5989 | 0.3900 | <.0001 |
| Emergent surgical | 0.5781 | 0.0929 | <.0001 |
| Emergent non-surgical | 1.2212 | 0.2081 | <.0001 |
| LAPS | 0.0274 | 0.00972 | 0.0048 |
| Elixhauser | 0.0534 | 0.0352 | 0.1292 |
| Cancer | -0.4009 | 0.0903 | <.0001 |
| Interaction: | | | |
| Agesq*LAPS | 2.088E-6 | 4.503E-6 | 0.6429 |
| Agesq1*LAPS | 2.41E-6 | 0.000011 | 0.8239 |
| Agesq2*LAPS | -0.00003 | 0.000037 | 0.4258 |
| Agesq*Elixhauser | -6.55E-7 | 0.000015 | 0.9661 |
| Agesq1*Elixhauser | -6.68E-6 | 0.000035 | 0.8488 |
| Agesq2*Elixhauser | 0.000028 | 0.000117 | 0.8129 |
| LAPS*Elixhauser | -0.00070 | 0.000218 | 0.0013 |

Exhibit 16: Performance of the models to mortality and morbidity

| | Mortality | | Morbidity | |
|---|---|---|---|---|
| | c-statistic (95% CI) | Hosmer-Lemeshow statistic (p-value) | c-statistic (95% CI) | Hosmer-Lemeshow statistic (p-value) |
| Final model (Escobar & cancer) | 0.8796 (0.8572 - 0.9020) | 6.9862 (0.5381) | 0.7415 (0.7252 - 0.7579) | 6.3546 (0.6076) |
| Escobar | 0.8759 (0.8529 - 0.8990) | 10.8904 (0.2080) | 0.7417 (0.7254 - 0.7580) | 9.5320 (0.2994) |
| Escobar$^{+}$ | 0.8760 (0.8537-0.8983) | 4.9367 (0.7643) | 0.7552 (0.7394 - 0.7709) | 6.9598 (0.5410) |
| CR-BHOM | 0.8539 (0.8305 - 0.8773) | 19.6481 (0.0118) | 0.7255 (0.7088 - 0.7422) | 16.0581 (0.0416) |

Exhibit 17: ROC curve for mortality (final model):

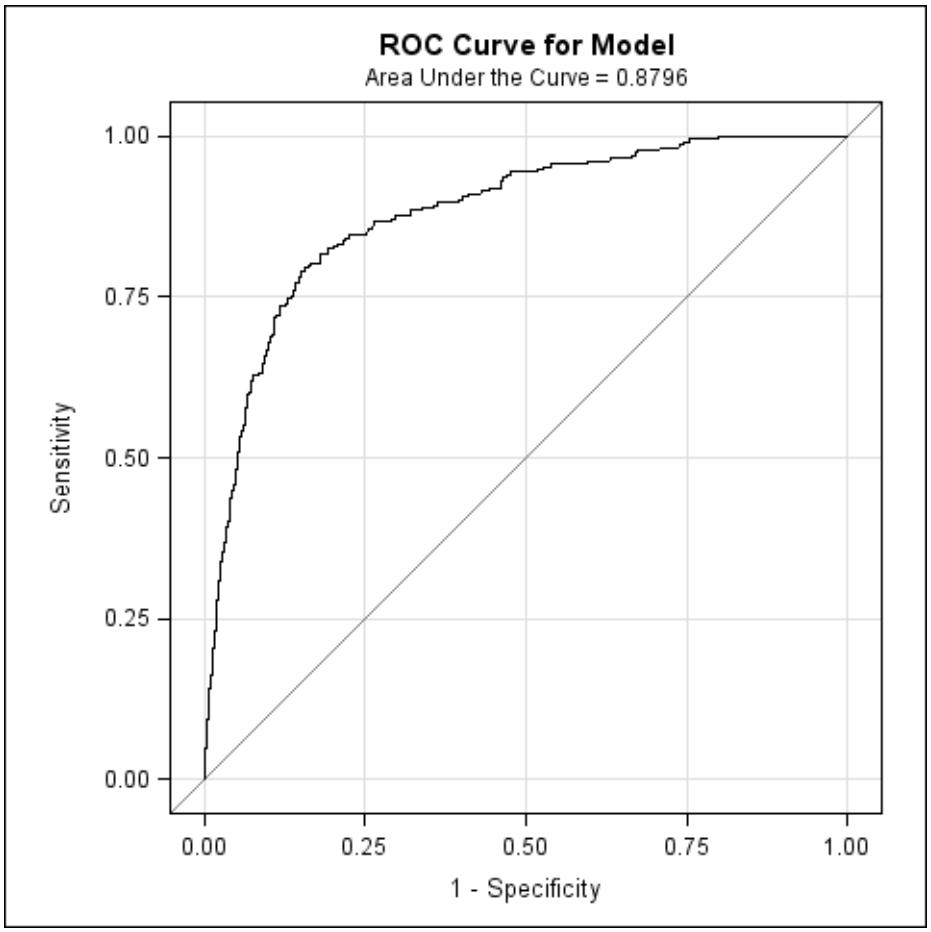


Exhibit 18: ROC for morbidity (final model):

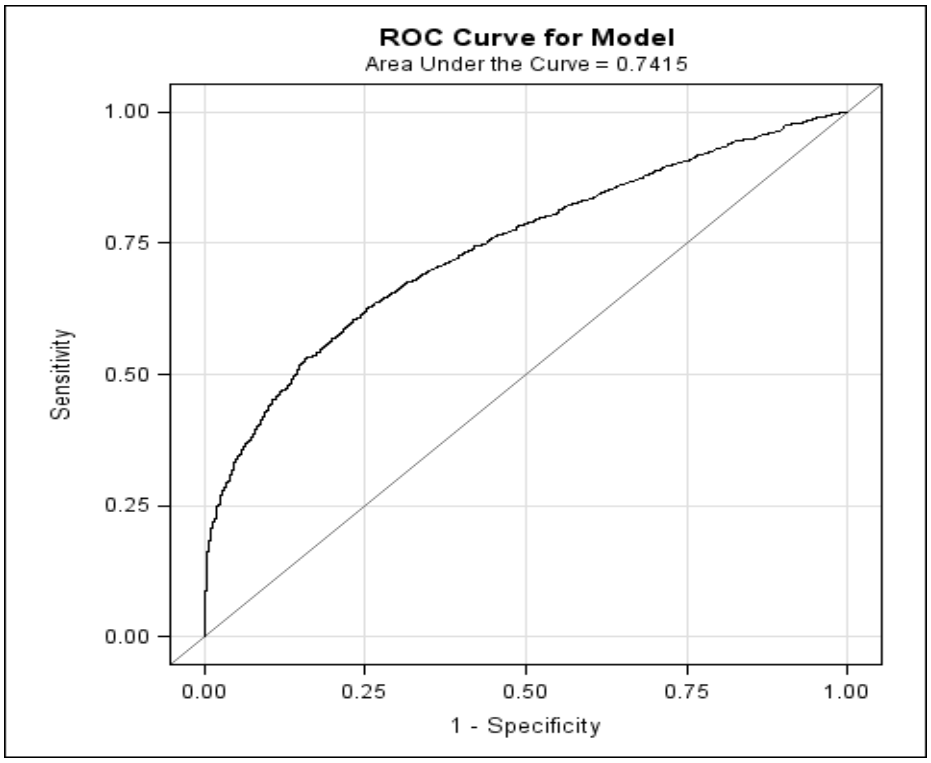


Exhibit 19: Likelihood ratio test for other variables added to the models

| | | | Mortality | | | Morbidity | | |
|---|---|---|---|---|---|---|---|---|
| Model | Covariates | Degrees of freedom | AIC | -2logL | p-value | AIC | -2logL | p-value |
| 1 | Escobar | 16 | 1409.515 | 1375.515 | <.0001 | 4952.723 | 4918.723 | <.0001 |
| 2 | Escobar + cancer | 17 | 1395.336 | 1359.336 | <.0001 | 4935.011 | 4899.011 | <.0001 |
| 3 | Escobar + cancer + laparoscopic | 18 | 1395.714 | 1357.714 | <.0001 | 4915.751 | 4877.751 | <.0001 |
| 4 | Escobar + cancer + laparoscopic + colon/rectal | 19 | 1393.828 | 1353.828 | <.0001 | 4917.720 | 4877.720 | <.0001 |
| 5 | Escobar + cancer + laparoscopic + colon/rectal + resection type | 23 | 1395.211 | 1347.211 | <.0001 | 4892.922 | 4844.922 | <.0001 |
| 6 | Escobar$^{+}$ | 26 | 1427.229 | 1373.229 | <.0001 | 4869.418 | 4815.418 | <.0001 |
| 7 | Escobar$^{+}$ + cancer | 27 | 1410.368 | 1354.368 | <.0001 | 4848.436 | 4792.436 | <.0001 |
| 8 | Escobar$^{+}$+ cancer + open/lap | 28 | 1411.053 | 1353.053 | <.0001 | 4817.295 | 4759.295 | <.0001 |
| 9 | Escobar$^{+}$+ cancer + open/lap + colon/rectal | 29 | 1408.881 | 1348.881 | <.0001 | 4819.179 | 4759.179 | <.0001 |
| 10 | Escobar$^{+}$+ cancer + open/lap + colon/rectal + resection type | 33 | 1411.448 | 1343.448 | <.0001 | 4788.170 | 4720.170 | <.0001 |
| 11 | CR-BHOM | 5 | 1479.93 | 1479.934 | <.0001 | 5109.48 | 5097.485 | <.0001 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 4 | | | 5 | | |
| 12 | CR-BHOM + cancer | 6 | 1466.968 | 1452.968 | <.0001 | 5098.129 | 5084.129 | <.0001 |
| 13 | CR-BHOM + cancer + open/lap | 7 | 1465.216 | 1449.216 | <.0001 | 5068.278 | 5052.278 | <.0001 |
| 14 | CR-BHOM + cancer + open/lap + colon/rectal | 8 | 1460.333 | 1442.333 | <.0001 | 5069.907 | 5051.907 | <.0001 |
| 15 | CR-BHOM + cancer + open/lap + colon/rectal + resection type | 12 | 1462.073 | 1436.073 | <.0001 | 5047.083 | 5021.083 | <.0001 |

Exhibit 20: Example of basic CUSUM graph

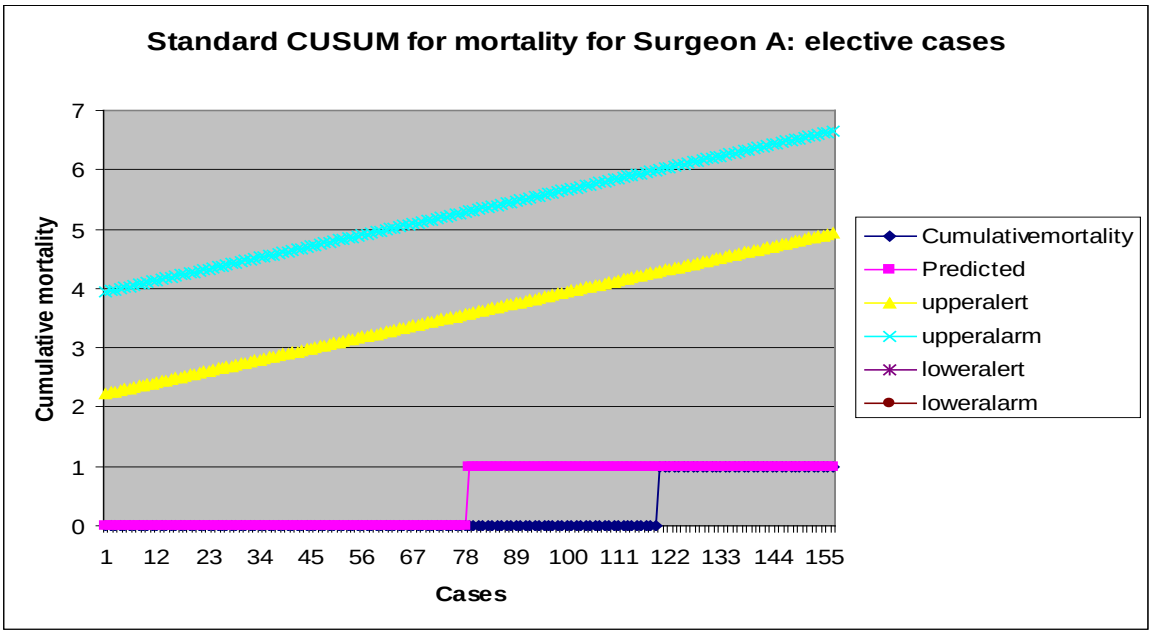



Exhibit 21: Example of risk-adjusted CUSUM graph

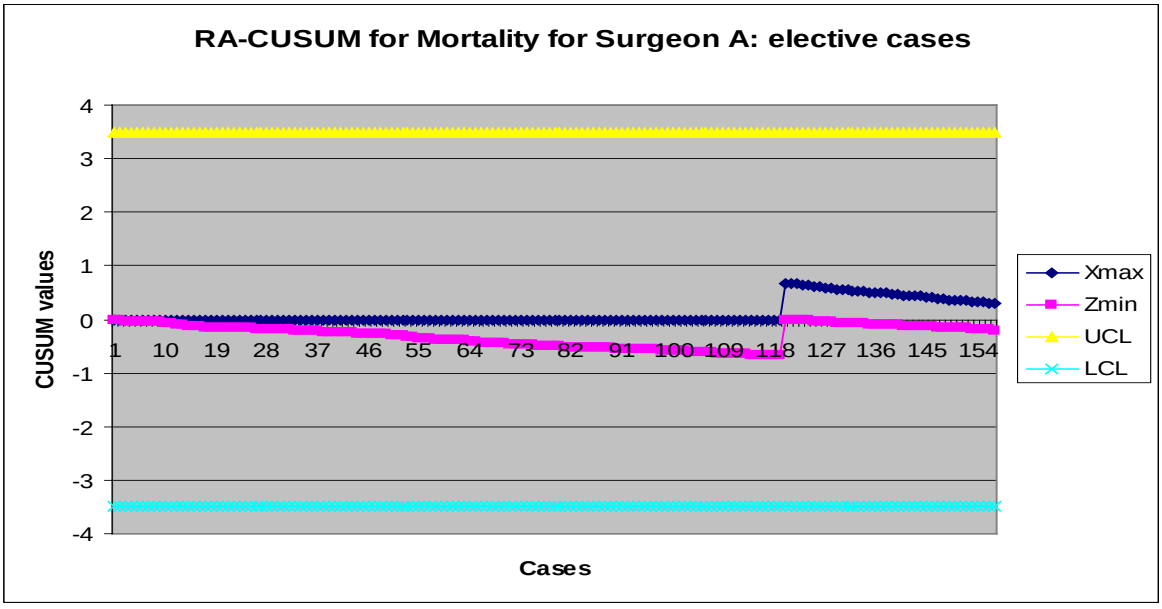


Exhibit 22: Example of VLAD plot for Surgeon A

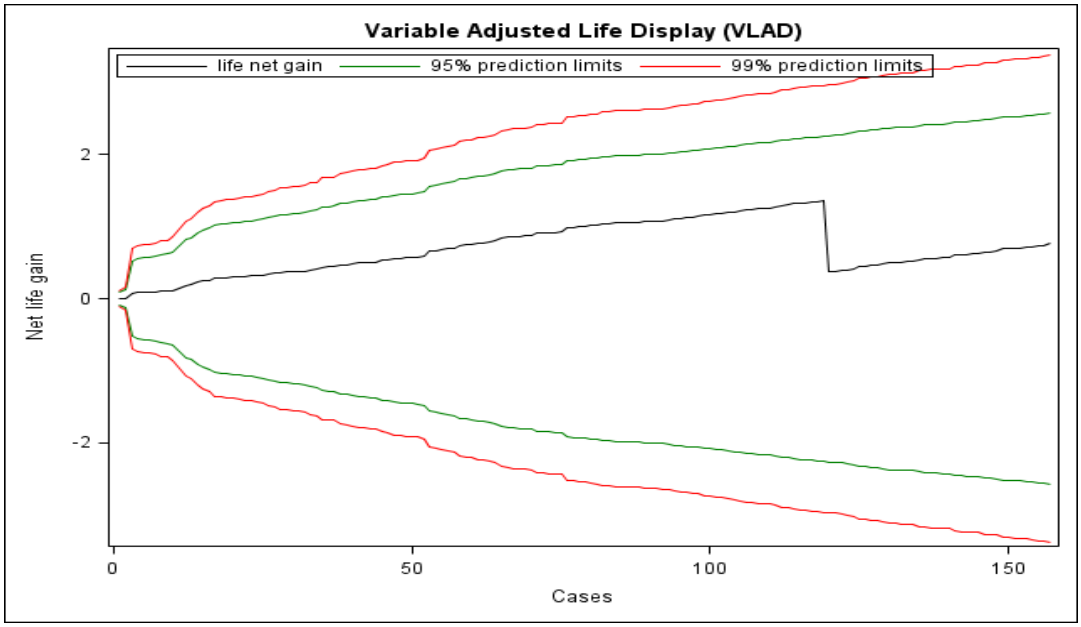



Exhibit 23: Example of unadjusted funnel plot

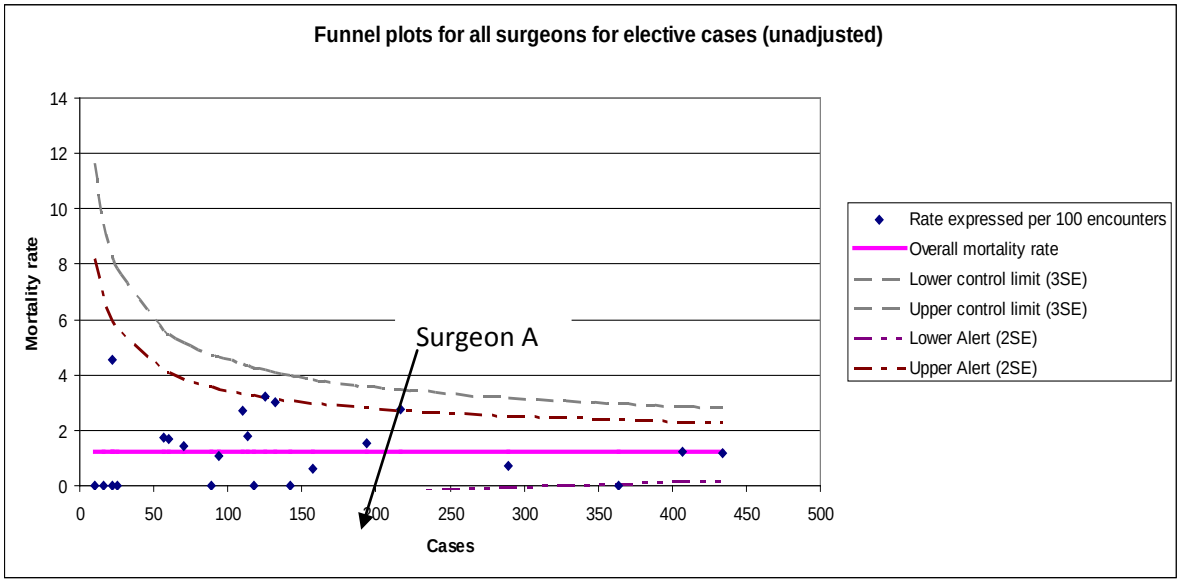


Exhibit 24a: Example of adjusted funnel plot

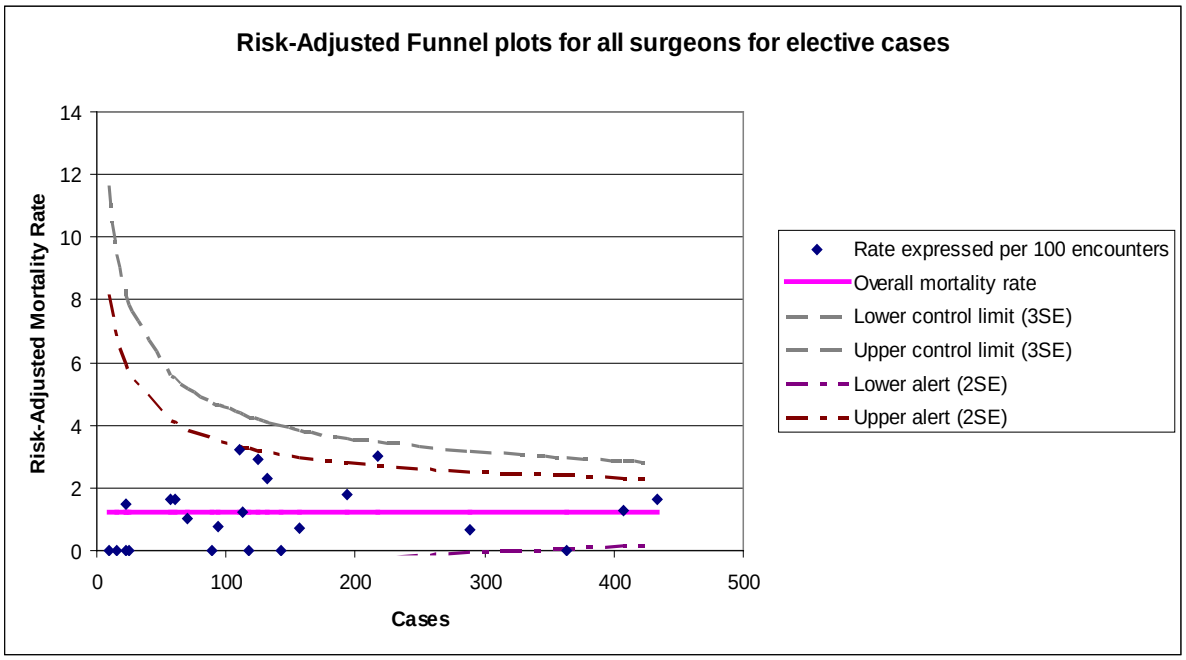



Exhibit 24b: Exhibit of adjusted funnel plot for elective cases with Surgeon A plotted

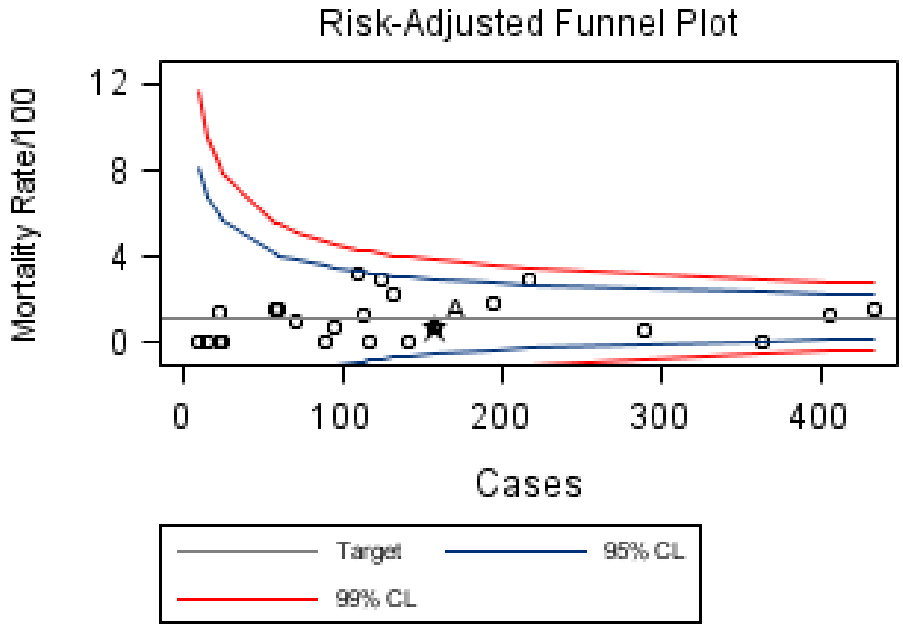


Exhibit 25: Summary of flags for bad outcomes

| | Elective mortality | Elective morbidity | Emergent mortality | Emergent morbidity |
|---|---|---|---|---|
| **Basic CUSUM** | | | | |
| Alarm | 0 | 1 | 0 | 0 |
| Alert | 4 | 4 | 3 | 1 |
| **Risk-adjusted CUSUM** | | | | |
| Upper confidence limit | 0 | 4 | 0 | 2 |
| **VLAD** | | | | |
| 99% Lower prediction limit | 4 | 3 | 2 | 1 |
| 95% lower prediction limit | 7 | 6 | 4 | 3 |
| **Unadjusted funnel plot** | | | | |
| 3 standard deviation | 0 | 1 | 0 | 0 |
| 2 standard deviation | 2 | 4 | 0 | 1 |
| **Risk-adjusted funnel plot** | | | | |
| 3 standard deviation | 0 | 1 | 0 | 0 |
| 2 standard deviation | 1 | 2 | 0 | 0 |

Exhibit 26: Summary of flags for good outcomes

| | Elective mortality | Elective morbidity | Emergent mortality | Emergent morbidity |
|---|---|---|---|---|
| **Basic CUSUM** | | | | |
| Alarm for improvement | 1 | 10 | 2 | 9 |
| Alert for improvement | 0 | 4 | 1 | 6 |
| **Risk-adjusted CUSUM** | | | | |
| Lower confidence limit | 0 | 4 | 0 | 5 |
| **VLAD** | | | | |
| 99% Upper prediction limit | 1 | 8 | 1 | 6 |
| 95% Upper prediction limit | 0 | 3 | 0 | 5 |
| **Unadjusted funnel plot** | | | | |
| 3 standard deviation (below) | 1 | 2 | 0 | 0 |
| 2 standard deviation (below) | 0 | 0 | 0 | 0 |
| **Risk-adjusted funnel plot** | | | | |
| 3 standard deviation (below) | 1 | 2 | 0 | 0 |
| 2 standard deviation (below) | 0 | 0 | 0 | 0 |

Exhibit 27: Summary of individual surgeon's elective and emergent cases mortality and morbidity: Proportion of bad outcomes from Basic CUSUM, Risk-adjusted CUSUM, VLAD, and funnel charts

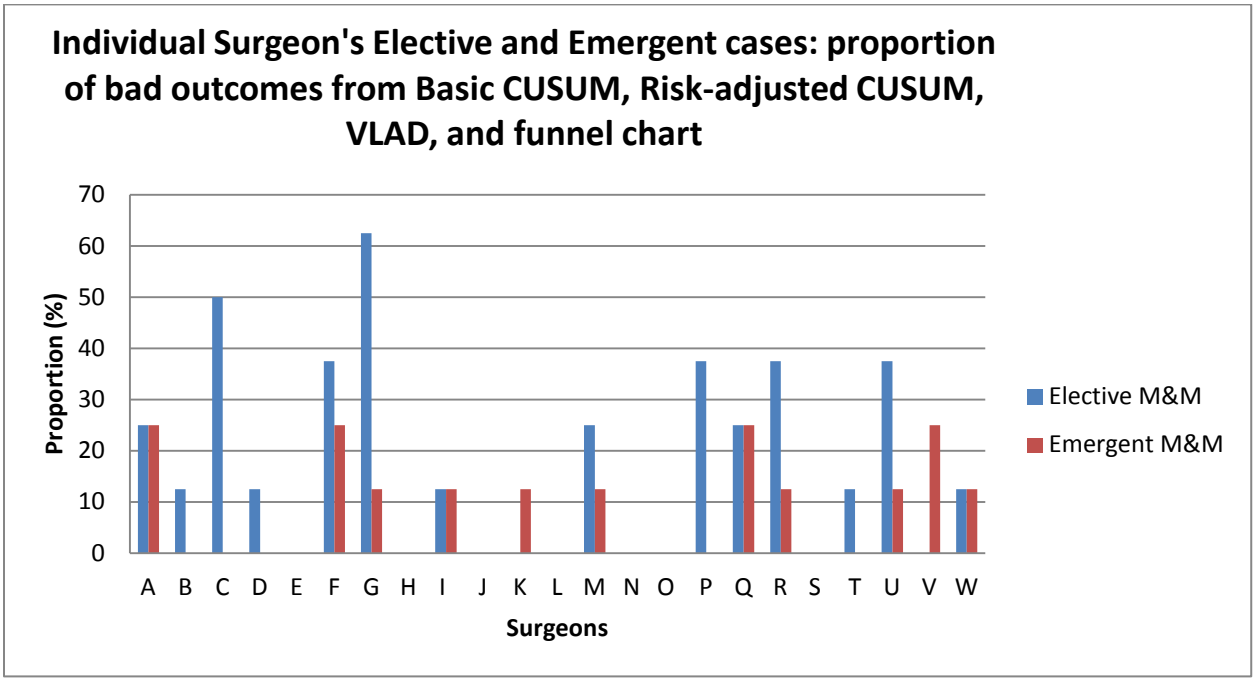


Exhibit 28: Survey demographics

Exhibit 28a Surgeon age

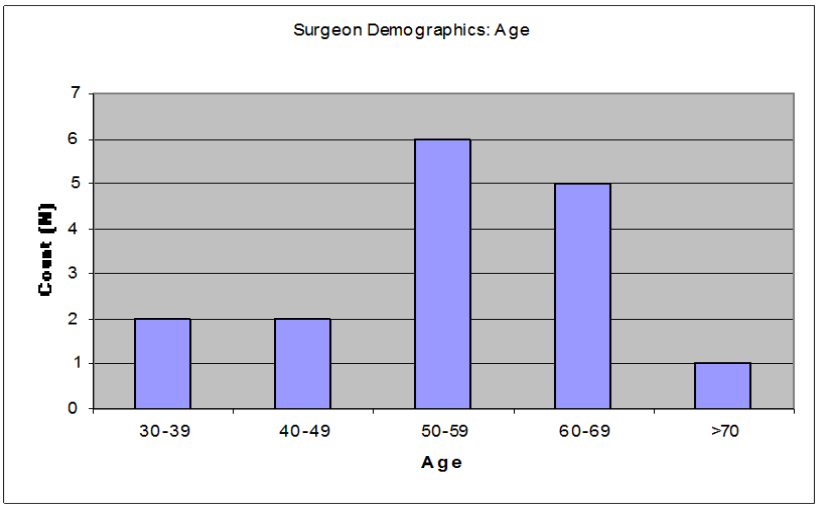



Exhibit 28b Surgeon gender

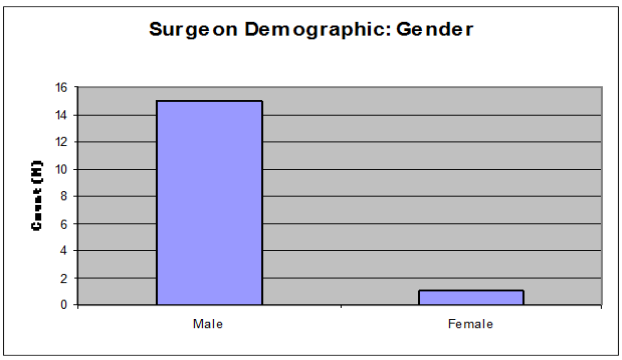



Exhibit 28c Years in practice for surgeons

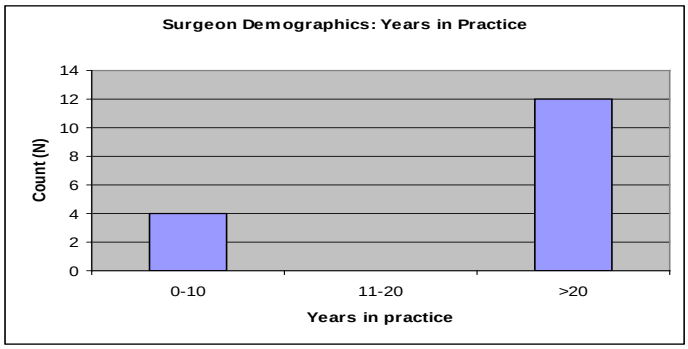


Exhibit 28d Surgeon training

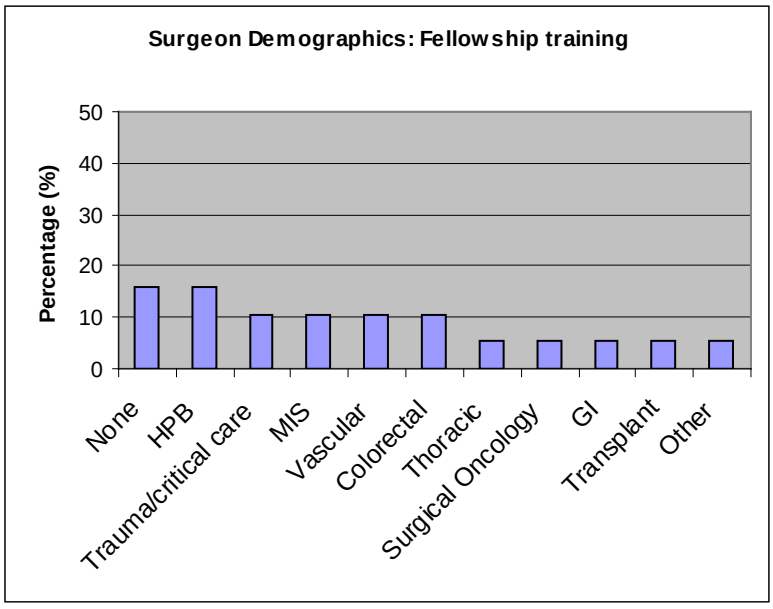



Exhibit 29 Surgeon's current colorectal practice

Exhibit 29a: Number colon and rectal cases per year

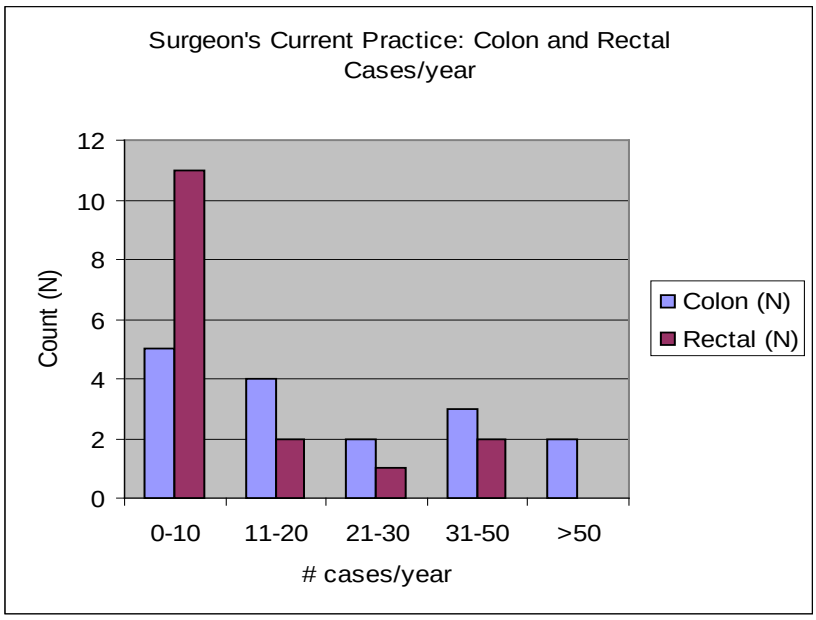


Exhibit 29b: Percentage of colorectal cases done emergently (self-reported)

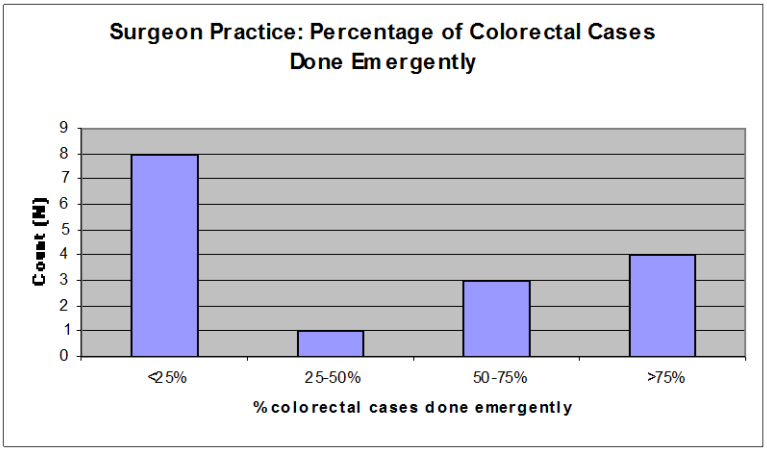



Exhibit 29c: Percentage of colorectal cases done laparoscopically (self-reported)

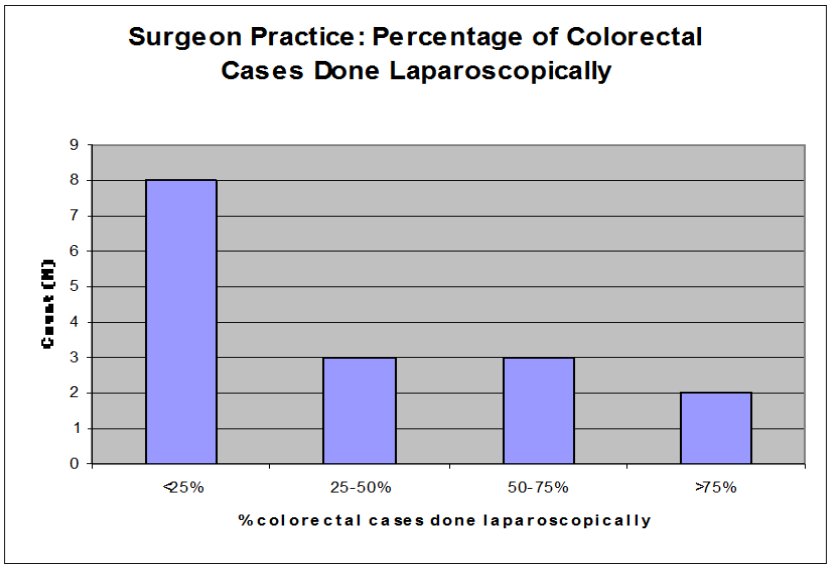


Exhibit 30: Acceptable monitoring methods for surgeons

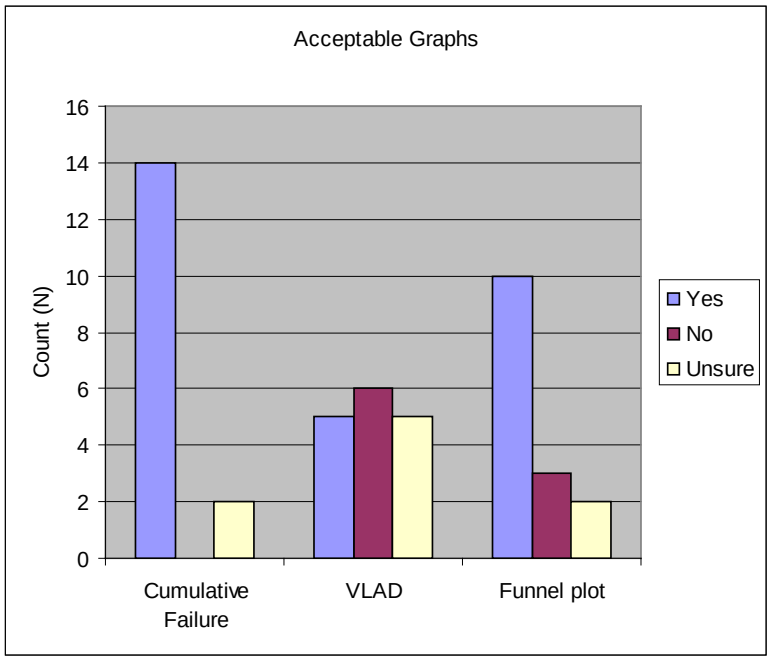
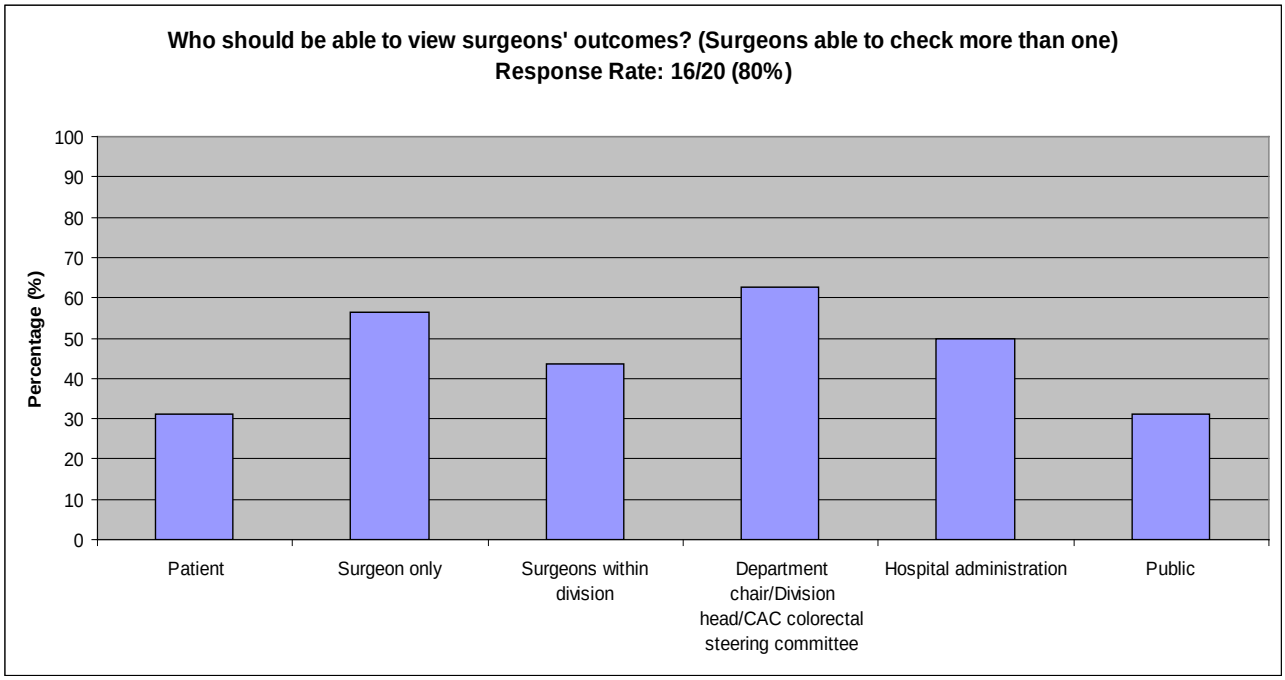



Exhibit 31: Surgeon's opinion on who should be able to view their outcomes



# Appendix K

Colorectal Surgical Performance of General Surgeons at the Ottawa Hospital from April 1, 2003-December 31, 2009

**Surgeon A Performance**

Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon A | Total | Surgeon A | Total | Surgeon A | Total |
| | | N=157 | N=3267 | N=44 | N=1713 | N=201 | N=4980 |
| Age | Mean ± SD | 63.01 ± 16.35 | 61.49 ± 15.97 | 64.30 ± 17.38 | 63.33 ± 17.34 | 63.29 ± 16.54 | 62.12 ± 16.47 |
| | Median (IQR) | 65 (55-75) | 64 (52-74) | 69 (58-78) | 66 (52-77) | 66 (55-75) | 64 (52-75) |
| Sex | F | 77 (49.0%) | 1423 (43.6%) | 24 (54.5%) | 888 (51.8%) | 101 (50.2%) | 2311 (46.4%) |
| | M | 80 (51.0%) | 1844 (56.4%) | 20 (45.5%) | 825 (48.2%) | 100 (49.8%) | 2669 (53.6%) |
| Comorbidity Score* | Mean ± SD | 4.91 ± 6.22 | 5.82 ± 6.53 | 6.68 ± 6.89 | 7.67 ± 7.87 | 5.30 ± 6.40 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-7) | 4 (0-9) | 4 (0-13) | 5 (0-16) | 4 (0-7) | 4 (0-11) |
| Diagnosis | Cancer | 94 (59.9%) | 2038 (62.4%) | 11 (25.0%) | 638 (37.2%) | 105 (52.2%) | 2676 (53.7%) |
| | Diverticular disease | 19 (12.1%) | 182 (5.6%) | 9 (20.5%) | 241 (14.1%) | 28 (13.9%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (1.9%) | 151 (4.6%) | <=5 (6.8%) | 82 (4.8%) | 6 (3.0%) | 233 (4.7%) |
| | Crohn's | 13 (8.3%) | 175 (5.4%) | <=5 (2.3%) | 98 (5.7%) | 14 (7.0%) | 273 (5.5%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 6 (13.6%) | 122 (7.1%) | 6 (3.0%) | 124 (2.5%) |
| | Other colitis | <=5 (0.6%) | <=5 (0.1%) | 0 (0.0%) | <=5 (0.2%) | <=5 (0.5%) | 6 (0.1%) |
| | Stoma related | 19 (12.1%) | 522 (16.0%) | 0 (0.0%) | 29 (1.7%) | 19 (9.5%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | <=5 (4.5%) | 137 (8.0%) | <=5 (1.0%) | 156 (3.1%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (2.3%) | 16 (0.9%) | <=5 (0.5%) | 16 (0.3%) |
| | Other | 8 (5.1%) | 160 (4.9%) | 11 (25.0%) | 292 (17.0%) | 19 (9.5%) | 452 (9.1%) |
| Open/lap | laparoscopic | 113 (72.0%) | 912 (27.9%) | 12 (27.3%) | 143 (8.3%) | 125 (62.2%) | 1055 (21.2%) |
| | open | 44 (28.0%) | 2355 (72.1%) | 32 (72.7%) | 1570 (91.7%) | 76 (37.8%) | 3925 (78.8%) |
| Resection type | APR | 7 (4.5%) | 291 (8.9%) | <=5 (2.3%) | 17 (1.0%) | 8 (4.0%) | 308 (6.2%) |
| | AR | 48 (30.6%) | 845 (25.9%) | <=5 (4.5%) | 141 (8.2%) | 50 (24.9%) | 986 (19.8%) |
| | Bypass | <=5 (3.2%) | 162 (5.0%) | <=5 (6.8%) | 321 (18.7%) | 8 (4.0%) | 483 (9.7%) |
| | Reversal | 18 (11.5%) | 495 (15.2%) | <=5 (2.3%) | 20 (1.2%) | 19 (9.5%) | 515 (10.3%) |
| | Segmental | 74 (47.1%) | 1404 (43.0%) | 33 (75.0%) | 1113 (65.0%) | 107 (53.2%) | 2517 (50.5%) |
| | Total | <=5 (3.2%) | 70 (2.1%) | <=5 (9.1%) | 101 (5.9%) | 9 (4.5%) | 171 (3.4%) |
| Surgery | colon | 102 (65.0%) | 2131 (65.2%) | 41 (93.2%) | 1555 (90.8%) | 143 (71.1%) | 3686 (74.0%) |
| | rectal | 55 (35.0%) | 1136 (34.8%) | <=5 (6.8%) | 158 (9.2%) | 58 (28.9%) | 1294 (26.0%) |
| Stoma | | 20 (12.7%) | 698 (21.4%) | 23 (52.3%) | 869 (50.7%) | 43 (21.4%) | 1567 (31.5%) |
| OR time, minutes | Mean ± SD | 255.93 ± 88.66 | 226.37 ± 96.11 | 208.05 ± 69.75 | 172.77 ± 72.97 | 245.40 ± 87.00 | 207.94 ± 92.40 |
| | Median (IQR) | 245 (202-301) | 213 (160-277) | 191 (162-243) | 160 (125- | 227 (186-290) | 191 (143-255) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | 205) | | |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon A | Total | Surgeon A | Total | Surgeon A | Total |
| | | N=157 | N=3267 | N=44 | N=1713 | N=201 | N=4980 |
| 30 day postoperative complication index* | 0 | 123 (78.3%) | 2722 (83.3%) | 19 (43.2%) | 864 (50.4%) | 142 (70.6%) | 3586 (72.0%) |
| | 2 | <=5 (3.2%) | 140 (4.3%) | 8 (18.2%) | 201 (11.7%) | 13 (6.5%) | 341 (6.8%) |
| | 3 | 20 (12.7%) | 240 (7.3%) | <=5 (11.4%) | 142 (8.3%) | 25 (12.4%) | 382 (7.7%) |
| | 4 | 8 (5.1%) | 125 (3.8%) | 7 (15.9%) | 312 (18.2%) | 15 (7.5%) | 437 (8.8%) |
| | 5 | <=5 (0.6%) | 40 (1.2%) | <=5 (11.4%) | 194 (11.3%) | 6 (3.0%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 9.74 ± 20.13 | 9.06 ± 11.67 | 35.32 ± 51.61 | 22.88 ± 28.95 | 15.34 ± 31.64 | 13.81 ± 20.51 |
| | Median (IQR) | 5 (3-9) | 6 (5-9) | 15 (8-47) | 13 (8-26) | 6 (3-12) | 8 (5-14) |
| 30 day Readmission | 1 | 12 (7.6%) | 183 (5.6%) | 6 (13.6%) | 124 (7.2%) | 18 (9.0%) | 307 (6.2%) |

*highest complication based on the modified Clavien-Dindo classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

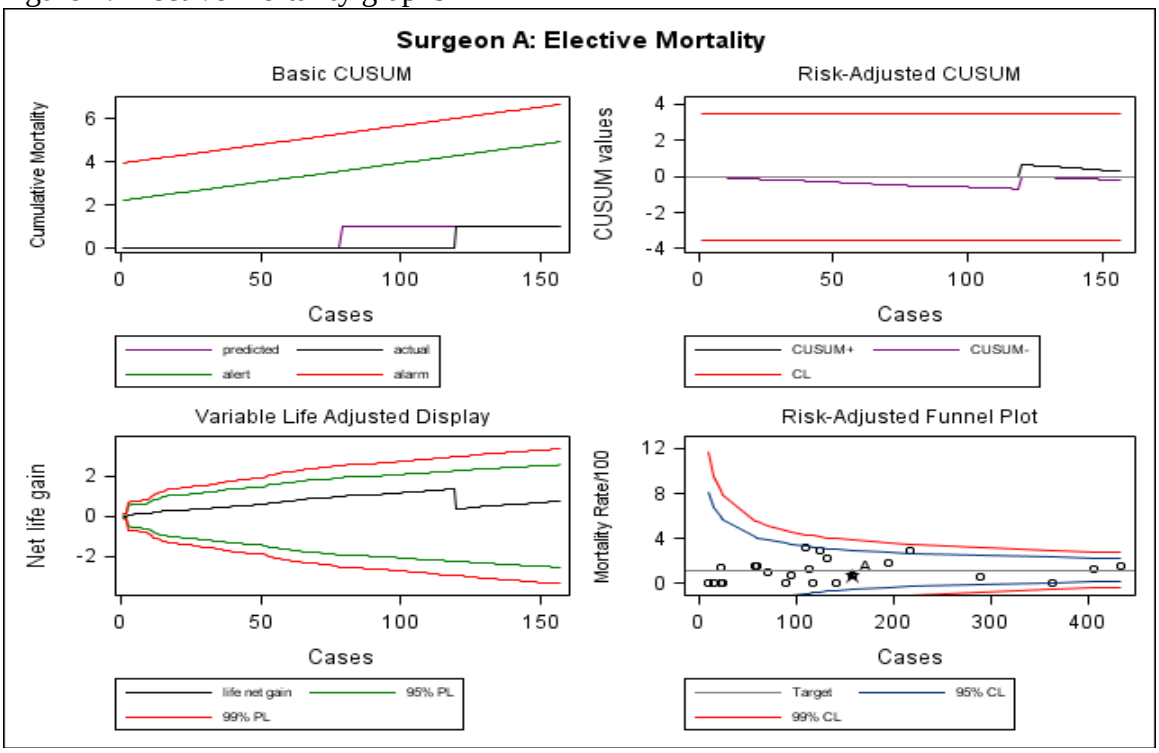



Figure 2: Elective morbidity graphs

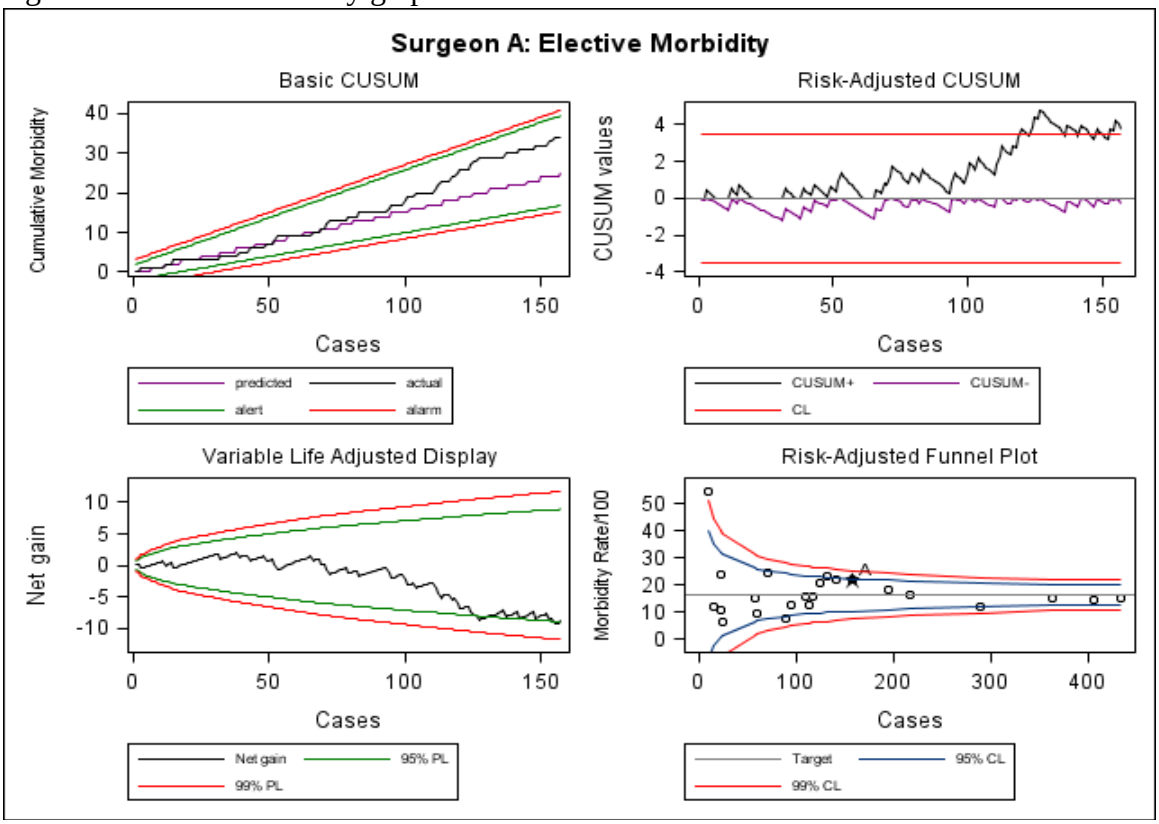


Figure 3: Emergent mortality graphs

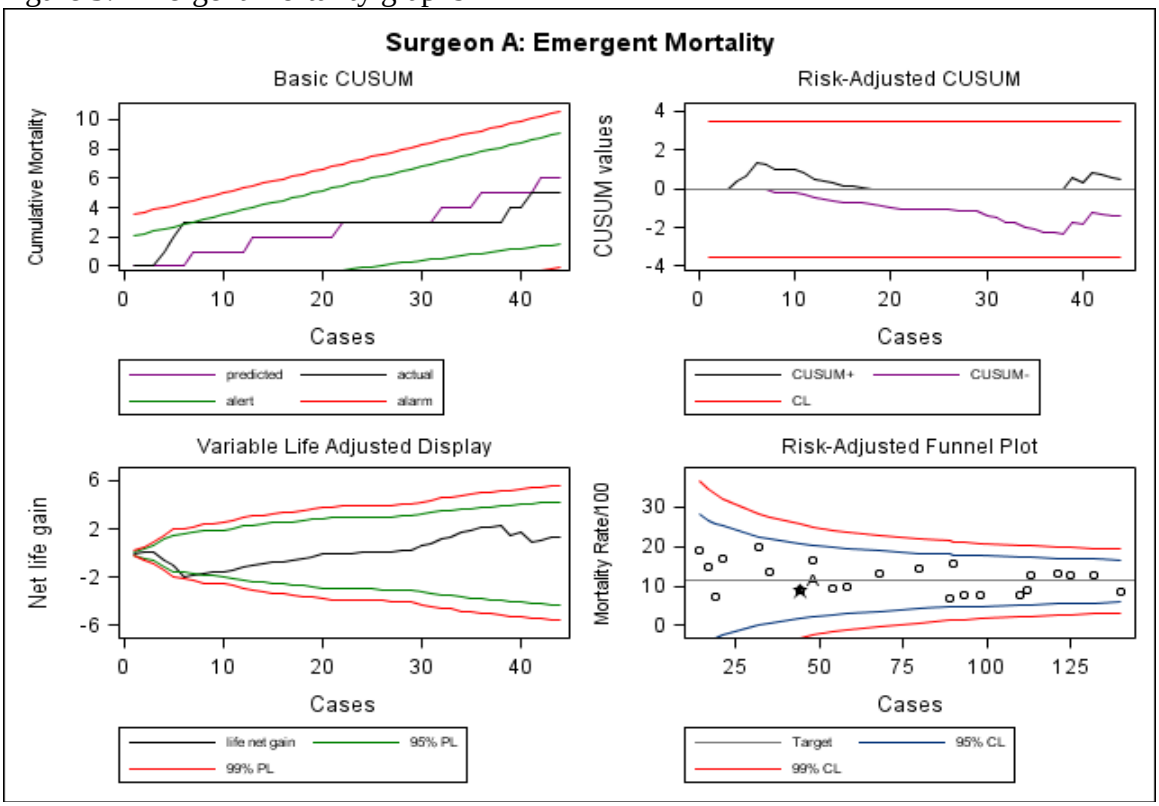
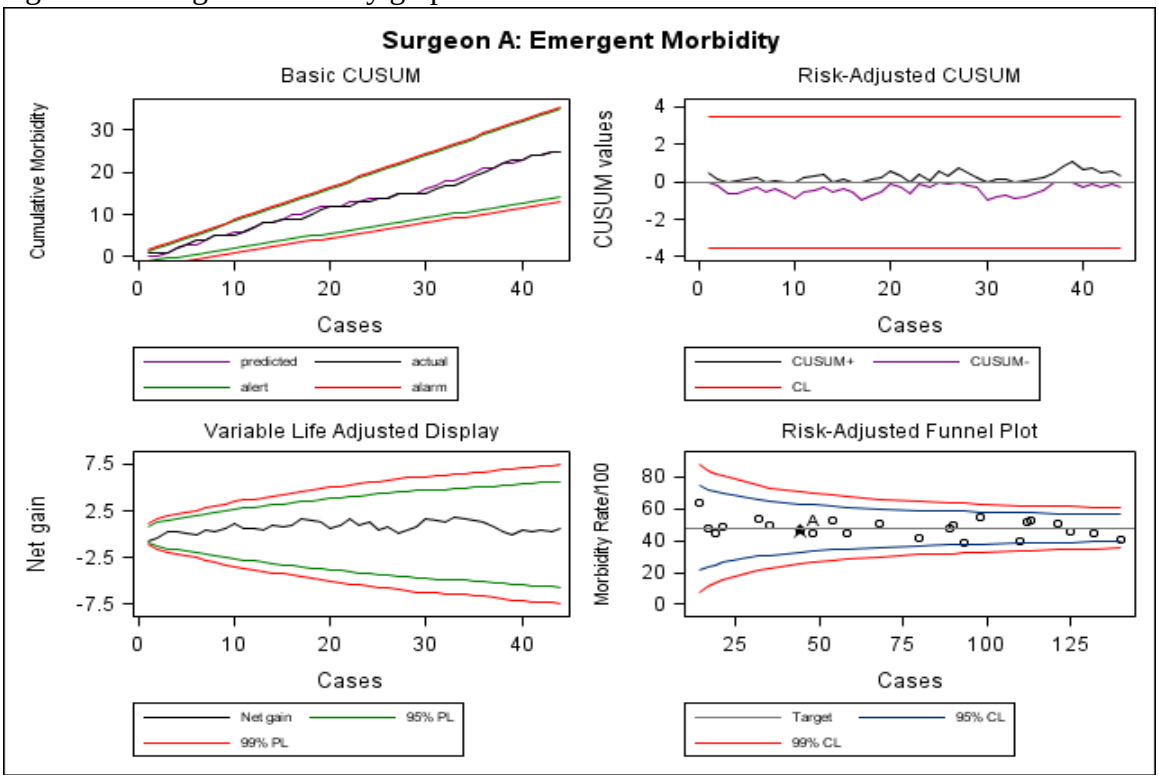



Figure 4: Emergent morbidity graphs



**Surgeon B Performance**

Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon B | Total | Surgeon B | Total | Surgeon B | Total |
| | | N=194 | N=3267 | N=19 | N=1713 | N=213 | N=4980 |
| Age, years | Mean ± SD | 58.71 ± 16.87 | 61.49 ± 15.97 | 60.74 ± 21.67 | 63.33 ± 17.34 | 58.89 ± 17.30 | 62.12 ± 16.47 |
| | Median (IQR) | 60 (48-72) | 64 (52-74) | 67 (37-78) | 66 (52-77) | 62 (48-72) | 64 (52-75) |
| Sex | F | 102 (52.6%) | 1423 (43.6%) | 12 (63.2%) | 888 (51.8%) | 114 (53.5%) | 2311 (46.4%) |
| | M | 92 (47.4%) | 1844 (56.4%) | 7 (36.8%) | 825 (48.2%) | 99 (46.5%) | 2669 (53.6%) |
| Comorbidity Score* | Mean ± SD | 4.79 ± 5.84 | 5.82 ± 6.53 | 8.11 ± 7.24 | 7.67 ± 7.87 | 5.09 ± 6.03 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-7) | 4 (0-9) | 5 (3-16) | 5 (0-16) | 4 (0-7) | 4 (0-11) |
| Diagnosis | Cancer | 102 (52.6%) | 2038 (62.4%) | 10 (52.6%) | 638 (37.2%) | 112 (52.6%) | 2676 (53.7%) |
| | Diverticular disease | 23 (11.9%) | 182 (5.6%) | <=5 (10.5%) | 241 (14.1%) | 25 (11.7%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (2.6%) | 151 (4.6%) | <=5 (5.3%) | 82 (4.8%) | 6 (2.8%) | 233 (4.7%) |
| | Crohn's | 21 (10.8%) | 175 (5.4%) | <=5 (26.3%) | 98 (5.7%) | 26 (12.2%) | 273 (5.5%) |
| | Ischemic colitis | <=5 (0.5%) | <=5 (0.1%) | 0 (0.0%) | 122 (7.1%) | <=5 (0.5%) | 124 (2.5%) |
| | Stoma related | 32 (16.5%) | 522 (16.0%) | <=5 (5.3%) | 29 (1.7%) | 33 (15.5%) | 551 (11.1%) |
| | Other | 10 (5.2%) | 160 (4.9%) | 0 (0.0%) | 292 (17.0%) | 10 (4.7%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 154 (79.4%) | 912 (27.9%) | 11 (57.9%) | 143 (8.3%) | 165 (77.5%) | 1055 (21.2%) |
| | Open | 40 (20.6%) | 2355 (72.1%) | 8 (42.1%) | 1570 (91.7%) | 48 (22.5%) | 3925 (78.8%) |
| Resection type | APR | 11 (5.7%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | 11 (5.2%) | 308 (6.2%) |
| | AR | 29 (14.9%) | 845 (25.9%) | <=5 (15.8%) | 141 (8.2%) | 32 (15.0%) | 986 (19.8%) |
| | bypass | 8 (4.1%) | 162 (5.0%) | <=5 (15.8%) | 321 (18.7%) | 11 (5.2%) | 483 (9.7%) |
| | reversal | 30 (15.5%) | 495 (15.2%) | <=5 (5.3%) | 20 (1.2%) | 31 (14.6%) | 515 (10.3%) |
| | segmental | 108 (55.7%) | 1404 (43.0%) | 10 (52.6%) | 1113 (65.0%) | 118 (55.4%) | 2517 (50.5%) |
| | total | 8 (4.1%) | 70 (2.1%) | <=5 (10.5%) | 101 (5.9%) | 10 (4.7%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 251.58 ± 88.62 | 226.37 ± 96.11 | 264.58 ± 103.09 | 172.77 ± 72.97 | 252.74 ± 89.81 | 207.94 ± 92.40 |
| | Median (IQR) | 245 (199-300) | 213 (160-277) | 240 (200-305) | 160 (125-205) | 244 (200-300) | 191 (143-255) |
| Stoma | | 33 (17.0%) | 698 (21.4%) | 8 (42.1%) | 869 (50.7%) | 41 (19.2%) | 1567 (31.5%) |
| Surgery | Colon | 154 (79.4%) | 2131 (65.2%) | 16 (84.2%) | 1555 (90.8%) | 170 (79.8%) | 3686 (74.0%) |
| | Rectal | 40 (20.6%) | 1136 (34.8%) | <=5 (15.8%) | 158 (9.2%) | 43 (20.2%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon B | Total | Surgeon B | Total | Surgeon B | Total |
| | | N=194 | N=3267 | N=19 | N=1713 | N=213 | N=4980 |
| Complication index* | 0 | 159 (82.0%) | 2722 (83.3%) | 11 (57.9%) | 864 (50.4%) | 170 (79.8%) | 3586 (72.0%) |
| | 2 | 12 (6.2%) | 140 (4.3%) | <=5 (21.1%) | 201 (11.7%) | 16 (7.5%) | 341 (6.8%) |
| | 3 | 14 (7.2%) | 240 (7.3%) | <=5 (10.5%) | 142 (8.3%) | 16 (7.5%) | 382 (7.7%) |
| | 4 | 6 (3.1%) | 125 (3.8%) | <=5 (5.3%) | 312 (18.2%) | 7 (3.3%) | 437 (8.8%) |
| | 5 | <=5 (1.5%) | 40 (1.2%) | <=5 (5.3%) | 194 (11.3%) | <=5 (1.9%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 8.11 ± 14.75 | 9.06 ± 11.67 | 26.53 ± 26.93 | 22.88 ± 28.95 | 9.75 ± 16.95 | 13.81 ± 20.51 |
| | Median (IQR) | 5 (4-8) | 6 (5-9) | 10 (8-48) | 13 (8-26) | 5 (4-8) | 8 (5-14) |
| 30 day readmission | 0 | 187 (96.4%) | 3072 (94.0%) | 17 (89.5%) | 1579 (92.2%) | 204 (95.8%) | 4651 (93.4%) |
| | 1 | 6 (3.1%) | 183 (5.6%) | <=5 (10.5%) | 124 (7.2%) | 8 (3.8%) | 307 (6.2%) |
| | 2 | <=5 (0.5%) | 12 (0.4%) | 0 (0.0%) | 10 (0.6%) | <=5 (0.5%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

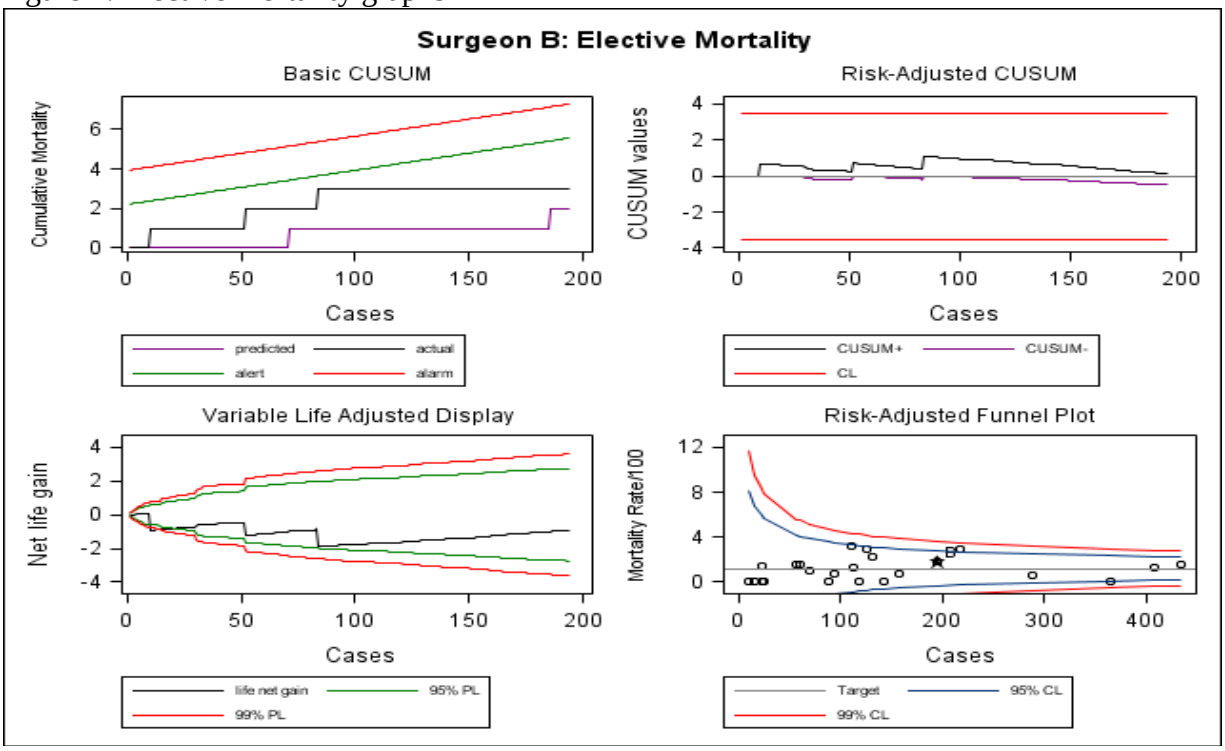



Figure 2: Elective morbidity graphs

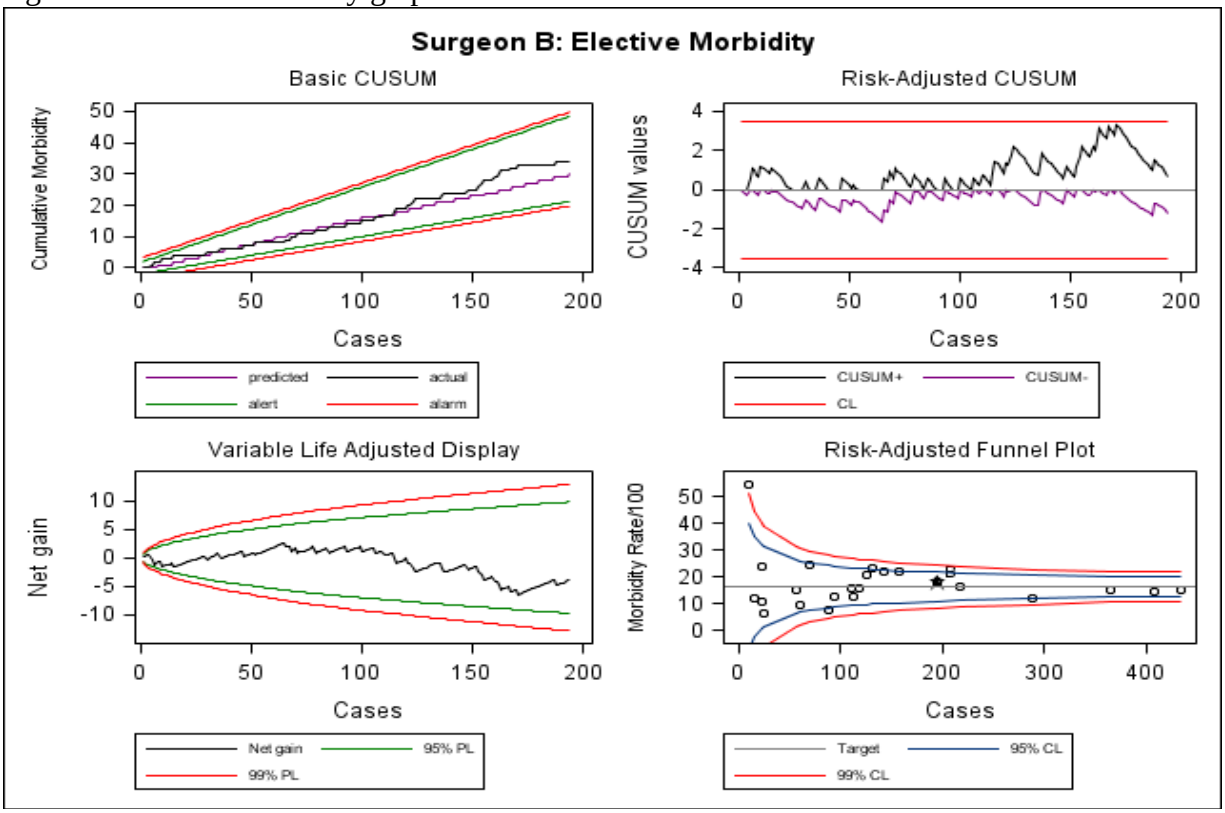


Figure 3: Emergent mortality graphs

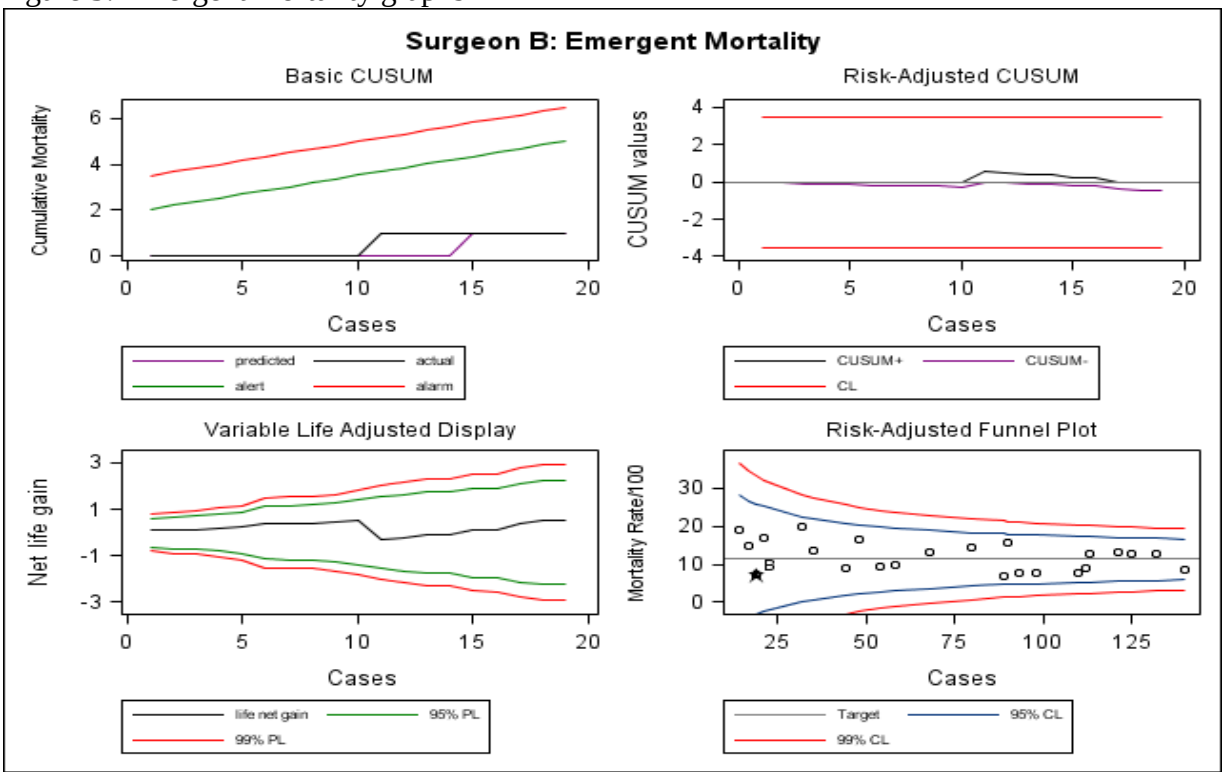
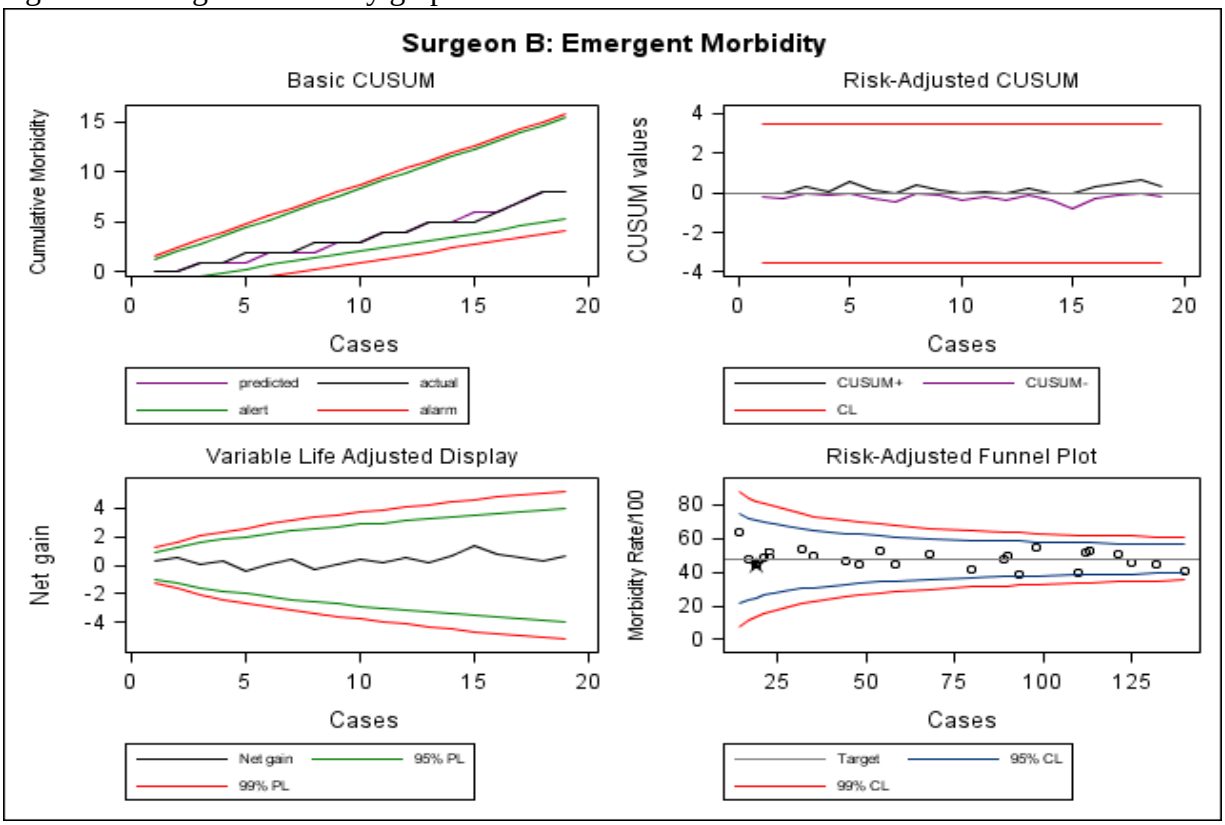



Figure 4: Emergent morbidity graphs



**Surgeon C Performance**

Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon C | Total | Surgeon C | Total | Surgeon C | Total |
| | | N=217 | N=3267 | N=140 | N=1713 | N=357 | N=4980 |
| Age | Mean ± SD | 63.47 ± 13.86 | 61.49 ± 15.97 | 63.73 ± 17.12 | 63.33 ± 17.34 | 63.57 ± 15.20 | 62.12 ± 16.47 |
| | Median (IQR) | 64 (56-74) | 64 (52-74) | 66 (53-78) | 66 (52-77) | 65 (54-76) | 64 (52-75) |
| Sex | F | 88 (40.6%) | 1423 (43.6%) | 63 (45.0%) | 888 (51.8%) | 151 (42.3%) | 2311 (46.4%) |
| | M | 129 (59.4%) | 1844 (56.4%) | 77 (55.0%) | 825 (48.2%) | 206 (57.7%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 5.65 ± 6.36 | 5.82 ± 6.53 | 8.12 ± 8.55 | 7.67 ± 7.87 | 6.62 ± 7.39 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-8) | 4 (0-9) | 5 (0-16) | 5 (0-16) | 4 (0-11) | 4 (0-11) |
| Diagnosis | Cancer | 145 (66.8%) | 2038 (62.4%) | 61 (43.6%) | 638 (37.2%) | 206 (57.7%) | 2676 (53.7%) |
| | Diverticular disease | 17 (7.8%) | 182 (5.6%) | 20 (14.3%) | 241 (14.1%) | 37 (10.4%) | 423 (8.5%) |
| | Ulcerative Colitis | <=5 (0.9%) | 151 (4.6%) | 8 (5.7%) | 82 (4.8%) | 10 (2.8%) | 233 (4.7%) |
| | Crohn's | 16 (7.4%) | 175 (5.4%) | 7 (5.0%) | 98 (5.7%) | 23 (6.4%) | 273 (5.5%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 9 (6.4%) | 122 (7.1%) | 9 (2.5%) | 124 (2.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (0.7%) | 45 (2.6%) | <=5 (0.3%) | 49 (1.0%) |
| | Polyp | <=5 (1.4%) | 8 (0.2%) | 0 (0.0%) | 0 (0.0%) | <=5 (0.8%) | 8 (0.2%) |
| | Stoma related | 29 (13.4%) | 522 (16.0%) | <=5 (2.1%) | 29 (1.7%) | 32 (9.0%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (0.5%) | 19 (0.6%) | 11 (7.9%) | 137 (8.0%) | 12 (3.4%) | 156 (3.1%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (0.7%) | 16 (0.9%) | <=5 (0.3%) | 16 (0.3%) |
| | Other | <=5 (1.8%) | 160 (4.9%) | 19 (13.6%) | 292 (17.0%) | 23 (6.4%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 6 (2.8%) | 912 (27.9%) | 10 (7.1%) | 143 (8.3%) | 16 (4.5%) | 1055 (21.2%) |
| | Open | 211 (97.2%) | 2355 (72.1%) | 130 (92.9%) | 1570 (91.7%) | 341 (95.5%) | 3925 (78.8%) |
| Resection type | APR | 10 (4.6%) | 291 (8.9%) | <=5 (2.9%) | 17 (1.0%) | 14 (3.9%) | 308 (6.2%) |
| | AR | 38 (17.5%) | 845 (25.9%) | 13 (9.3%) | 141 (8.2%) | 51 (14.3%) | 986 (19.8%) |
| | bypass | <=5 (2.3%) | 162 (5.0%) | 21 (15.0%) | 321 (18.7%) | 26 (7.3%) | 483 (9.7%) |
| | reversal | 29 (13.4%) | 495 (15.2%) | <=5 (2.1%) | 20 (1.2%) | 32 (9.0%) | 515 (10.3%) |
| | segmental | 130 (59.9%) | 1404 (43.0%) | 90 (64.3%) | 1113 (65.0%) | 220 (61.6%) | 2517 (50.5%) |
| | total | <=5 (2.3%) | 70 (2.1%) | 9 (6.4%) | 101 (5.9%) | 14 (3.9%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 200.04 ± 89.77 | 226.37 ± 96.11 | 193.76 ± 98.41 | 172.77 ± 72.97 | 197.58 ± 93.17 | 207.94 ± 92.40 |
| | Median (IQR) | 190 (144-235) | 213 (160-277) | 174 (144-219) | 160 (125-205) | 182 (144-228) | 191 (143-255) |
| Stoma | | 27 (12.4%) | 698 (21.4%) | 62 (44.3%) | 869 (50.7%) | 89 (24.9%) | 1567 (31.5%) |
| Surgery | Colon | 169 (77.9%) | 2131 (65.2%) | 123 (87.9%) | 1555 (90.8%) | 292 (81.8%) | 3686 (74.0%) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Rectal | 48 (22.1%) | 1136 (34.8%) | 17 (12.1%) | 158 (9.2%) | 65 (18.2%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon C | Total | Surgeon C | Total | Surgeon C | Total |
| | | N=217 | N=3267 | N=140 | N=1713 | N=357 | N=4980 |
| 30 day postoperative complication index* | 0 | 179 (82.5%) | 2722 (83.3%) | 82 (58.6%) | 864 (50.4%) | 261 (73.1%) | 3586 (72.0%) |
| | 2 | 6 (2.8%) | 140 (4.3%) | 11 (7.9%) | 201 (11.7%) | 17 (4.8%) | 341 (6.8%) |
| | 3 | 16 (7.4%) | 240 (7.3%) | 14 (10.0%) | 142 (8.3%) | 30 (8.4%) | 382 (7.7%) |
| | 4 | 10 (4.6%) | 125 (3.8%) | 22 (15.7%) | 312 (18.2%) | 32 (9.0%) | 437 (8.8%) |
| | 5 | 6 (2.8%) | 40 (1.2%) | 11 (7.9%) | 194 (11.3%) | 17 (4.8%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 8.55 ± 7.90 | 9.06 ± 11.67 | 18.69 ± 23.47 | 22.88 ± 28.95 | 12.52 ± 16.66 | 13.81 ± 20.51 |
| | Median (IQR) | 6 (5-9) | 6 (5-9) | 11 (8-20) | 13 (8-26) | 8 (5-12) | 8 (5-14) |
| 30 day readmission | 0 | 207 (95.4%) | 3072 (94.0%) | 126 (90.0%) | 1579 (92.2%) | 333 (93.3%) | 4651 (93.4%) |
| | 1 | 10 (4.6%) | 183 (5.6%) | 14 (10.0%) | 124 (7.2%) | 24 (6.7%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

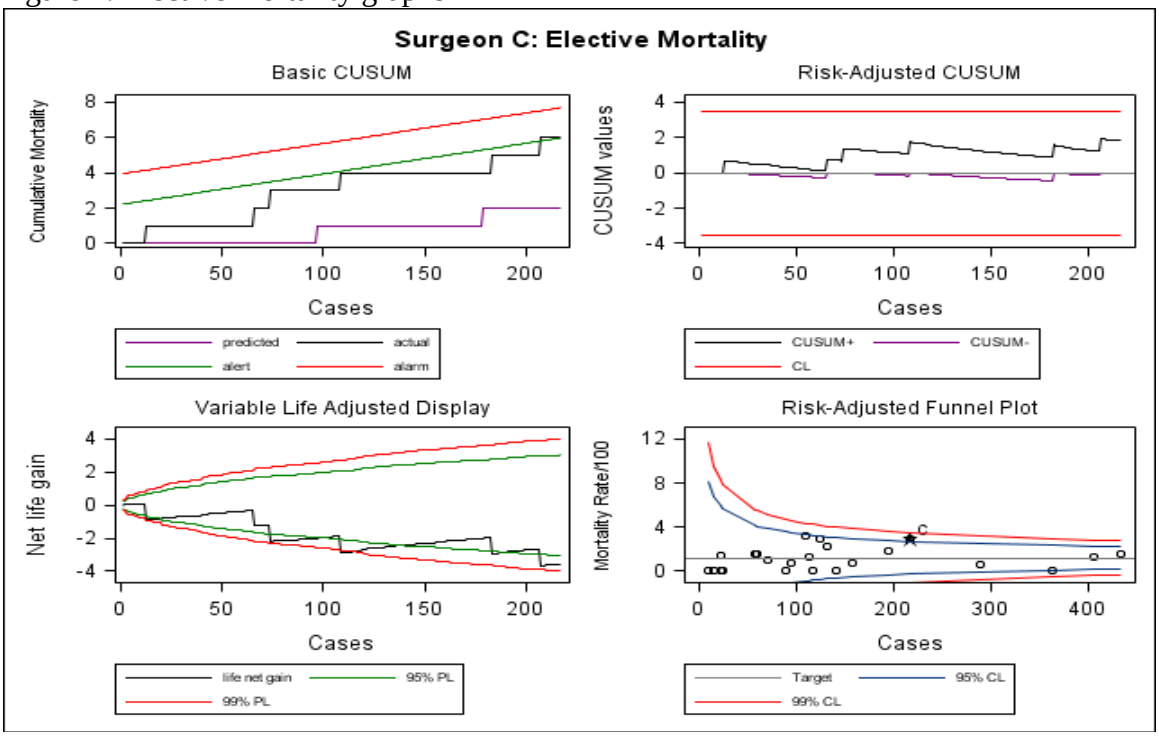



Figure 2: Elective morbidity graphs

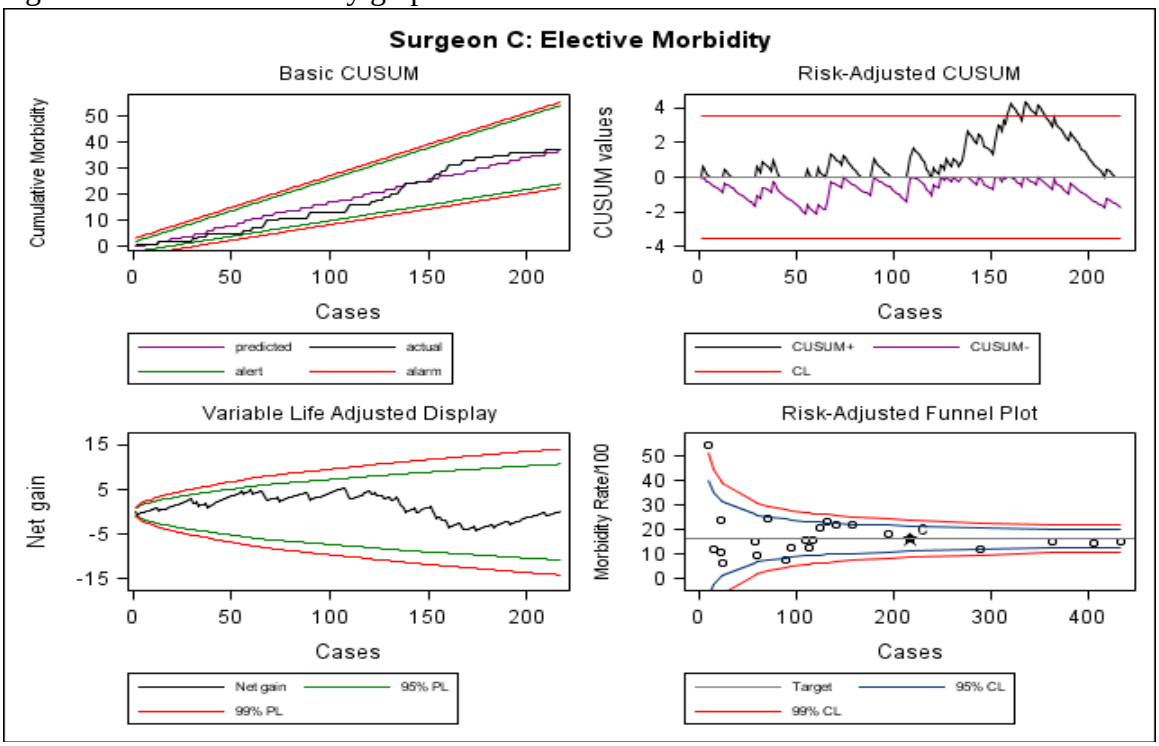


Figure 3: Emergent mortality graphs

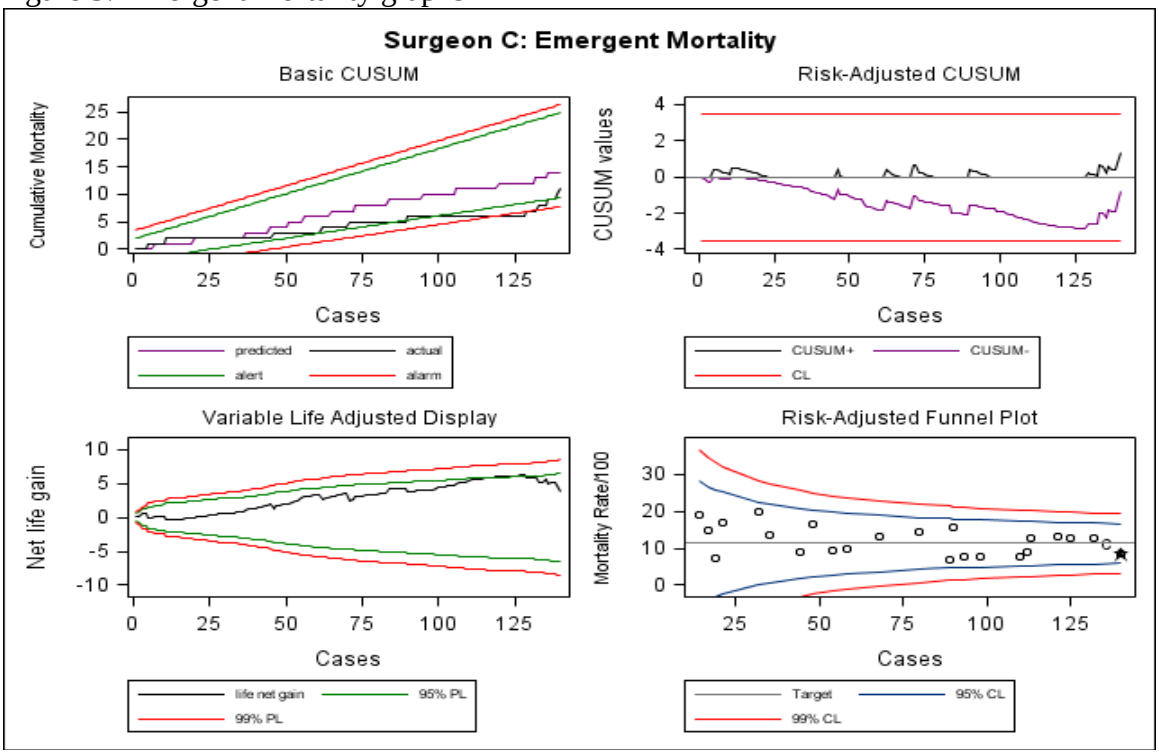



Figure 4: Emergent morbidity graphs

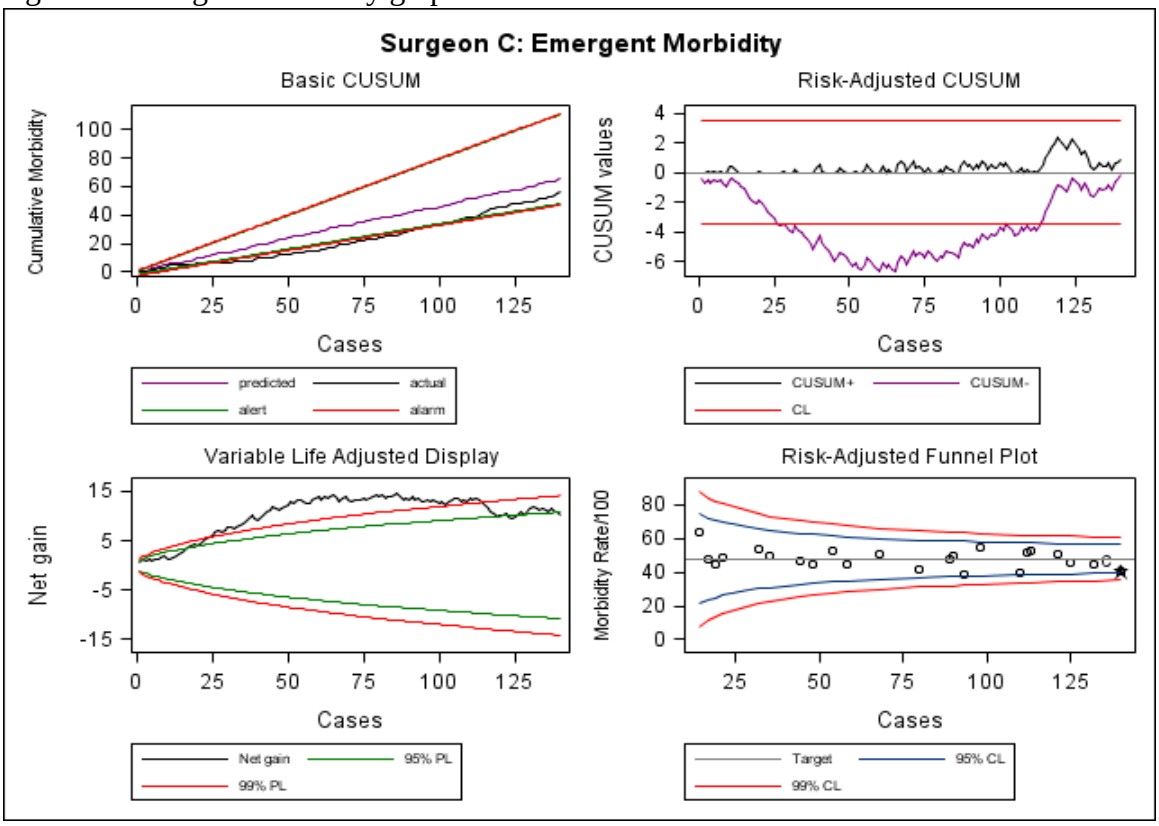


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon D | Total | Surgeon D | Total | Surgeon D | Total |
| | | N=289 | N=3267 | N=132 | N=1713 | N=421 | N=4980 |
| Age | Mean ± SD | 65.46 ± 13.40 | 61.49 ± 15.97 | 63.94 ± 16.48 | 63.33 ± 17.34 | 64.99 ± 14.44 | 62.12 ± 16.47 |
| | Median (IQR) | 67 (57-75) | 64 (52-74) | 66 (57-78) | 66 (52-77) | 67 (57-77) | 64 (52-75) |
| Sex | F | 118 (40.8%) | 1423 (43.6%) | 80 (60.6%) | 888 (51.8%) | 198 (47.0%) | 2311 (46.4%) |
| | M | 171 (59.2%) | 1844 (56.4%) | 52 (39.4%) | 825 (48.2%) | 223 (53.0%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 6.31 ± 5.94 | 5.82 ± 6.53 | 8.63 ± 8.72 | 7.67 ± 7.87 | 7.04 ± 7.01 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (4-9) | 4 (0-9) | 6 (0-16) | 5 (0-16) | 4 (3-13) | 4 (0-11) |
| Diagnosis | Cancer | 233 (80.6%) | 2038 (62.4%) | 64 (48.5%) | 638 (37.2%) | 297 (70.5%) | 2676 (53.7%) |
| | Diverticular disease | 20 (6.9%) | 182 (5.6%) | 17 (12.9%) | 241 (14.1%) | 37 (8.8%) | 423 (8.5%) |
| | Ulcerative colitis | 0 (0.0%) | 151 (4.6%) | <=5 (3.8%) | 82 (4.8%) | <=5 (1.2%) | 233 (4.7%) |
| | Crohn's | 9 (3.1%) | 175 (5.4%) | <=5 (3.8%) | 98 (5.7%) | 14 (3.3%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (3.8%) | 45 (2.6%) | <=5 (1.2%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 6 (4.5%) | 122 (7.1%) | 6 (1.4%) | 124 (2.5%) |
| | Other colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (0.8%) | <=5 (0.2%) | <=5 (0.2%) | 6 (0.1%) |
| | Stoma related | 17 (5.9%) | 522 (16.0%) | <=5 (0.8%) | 29 (1.7%) | 18 (4.3%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (0.3%) | 19 (0.6%) | 11 (8.3%) | 137 (8.0%) | 12 (2.9%) | 156 (3.1%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (0.8%) | 16 (0.9%) | <=5 (0.2%) | 16 (0.3%) |
| | Other colitis | 9 (3.1%) | 160 (4.9%) | 16 (12.1%) | 292 (17.0%) | 25 (5.9%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 191 (66.1%) | 912 (27.9%) | 22 (16.7%) | 143 (8.3%) | 213 (50.6%) | 1055 (21.2%) |
| | Open | 98 (33.9%) | 2355 (72.1%) | 110 (83.3%) | 1570 (91.7%) | 208 (49.4%) | 3925 (78.8%) |
| Resection type | APR | 26 (9.0%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | 26 (6.2%) | 308 (6.2%) |
| | AR | 72 (24.9%) | 845 (25.9%) | 18 (13.6%) | 141 (8.2%) | 90 (21.4%) | 986 (19.8%) |
| | bypass | 7 (2.4%) | 162 (5.0%) | 17 (12.9%) | 321 (18.7%) | 24 (5.7%) | 483 (9.7%) |
| | reversal | 16 (5.5%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | 16 (3.8%) | 515 (10.3%) |
| | segmental | 167 (57.8%) | 1404 (43.0%) | 91 (68.9%) | 1113 (65.0%) | 258 (61.3%) | 2517 (50.5%) |
| | total | <=5 (0.3%) | 70 (2.1%) | 6 (4.5%) | 101 (5.9%) | 7 (1.7%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 219.03 ± 65.59 | 226.37 ± 96.11 | 161.70 ± 57.44 | 172.77 ± 72.97 | 201.05 ± 68.47 | 207.94 ± 92.40 |
| | Median (IQR) | 210 (178-261) | 213 (160-277) | 150 (121-194) | 160 (125-205) | 193 (153-245) | 191 (143-255) |
| Stoma | | 40 (13.8%) | 698 (21.4%) | 50 (37.9%) | 869 (50.7%) | 90 (21.4%) | 1567 (31.5%) |
| Surgery | Colon | 191 (66.1%) | 2131 (65.2%) | 114 (86.4%) | 1555 (90.8%) | 305 (72.4%) | 3686 (74.0%) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Rectal | 98 (33.9%) | 1136 (34.8%) | 18 (13.6%) | 158 (9.2%) | 116 (27.6%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon D | Total | Surgeon D | Total | Surgeon D | Total |
| | | N=289 | N=3267 | N=132 | N=1713 | N=421 | N=4980 |
| 30 day postoperative complication index* | 0 | 255 (88.2%) | 2722 (83.3%) | 71 (53.8%) | 864 (50.4%) | 326 (77.4%) | 3586 (72.0%) |
| | 2 | 12 (4.2%) | 140 (4.3%) | 17 (12.9%) | 201 (11.7%) | 29 (6.9%) | 341 (6.8%) |
| | 3 | 10 (3.5%) | 240 (7.3%) | 9 (6.8%) | 142 (8.3%) | 19 (4.5%) | 382 (7.7%) |
| | 4 | 10 (3.5%) | 125 (3.8%) | 20 (15.2%) | 312 (18.2%) | 30 (7.1%) | 437 (8.8%) |
| | 5 | <=5 (0.7%) | 40 (1.2%) | 15 (11.4%) | 194 (11.3%) | 17 (4.0%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 7.52 ± 13.56 | 9.06 ± 11.67 | 22.77 ± 30.24 | 22.88 ± 28.95 | 12.30 ± 21.48 | 13.81 ± 20.51 |
| | Median (IQR) | 5 (4-6) | 6 (5-9) | 13 (9-23) | 13 (8-26) | 6 (4-11) | 8 (5-14) |
| 30 day readmission | 0 | 276 (95.5%) | 3072 (94.0%) | 122 (92.4%) | 1579 (92.2%) | 398 (94.5%) | 4651 (93.4%) |
| | 1 | 12 (4.2%) | 183 (5.6%) | 9 (6.8%) | 124 (7.2%) | 21 (5.0%) | 307 (6.2%) |
| | 2 | <=5 (0.3%) | 12 (0.4%) | <=5 (0.8%) | 10 (0.6%) | <=5 (0.5%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

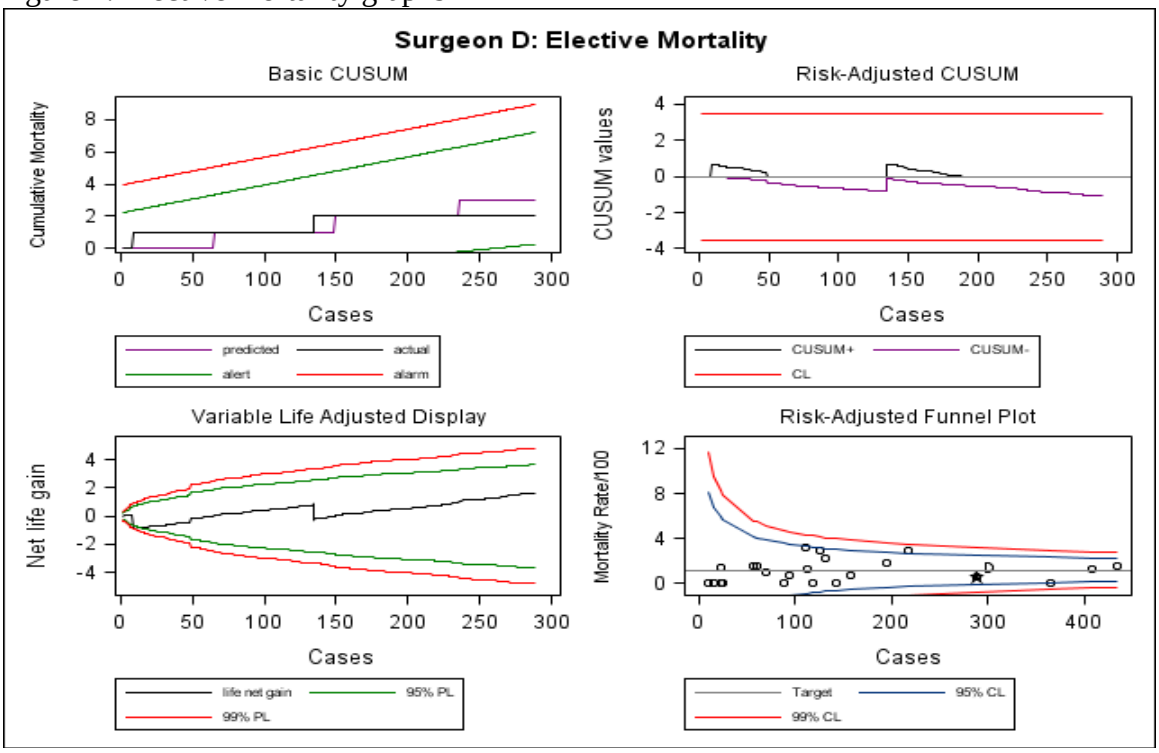



Figure 2: Elective morbidity graphs

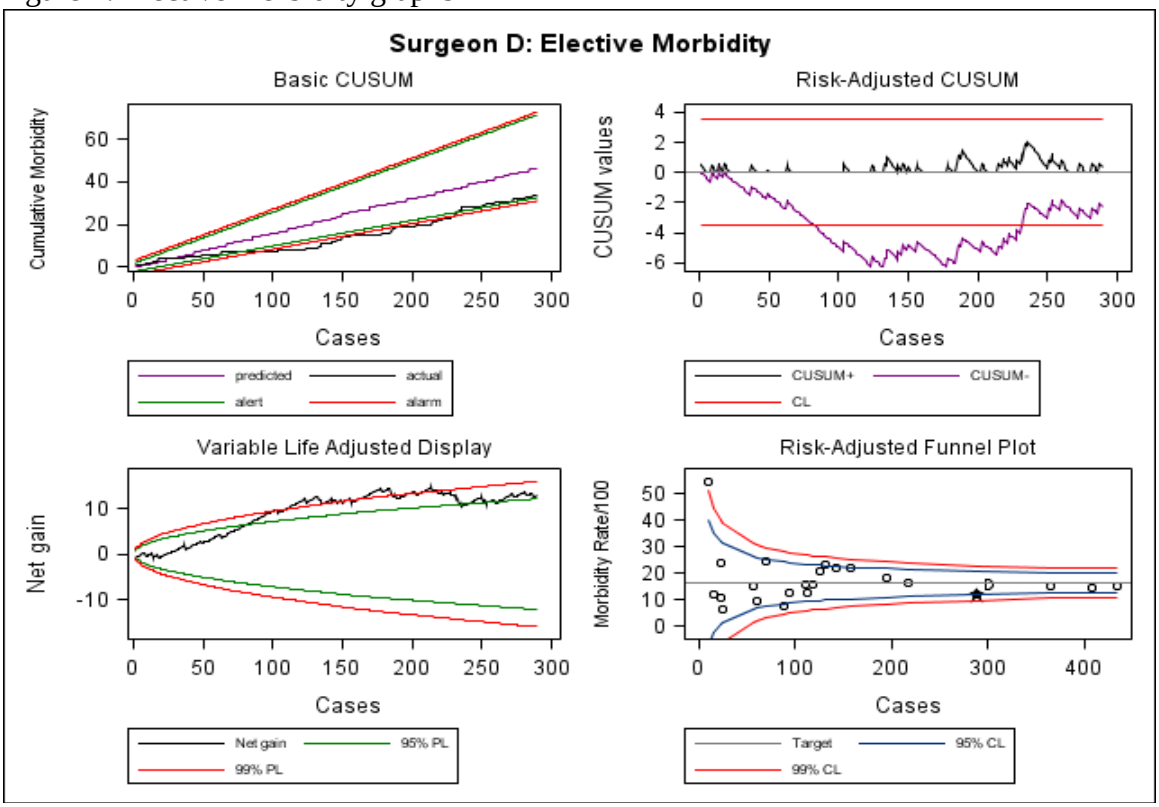


Figure 3: Emergent mortality graphs

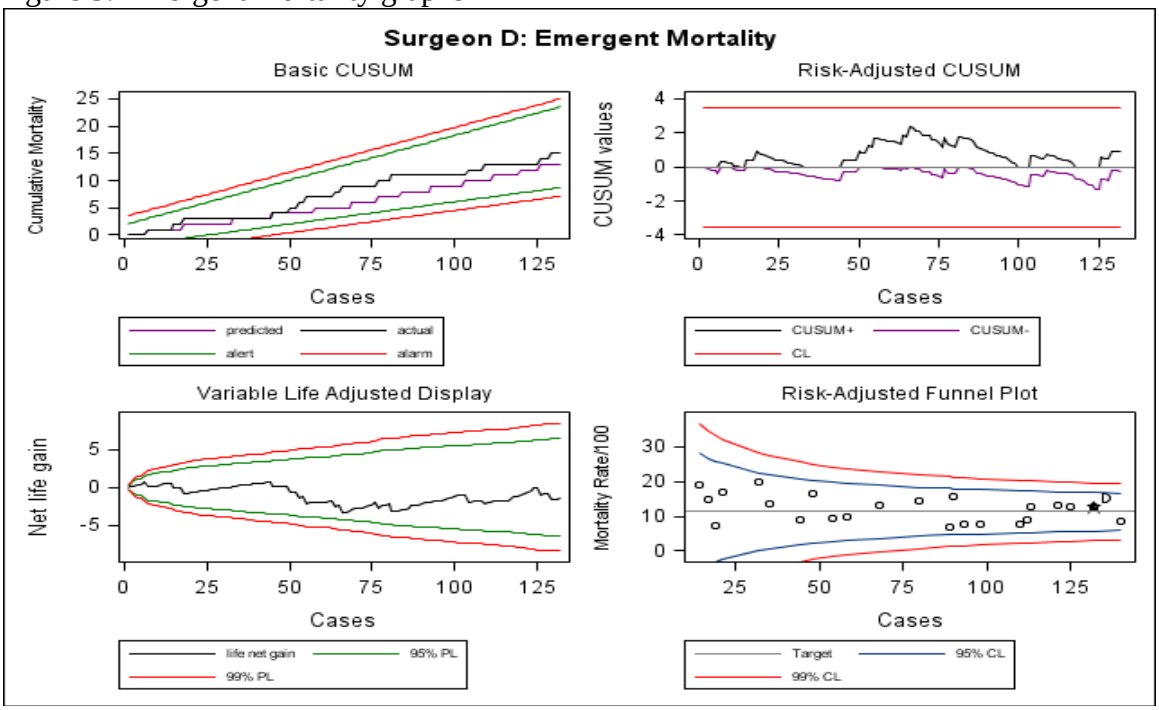



Figure 4: Emergent morbidity graphs

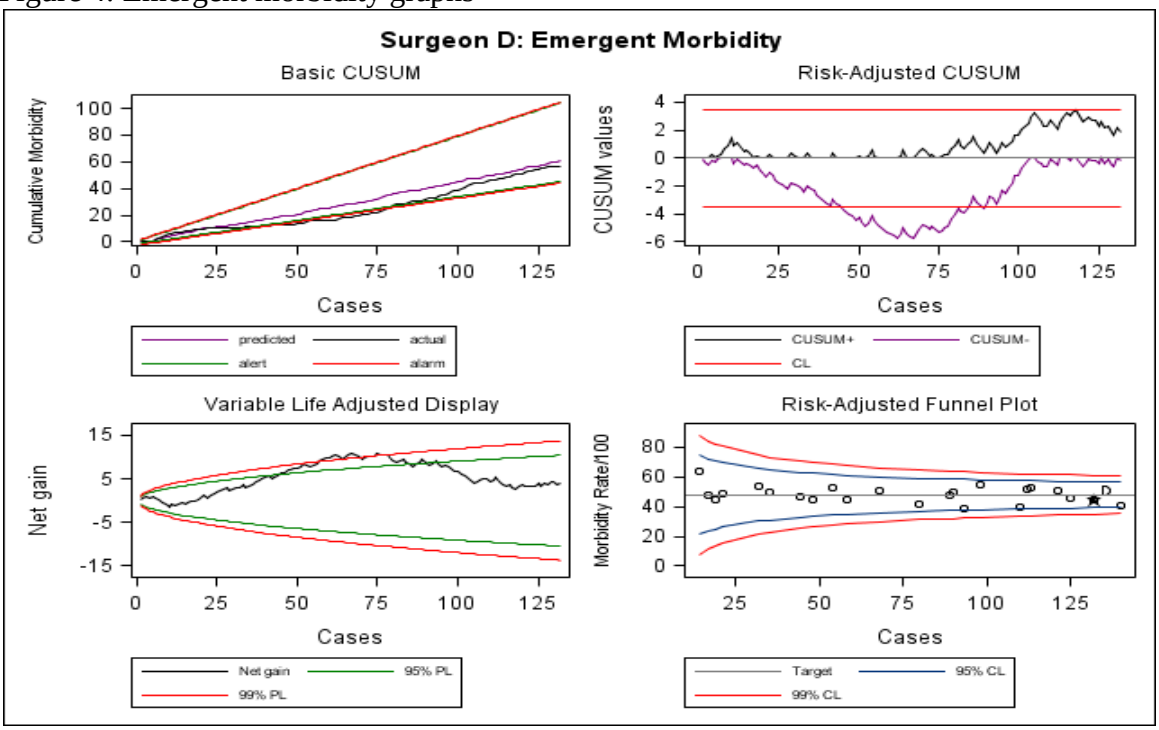


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon E | Total | Surgeon E | Total | Surgeon E | Total |
| | | N=113 | N=3267 | N=80 | N=1713 | N=193 | N=4980 |
| Age | Mean ± SD | 66.68 ± 14.09 | 61.49 ± 15.97 | 64.35 ± 19.31 | 63.33 ± 17.34 | 65.72 ± 16.45 | 62.12 ± 16.47 |
| | Median (IQR) | 71 (57-76) | 64 (52-74) | 67 (52-80) | 66 (52-77) | 69 (56-77) | 64 (52-75) |
| Sex | F | 51 (45.1%) | 1423 (43.6%) | 47 (58.8%) | 888 (51.8%) | 98 (50.8%) | 2311 (46.4%) |
| | M | 62 (54.9%) | 1844 (56.4%) | 33 (41.3%) | 825 (48.2%) | 95 (49.2%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 6.16 ± 7.37 | 5.82 ± 6.53 | 7.01 ± 7.61 | 7.67 ± 7.87 | 6.51 ± 7.46 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-9) | 4 (0-9) | 4 (0-16) | 5 (0-16) | 4 (0-12) | 4 (0-11) |
| Diagnosis | Cancer | 68 (60.2%) | 2038 (62.4%) | 34 (42.5%) | 638 (37.2%) | 102 (52.8%) | 2676 (53.7%) |
| | Diverticular disease | 13 (11.5%) | 182 (5.6%) | 11 (13.8%) | 241 (14.1%) | 24 (12.4%) | 423 (8.5%) |
| | Ulcerative colitis | 0 (0.0%) | 151 (4.6%) | 6 (7.5%) | 82 (4.8%) | 6 (3.1%) | 233 (4.7%) |
| | Crohn's | <=5 (3.5%) | 175 (5.4%) | <=5 (5.0%) | 98 (5.7%) | 8 (4.1%) | 273 (5.5%) |
| | Infectious colitis | <=5 (0.9%) | <=5 (0.1%) | <=5 (3.8%) | 45 (2.6%) | <=5 (2.1%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (3.8%) | 122 (7.1%) | <=5 (1.6%) | 124 (2.5%) |
| | Polyp | <=5 (0.9%) | 8 (0.2%) | 0 (0.0%) | 0 (0.0%) | <=5 (0.5%) | 8 (0.2%) |
| | Stoma related | 15 (13.3%) | 522 (16.0%) | <=5 (1.3%) | 29 (1.7%) | 16 (8.3%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (0.9%) | 19 (0.6%) | <=5 (6.3%) | 137 (8.0%) | 6 (3.1%) | 156 (3.1%) |
| | Hernia | <=5 (0.9%) | <=5 (0.1%) | 0 (0.0%) | 10 (0.6%) | <=5 (0.5%) | 13 (0.3%) |
| | Other | 9 (8.0%) | 160 (4.9%) | 13 (16.3%) | 292 (17.0%) | 22 (11.4%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 16 (14.2%) | 912 (27.9%) | <=5 (3.8%) | 143 (8.3%) | 19 (9.8%) | 1055 (21.2%) |
| | Open | 97 (85.8%) | 2355 (72.1%) | 77 (96.3%) | 1570 (91.7%) | 174 (90.2%) | 3925 (78.8%) |
| Resection type | APR | 6 (5.3%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | 6 (3.1%) | 308 (6.2%) |
| | AR | 16 (14.2%) | 845 (25.9%) | <=5 (6.3%) | 141 (8.2%) | 21 (10.9%) | 986 (19.8%) |
| | bypass | 7 (6.2%) | 162 (5.0%) | 19 (23.8%) | 321 (18.7%) | 26 (13.5%) | 483 (9.7%) |
| | reversal | 15 (13.3%) | 495 (15.2%) | <=5 (2.5%) | 20 (1.2%) | 17 (8.8%) | 515 (10.3%) |
| | segmental | 68 (60.2%) | 1404 (43.0%) | 49 (61.3%) | 1113 (65.0%) | 117 (60.6%) | 2517 (50.5%) |
| | total | <=5 (0.9%) | 70 (2.1%) | <=5 (6.3%) | 101 (5.9%) | 6 (3.1%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 259.42 ± 97.41 | 226.37 ± 96.11 | 200.86 ± 70.26 | 172.77 ± 72.97 | 235.15 ± 91.67 | 207.94 ± 92.40 |
| | Median (IQR) | 247 (201-297) | 213 (160-277) | 189 (157-251) | 160 (125-205) | 224 (175-286) | 191 (143-255) |
| Stoma | | 34 (30.1%) | 698 (21.4%) | 41 (51.3%) | 869 (50.7%) | 75 (38.9%) | 1567 (31.5%) |
| Surgery | Colon | 91 (80.5%) | 2131 (65.2%) | 75 (93.8%) | 1555 (90.8%) | 166 (86.0%) | 3686 (74.0%) |
| | Rectal | 22 (19.5%) | 1136 (34.8%) | <=5 (6.3%) | 158 (9.2%) | 27 (14.0%) | 1294 (26.0%) |

*Using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon E | Total | Surgeon E | Total | Surgeon E | Total |
| | | N=113 | N=3267 | N=80 | N=1713 | N=193 | N=4980 |
| 30 day postoperative complication index* | 0 | 97 (85.8%) | 2722 (83.3%) | 44 (55.0%) | 864 (50.4%) | 141 (73.1%) | 3586 (72.0%) |
| | 2 | <=5 (2.7%) | 140 (4.3%) | 9 (11.3%) | 201 (11.7%) | 12 (6.2%) | 341 (6.8%) |
| | 3 | 8 (7.1%) | 240 (7.3%) | <=5 (6.3%) | 142 (8.3%) | 13 (6.7%) | 382 (7.7%) |
| | 4 | <=5 (2.7%) | 125 (3.8%) | 11 (13.8%) | 312 (18.2%) | 14 (7.3%) | 437 (8.8%) |
| | 5 | <=5 (1.8%) | 40 (1.2%) | 11 (13.8%) | 194 (11.3%) | 13 (6.7%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 11.42 ± 13.66 | 9.06 ± 11.67 | 17.16 ± 16.87 | 22.88 ± 28.95 | 13.80 ± 15.30 | 13.81 ± 20.51 |
| | Median (IQR) | 7 (6-10) | 6 (5-9) | 12 (8-21) | 13 (8-26) | 8 (7-14) | 8 (5-14) |
| 30 day readmission | 0 | 106 (93.8%) | 3072 (94.0%) | 72 (90.0%) | 1579 (92.2%) | 178 (92.2%) | 4651 (93.4%) |
| | 1 | 7 (6.2%) | 183 (5.6%) | 6 (7.5%) | 124 (7.2%) | 13 (6.7%) | 307 (6.2%) |
| | 2 | 0 (0.0%) | 12 (0.4%) | <=5 (2.5%) | 10 (0.6%) | <=5 (1.0%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

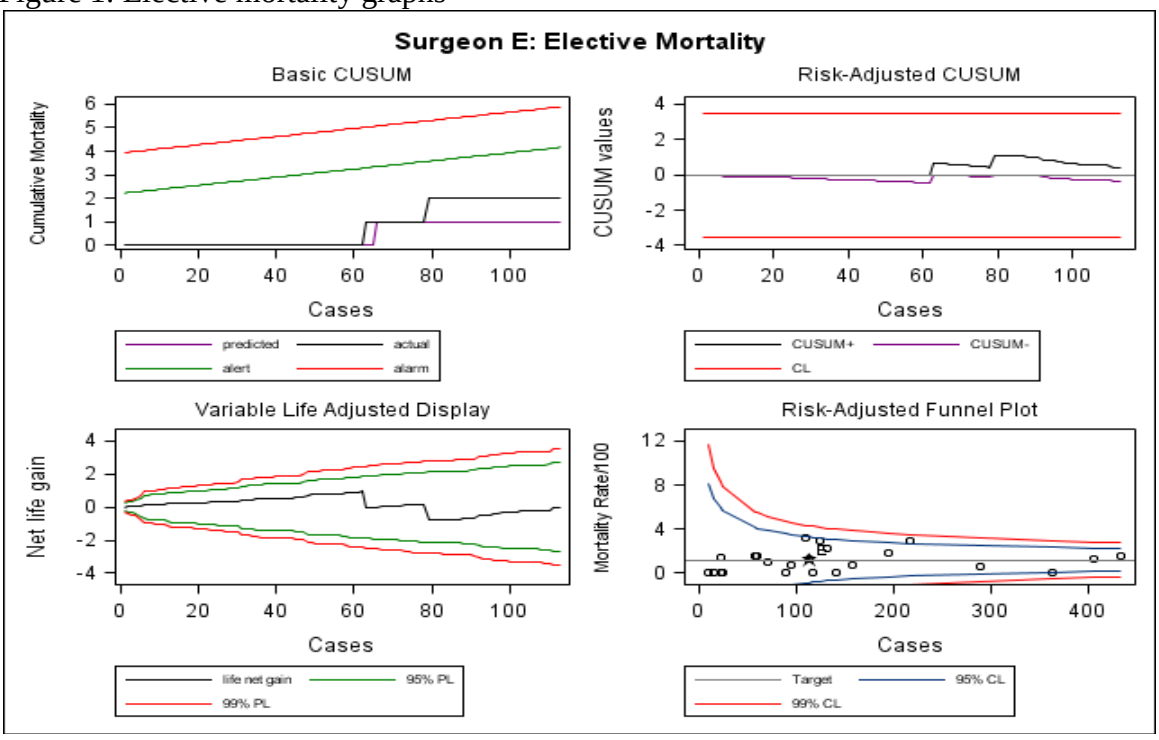



Figure 2: Elective morbidity graphs

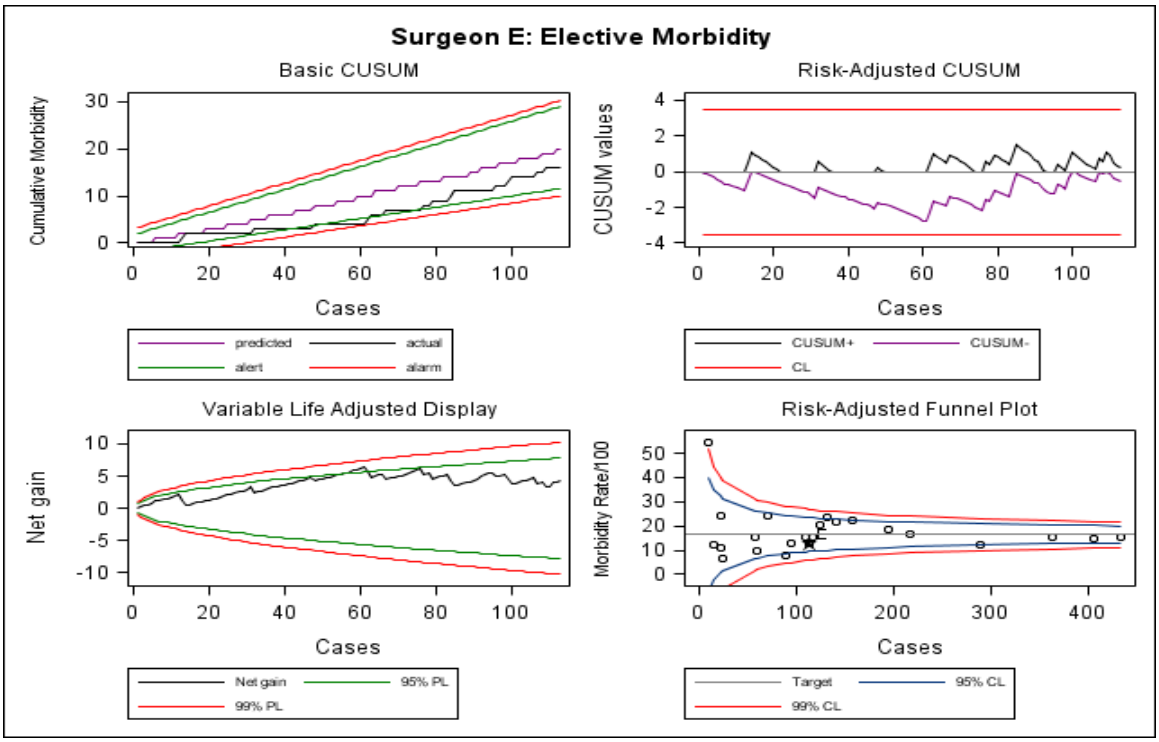


Figure 3: Emergent mortality graphs

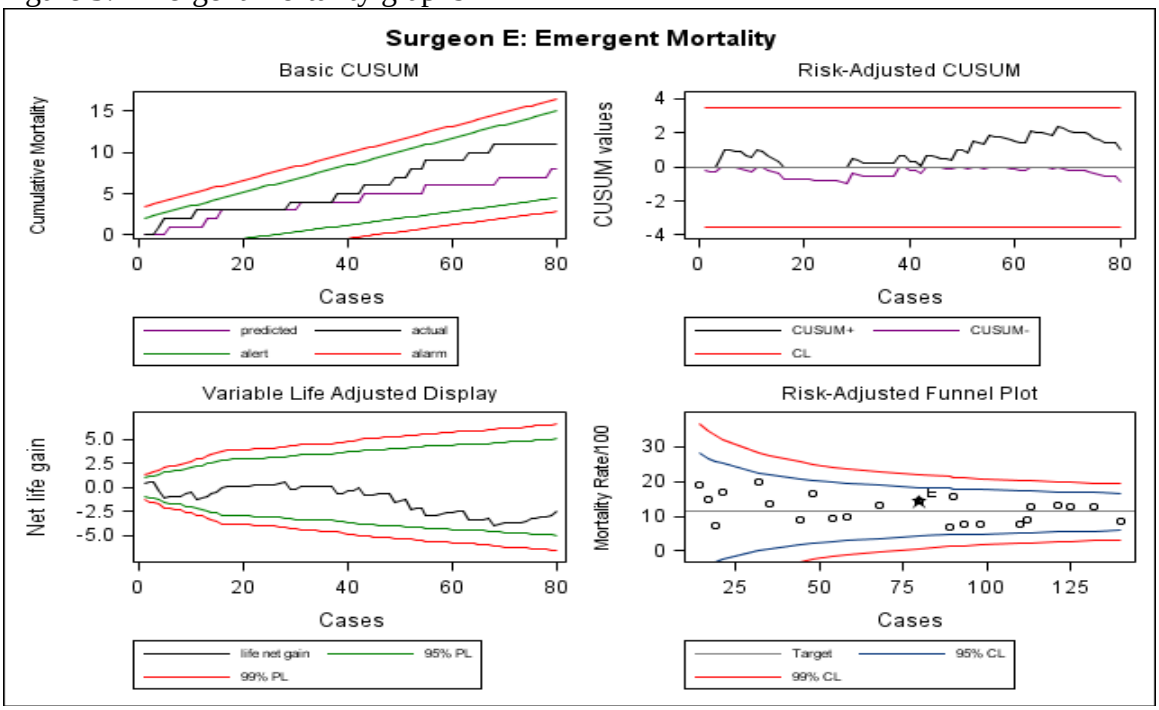
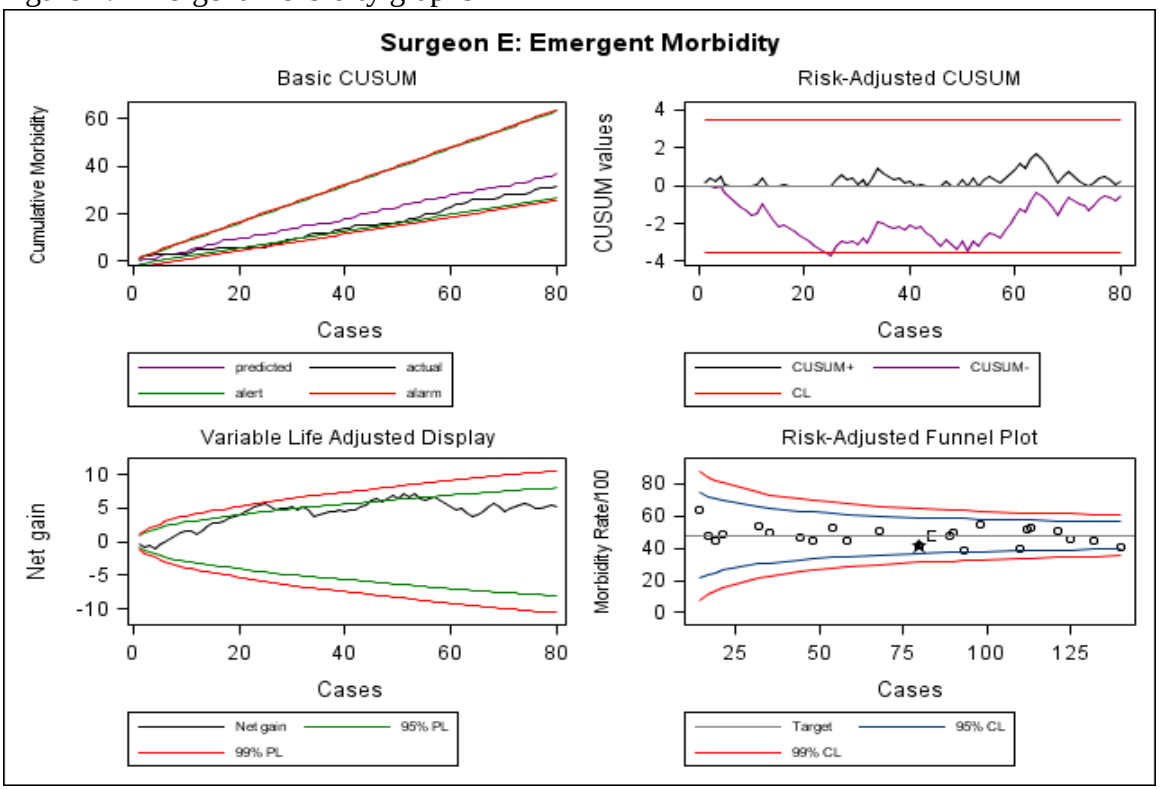



Figure 4: Emergent morbidity graphs



**Surgeon F Performance**

Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon F | Total | Surgeon F | Total | Surgeon F | Total |
| | | N=110 | N=3267 | N=113 | N=1713 | N=223 | N=4980 |
| Age | Mean ± SD | 60.43 ± 14.58 | 61.49 ± 15.97 | 63.41 ± 17.75 | 63.33 ± 17.34 | 61.94 ± 16.30 | 62.12 ± 16.47 |
| | Median (IQR) | 60 (49-72) | 64 (52-74) | 65 (54-78) | 66 (52-77) | 64 (51-74) | 64 (52-75) |
| Sex | F | 53 (48.2%) | 1423 (43.6%) | 46 (40.7%) | 888 (51.8%) | 99 (44.4%) | 2311 (46.4%) |
| | M | 57 (51.8%) | 1844 (56.4%) | 67 (59.3%) | 825 (48.2%) | 124 (55.6%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 4.59 ± 6.30 | 5.82 ± 6.53 | 6.73 ± 7.39 | 7.67 ± 7.87 | 5.68 ± 6.95 | 6.46 ± 7.08 |
| | Median (IQR) | 0 (0-9) | 4 (0-9) | 4 (0-12) | 5 (0-16) | 4 (0-10) | 4 (0-11) |
| Diagnosis | Cancer | 43 (39.1%) | 2038 (62.4%) | 39 (34.5%) | 638 (37.2%) | 82 (36.8%) | 2676 (53.7%) |
| | Diverticular disease | 11 (10.0%) | 182 (5.6%) | 14 (12.4%) | 241 (14.1%) | 25 (11.2%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (3.6%) | 151 (4.6%) | 6 (5.3%) | 82 (4.8%) | 10 (4.5%) | 233 (4.7%) |
| | Crohn's | 9 (8.2%) | 175 (5.4%) | <=5 (4.4%) | 98 (5.7%) | 14 (6.3%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (2.7%) | 45 (2.6%) | <=5 (1.3%) | 49 (1.0%) |
| | Ischemic colitis | <=5 (0.9%) | <=5 (0.1%) | 8 (7.1%) | 122 (7.1%) | 9 (4.0%) | 124 (2.5%) |
| | Stoma related | 28 (25.5%) | 522 (16.0%) | <=5 (2.7%) | 29 (1.7%) | 31 (13.9%) | 551 (11.1%) |
| | Hernia | 0 (0.0%) | <=5 (0.1%) | <=5 (0.9%) | 10 (0.6%) | <=5 (0.4%) | 13 (0.3%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (1.8%) | 16 (0.9%) | <=5 (0.9%) | 16 (0.3%) |
| | Volvulus/bowel obstruction | <=5 (3.6%) | 19 (0.6%) | 9 (8.0%) | 137 (8.0%) | 13 (5.8%) | 156 (3.1%) |
| | other | 10 (9.1%) | 160 (4.9%) | 23 (20.4%) | 292 (17.0%) | 33 (14.8%) | 452 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | (9.1%) |
| Open/lap | Laparoscopic | 41 (37.3%) | 912 (27.9%) | 18 (15.9%) | 143 (8.3%) | 59 (26.5%) | 1055 (21.2%) |
| | Open | 69 (62.7%) | 2355 (72.1%) | 95 (84.1%) | 1570 (91.7%) | 164 (73.5%) | 3925 (78.8%) |
| Resection type | APR | <=5 (3.6%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | <=5 (1.8%) | 308 (6.2%) |
| | AR | 11 (10.0%) | 845 (25.9%) | 6 (5.3%) | 141 (8.2%) | 17 (7.6%) | 986 (19.8%) |
| | bypass | <=5 (4.5%) | 162 (5.0%) | 17 (15.0%) | 321 (18.7%) | 22 (9.9%) | 483 (9.7%) |
| | reversal | 31 (28.2%) | 495 (15.2%) | <=5 (1.8%) | 20 (1.2%) | 33 (14.8%) | 515 (10.3%) |
| | segmental | 57 (51.8%) | 1404 (43.0%) | 81 (71.7%) | 1113 (65.0%) | 138 (61.9%) | 2517 (50.5%) |
| | total | <=5 (1.8%) | 70 (2.1%) | 7 (6.2%) | 101 (5.9%) | 9 (4.0%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 205.44 ± 83.11 | 226.37 ± 96.11 | 174.97 ± 70.24 | 172.77 ± 72.97 | 190.07 ± 78.22 | 207.94 ± 92.40 |
| | Median (IQR) | 195 (162-232) | 213 (160-277) | 164 (131-204) | 160 (125-205) | 181 (145-219) | 191 (143-255) |
| Stoma | | 15 (13.6%) | 698 (21.4%) | 48 (42.5%) | 869 (50.7%) | 63 (28.3%) | 1567 (31.5%) |
| Surgery | Colon | 95 (86.4%) | 2131 (65.2%) | 107 (94.7%) | 1555 (90.8%) | 202 (90.6%) | 3686 (74.0%) |
| | Rectal | 15 (13.6%) | 1136 (34.8%) | 6 (5.3%) | 158 (9.2%) | 21 (9.4%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

**Surgeon F Performance**

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon F | Total | Surgeon F | Total | Surgeon F | Total |
| | | N=110 | N=3267 | N=113 | N=1713 | N=223 | N=4980 |
| 30 day postoperative complication index* | 0 | 92 (83.6%) | 2722 (83.3%) | 55 (48.7%) | 864 (50.4%) | 147 (65.9%) | 3586 (72.0%) |
| | 2 | <=5 (3.6%) | 140 (4.3%) | 16 (14.2%) | 201 (11.7%) | 20 (9.0%) | 341 (6.8%) |
| | 3 | 6 (5.5%) | 240 (7.3%) | 8 (7.1%) | 142 (8.3%) | 14 (6.3%) | 382 (7.7%) |
| | 4 | <=5 (4.5%) | 125 (3.8%) | 21 (18.6%) | 312 (18.2%) | 26 (11.7%) | 437 (8.8%) |
| | 5 | <=5 (2.7%) | 40 (1.2%) | 13 (11.5%) | 194 (11.3%) | 16 (7.2%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 9.07 ± 11.90 | 9.06 ± 11.67 | 21.75 ± 34.16 | 22.88 ± 28.95 | 15.50 ± 26.43 | 13.81 ± 20.51 |
| | Median (IQR) | 6 (5-9) | 6 (5-9) | 14 (9-22) | 13 (8-26) | 9 (6-16) | 8 (5-14) |
| 30 day readmission | 0 | 99 (90.0%) | 3072 (94.0%) | 106 (93.8%) | 1579 (92.2%) | 205 (91.9%) | 4651 (93.4%) |
| | 1 | 10 (9.1%) | 183 (5.6%) | 7 (6.2%) | 124 (7.2%) | 17 (7.6%) | 307 (6.2%) |
| | 2 | <=5 (0.9%) | 12 (0.4%) | 0 (0.0%) | 10 (0.6%) | <=5 (0.4%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

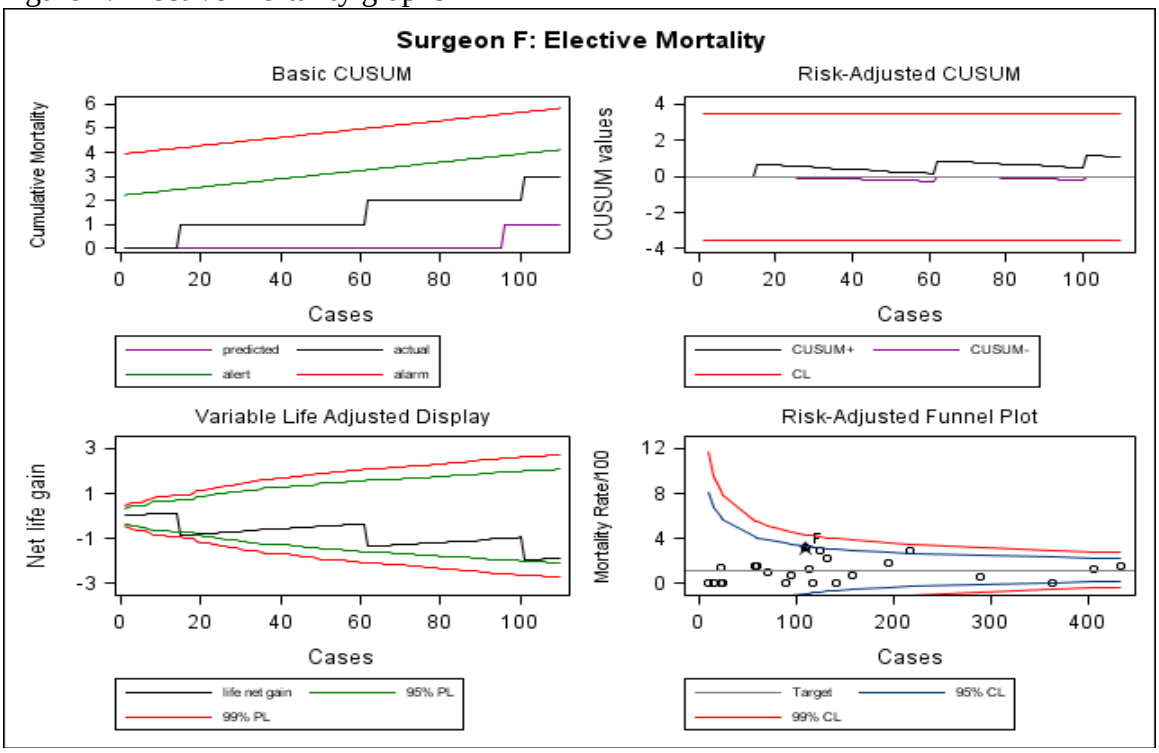



Figure 2: Elective morbidity graphs

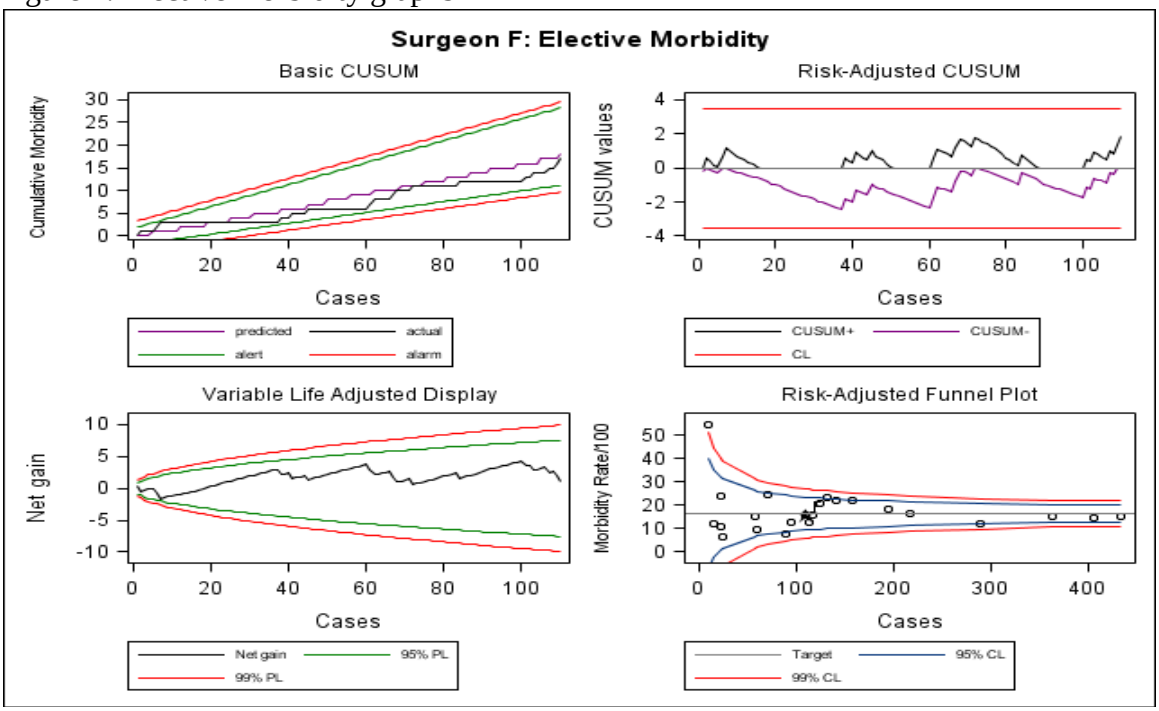


Figure 3: Emergent mortality graphs

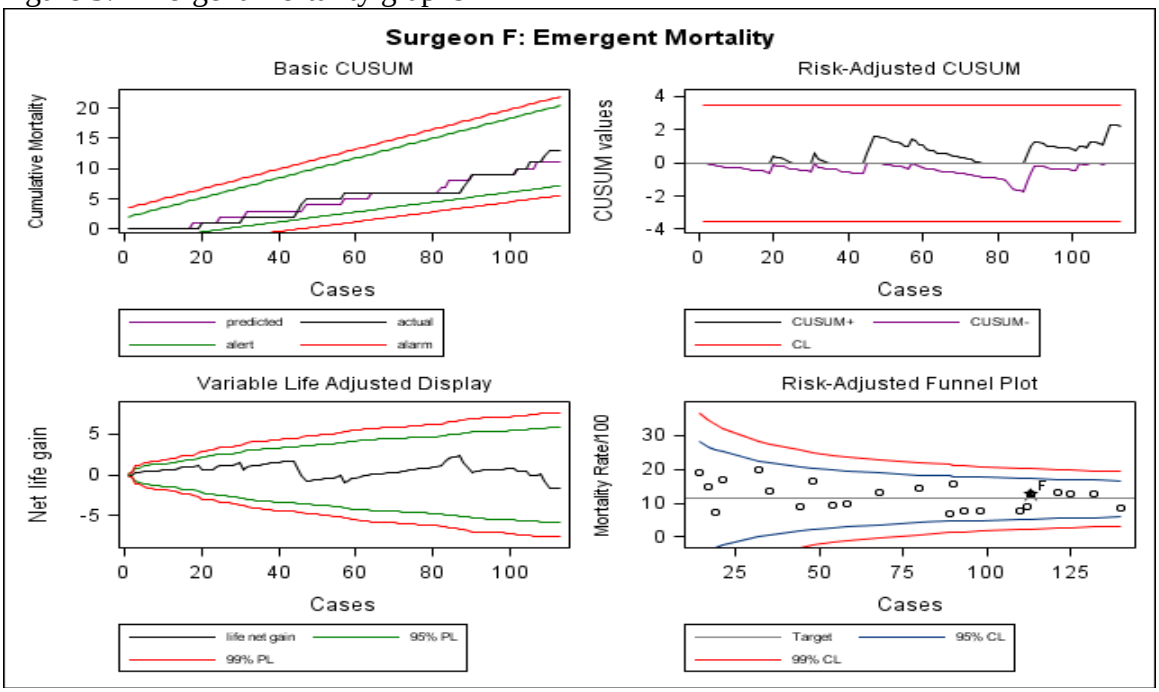



Figure 4: Emergent morbidity graphs

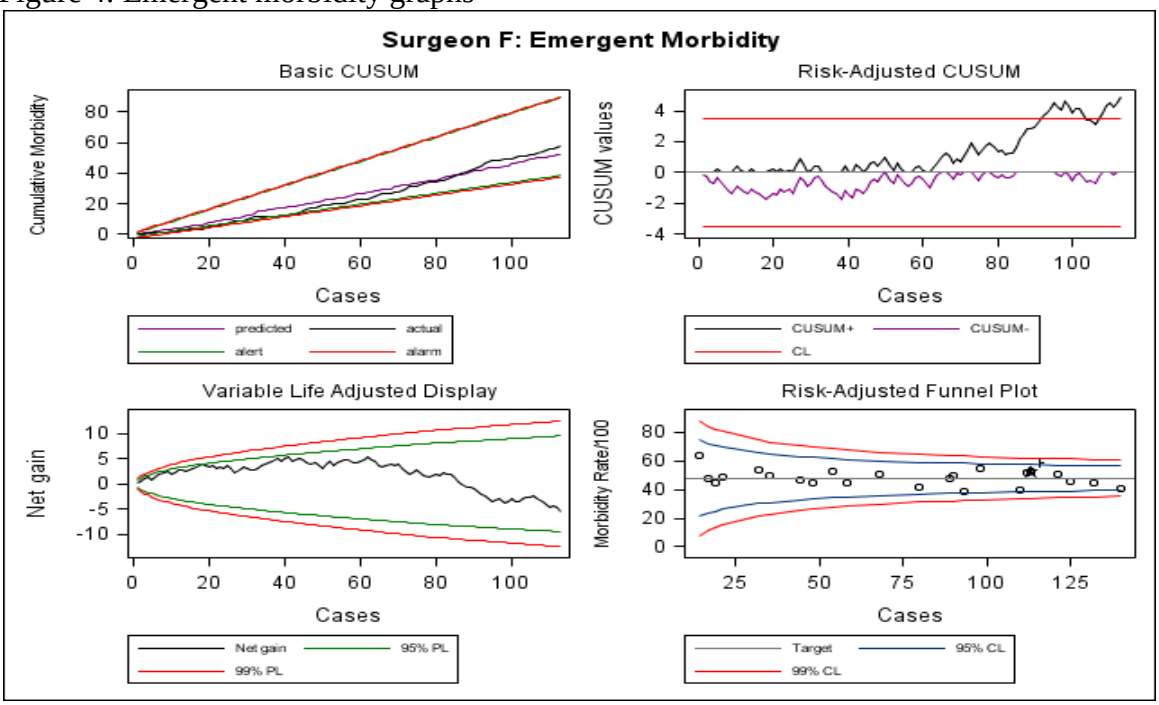


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon G | Total | Surgeon G | Total | Surgeon G | Total |
| | | N=132 | N=3267 | N=90 | N=1713 | N=222 | N=4980 |
| Age | Mean ± SD | 65.08 ± 13.77 | 61.49 ± 15.97 | 66.36 ± 17.05 | 63.33 ± 17.34 | 65.59 ± 15.16 | 62.12 ± 16.47 |
| | Median (IQR) | 65 (57-75) | 64 (52-74) | 69 (58-80) | 66 (52-77) | 68 (57-77) | 64 (52-75) |
| Sex | F | 57 (43.2%) | 1423 (43.6%) | 50 (55.6%) | 888 (51.8%) | 107 (48.2%) | 2311 (46.4%) |
| | M | 75 (56.8%) | 1844 (56.4%) | 40 (44.4%) | 825 (48.2%) | 115 (51.8%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 7.20 ± 7.13 | 5.82 ± 6.53 | 7.13 ± 7.37 | 7.67 ± 7.87 | 7.18 ± 7.21 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-16) | 4 (0-9) | 5 (0-13) | 5 (0-16) | 4 (0-15) | 4 (0-11) |
| Diagnosis | Cancer | 84 (63.6%) | 2038 (62.4%) | 30 (33.3%) | 638 (37.2%) | 114 (51.4%) | 2676 (53.7%) |
| | Diverticular disease | 15 (11.4%) | 182 (5.6%) | 20 (22.2%) | 241 (14.1%) | 35 (15.8%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (0.8%) | 151 (4.6%) | <=5 (1.1%) | 82 (4.8%) | <=5 (0.9%) | 233 (4.7%) |
| | Crohn's | 0 (0.0%) | 175 (5.4%) | <=5 (5.6%) | 98 (5.7%) | <=5 (2.3%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (2.2%) | 45 (2.6%) | <=5 (0.9%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (5.6%) | 122 (7.1%) | <=5 (2.3%) | 124 (2.5%) |
| | Stoma related | 17 (12.9%) | 522 (16.0%) | <=5 (1.1%) | 29 (1.7%) | 18 (8.1%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | <=5 (4.4%) | 137 (8.0%) | <=5 (1.8%) | 156 (3.1%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (1.1%) | 16 (0.9%) | <=5 (0.5%) | 16 (0.3%) |
| | Other | 15 (11.4%) | 160 (4.9%) | 21 (23.3%) | 292 (17.0%) | 36 (16.2%) | 452 (9.1%) |
| Open/lap | Laparoscopic | <=5 (3.8%) | 912 (27.9%) | <=5 (1.1%) | 143 (8.3%) | 6 (2.7%) | 1055 (21.2%) |
| | Open | 127 (96.2%) | 2355 (72.1%) | 89 (98.9%) | 1570 (91.7%) | 216 (97.3%) | 3925 (78.8%) |
| Resection type | APR | <=5 (3.8%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | <=5 (2.3%) | 308 (6.2%) |
| | AR | 32 (24.2%) | 845 (25.9%) | 6 (6.7%) | 141 (8.2%) | 38 (17.1%) | 986 (19.8%) |
| | bypass | 7 (5.3%) | 162 (5.0%) | 13 (14.4%) | 321 (18.7%) | 20 (9.0%) | 483 (9.7%) |
| | reversal | 19 (14.4%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | 19 (8.6%) | 515 (10.3%) |
| | segmental | 63 (47.7%) | 1404 (43.0%) | 64 (71.1%) | 1113 (65.0%) | 127 (57.2%) | 2517 (50.5%) |
| | total | 6 (4.5%) | 70 (2.1%) | 7 (7.8%) | 101 (5.9%) | 13 (5.9%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 157.70 ± 53.62 | 226.37 ± 96.11 | 139.81 ± 77.31 | 172.77 ± 72.97 | 150.45 ± 64.72 | 207.94 ± 92.40 |
| | Median (IQR) | 154 (117-186) | 213 (160-277) | 126 (105-158) | 160 (125-205) | 140 (110-175) | 191 (143-255) |
| Stoma | | 26 (19.7%) | 698 (21.4%) | 50 (55.6%) | 869 (50.7%) | 76 (34.2%) | 1567 (31.5%) |
| Surgery | Colon | 95 (72.0%) | 2131 (65.2%) | 84 (93.3%) | 1555 (90.8%) | 179 (80.6%) | 3686 (74.0%) |
| | Rectal | 37 (28.0%) | 1136 (34.8%) | 6 (6.7%) | 158 (9.2%) | 43 (19.4%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon G | Total | Surgeon G | Total | Surgeon G | Total |
| | | N=132 | N=3267 | N=90 | N=1713 | N=222 | N=4980 |
| 30 day postoperative complication index* | 0 | 98 (74.2%) | 2722 (83.3%) | 48 (53.3%) | 864 (50.4%) | 146 (65.8%) | 3586 (72.0%) |
| | 2 | <=5 (2.3%) | 140 (4.3%) | 7 (7.8%) | 201 (11.7%) | 10 (4.5%) | 341 (6.8%) |
| | 3 | 17 (12.9%) | 240 (7.3%) | 9 (10.0%) | 142 (8.3%) | 26 (11.7%) | 382 (7.7%) |
| | 4 | 10 (7.6%) | 125 (3.8%) | 12 (13.3%) | 312 (18.2%) | 22 (9.9%) | 437 (8.8%) |
| | 5 | <=5 (3.0%) | 40 (1.2%) | 14 (15.6%) | 194 (11.3%) | 18 (8.1%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 16.81 ± 24.92 | 9.06 ± 11.67 | 24.62 ± 31.52 | 22.88 ± 28.95 | 19.98 ± 27.98 | 13.81 ± 20.51 |
| | Median (IQR) | 9 (6-15) | 6 (5-9) | 17 (9-25) | 13 (8-26) | 11 (6-21) | 8 (5-14) |
| 30 day readmission | 0 | 121 (91.7%) | 3072 (94.0%) | 85 (94.4%) | 1579 (92.2%) | 206 (92.8%) | 4651 (93.4%) |
| | 1 | 9 (6.8%) | 183 (5.6%) | <=5 (4.4%) | 124 (7.2%) | 13 (5.9%) | 307 (6.2%) |
| | 2 | <=5 (1.5%) | 12 (0.4%) | <=5 (1.1%) | 10 (0.6%) | <=5 (1.4%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

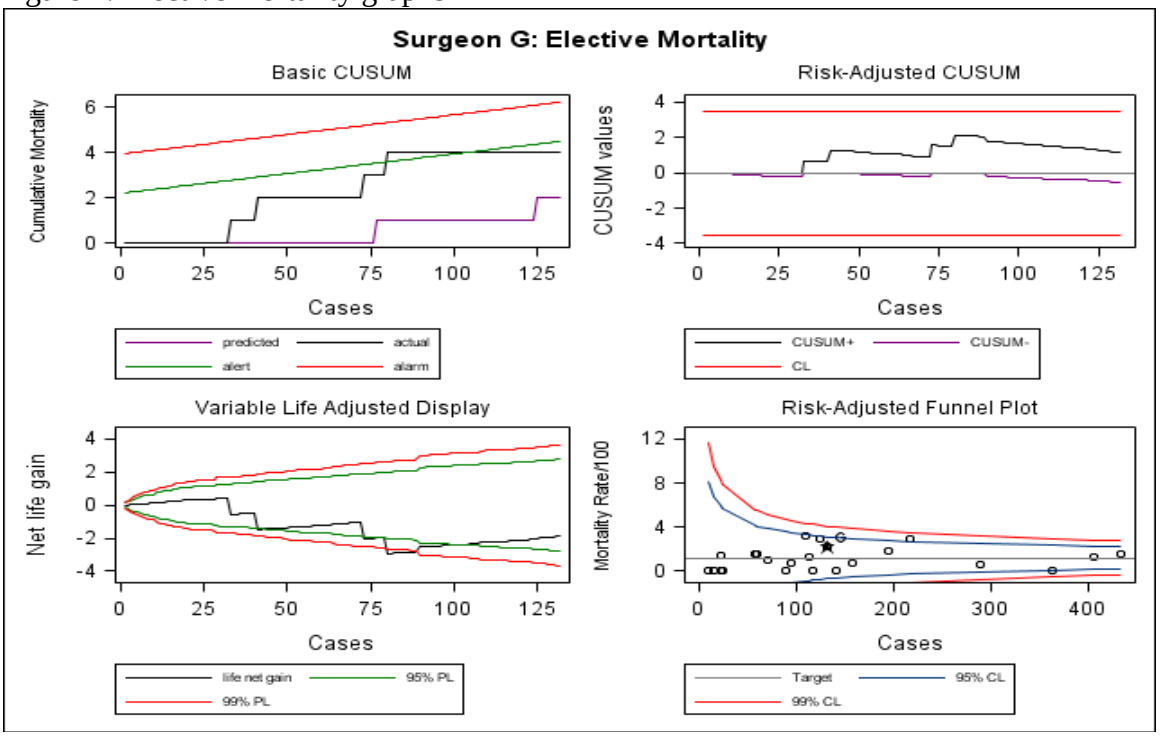



Figure 2: Elective morbidity graphs

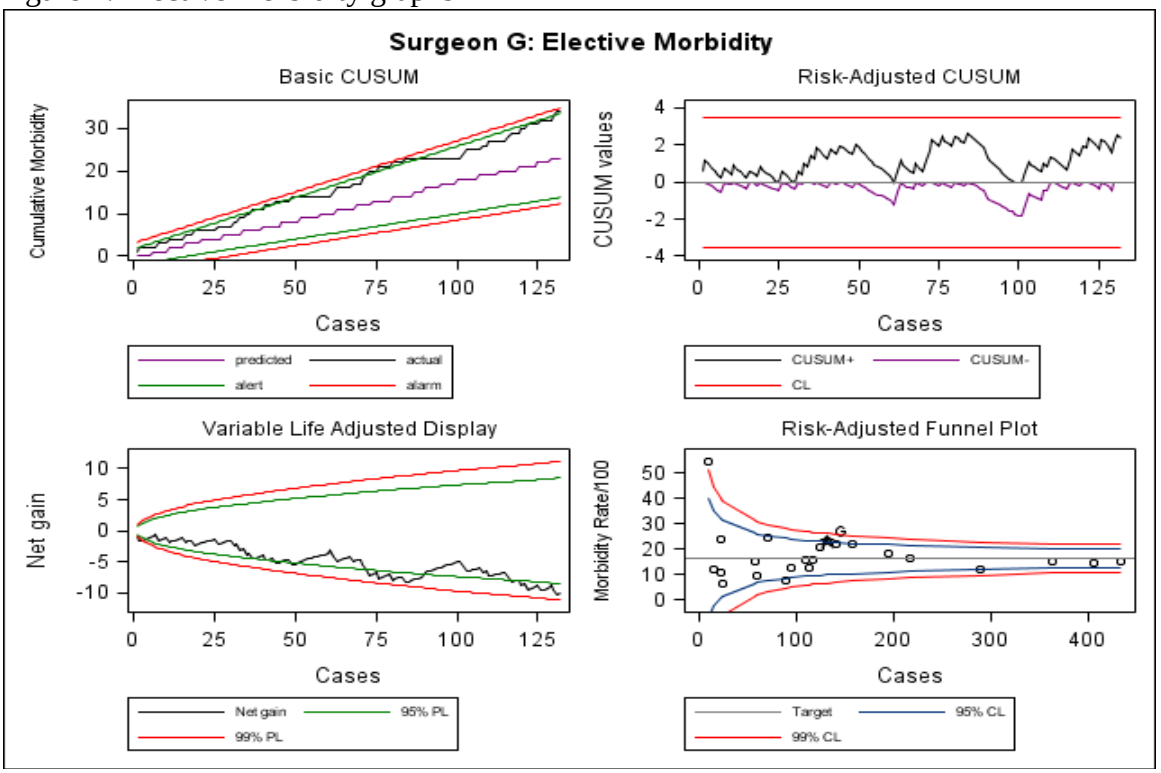


Figure 3: Emergent mortality graphs

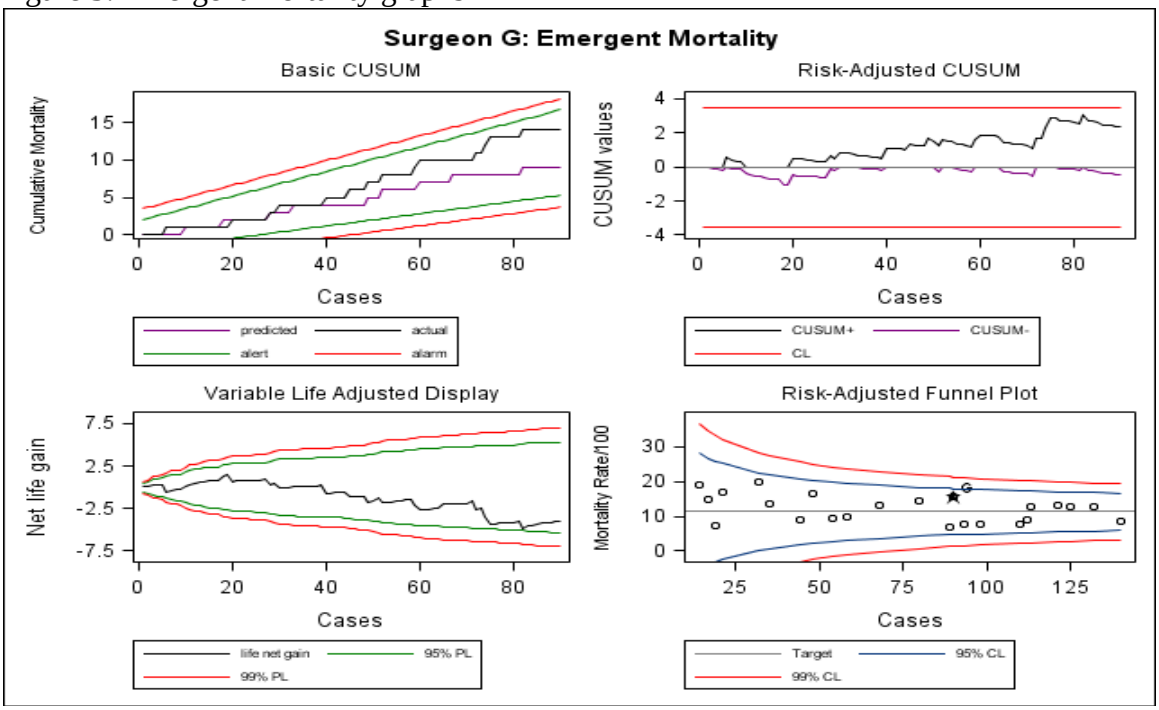
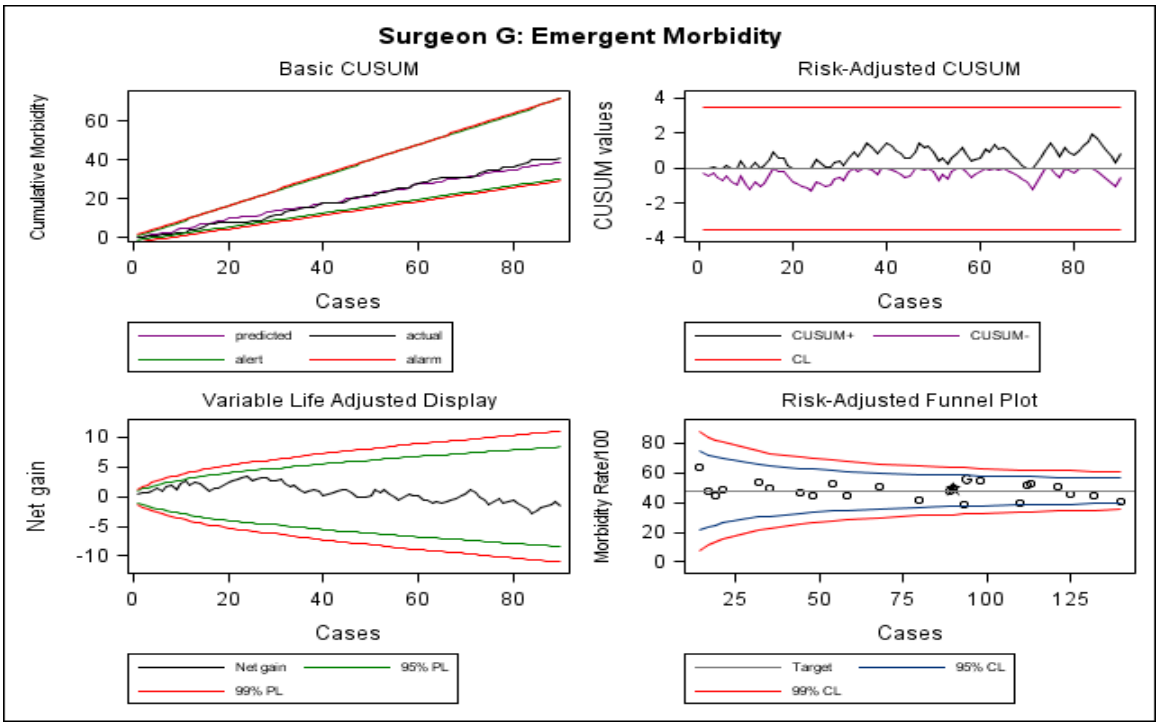



Figure 4: Emergent morbidity graphs



**Surgeon H Performance**

Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon H | Total | Surgeon H | Total | Surgeon H | Total |
| | | N=118 | N=3267 | N=93 | N=1713 | N=211 | N=4980 |
| Age | Mean ± SD | 62.75 ± 16.96 | 61.49 ± 15.97 | 61.53 ± 18.74 | 63.33 ± 17.34 | 62.21 ± 17.74 | 62.12 ± 16.47 |
| | Median (IQR) | 64 (52-78) | 64 (52-74) | 68 (48-76) | 66 (52-77) | 66 (51-76) | 64 (52-75) |
| Sex | F | 61 (51.7%) | 1423 (43.6%) | 48 (51.6%) | 888 (51.8%) | 109 (51.7%) | 2311 (46.4%) |
| | M | 57 (48.3%) | 1844 (56.4%) | 45 (48.4%) | 825 (48.2%) | 102 (48.3%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 5.40 ± 6.29 | 5.82 ± 6.53 | 7.34 ± 7.92 | 7.67 ± 7.87 | 6.26 ± 7.10 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-9) | 4 (0-9) | 4 (0-15) | 5 (0-16) | 4 (0-12) | 4 (0-11) |
| Diagnosis | Cancer | 68 (57.6%) | 2038 (62.4%) | 26 (28.0%) | 638 (37.2%) | 94 (44.5%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (2.5%) | 182 (5.6%) | 10 (10.8%) | 241 (14.1%) | 13 (6.2%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (4.2%) | 151 (4.6%) | 8 (8.6%) | 82 (4.8%) | 13 (6.2%) | 233 (4.7%) |
| | Crohn's | 8 (6.8%) | 175 (5.4%) | 13 (14.0%) | 98 (5.7%) | 21 (10.0%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (1.1%) | 45 (2.6%) | <=5 (0.5%) | 49 (1.0%) |
| | Ischemic gut | 0 (0.0%) | <=5 (0.1%) | 12 (12.9%) | 122 (7.1%) | 12 (5.7%) | 124 (2.5%) |
| | Polyp | <=5 (0.8%) | 8 (0.2%) | 0 (0.0%) | 0 (0.0%) | <=5 (0.5%) | 8 (0.2%) |
| | Stoma related | 19 (16.1%) | 522 (16.0%) | 0 (0.0%) | 29 (1.7%) | 19 (9.0%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (3.4%) | 19 (0.6%) | 7 (7.5%) | 137 (8.0%) | 11 (5.2%) | 156 (3.1%) |
| | Hernia | <=5 (1.7%) | <=5 (0.1%) | 0 (0.0%) | 10 (0.6%) | <=5 (0.9%) | 13 (0.3%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (2.2%) | 16 (0.9%) | <=5 (0.9%) | 16 (0.3%) |
| | Other | 8 (6.8%) | 160 (4.9%) | 14 (15.1%) | 292 (17.0%) | 22 (10.4%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 11 (9.3%) | 912 (27.9%) | <=5 (3.2%) | 143 (8.3%) | 14 (6.6%) | 1055 (21.2%) |
| | Open | 107 (90.7%) | 2355 (72.1%) | 90 (96.8%) | 1570 (91.7%) | 197 (93.4%) | 3925 (78.8%) |
| Resection type | APR | <=5 (3.4%) | 291 (8.9%) | <=5 (1.1%) | 17 (1.0%) | <=5 (2.4%) | 308 (6.2%) |
| | AR | 17 (14.4%) | 845 (25.9%) | 6 (6.5%) | 141 (8.2%) | 23 (10.9%) | 986 (19.8%) |
| | bypass | 12 (10.2%) | 162 (5.0%) | 14 (15.1%) | 321 (18.7%) | 26 (12.3%) | 483 (9.7%) |
| | reversal | 11 (9.3%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | 11 (5.2%) | 515 (10.3%) |
| | segmental | 72 (61.0%) | 1404 (43.0%) | 65 (69.9%) | 1113 (65.0%) | 137 (64.9%) | 2517 (50.5%) |
| | total | <=5 (1.7%) | 70 (2.1%) | 7 (7.5%) | 101 (5.9%) | 9 (4.3%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 237.49 ± 109.24 | 226.37 ± 96.11 | 185.59 ± 71.14 | 172.77 ± 72.97 | 214.62 ± 97.64 | 207.94 ± 92.40 |
| | Median (IQR) | 219 (171-270) | 213 (160-277) | 166 (140-210) | 160 (125-205) | 193 (153-243) | 191 (143-255) |
| Stoma | | 28 (23.7%) | 698 (21.4%) | 56 (60.2%) | 869 (50.7%) | 84 (39.8%) | 1567 (31.5%) |
| Surgery | Colon | 97 (82.2%) | 2131 (65.2%) | 86 (92.5%) | 1555 (90.8%) | 183 (86.7%) | 3686 (74.0%) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Rectal | 21 (17.8%) | 1136 (34.8%) | 7 (7.5%) | 158 (9.2%) | 28 (13.3%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon H | Total | Surgeon H | Total | Surgeon H | Total |
| | | N=118 | N=3267 | N=93 | N=1713 | N=211 | N=4980 |
| 30 day postoperative complication index* | 0 | 99 (83.9%) | 2722 (83.3%) | 55 (59.1%) | 864 (50.4%) | 154 (73.0%) | 3586 (72.0%) |
| | 2 | <=5 (1.7%) | 140 (4.3%) | <=5 (5.4%) | 201 (11.7%) | 7 (3.3%) | 341 (6.8%) |
| | 3 | 12 (10.2%) | 240 (7.3%) | 9 (9.7%) | 142 (8.3%) | 21 (10.0%) | 382 (7.7%) |
| | 4 | <=5 (4.2%) | 125 (3.8%) | 16 (17.2%) | 312 (18.2%) | 21 (10.0%) | 437 (8.8%) |
| | 5 | 0 (0.0%) | 40 (1.2%) | 8 (8.6%) | 194 (11.3%) | 8 (3.8%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 9.24 ± 10.45 | 9.06 ± 11.67 | 22.20 ± 27.56 | 22.88 ± 28.95 | 14.95 ± 20.86 | 13.81 ± 20.51 |
| | Median (IQR) | 6 (5-9) | 6 (5-9) | 13 (8-24) | 13 (8-26) | 8 (6-16) | 8 (5-14) |
| 30 day readmission | 0 | 112 (94.9%) | 3072 (94.0%) | 87 (93.5%) | 1579 (92.2%) | 199 (94.3%) | 4651 (93.4%) |
| | 1 | 6 (5.1%) | 183 (5.6%) | 6 (6.5%) | 124 (7.2%) | 12 (5.7%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

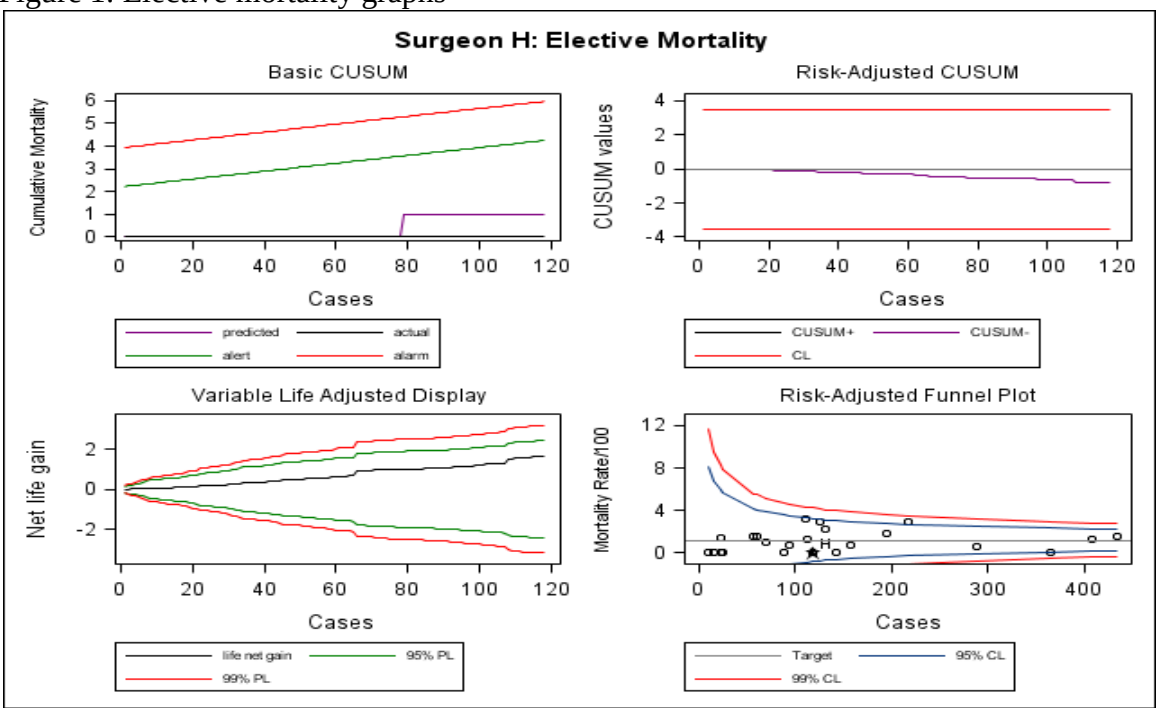



Figure 2: Elective morbidity graphs

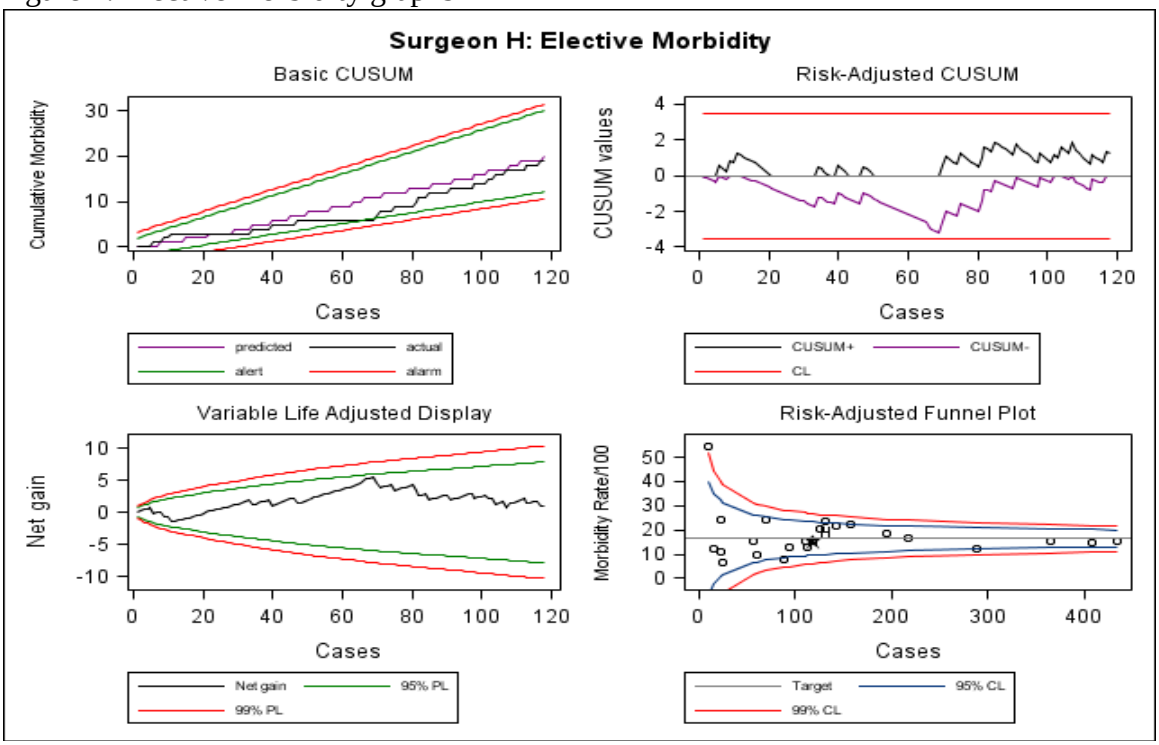


Figure 3: Emergent mortality graphs

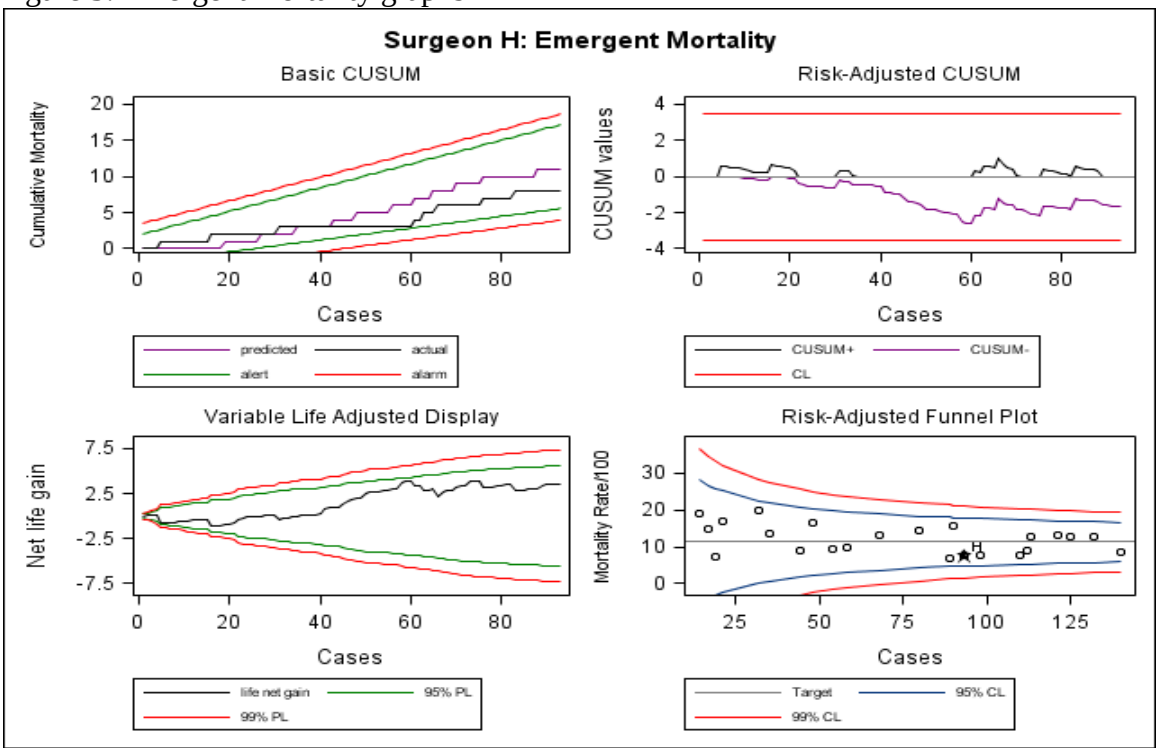



Figure 4: Emergent morbidity graphs

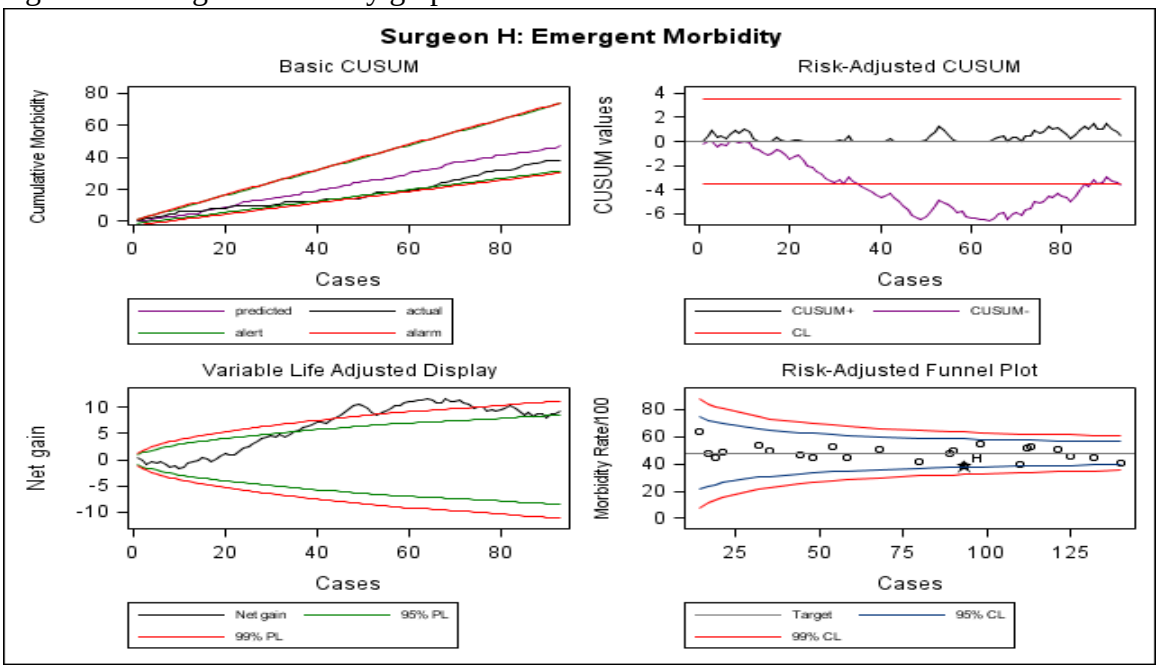


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon I | Total | Surgeon I | Total | Surgeon I | Total |
| | | N=407 | N=3267 | N=35 | N=1713 | N=442 | N=4980 |
| Age | Mean ± SD | 62.43 ± 14.88 | 61.49 ± 15.97 | 59.26 ± 16.81 | 63.33 ± 17.34 | 62.18 ± 15.04 | 62.12 ± 16.47 |
| | Median (IQR) | 65 (54-73) | 64 (52-74) | 57 (46-76) | 66 (52-77) | 65 (53-73) | 64 (52-75) |
| Sex | F | 135 (33.2%) | 1423 (43.6%) | 17 (48.6%) | 888 (51.8%) | 152 (34.4%) | 2311 (46.4%) |
| | M | 272 (66.8%) | 1844 (56.4%) | 18 (51.4%) | 825 (48.2%) | 290 (65.6%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 6.95 ± 6.64 | 5.82 ± 6.53 | 9.14 ± 7.37 | 7.67 ± 7.87 | 7.12 ± 6.72 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (4-10) | 4 (0-9) | 9 (4-16) | 5 (0-16) | 4 (4-11) | 4 (0-11) |
| Diagnosis | Cancer | 338 (83.0%) | 2038 (62.4%) | 20 (57.1%) | 638 (37.2%) | 358 (81.0%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (0.5%) | 182 (5.6%) | 0 (0.0%) | 241 (14.1%) | <=5 (0.5%) | 423 (8.5%) |
| | Ulcerative colitis | 15 (3.7%) | 151 (4.6%) | <=5 (5.7%) | 82 (4.8%) | 17 (3.8%) | 233 (4.7%) |
| | Crohn's | <=5 (1.0%) | 175 (5.4%) | <=5 (5.7%) | 98 (5.7%) | 6 (1.4%) | 273 (5.5%) |
| | Infectious colitis | <=5 (0.2%) | <=5 (0.1%) | 0 (0.0%) | 45 (2.6%) | <=5 (0.2%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (5.7%) | 122 (7.1%) | <=5 (0.5%) | 124 (2.5%) |
| | Stoma related | 35 (8.6%) | 522 (16.0%) | <=5 (2.9%) | 29 (1.7%) | 36 (8.1%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (0.2%) | 19 (0.6%) | <=5 (11.4%) | 137 (8.0%) | <=5 (1.1%) | 156 (3.1%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (2.9%) | 16 (0.9%) | <=5 (0.2%) | 16 (0.3%) |
| | Other | 11 (2.7%) | 160 (4.9%) | <=5 (8.6%) | 292 (17.0%) | 14 (3.2%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 47 (11.5%) | 912 (27.9%) | 7 (20.0%) | 143 (8.3%) | 54 (12.2%) | 1055 (21.2%) |
| | Open | 360 (88.5%) | 2355 (72.1%) | 28 (80.0%) | 1570 (91.7%) | 388 (87.8%) | 3925 (78.8%) |
| Resection type | APR | 63 (15.5%) | 291 (8.9%) | <=5 (14.3%) | 17 (1.0%) | 68 (15.4%) | 308 (6.2%) |
| | AR | 162 (39.8%) | 845 (25.9%) | <=5 (8.6%) | 141 (8.2%) | 165 (37.3%) | 986 (19.8%) |
| | bypass | 13 (3.2%) | 162 (5.0%) | 7 (20.0%) | 321 (18.7%) | 20 (4.5%) | 483 (9.7%) |
| | reversal | 36 (8.8%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | 36 (8.1%) | 515 (10.3%) |
| | segmental | 126 (31.0%) | 1404 (43.0%) | 18 (51.4%) | 1113 (65.0%) | 144 (32.6%) | 2517 (50.5%) |
| | total | 7 (1.7%) | 70 (2.1%) | <=5 (5.7%) | 101 (5.9%) | 9 (2.0%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 194.06 ± 67.99 | 226.37 ± 96.11 | 168.31 ± 52.52 | 172.77 ± 72.97 | 192.02 ± 67.21 | 207.94 ± 92.40 |
| | Median (IQR) | 189 (152-233) | 213 (160-277) | 156 (133-205) | 160 (125-205) | 187 (149-230) | 191 (143-255) |
| Stoma | | 117 (28.7%) | 698 (21.4%) | 18 (51.4%) | 869 (50.7%) | 135 (30.5%) | 1567 (31.5%) |
| Surgery | Colon | 182 (44.7%) | 2131 (65.2%) | 27 (77.1%) | 1555 (90.8%) | 209 (47.3%) | 3686 (74.0%) |
| | Rectal | 225 (55.3%) | 1136 (34.8%) | 8 (22.9%) | 158 (9.2%) | 233 (52.7%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon I | Total | Surgeon I | Total | Surgeon I | Total |
| | | N=407 | N=3267 | N=35 | N=1713 | N=442 | N=4980 |
| 30 day postoperative complication index* | 0 | 346 (85.0%) | 2722 (83.3%) | 20 (57.1%) | 864 (50.4%) | 366 (82.8%) | 3586 (72.0%) |
| | 2 | 13 (3.2%) | 140 (4.3%) | <=5 (14.3%) | 201 (11.7%) | 18 (4.1%) | 341 (6.8%) |
| | 3 | 27 (6.6%) | 240 (7.3%) | <=5 (5.7%) | 142 (8.3%) | 29 (6.6%) | 382 (7.7%) |
| | 4 | 16 (3.9%) | 125 (3.8%) | <=5 (11.4%) | 312 (18.2%) | 20 (4.5%) | 437 (8.8%) |
| | 5 | <=5 (1.2%) | 40 (1.2%) | <=5 (11.4%) | 194 (11.3%) | 9 (2.0%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 8.54 ± 6.69 | 9.06 ± 11.67 | 22.17 ± 25.07 | 22.88 ± 28.95 | 9.62 ± 10.16 | 13.81 ± 20.51 |
| | Median (IQR) | 7 (6-9) | 6 (5-9) | 11 (6-28) | 13 (8-26) | 7 (6-10) | 8 (5-14) |
| 30 day readmission | 0 | 392 (96.3%) | 3072 (94.0%) | 33 (94.3%) | 1579 (92.2%) | 425 (96.2%) | 4651 (93.4%) |
| | 1 | 14 (3.4%) | 183 (5.6%) | <=5 (5.7%) | 124 (7.2%) | 16 (3.6%) | 307 (6.2%) |
| | 2 | <=5 (0.2%) | 12 (0.4%) | 0 (0.0%) | 10 (0.6%) | <=5 (0.2%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

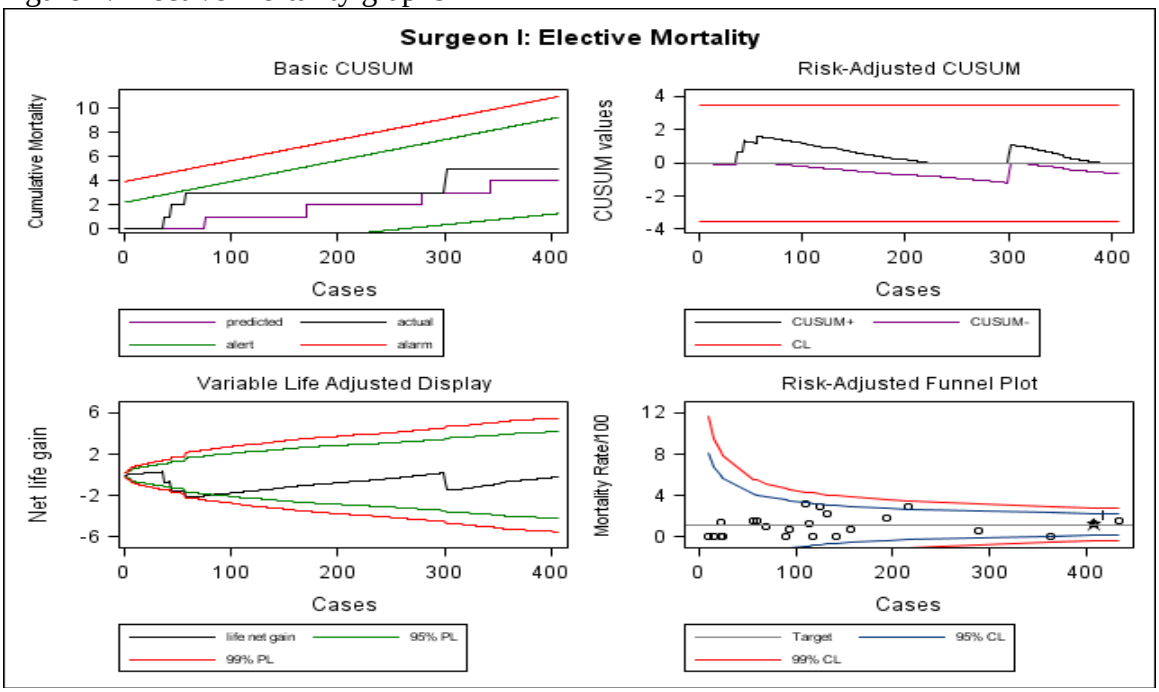



Figure 2: Elective morbidity graphs

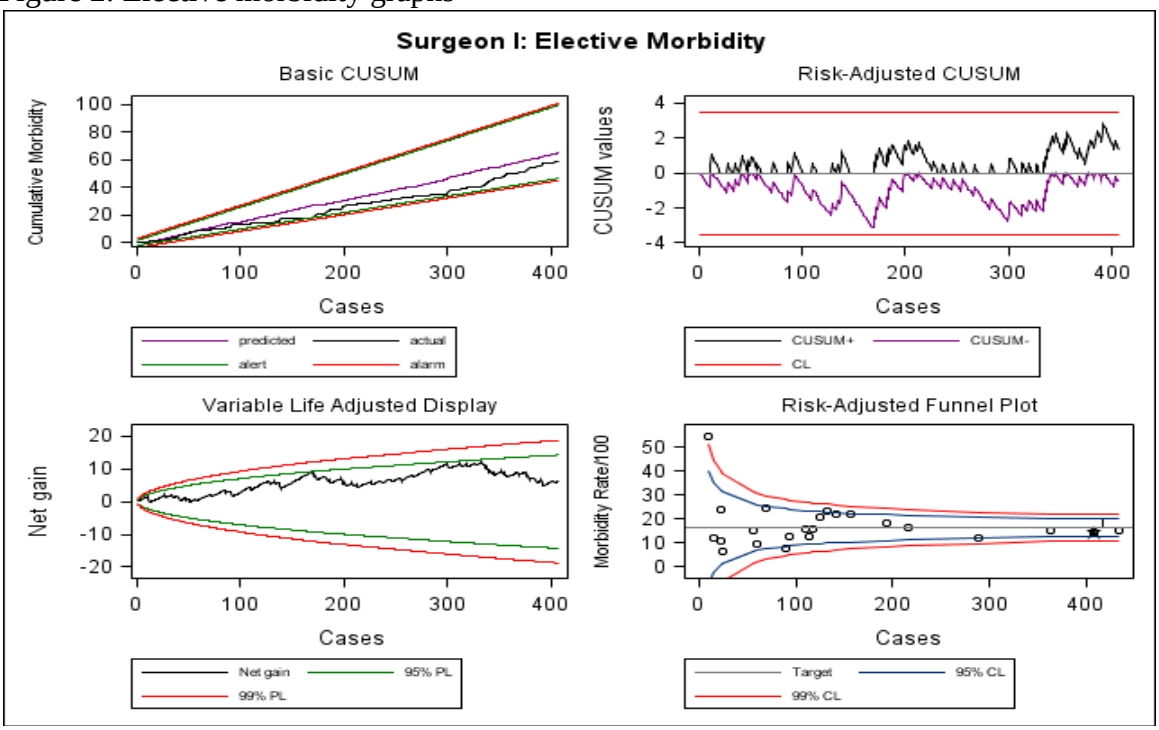


Figure 3: Emergent mortality graphs

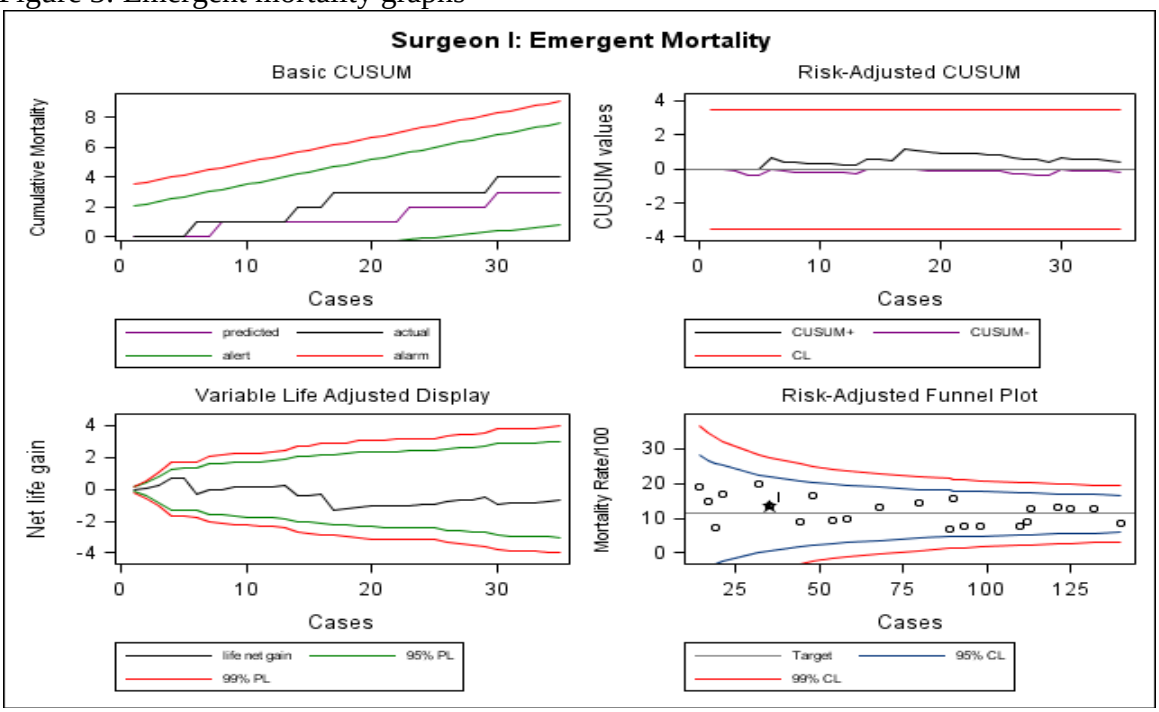



Figure 4: Emergent morbidity graphs

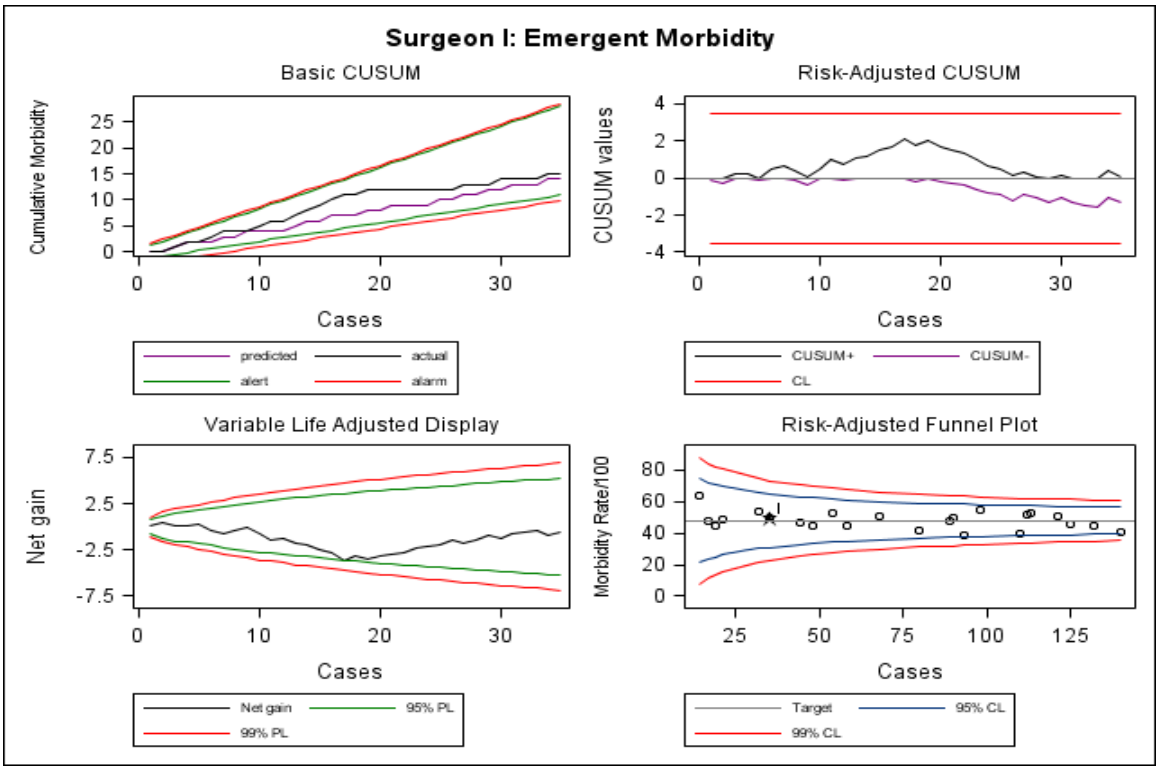


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon J | Total | Surgeon J | Total | Surgeon J | Total |
| | | N=89 | N=3267 | N=58 | N=1713 | N=147 | N=4980 |
| Age | Mean ± SD | 65.96 ± 14.97 | 61.49 ± 15.97 | 65.72 ± 16.64 | 63.33 ± 17.34 | 65.86 ± 15.60 | 62.12 ± 16.47 |
| | Median (IQR) | 69 (57-76) | 64 (52-74) | 70 (54-78) | 66 (52-77) | 69 (56-77) | 64 (52-75) |
| Sex | F | 39 (43.8%) | 1423 (43.6%) | 32 (55.2%) | 888 (51.8%) | 71 (48.3%) | 2311 (46.4%) |
| | M | 50 (56.2%) | 1844 (56.4%) | 26 (44.8%) | 825 (48.2%) | 76 (51.7%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 6.21 ± 6.67 | 5.82 ± 6.53 | 7.21 ± 7.55 | 7.67 ± 7.87 | 6.61 ± 7.02 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-11) | 4 (0-9) | 5 (0-10) | 5 (0-16) | 4 (0-11) | 4 (0-11) |
| Diagnosis | Cancer | 64 (71.9%) | 2038 (62.4%) | 18 (31.0%) | 638 (37.2%) | 82 (55.8%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (4.5%) | 182 (5.6%) | 9 (15.5%) | 241 (14.1%) | 13 (8.8%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (1.1%) | 151 (4.6%) | 6 (10.3%) | 82 (4.8%) | 7 (4.8%) | 233 (4.7%) |
| | Crohn's | 7 (7.9%) | 175 (5.4%) | <=5 (1.7%) | 98 (5.7%) | 8 (5.4%) | 273 (5.5%) |
| | Infectious colitis | <=5 (1.1%) | <=5 (0.1%) | <=5 (3.4%) | 45 (2.6%) | <=5 (2.0%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (5.2%) | 122 (7.1%) | <=5 (2.0%) | 124 (2.5%) |
| | Stoma related | 7 (7.9%) | 522 (16.0%) | <=5 (1.7%) | 29 (1.7%) | 8 (5.4%) | 551 (11.1%) |
| | Polyp | <=5 (1.1%) | 8 (0.2%) | 0 (0.0%) | 0 (0.0%) | <=5 (0.7%) | 8 (0.2%) |
| | Volvulus/Bowel obstruction | <=5 (2.2%) | 19 (0.6%) | <=5 (8.6%) | 137 (8.0%) | 7 (4.8%) | 156 (3.1%) |
| | Hernia | 0 (0.0%) | <=5 (0.1%) | <=5 (1.7%) | 10 (0.6%) | <=5 (0.7%) | 13 (0.3%) |
| | Other | <=5 (2.2%) | 160 (4.9%) | 12 (20.7%) | 292 (17.0%) | 14 (9.5%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 12 (13.5%) | 912 (27.9%) | <=5 (1.7%) | 143 (8.3%) | 13 (8.8%) | 1055 (21.2%) |
| | Open | 77 (86.5%) | 2355 (72.1%) | 57 (98.3%) | 1570 (91.7%) | 134 (91.2%) | 3925 (78.8%) |
| Resection type | AR | 16 (18.0%) | 845 (25.9%) | <=5 (6.9%) | 141 (8.2%) | 20 (13.6%) | 986 (19.8%) |
| | bypass | <=5 (2.2%) | 162 (5.0%) | 10 (17.2%) | 321 | 12 (8.2%) | 483 (9.7%) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | (18.7%) | | |
| | reversal | 8 (9.0%) | 495 (15.2%) | <=5 (1.7%) | 20 (1.2%) | 9 (6.1%) | 515 (10.3%) |
| | segmental | 63 (70.8%) | 1404 (43.0%) | 37 (63.8%) | 1113 (65.0%) | 100 (68.0%) | 2517 (50.5%) |
| | total | 0 (0.0%) | 70 (2.1%) | 6 (10.3%) | 101 (5.9%) | 6 (4.1%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 220.96 ± 74.23 | 226.37 ± 96.11 | 183.67 ± 48.46 | 172.77 ± 72.97 | 206.24 ± 67.62 | 207.94 ± 92.40 |
| | Median (IQR) | 205 (174-248) | 213 (160-277) | 183 (155-218) | 160 (125-205) | 192 (169-235) | 191 (143-255) |
| Stoma | | <=5 (5.6%) | 698 (21.4%) | 39 (67.2%) | 869 (50.7%) | 44 (29.9%) | 1567 (31.5%) |
| Surgery | Colon | 73 (82.0%) | 2131 (65.2%) | 54 (93.1%) | 1555 (90.8%) | 127 (86.4%) | 3686 (74.0%) |
| | Rectal | 16 (18.0%) | 1136 (34.8%) | <=5 (6.9%) | 158 (9.2%) | 20 (13.6%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon J | Total | Surgeon J | Total | Surgeon J | Total |
| | | N=89 | N=3267 | N=58 | N=1713 | N=147 | N=4980 |
| 30 day postoperative complication index* | 0 | 82 (92.1%) | 2722 (83.3%) | 27 (46.6%) | 864 (50.4%) | 109 (74.1%) | 3586 (72.0%) |
| | 2 | 0 (0.0%) | 140 (4.3%) | <=5 (6.9%) | 201 (11.7%) | <=5 (2.7%) | 341 (6.8%) |
| | 3 | <=5 (5.6%) | 240 (7.3%) | 8 (13.8%) | 142 (8.3%) | 13 (8.8%) | 382 (7.7%) |
| | 4 | <=5 (2.2%) | 125 (3.8%) | 12 (20.7%) | 312 (18.2%) | 14 (9.5%) | 437 (8.8%) |
| | 5 | 0 (0.0%) | 40 (1.2%) | 7 (12.1%) | 194 (11.3%) | 7 (4.8%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 7.96 ± 6.51 | 9.06 ± 11.67 | 27.16 ± 29.25 | 22.88 ± 28.95 | 15.53 ± 21.17 | 13.81 ± 20.51 |
| | Median (IQR) | 7 (5-9) | 6 (5-9) | 19 (10-31) | 13 (8-26) | 8 (6-17) | 8 (5-14) |
| 30 day readmission | 0 | 83 (93.3%) | 3072 (94.0%) | 50 (86.2%) | 1579 (92.2%) | 133 (90.5%) | 4651 (93.4%) |
| | 1 | 6 (6.7%) | 183 (5.6%) | 7 (12.1%) | 124 (7.2%) | 13 (8.8%) | 307 (6.2%) |
| | 2 | 0 (0.0%) | 12 (0.4%) | <=5 (1.7%) | 10 (0.6%) | <=5 (0.7%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

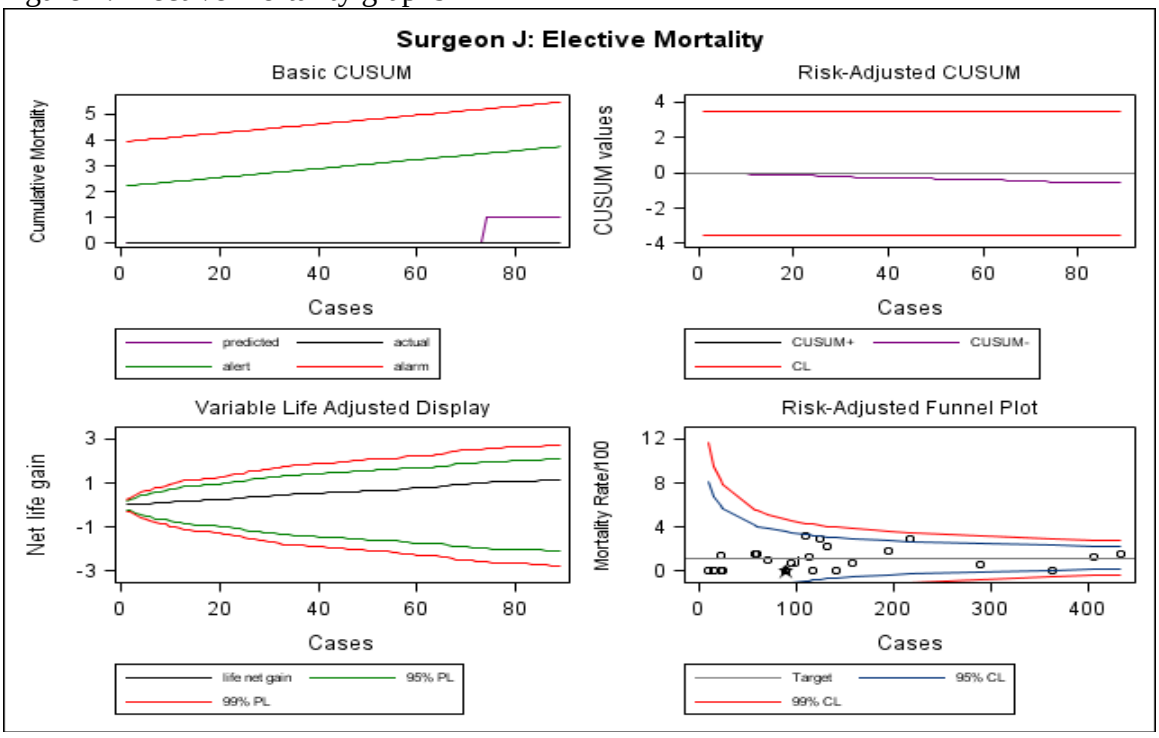



Figure 2: Elective morbidity graphs

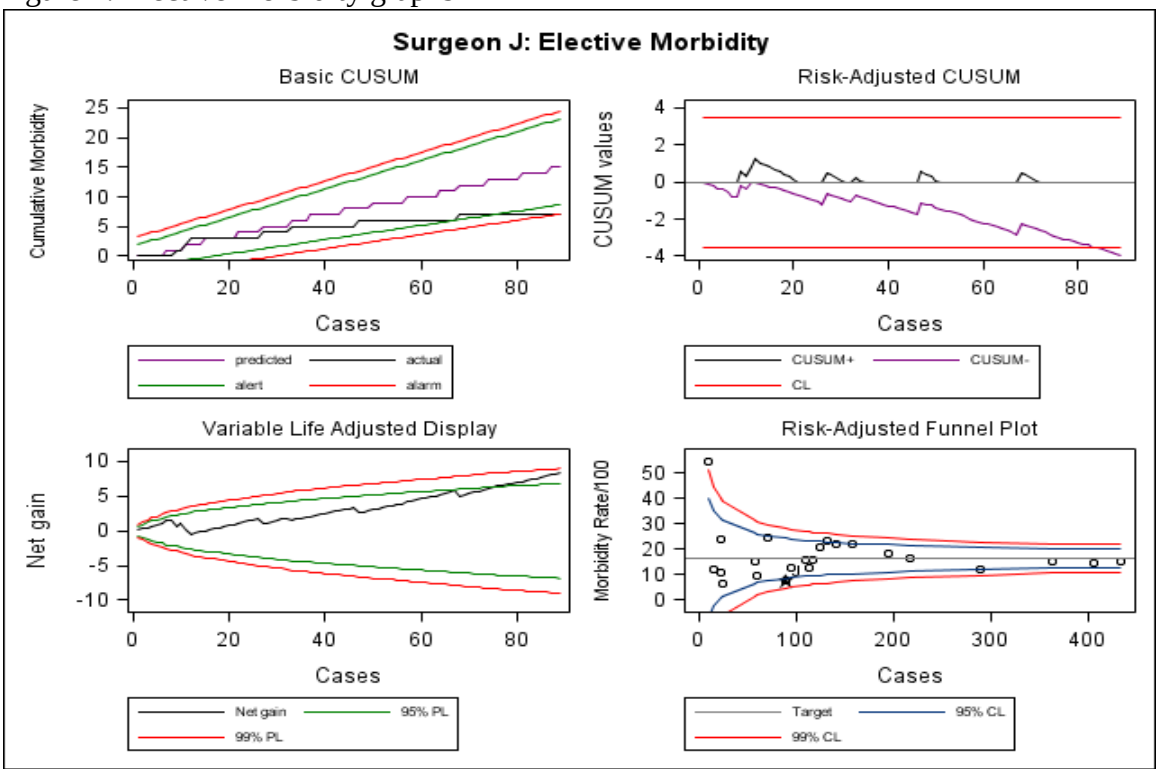


Figure 3: Emergent mortality graphs

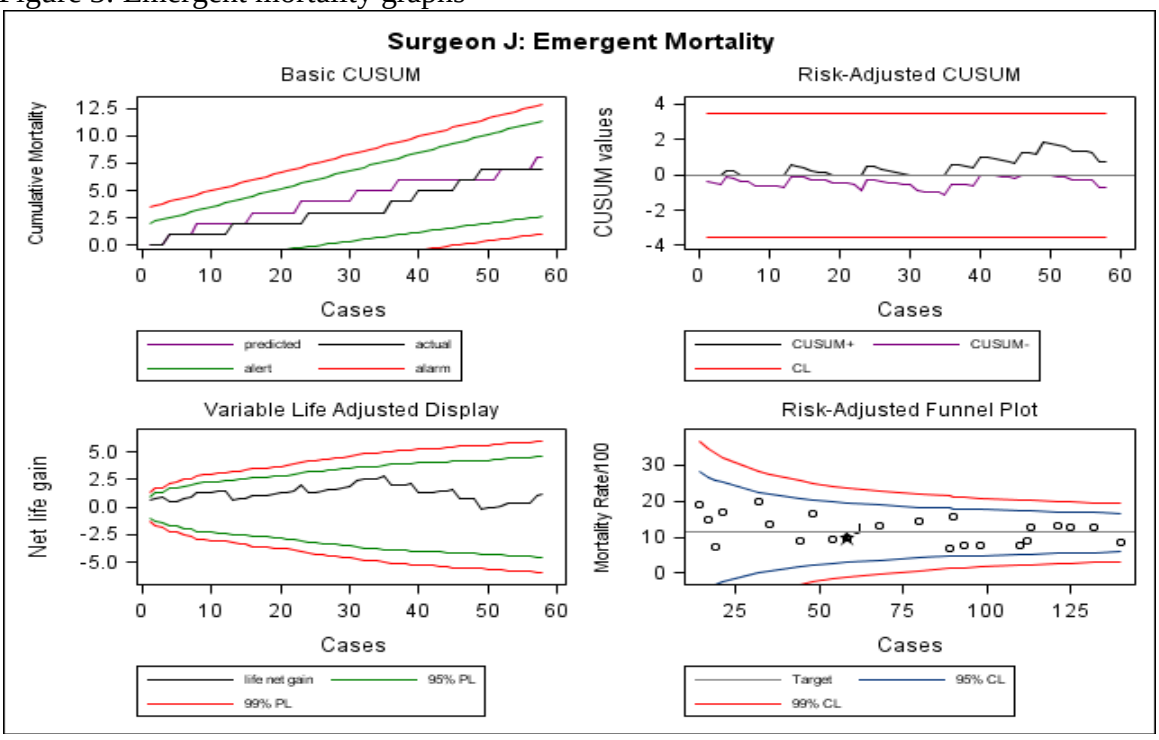



Figure 4: Emergent morbidity graphs

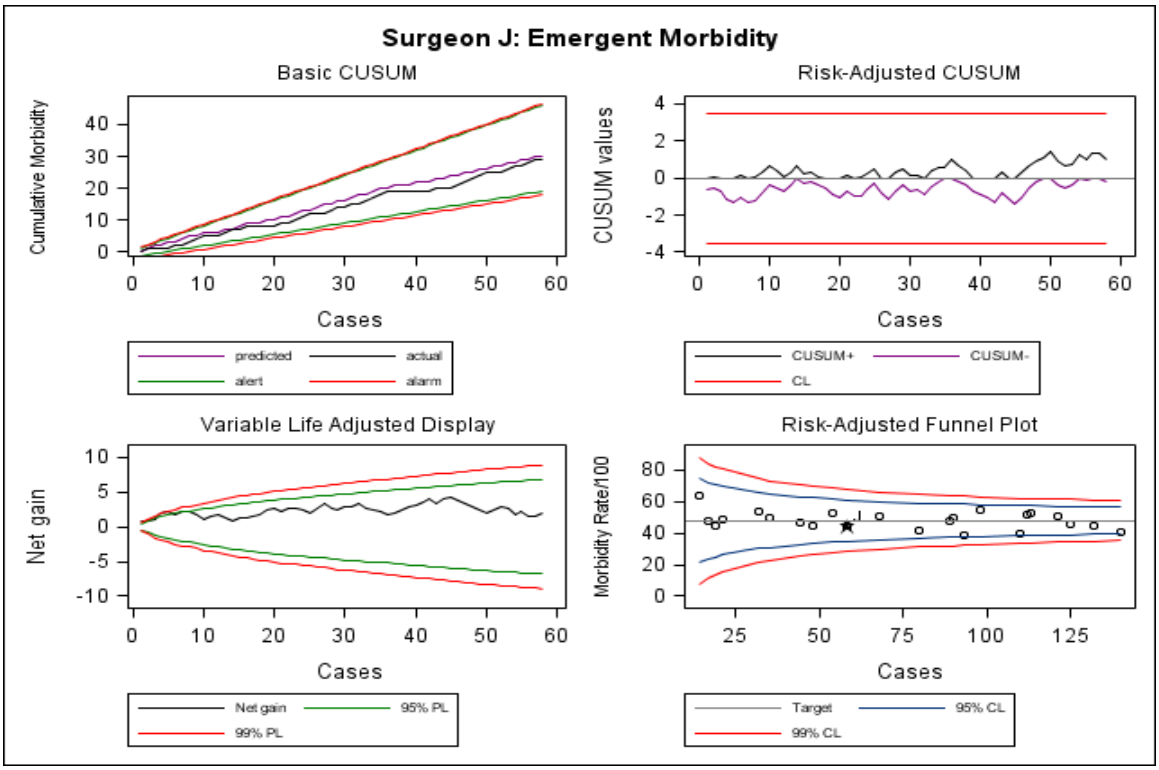


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon K | Total | Surgeon K | Total | Surgeon K | Total |
| | | N=22 | N=3267 | N=54 | N=1713 | N=76 | N=4980 |
| Age | Mean ± SD | 59.00 ± 19.01 | 61.49 ± 15.97 | 66.91 ± 15.39 | 63.33 ± 17.34 | 64.62 ± 16.78 | 62.12 ± 16.47 |
| | Median (IQR) | 60 (44-72) | 64 (52-74) | 69 (59-79) | 66 (52-77) | 68 (55-78) | 64 (52-75) |
| Sex | F | 11 (50.0%) | 1423 (43.6%) | 25 (46.3%) | 888 (51.8%) | 36 (47.4%) | 2311 (46.4%) |
| | M | 11 (50.0%) | 1844 (56.4%) | 29 (53.7%) | 825 (48.2%) | 40 (52.6%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 5.36 ± 7.01 | 5.82 ± 6.53 | 7.24 ± 6.73 | 7.67 ± 7.87 | 6.70 ± 6.82 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-5) | 4 (0-9) | 6 (2-12) | 5 (0-16) | 5 (0-11) | 4 (0-11) |
| Diagnosis | Cancer | 9 (40.9%) | 2038 (62.4%) | 10 (18.5%) | 638 (37.2%) | 19 (25.0%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (9.1%) | 182 (5.6%) | 13 (24.1%) | 241 (14.1%) | 15 (19.7%) | 423 (8.5%) |
| | Ulcerative colitis | 0 (0.0%) | 151 (4.6%) | <=5 (1.9%) | 82 (4.8%) | <=5 (1.3%) | 233 (4.7%) |
| | Crohn's | <=5 (13.6%) | 175 (5.4%) | <=5 (5.6%) | 98 (5.7%) | 6 (7.9%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (1.9%) | 45 (2.6%) | <=5 (1.3%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (5.6%) | 122 (7.1%) | <=5 (3.9%) | 124 (2.5%) |
| | Stoma related | <=5 (18.2%) | 522 (16.0%) | 0 (0.0%) | 29 (1.7%) | <=5 (5.3%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (4.5%) | 19 (0.6%) | 7 (13.0%) | 137 (8.0%) | 8 (10.5%) | 156 (3.1%) |
| | Hernia | 0 (0.0%) | <=5 (0.1%) | <=5 (1.9%) | 10 (0.6%) | <=5 (1.3%) | 13 (0.3%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (1.9%) | 16 (0.9%) | <=5 (1.3%) | 16 (0.3%) |
| | Other | <=5 (13.6%) | 160 (4.9%) | 14 (25.9%) | 292 (17.0%) | 17 (22.4%) | 452 (9.1%) |
| Open/lap | Laparoscopic | <=5 (4.5%) | 912 (27.9%) | <=5 (1.9%) | 143 (8.3%) | <=5 (2.6%) | 1055 (21.2%) |
| | Open | 21 (95.5%) | 2355 (72.1%) | 53 (98.1%) | 1570 (91.7%) | 74 (97.4%) | 3925 (78.8%) |
| Resection type | AR | <=5 (18.2%) | 845 (25.9%) | <=5 (9.3%) | 141 (8.2%) | 9 (11.8%) | 986 (19.8%) |
| | bypass | <=5 (18.2%) | 162 (5.0%) | 7 (13.0%) | 321 (18.7%) | 11 (14.5%) | 483 (9.7%) |
| | reversal | <=5 (9.1%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | <=5 (2.6%) | 515 (10.3%) |
| | segmental | 12 (54.5%) | 1404 (43.0%) | 41 (75.9%) | 1113 (65.0%) | 53 (69.7%) | 2517 (50.5%) |
| | total | 0 (0.0%) | 70 (2.1%) | <=5 (1.9%) | 101 (5.9%) | <=5 (1.3%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 179.95 ± 65.12 | 226.37 ± 96.11 | 168.59 ± 60.60 | 172.77 ± 72.97 | 171.88 ± 61.72 | 207.94 ± 92.40 |
| | Median (IQR) | 181 (135-221) | 213 (160-277) | 161 (129-190) | 160 (125-205) | 166 (130-209) | 191 (143-255) |
| Stoma | | 10 (45.5%) | 698 (21.4%) | 34 (63.0%) | 869 (50.7%) | 44 (57.9%) | 1567 (31.5%) |
| Surgery | Colon | 18 (81.8%) | 2131 (65.2%) | 49 (90.7%) | 1555 (90.8%) | 67 (88.2%) | 3686 (74.0%) |
| | Rectal | <=5 (18.2%) | 1136 (34.8%) | <=5 (9.3%) | 158 (9.2%) | 9 (11.8%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon K | Total | Surgeon K | Total | Surgeon K | Total |
| | | N=22 | N=3267 | N=54 | N=1713 | N=76 | N=4980 |
| 30 day postoperative complication index* | 0 | 19 (86.4%) | 2722 (83.3%) | 20 (37.0%) | 864 (50.4%) | 39 (51.3%) | 3586 (72.0%) |
| | 2 | <=5 (4.5%) | 140 (4.3%) | <=5 (1.9%) | 201 (11.7%) | <=5 (2.6%) | 341 (6.8%) |
| | 3 | 0 (0.0%) | 240 (7.3%) | <=5 (3.7%) | 142 (8.3%) | <=5 (2.6%) | 382 (7.7%) |
| | 4 | <=5 (4.5%) | 125 (3.8%) | 24 (44.4%) | 312 (18.2%) | 25 (32.9%) | 437 (8.8%) |
| | 5 | <=5 (4.5%) | 40 (1.2%) | 7 (13.0%) | 194 (11.3%) | 8 (10.5%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 10.64 ± 8.45 | 9.06 ± 11.67 | 30.91 ± 31.77 | 22.88 ± 28.95 | 25.04 ± 28.62 | 13.81 ± 20.51 |
| | Median (IQR) | 9 (6-10) | 6 (5-9) | 18 (9-33) | 13 (8-26) | 12 (8-31) | 8 (5-14) |
| 30 day readmission | 0 | 20 (90.9%) | 3072 (94.0%) | 52 (96.3%) | 1579 (92.2%) | 72 (94.7%) | 4651 (93.4%) |
| | 1 | <=5 (9.1%) | 183 (5.6%) | <=5 (3.7%) | 124 (7.2%) | <=5 (5.3%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

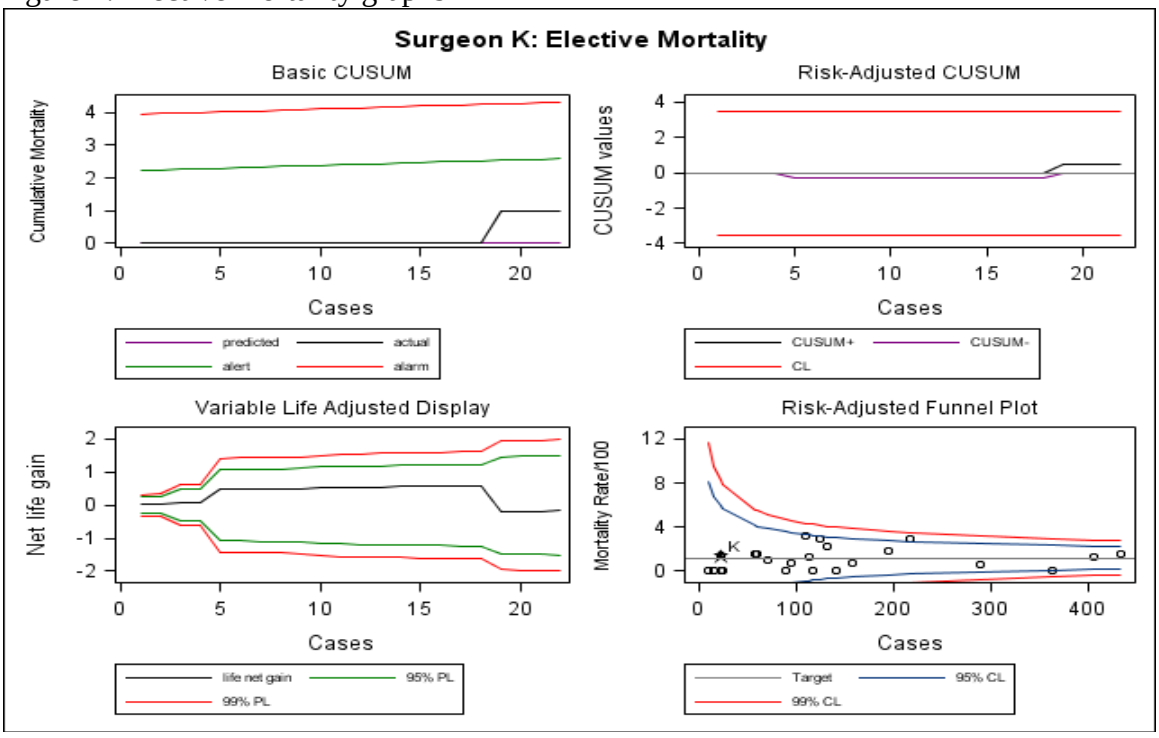



Figure 2: Elective morbidity graphs

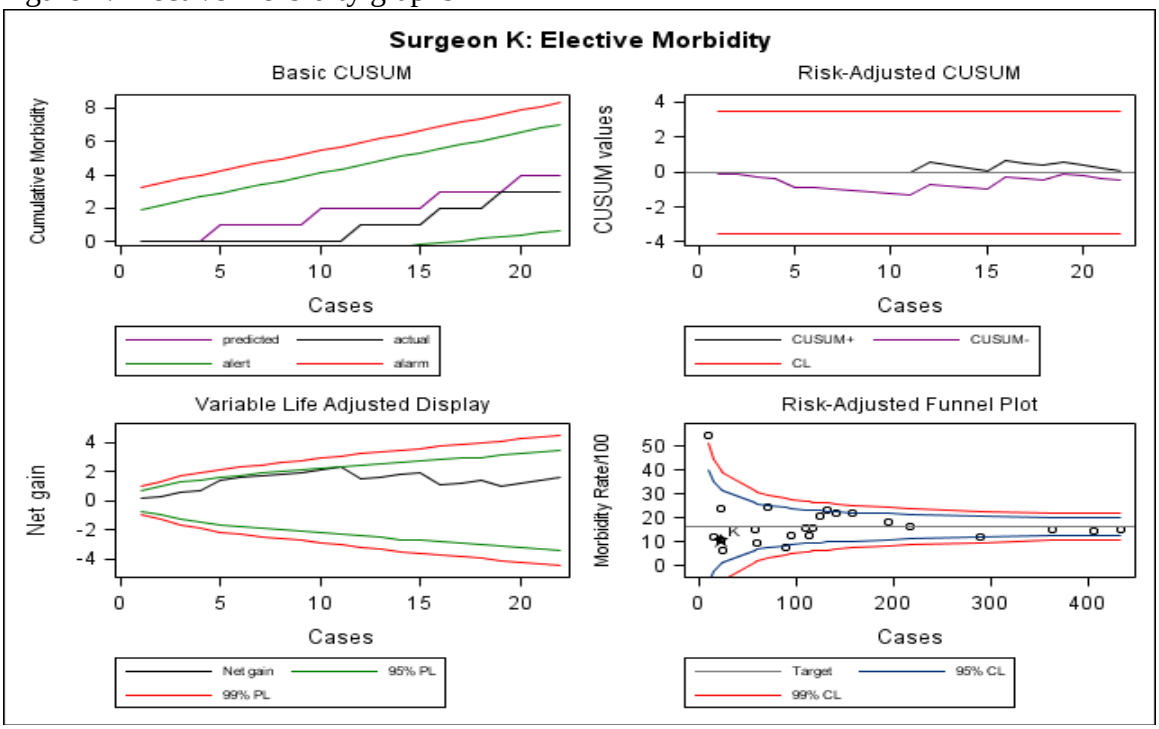


Figure 3: Emergent mortality graphs

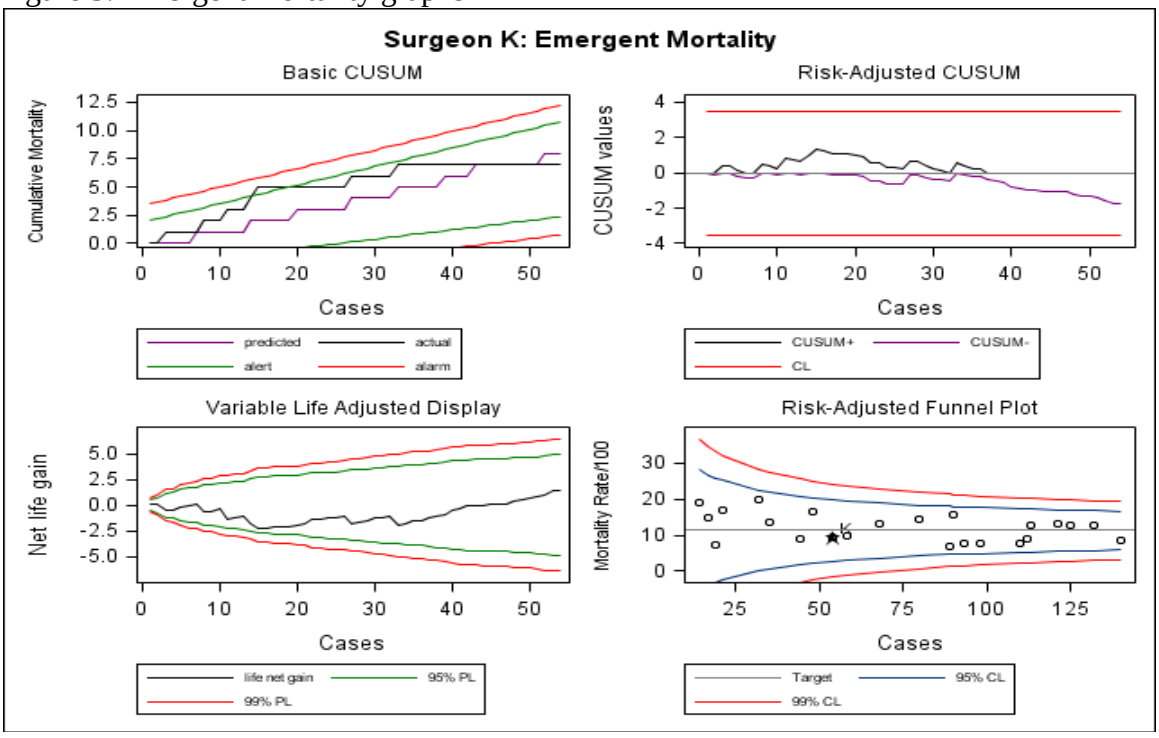
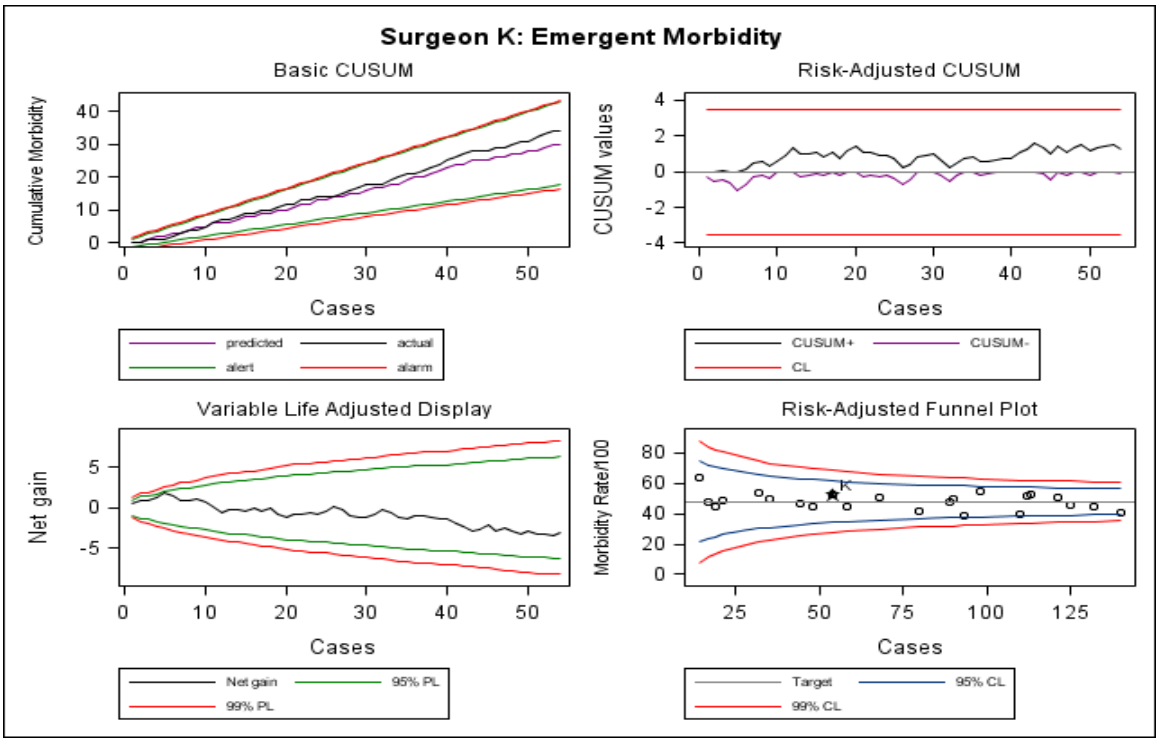



Figure 4: Emergent morbidity graphs



**Surgeon L Performance**

Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon L | Total | Surgeon L | Total | Surgeon L | Total |
| | | N=25 | N=3267 | N=68 | N=1713 | N=93 | N=4980 |
| Age | Mean ± SD | 61.92 ± 15.77 | 61.49 ± 15.97 | 65.03 ± 14.56 | 63.33 ± 17.34 | 64.19 ± 14.88 | 62.12 ± 16.47 |
| | Median (IQR) | 64 (52-77) | 64 (52-74) | 67 (53-77) | 66 (52-77) | 66 (52-77) | 64 (52-75) |
| Sex | F | 13 (52.0%) | 1423 (43.6%) | 35 (51.5%) | 888 (51.8%) | 48 (51.6%) | 2311 (46.4%) |
| | M | 12 (48.0%) | 1844 (56.4%) | 33 (48.5%) | 825 (48.2%) | 45 (48.4%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 4.64 ± 6.30 | 5.82 ± 6.53 | 8.18 ± 7.54 | 7.67 ± 7.87 | 7.23 ± 7.36 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-7) | 4 (0-9) | 5 (2-16) | 5 (0-16) | 5 (0-12) | 4 (0-11) |
| Diagnosis | Cancer | 7 (28.0%) | 2038 (62.4%) | 17 (25.0%) | 638 (37.2%) | 24 (25.8%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (12.0%) | 182 (5.6%) | 11 (16.2%) | 241 (14.1%) | 14 (15.1%) | 423 (8.5%) |
| | Ulcerative colitis | 0 (0.0%) | 151 (4.6%) | <=5 (1.5%) | 82 (4.8%) | <=5 (1.1%) | 233 (4.7%) |
| | Crohn's | 0 (0.0%) | 175 (5.4%) | <=5 (2.9%) | 98 (5.7%) | <=5 (2.2%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (4.4%) | 45 (2.6%) | <=5 (3.2%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 6 (8.8%) | 122 (7.1%) | 6 (6.5%) | 124 (2.5%) |
| | Stoma related | 14 (56.0%) | 522 (16.0%) | <=5 (1.5%) | 29 (1.7%) | 15 (16.1%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | 14 (20.6%) | 137 (8.0%) | 14 (15.1%) | 156 (3.1%) |
| | Hernia | 0 (0.0%) | <=5 (0.1%) | <=5 (1.5%) | 10 (0.6%) | <=5 (1.1%) | 13 (0.3%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (1.5%) | 16 (0.9%) | <=5 (1.1%) | 16 (0.3%) |
| | Other | <=5 (4.0%) | 160 (4.9%) | 11 (16.2%) | 292 (17.0%) | 12 (12.9%) | 452 (9.1%) |
| Open/lap | Open | 25 (100.0%) | 2355 (72.1%) | 68 (100.0%) | 1570 (91.7%) | 93 (100.0%) | 3925 (78.8%) |
| Resection type | AR | 0 (0.0%) | 845 (25.9%) | <=5 (5.9%) | 141 (8.2%) | <=5 (4.3%) | 986 (19.8%) |
| | bypass | 6 (24.0%) | 162 (5.0%) | 17 (25.0%) | 321 (18.7%) | 23 (24.7%) | 483 (9.7%) |
| | reversal | 11 (44.0%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | 11 (11.8%) | 515 (10.3%) |
| | segmental | 8 (32.0%) | 1404 (43.0%) | 43 (63.2%) | 1113 (65.0%) | 51 (54.8%) | 2517 (50.5%) |
| | total | 0 (0.0%) | 70 (2.1%) | <=5 (5.9%) | 101 (5.9%) | <=5 (4.3%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 221.64 ± 89.05 | 226.37 ± 96.11 | 180.72 ± 63.82 | 172.77 ± 72.97 | 191.72 ± 73.26 | 207.94 ± 92.40 |
| | Median (IQR) | 210 (156-278) | 213 (160-277) | 170 (138-219) | 160 (125-205) | 175 (138-239) | 191 (143-255) |
| Stoma | | 6 (24.0%) | 698 (21.4%) | 37 (54.4%) | 869 (50.7%) | 43 (46.2%) | 1567 (31.5%) |
| Surgery | Colon | 25 (100.0%) | 2131 (65.2%) | 64 (94.1%) | 1555 (90.8%) | 89 (95.7%) | 3686 (74.0%) |
| | Rectal | 0 (0.0%) | 1136 (34.8%) | <=5 (5.9%) | 158 (9.2%) | <=5 (4.3%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon L | Total | Surgeon L | Total | Surgeon L | Total |
| | | N=25 | N=3267 | N=68 | N=1713 | N=93 | N=4980 |
| 30 day postoperative complication index* | 0 | 23 (92.0%) | 2722 (83.3%) | 28 (41.2%) | 864 (50.4%) | 51 (54.8%) | 3586 (72.0%) |
| | 2 | <=5 (4.0%) | 140 (4.3%) | 7 (10.3%) | 201 (11.7%) | 8 (8.6%) | 341 (6.8%) |
| | 3 | 0 (0.0%) | 240 (7.3%) | <=5 (7.4%) | 142 (8.3%) | <=5 (5.4%) | 382 (7.7%) |
| | 4 | <=5 (4.0%) | 125 (3.8%) | 18 (26.5%) | 312 (18.2%) | 19 (20.4%) | 437 (8.8%) |
| | 5 | 0 (0.0%) | 40 (1.2%) | 10 (14.7%) | 194 (11.3%) | 10 (10.8%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 9.36 ± 13.10 | 9.06 ± 11.67 | 35.29 ± 59.46 | 22.88 ± 28.95 | 28.32 ± 52.47 | 13.81 ± 20.51 |
| | Median (IQR) | 6 (5-8) | 6 (5-9) | 15 (10-27) | 13 (8-26) | 12 (7-23) | 8 (5-14) |
| 30 day readmission | 0 | 24 (96.0%) | 3072 (94.0%) | 64 (94.1%) | 1579 (92.2%) | 88 (94.6%) | 4651 (93.4%) |
| | 1 | 0 (0.0%) | 183 (5.6%) | <=5 (5.9%) | 124 (7.2%) | <=5 (4.3%) | 307 (6.2%) |
| | 2 | <=5 (4.0%) | 12 (0.4%) | 0 (0.0%) | 10 (0.6%) | <=5 (1.1%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

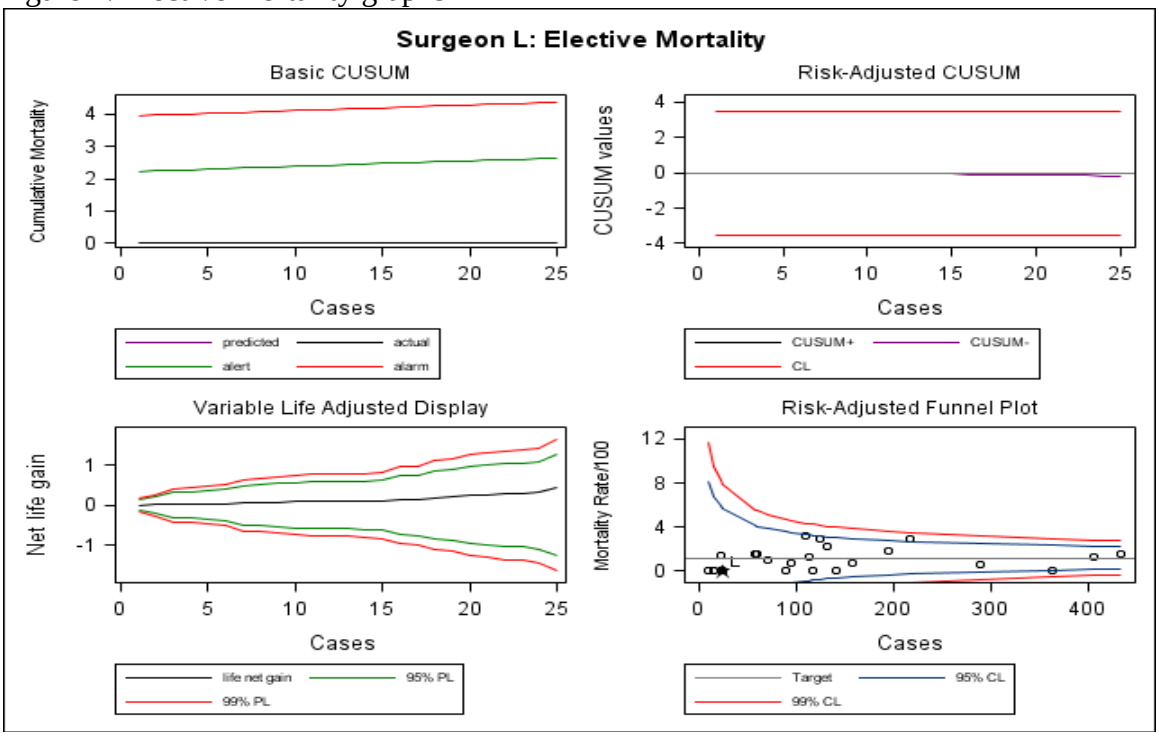



Figure 2: Elective morbidity graphs

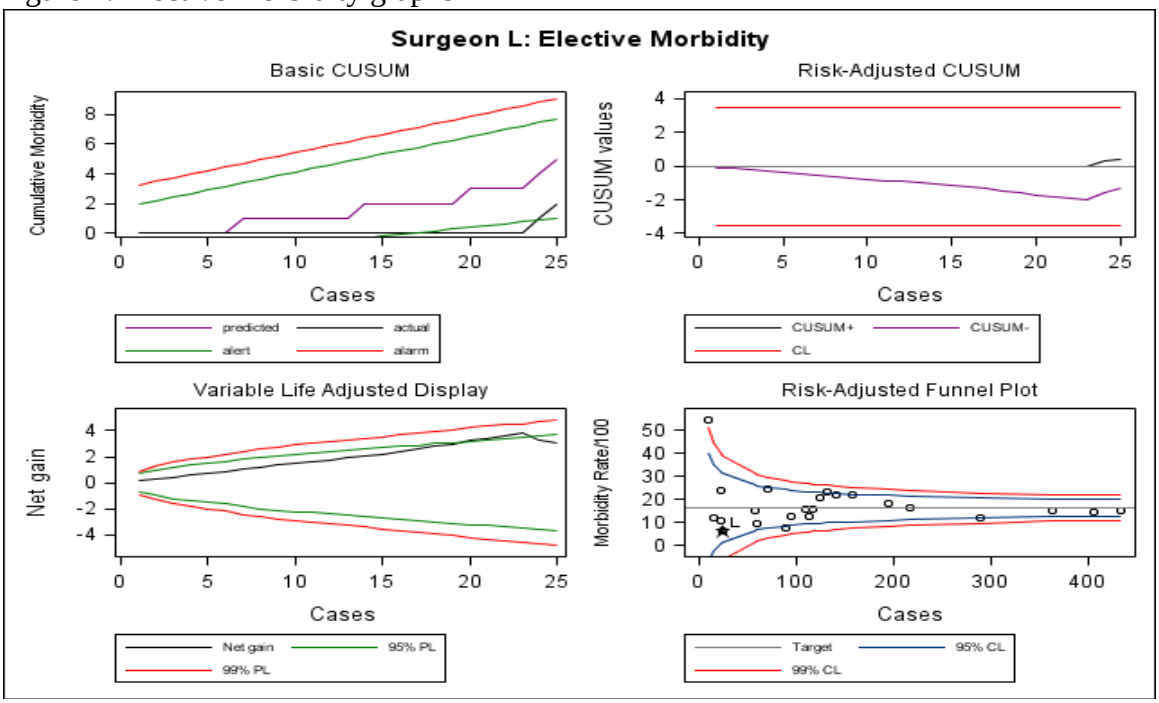


Figure 3: Emergent mortality graphs

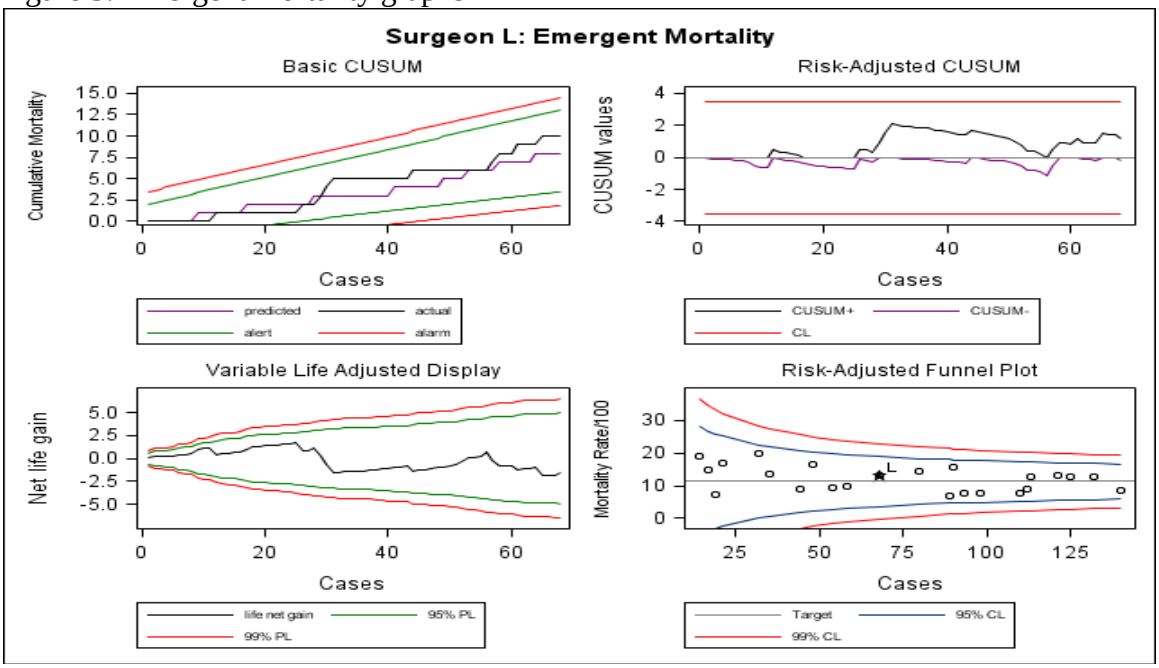



Figure 4: Emergent morbidity graphs

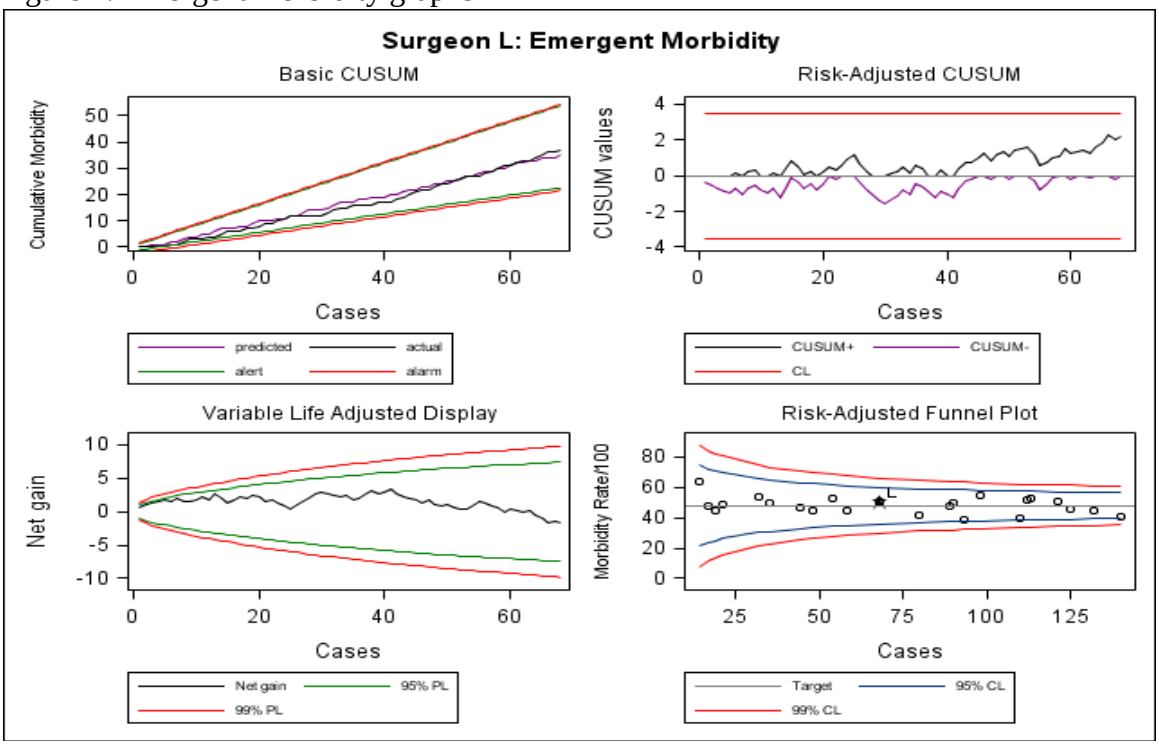


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon M | Total | Surgeon M | Total | Surgeon M | Total |
| | | N=434 | N=3267 | N=98 | N=1713 | N=532 | N=4980 |
| Age | Mean ± SD | 52.96 ± 17.98 | 61.49 ± 15.97 | 57.72 ± 19.77 | 63.33 ± 17.34 | 53.84 ± 18.40 | 62.12 ± 16.47 |
| | Median (IQR) | 54 (38-68) | 64 (52-74) | 60 (45-74) | 66 (52-77) | 55 (40-69) | 64 (52-75) |
| Sex | F | 209 (48.2%) | 1423 (43.6%) | 59 (60.2%) | 888 (51.8%) | 268 (50.4%) | 2311 (46.4%) |
| | M | 225 (51.8%) | 1844 (56.4%) | 39 (39.8%) | 825 (48.2%) | 264 (49.6%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 3.64 ± 5.43 | 5.82 ± 6.53 | 7.32 ± 7.67 | 7.67 ± 7.87 | 4.32 ± 6.07 | 6.46 ± 7.08 |
| | Median (IQR) | 0 (0-4) | 4 (0-9) | 4 (0-16) | 5 (0-16) | 3 (0-5) | 4 (0-11) |
| Diagnosis | Cancer | 160 (36.9%) | 2038 (62.4%) | 34 (34.7%) | 638 (37.2%) | 194 (36.5%) | 2676 (53.7%) |
| | Diverticular disease | 11 (2.5%) | 182 (5.6%) | 11 (11.2%) | 241 (14.1%) | 22 (4.1%) | 423 (8.5%) |
| | Ulcerative colitis | 85 (19.6%) | 151 (4.6%) | 11 (11.2%) | 82 (4.8%) | 96 (18.0%) | 233 (4.7%) |
| | Crohn's | 49 (11.3%) | 175 (5.4%) | 9 (9.2%) | 98 (5.7%) | 58 (10.9%) | 273 (5.5%) |
| | Infectious colitis | <=5 (0.2%) | <=5 (0.1%) | <=5 (4.1%) | 45 (2.6%) | <=5 (0.9%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (4.1%) | 122 (7.1%) | <=5 (0.8%) | 124 (2.5%) |
| | Other colitis | <=5 (0.2%) | <=5 (0.1%) | 0 (0.0%) | <=5 (0.2%) | <=5 (0.2%) | 6 (0.1%) |
| | Stoma related | 99 (22.8%) | 522 (16.0%) | 0 (0.0%) | 29 (1.7%) | 99 (18.6%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | 7 (7.1%) | 137 (8.0%) | 7 (1.3%) | 156 (3.1%) |
| | Hernia | 0 (0.0%) | <=5 (0.1%) | <=5 (2.0%) | 10 (0.6%) | <=5 (0.4%) | 13 (0.3%) |
| | Other | 28 (6.5%) | 160 (4.9%) | 16 (16.3%) | 292 (17.0%) | 44 (8.3%) | 452 (9.1%) |

**Surgeon M Performance**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Open/lap | Laparoscopic | 43 (9.9%) | 912 (27.9%) | <=5 (3.1%) | 143 (8.3%) | 46 (8.6%) | 1055 (21.2%) |
| | Open | 391 (90.1%) | 2355 (72.1%) | 95 (96.9%) | 1570 (91.7%) | 486 (91.4%) | 3925 (78.8%) |
| Resection type | APR | 53 (12.2%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | 53 (10.0%) | 308 (6.2%) |
| | AR | 160 (36.9%) | 845 (25.9%) | 7 (7.1%) | 141 (8.2%) | 167 (31.4%) | 986 (19.8%) |
| | bypass | 30 (6.9%) | 162 (5.0%) | 31 (31.6%) | 321 (18.7%) | 61 (11.5%) | 483 (9.7%) |
| | reversal | 93 (21.4%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | 93 (17.5%) | 515 (10.3%) |
| | segmental | 89 (20.5%) | 1404 (43.0%) | 52 (53.1%) | 1113 (65.0%) | 141 (26.5%) | 2517 (50.5%) |
| | total | 9 (2.1%) | 70 (2.1%) | 8 (8.2%) | 101 (5.9%) | 17 (3.2%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 236.93 ± 97.70 | 226.37 ± 96.11 | 185.71 ± 69.94 | 172.77 ± 72.97 | 227.50 ± 95.24 | 207.94 ± 92.40 |
| | Median (IQR) | 235 (166-307) | 213 (160-277) | 169 (136-226) | 160 (125-205) | 222 (148-291) | 191 (143-255) |
| Stoma | | 108 (24.9%) | 698 (21.4%) | 58 (59.2%) | 869 (50.7%) | 166 (31.2%) | 1567 (31.5%) |
| Surgery | Colon | 221 (50.9%) | 2131 (65.2%) | 91 (92.9%) | 1555 (90.8%) | 312 (58.6%) | 3686 (74.0%) |
| | Rectal | 213 (49.1%) | 1136 (34.8%) | 7 (7.1%) | 158 (9.2%) | 220 (41.4%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon M | Total | Surgeon M | Total | Surgeon M | Total |
| | | N=434 | N=3267 | N=98 | N=1713 | N=532 | N=4980 |

**Surgeon M Performance**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 30 day postoperative complication index* | 0 | 368 (84.8%) | 2722 (83.3%) | 43 (43.9%) | 864 (50.4%) | 411 (77.3%) | 3586 (72.0%) |
| | 2 | 28 (6.5%) | 140 (4.3%) | 20 (20.4%) | 201 (11.7%) | 48 (9.0%) | 341 (6.8%) |
| | 3 | 23 (5.3%) | 240 (7.3%) | 11 (11.2%) | 142 (8.3%) | 34 (6.4%) | 382 (7.7%) |
| | 4 | 10 (2.3%) | 125 (3.8%) | 17 (17.3%) | 312 (18.2%) | 27 (5.1%) | 437 (8.8%) |
| | 5 | <=5 (1.2%) | 40 (1.2%) | 7 (7.1%) | 194 (11.3%) | 12 (2.3%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 8.44 ± 8.38 | 9.06 ± 11.67 | 21.39 ± 17.60 | 22.88 ± 28.95 | 10.83 ± 11.79 | 13.81 ± 20.51 |
| | Median (IQR) | 7 (5-10) | 6 (5-9) | 15 (9-29) | 13 (8-26) | 7 (6-12) | 8 (5-14) |
| 30 day readmission | 0 | 408 (94.0%) | 3072 (94.0%) | 90 (91.8%) | 1579 (92.2%) | 498 (93.6%) | 4651 (93.4%) |
| | 1 | 26 (6.0%) | 183 (5.6%) | 7 (7.1%) | 124 (7.2%) | 33 (6.2%) | 307 (6.2%) |
| | 2 | 0 (0.0%) | 12 (0.4%) | <=5 (1.0%) | 10 (0.6%) | <=5 (0.2%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

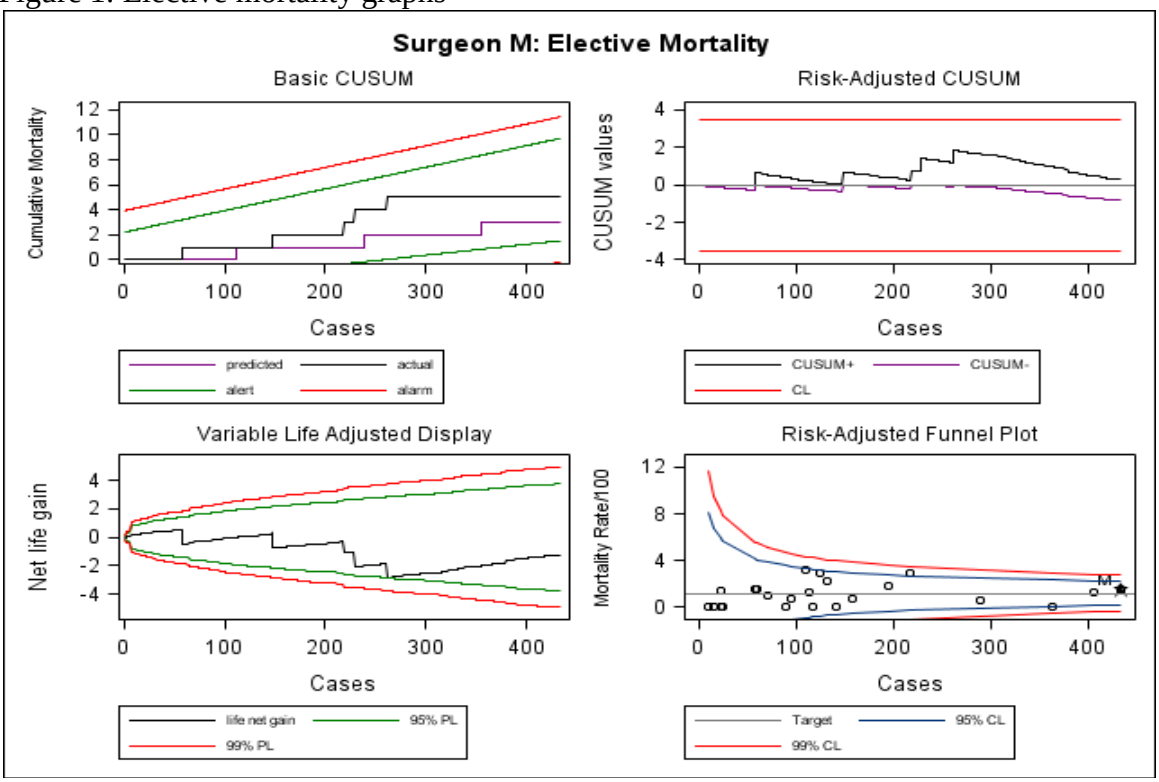



Figure 2: Elective morbidity graphs

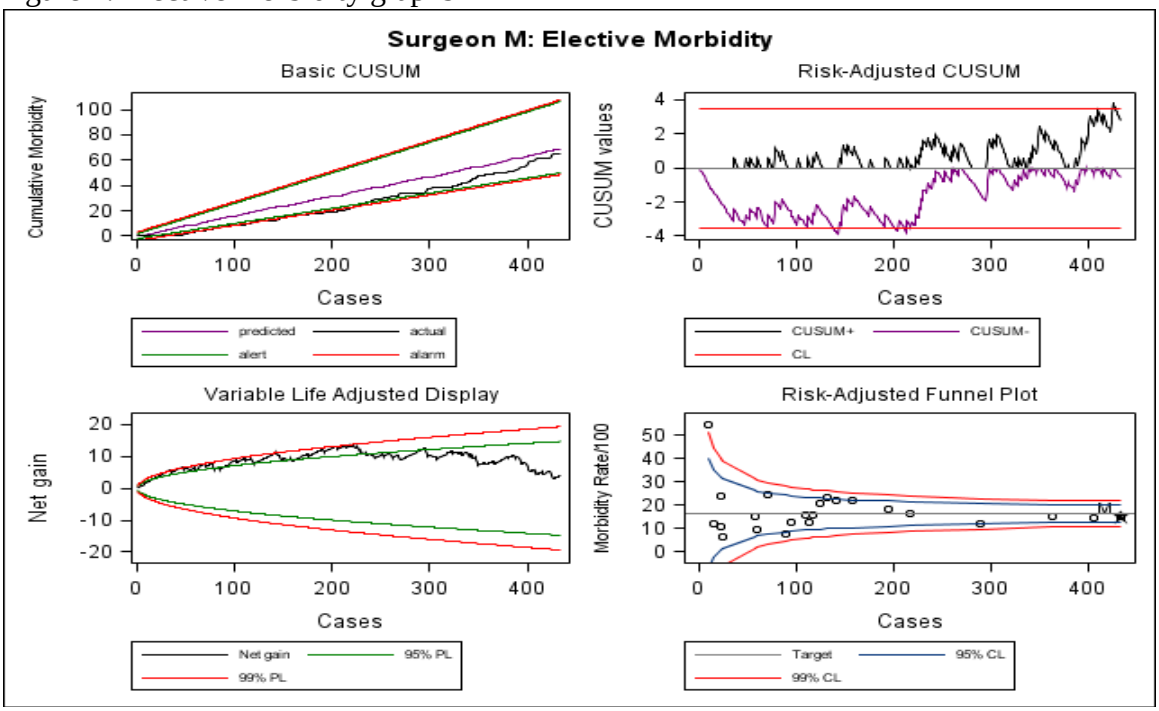


Figure 3: Emergent mortality graphs

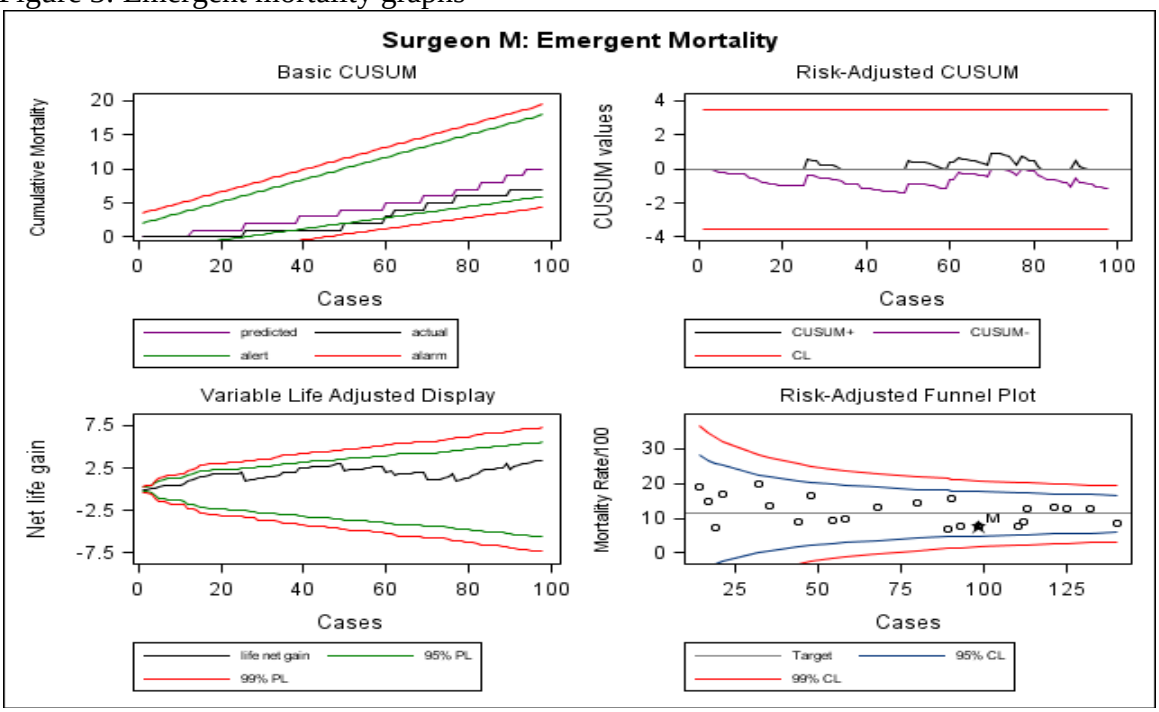



Figure 4: Emergent morbidity graphs

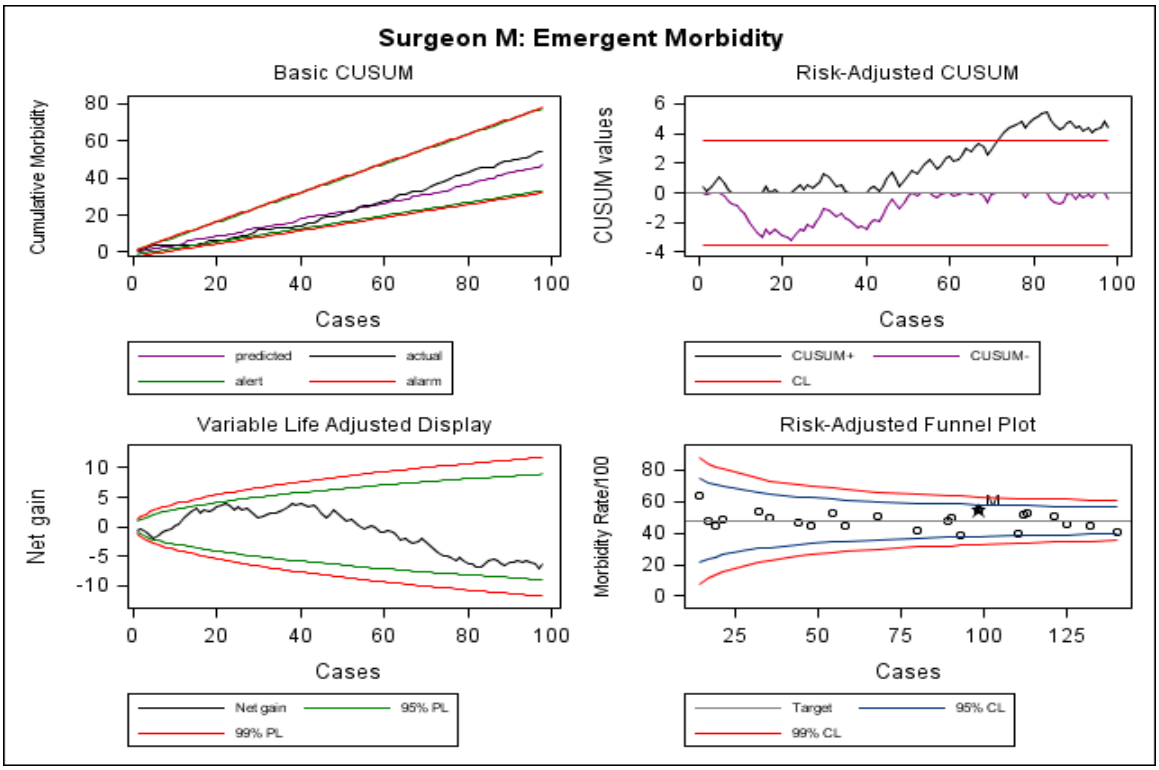


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon N | Total | Surgeon N | Total | Surgeon N | Total |
| | | N=94 | N=3267 | N=125 | N=1713 | N=219 | N=4980 |
| Age | Mean ± SD | 59.41 ± 16.79 | 61.49 ± 15.97 | 65.51 ± 15.65 | 63.33 ± 17.34 | 62.89 ± 16.39 | 62.12 ± 16.47 |
| | Median (IQR) | 60 (50-72) | 64 (52-74) | 68 (57-78) | 66 (52-77) | 65 (54-76) | 64 (52-75) |
| Sex | F | 46 (48.9%) | 1423 (43.6%) | 64 (51.2%) | 888 (51.8%) | 110 (50.2%) | 2311 (46.4%) |
| | M | 48 (51.1%) | 1844 (56.4%) | 61 (48.8%) | 825 (48.2%) | 109 (49.8%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 8.00 ± 8.32 | 5.82 ± 6.53 | 9.50 ± 8.93 | 7.67 ± 7.87 | 8.86 ± 8.68 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-16) | 4 (0-9) | 8 (3-16) | 5 (0-16) | 5 (0-16) | 4 (0-11) |
| Diagnosis | Cancer | 53 (56.4%) | 2038 (62.4%) | 50 (40.0%) | 638 (37.2%) | 103 (47.0%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (3.2%) | 182 (5.6%) | 17 (13.6%) | 241 (14.1%) | 20 (9.1%) | 423 (8.5%) |
| | Ulcerative colitis | 0 (0.0%) | 151 (4.6%) | <=5 (2.4%) | 82 (4.8%) | <=5 (1.4%) | 233 (4.7%) |
| | Crohn's | 12 (12.8%) | 175 (5.4%) | <=5 (4.0%) | 98 (5.7%) | 17 (7.8%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (3.2%) | 45 (2.6%) | <=5 (1.8%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 6 (4.8%) | 122 (7.1%) | 6 (2.7%) | 124 (2.5%) |
| | Stoma related | 21 (22.3%) | 522 (16.0%) | <=5 (2.4%) | 29 (1.7%) | 24 (11.0%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (1.1%) | 19 (0.6%) | 9 (7.2%) | 137 (8.0%) | 10 (4.6%) | 156 (3.1%) |
| | Hernia | 0 (0.0%) | <=5 (0.1%) | <=5 (1.6%) | 10 (0.6%) | <=5 (0.9%) | 13 (0.3%) |
| | Other | <=5 (4.3%) | 160 (4.9%) | 26 (20.8%) | 292 (17.0%) | 30 (13.7%) | 452 (9.1%) |
| Open/lap | Laparoscopic | <=5 (2.1%) | 912 (27.9%) | <=5 (0.8%) | 143 (8.3%) | <=5 (1.4%) | 1055 (21.2%) |
| | Open | 92 (97.9%) | 2355 (72.1%) | 124 (99.2%) | 1570 (91.7%) | 216 (98.6%) | 3925 (78.8%) |
| Resection type | APR | <=5 (3.2%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | <=5 (1.4%) | 308 (6.2%) |
| | AR | 6 (6.4%) | 845 (25.9%) | <=5 (2.4%) | 141 (8.2%) | 9 (4.1%) | 986 (19.8%) |
| | bypass | 7 (7.4%) | 162 (5.0%) | 35 (28.0%) | 321 (18.7%) | 42 (19.2%) | 483 (9.7%) |
| | revers | 21 (22.3%) | 495 (15.2%) | <=5 (4.0%) | 20 (1.2%) | 26 (11.9%) | 515 (10.3%) |
| | segmen | 57 (60.6%) | 1404 (43.0%) | 78 (62.4%) | 1113 (65.0%) | 135 (61.6%) | 2517 (50.5%) |
| | total | 0 (0.0%) | 70 (2.1%) | <=5 (3.2%) | 101 (5.9%) | <=5 (1.8%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 184.30 ± 93.52 | 226.37 ± 96.11 | 155.62 ± 55.15 | 172.77 ± 72.97 | 167.93 ± 75.26 | 207.94 ± 92.40 |
| | Median (IQR) | 158 (120-220) | 213 (160-277) | 141 (119-195) | 160 (125-205) | 150 (119-201) | 191 (143-255) |
| Stoma | | 17 (18.1%) | 698 (21.4%) | 67 (53.6%) | 869 (50.7%) | 84 (38.4%) | 1567 (31.5%) |
| Surgery | Colon | 85 (90.4%) | 2131 (65.2%) | 122 (97.6%) | 1555 (90.8%) | 207 (94.5%) | 3686 (74.0%) |
| | Rectal | 9 (9.6%) | 1136 (34.8%) | <=5 (2.4%) | 158 (9.2%) | 12 (5.5%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon N | Total | Surgeon N | Total | Surgeon N | Total |
| | | N=94 | N=3267 | N=125 | N=1713 | N=219 | N=4980 |
| 30 day postoperative complication index* | 0 | 80 (85.1%) | 2722 (83.3%) | 60 (48.0%) | 864 (50.4%) | 140 (63.9%) | 3586 (72.0%) |
| | 2 | <=5 (3.2%) | 140 (4.3%) | 18 (14.4%) | 201 (11.7%) | 21 (9.6%) | 341 (6.8%) |
| | 3 | 7 (7.4%) | 240 (7.3%) | 8 (6.4%) | 142 (8.3%) | 15 (6.8%) | 382 (7.7%) |
| | 4 | <=5 (3.2%) | 125 (3.8%) | 20 (16.0%) | 312 (18.2%) | 23 (10.5%) | 437 (8.8%) |
| | 5 | <=5 (1.1%) | 40 (1.2%) | 19 (15.2%) | 194 (11.3%) | 20 (9.1%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 8.95 ± 6.18 | 9.06 ± 11.67 | 23.55 ± 21.47 | 22.88 ± 28.95 | 17.28 ± 18.19 | 13.81 ± 20.51 |
| | Median (IQR) | 7 (5-10) | 6 (5-9) | 17 (9-30) | 13 (8-26) | 11 (6-21) | 8 (5-14) |
| 30 day readmission | 0 | 87 (92.6%) | 3072 (94.0%) | 114 (91.2%) | 1579 (92.2%) | 201 (91.8%) | 4651 (93.4%) |
| | 1 | 6 (6.4%) | 183 (5.6%) | 10 (8.0%) | 124 (7.2%) | 16 (7.3%) | 307 (6.2%) |
| | 2 | <=5 (1.1%) | 12 (0.4%) | <=5 (0.8%) | 10 (0.6%) | <=5 (0.9%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

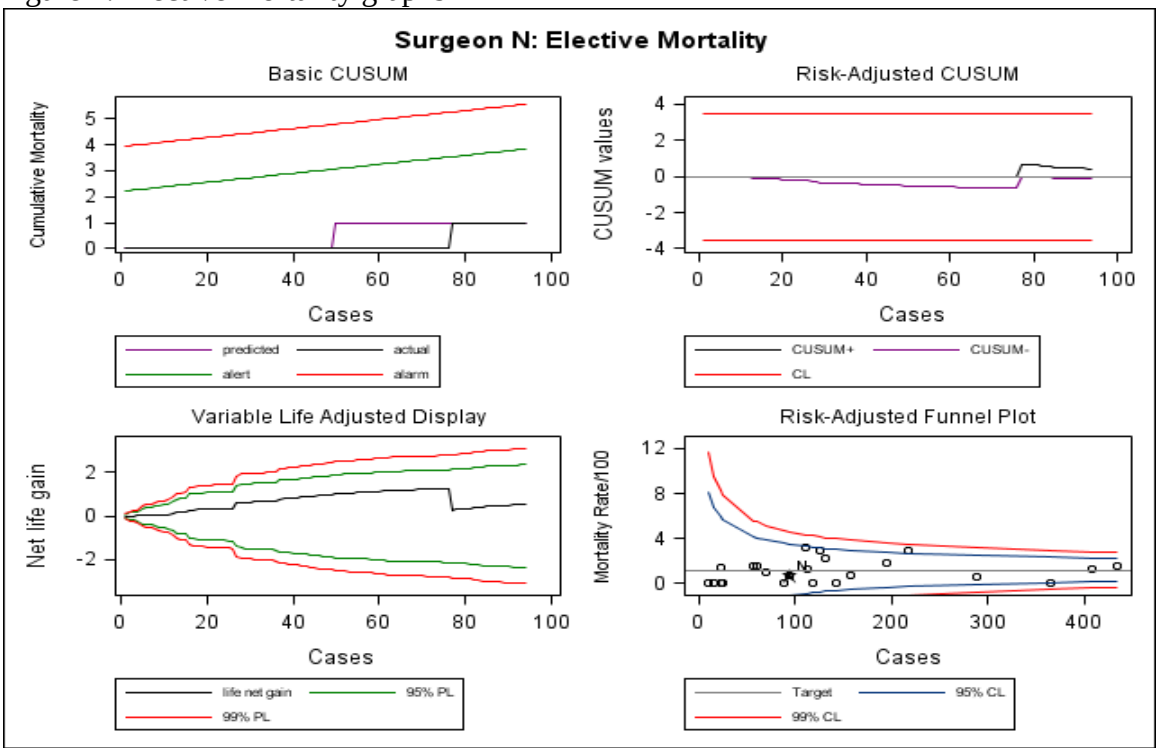



Figure 2: Elective morbidity graphs

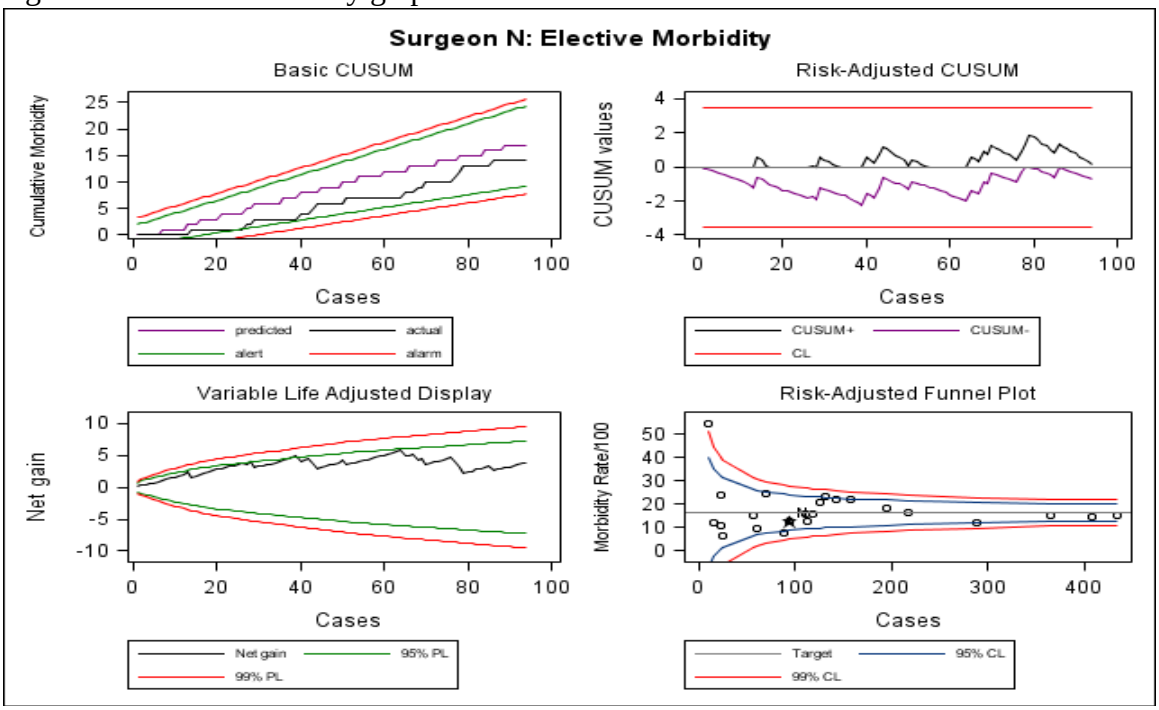


Figure 3: Emergent mortality graphs

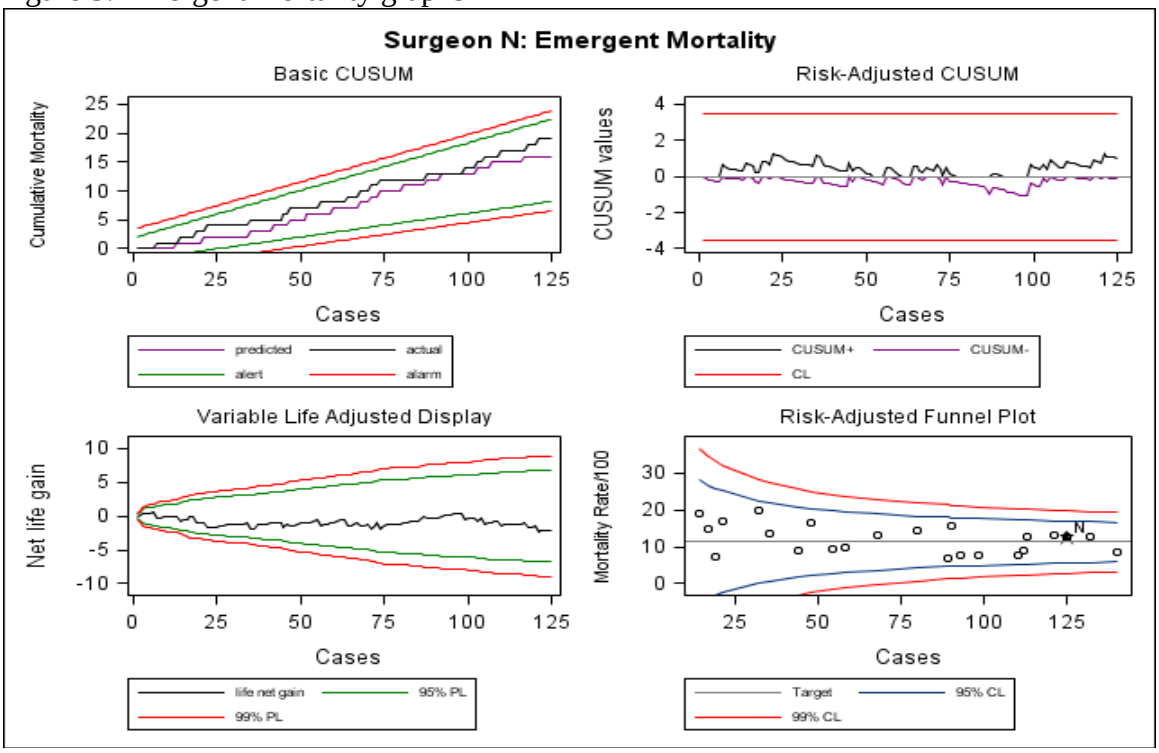
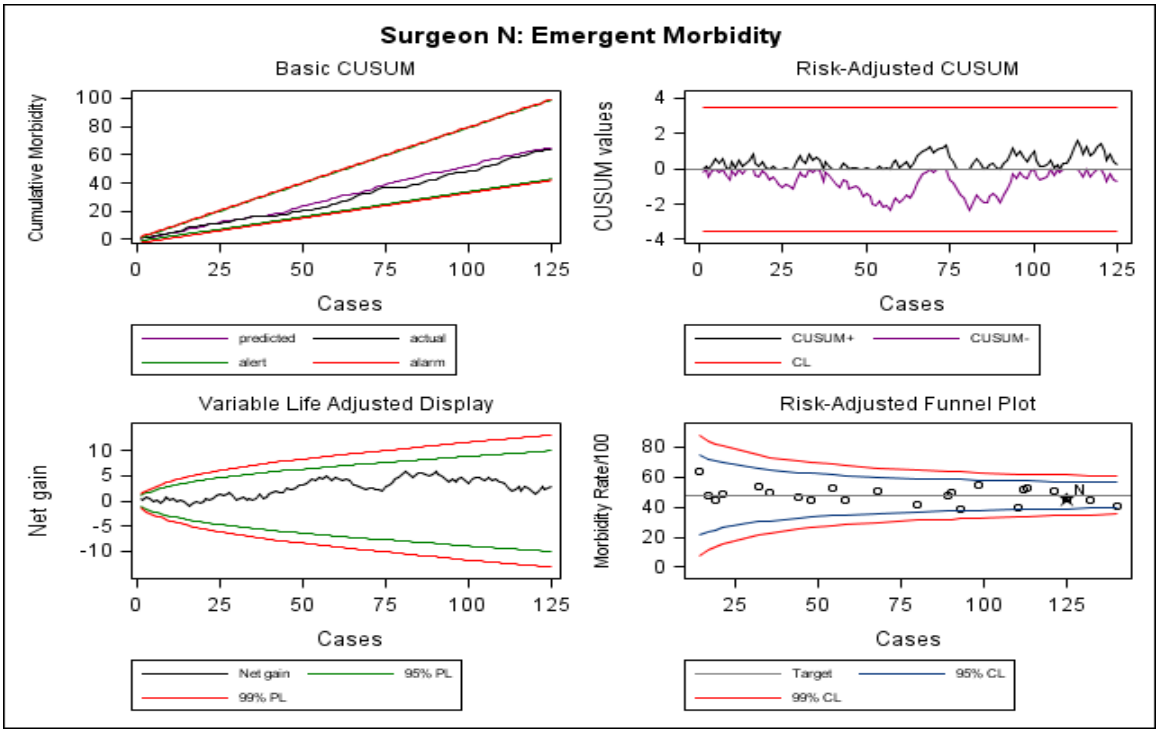



Figure 4: Emergent morbidity graphs



**Surgeon O Performance**

Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon O | Total | Surgeon O | Total | Surgeon O | Total |
| | | N=16 | N=3267 | N=17 | N=1713 | N=33 | N=4980 |
| Age | Mean ± SD | 53.31 ± 19.67 | 61.49 ± 15.97 | 70.76 ± 17.02 | 63.33 ± 17.34 | 62.30 ± 20.12 | 62.12 ± 16.47 |
| | Median (IQR) | 56 (38-71) | 64 (52-74) | 76 (61-83) | 66 (52-77) | 64 (44-80) | 64 (52-75) |
| Sex | F | <=5 (31.3%) | 1423 (43.6%) | 8 (47.1%) | 888 (51.8%) | 13 (39.4%) | 2311 (46.4%) |
| | M | 11 (68.8%) | 1844 (56.4%) | 9 (52.9%) | 825 (48.2%) | 20 (60.6%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 3.50 ± 4.82 | 5.82 ± 6.53 | 8.65 ± 7.74 | 7.67 ± 7.87 | 6.15 ± 6.90 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-5) | 4 (0-9) | 5 (4-16) | 5 (0-16) | 4 (0-6) | 4 (0-11) |
| Diagnosis | Cancer | 6 (37.5%) | 2038 (62.4%) | 6 (35.3%) | 638 (37.2%) | 12 (36.4%) | 2676 (53.7%) |
| | Diverticular disease | 0 (0.0%) | 182 (5.6%) | <=5 (23.5%) | 241 (14.1%) | <=5 (12.1%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (12.5%) | 151 (4.6%) | 0 (0.0%) | 82 (4.8%) | <=5 (6.1%) | 233 (4.7%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (11.8%) | 45 (2.6%) | <=5 (6.1%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (5.9%) | 122 (7.1%) | <=5 (3.0%) | 124 (2.5%) |
| | Other colitis | <=5 (6.3%) | <=5 (0.1%) | 0 (0.0%) | <=5 (0.2%) | <=5 (3.0%) | 6 (0.1%) |
| | Stoma related | <=5 (25.0%) | 522 (16.0%) | 0 (0.0%) | 29 (1.7%) | <=5 (12.1%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | <=5 (11.8%) | 137 (8.0%) | <=5 (6.1%) | 156 (3.1%) |
| | Other | <=5 (18.8%) | 160 (4.9%) | <=5 (11.8%) | 292 (17.0%) | <=5 (15.2%) | 452 (9.1%) |
| Open/lap | Open | 16 (100.0%) | 2355 (72.1%) | 17 (100.0%) | 1570 (91.7%) | 33 (100.0%) | 3925 (78.8%) |
| Resection type | APR | <=5 (6.3%) | 291 (8.9%) | <=5 (5.9%) | 17 (1.0%) | <=5 (6.1%) | 308 (6.2%) |
| | AR | <=5 (18.8%) | 845 (25.9%) | <=5 (5.9%) | 141 (8.2%) | <=5 (12.1%) | 986 (19.8%) |
| | bypass | <=5 (12.5%) | 162 (5.0%) | <=5 (11.8%) | 321 (18.7%) | <=5 (12.1%) | 483 (9.7%) |
| | reversal | <=5 (25.0%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | <=5 (12.1%) | 515 (10.3%) |
| | segmental | <=5 (31.3%) | 1404 (43.0%) | 13 (76.5%) | 1113 (65.0%) | 18 (54.5%) | 2517 (50.5%) |
| | total | <=5 (6.3%) | 70 (2.1%) | 0 (0.0%) | 101 (5.9%) | <=5 (3.0%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 221.56 ± 96.18 | 226.37 ± 96.11 | 211.18 ± 64.37 | 172.77 ± 72.97 | 216.21 ± 80.23 | 207.94 ± 92.40 |
| | Median (IQR) | 208 (140-275) | 213 (160-277) | 202 (175-228) | 160 (125-205) | 202 (174-274) | 191 (143-255) |
| Stoma | | 7 (43.8%) | 698 (21.4%) | 8 (47.1%) | 869 (50.7%) | 15 (45.5%) | 1567 (31.5%) |
| Surgery | Colon | 12 (75.0%) | 2131 (65.2%) | 15 (88.2%) | 1555 (90.8%) | 27 (81.8%) | 3686 (74.0%) |
| | Rectal | <=5 (25.0%) | 1136 (34.8%) | <=5 (11.8%) | 158 (9.2%) | 6 (18.2%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon O | Total | Surgeon O | Total | Surgeon O | Total |
| | | N=16 | N=3267 | N=17 | N=1713 | N=33 | N=4980 |
| 30 day postoperative complication index* | 0 | 14 (87.5%) | 2722 (83.3%) | 9 (52.9%) | 864 (50.4%) | 23 (69.7%) | 3586 (72.0%) |
| | 3 | <=5 (12.5%) | 240 (7.3%) | <=5 (23.5%) | 142 (8.3%) | 6 (18.2%) | 382 (7.7%) |
| | 4 | 0 (0.0%) | 125 (3.8%) | <=5 (5.9%) | 312 (18.2%) | <=5 (3.0%) | 437 (8.8%) |
| | 5 | 0 (0.0%) | 40 (1.2%) | <=5 (17.6%) | 194 (11.3%) | <=5 (9.1%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 10.69 ± 10.43 | 9.06 ± 11.67 | 22.18 ± 17.77 | 22.88 ± 28.95 | 16.61 ± 15.59 | 13.81 ± 20.51 |
| | Median (IQR) | 7 (5-10) | 6 (5-9) | 20 (11-26) | 13 (8-26) | 11 (7-24) | 8 (5-14) |
| 30 day readmission | 0 | 15 (93.8%) | 3072 (94.0%) | 16 (94.1%) | 1579 (92.2%) | 31 (93.9%) | 4651 (93.4%) |
| | 1 | <=5 (6.3%) | 183 (5.6%) | <=5 (5.9%) | 124 (7.2%) | <=5 (6.1%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

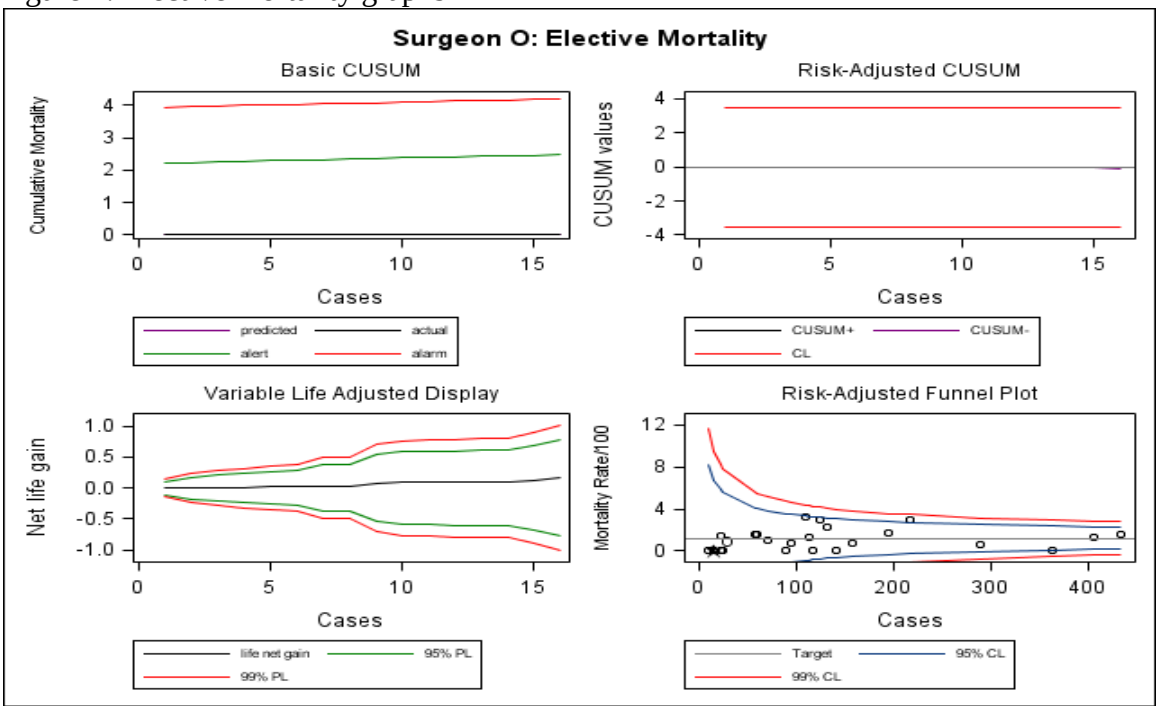



Figure 2: Elective morbidity graphs

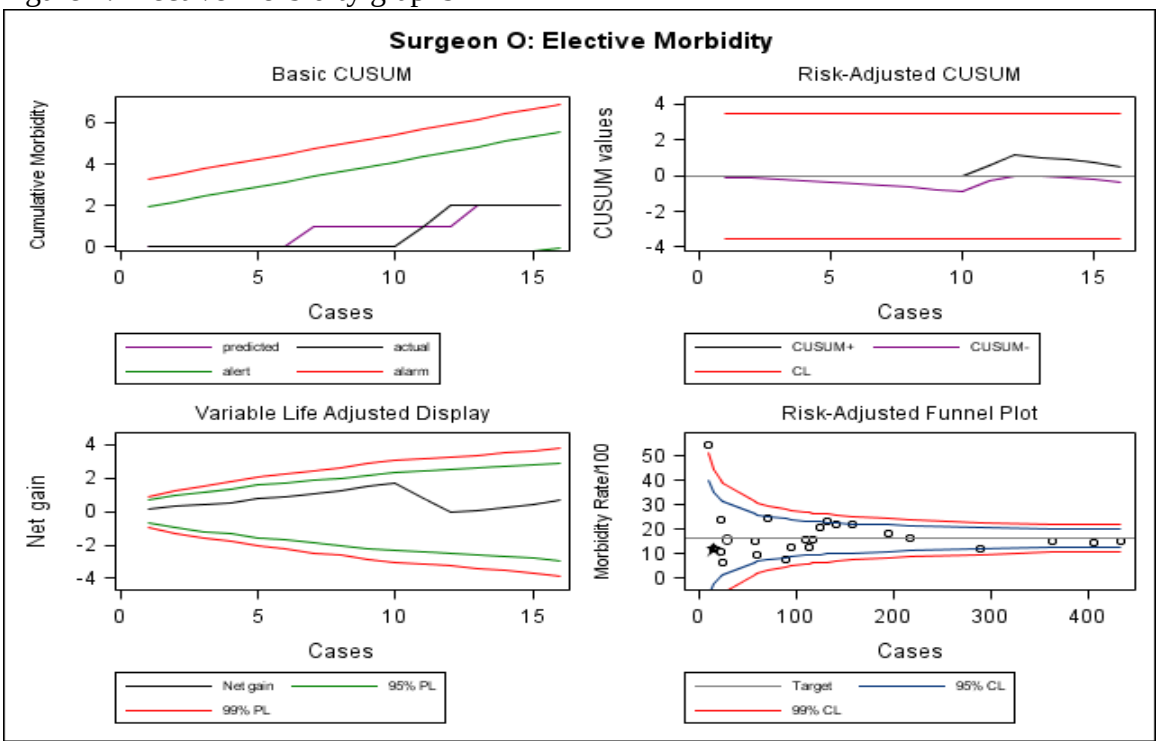


Figure 3: Emergent mortality graphs

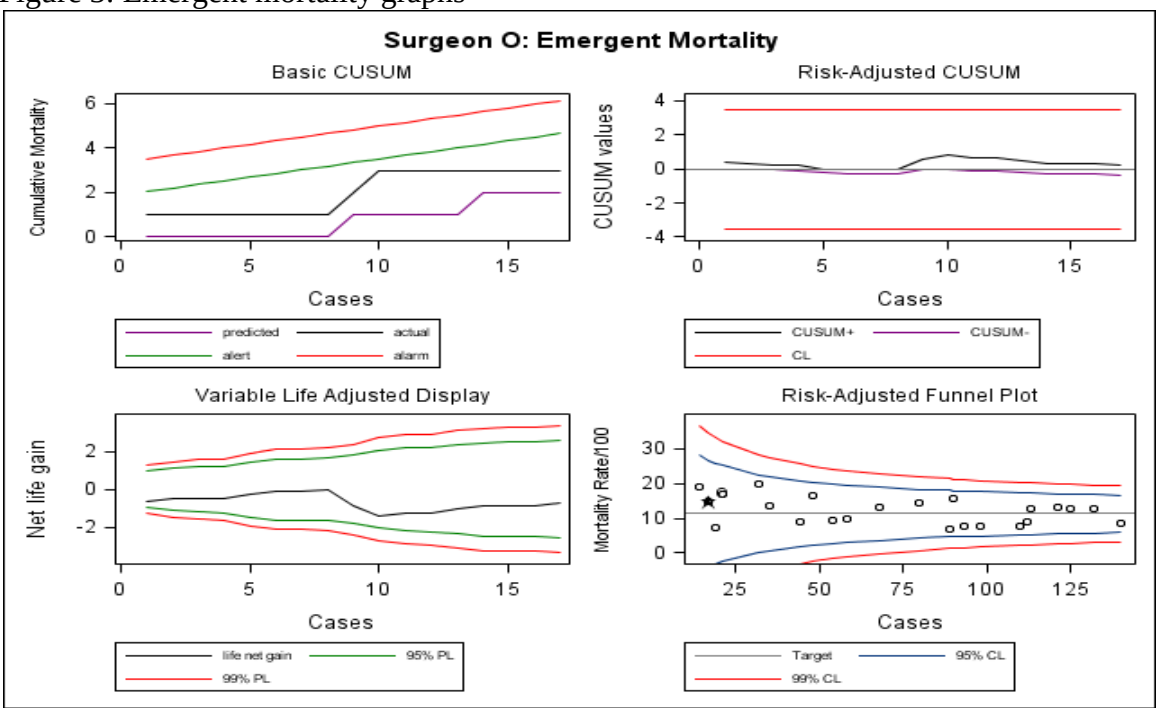



Figure 4: Emergent morbidity graphs

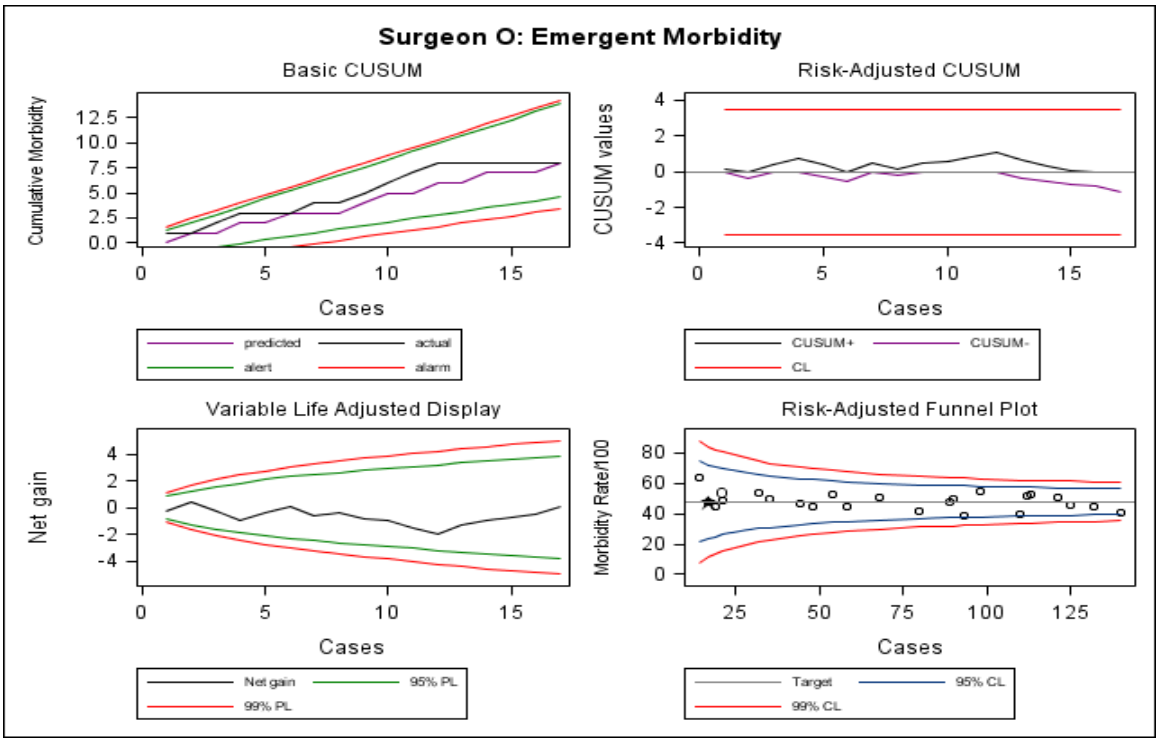


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon P | Total | Surgeon P | Total | Surgeon P | Total |
| | | N=125 | N=3267 | N=89 | N=1713 | N=214 | N=4980 |
| Age | Mean ± SD | 62.57 ± 15.58 | 61.49 ± 15.97 | 62.65 ± 18.29 | 63.33 ± 17.34 | 62.60 ± 16.72 | 62.12 ± 16.47 |
| | Median (IQR) | 65 (52-75) | 64 (52-74) | 66 (52-78) | 66 (52-77) | 66 (52-77) | 64 (52-75) |
| Sex | F | 65 (52.0%) | 1423 (43.6%) | 48 (53.9%) | 888 (51.8%) | 113 (52.8%) | 2311 (46.4%) |
| | M | 60 (48.0%) | 1844 (56.4%) | 41 (46.1%) | 825 (48.2%) | 101 (47.2%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 5.05 ± 6.14 | 5.82 ± 6.53 | 5.63 ± 6.95 | 7.67 ± 7.87 | 5.29 ± 6.48 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-7) | 4 (0-9) | 4 (0-9) | 5 (0-16) | 4 (0-8) | 4 (0-11) |
| Diagnosis | Cancer | 70 (56.0%) | 2038 (62.4%) | 24 (27.0%) | 638 (37.2%) | 94 (43.9%) | 2676 (53.7%) |
| | Diverticular disease | 12 (9.6%) | 182 (5.6%) | 12 (13.5%) | 241 (14.1%) | 24 (11.2%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (1.6%) | 151 (4.6%) | 7 (7.9%) | 82 (4.8%) | 9 (4.2%) | 233 (4.7%) |
| | Crohn's | <=5 (4.0%) | 175 (5.4%) | 12 (13.5%) | 98 (5.7%) | 17 (7.9%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (1.1%) | 45 (2.6%) | <=5 (0.5%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 10 (11.2%) | 122 (7.1%) | 10 (4.7%) | 124 (2.5%) |
| | Other colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (1.1%) | <=5 (0.2%) | <=5 (0.5%) | 6 (0.1%) |
| | Stoma related | 25 (20.0%) | 522 (16.0%) | <=5 (2.2%) | 29 (1.7%) | 27 (12.6%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (0.8%) | 19 (0.6%) | <=5 (4.5%) | 137 (8.0%) | <=5 (2.3%) | 156 (3.1%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (2.2%) | 16 (0.9%) | <=5 (0.9%) | 16 (0.3%) |
| | Polyp | <=5 (0.8%) | 8 (0.2%) | 0 (0.0%) | 0 (0.0%) | <=5 (0.5%) | 8 (0.2%) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Other | 9 (7.2%) | 160 (4.9%) | 14 (15.7%) | 292 (17.0%) | 23 (10.7%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 30 (24.0%) | 912 (27.9%) | 7 (7.9%) | 143 (8.3%) | 37 (17.3%) | 1055 (21.2%) |
| | Open | 95 (76.0%) | 2355 (72.1%) | 82 (92.1%) | 1570 (91.7%) | 177 (82.7%) | 3925 (78.8%) |
| Resection type | APR | <=5 (0.8%) | 291 (8.9%) | <=5 (1.1%) | 17 (1.0%) | <=5 (0.9%) | 308 (6.2%) |
| | AR | 22 (17.6%) | 845 (25.9%) | <=5 (5.6%) | 141 (8.2%) | 27 (12.6%) | 986 (19.8%) |
| | bypass | <=5 (1.6%) | 162 (5.0%) | 6 (6.7%) | 321 (18.7%) | 8 (3.7%) | 483 (9.7%) |
| | reversal | 26 (20.8%) | 495 (15.2%) | <=5 (1.1%) | 20 (1.2%) | 27 (12.6%) | 515 (10.3%) |
| | segmental | 71 (56.8%) | 1404 (43.0%) | 62 (69.7%) | 1113 (65.0%) | 133 (62.1%) | 2517 (50.5%) |
| | total | <=5 (2.4%) | 70 (2.1%) | 14 (15.7%) | 101 (5.9%) | 17 (7.9%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 179.48 ± 59.12 | 226.37 ± 96.11 | 139.75 ±42.28 | 172.77 ± 72.97 | 162.96 ± 56.20 | 207.94 ± 92.40 |
| | Median (IQR) | 170 (141-210) | 213 (160-277) | 137 (108-161) | 160 (125-205) | 157 (127-189) | 191 (143-255) |
| Stoma | | 11 (8.8%) | 698 (21.4%) | 38 (42.7%) | 869 (50.7%) | 49 (22.9%) | 1567 (31.5%) |
| Surgery | Colon | 102 (81.6%) | 2131 (65.2%) | 83 (93.3%) | 1555 (90.8%) | 185 (86.4%) | 3686 (74.0%) |
| | Rectal | 23 (18.4%) | 1136 (34.8%) | 6 (6.7%) | 158 (9.2%) | 29 (13.6%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon P | Total | Surgeon P | Total | Surgeon P | Total |
| | | N=125 | N=3267 | N=89 | N=1713 | N=214 | N=4980 |
| 30 day postoperative complication index* | 0 | 98 (78.4%) | 2722 (83.3%) | 44 (49.4%) | 864 (50.4%) | 142 (66.4%) | 3586 (72.0%) |
| | 2 | <=5 (2.4%) | 140 (4.3%) | 10 (11.2%) | 201 (11.7%) | 13 (6.1%) | 341 (6.8%) |
| | 3 | 14 (11.2%) | 240 (7.3%) | 6 (6.7%) | 142 (8.3%) | 20 (9.3%) | 382 (7.7%) |
| | 4 | 6 (4.8%) | 125 (3.8%) | 23 (25.8%) | 312 (18.2%) | 29 (13.6%) | 437 (8.8%) |
| | 5 | <=5 (3.2%) | 40 (1.2%) | 6 (6.7%) | 194 (11.3%) | 10 (4.7%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 10.73 ± 12.71 | 9.06 ± 11.67 | 30.35 ± 34.17 | 22.88 ± 28.95 | 18.89 ± 25.89 | 13.81 ± 20.51 |
| | Median (IQR) | 6 (5-10) | 6 (5-9) | 17 (11-39) | 13 (8-26) | 9 (6-22) | 8 (5-14) |
| 30 day readmission | 0 | 116 (92.8%) | 3072 (94.0%) | 86 (96.6%) | 1579 (92.2%) | 202 (94.4%) | 4651 (93.4%) |
| | 1 | 8 (6.4%) | 183 (5.6%) | <=5 (3.4%) | 124 (7.2%) | 11 (5.1%) | 307 (6.2%) |
| | 2 | <=5 (0.8%) | 12 (0.4%) | 0 (0.0%) | 10 (0.6%) | <=5 (0.5%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

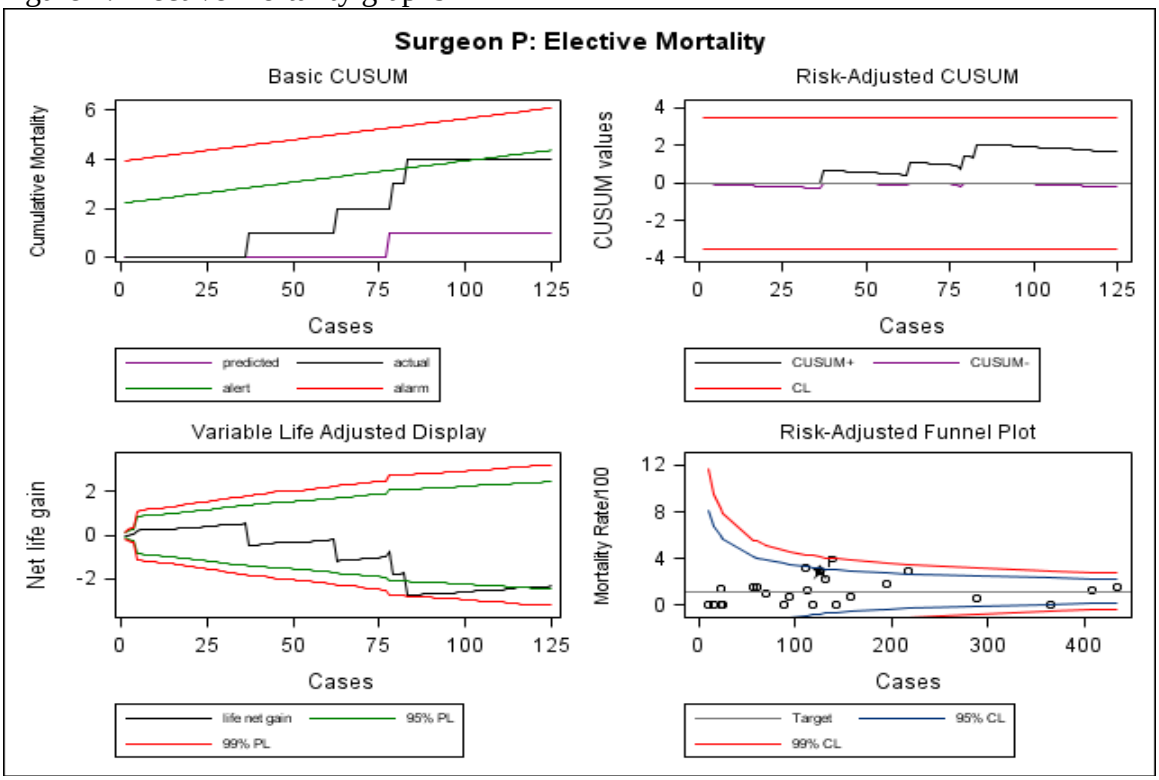



Figure 2: Elective morbidity graphs

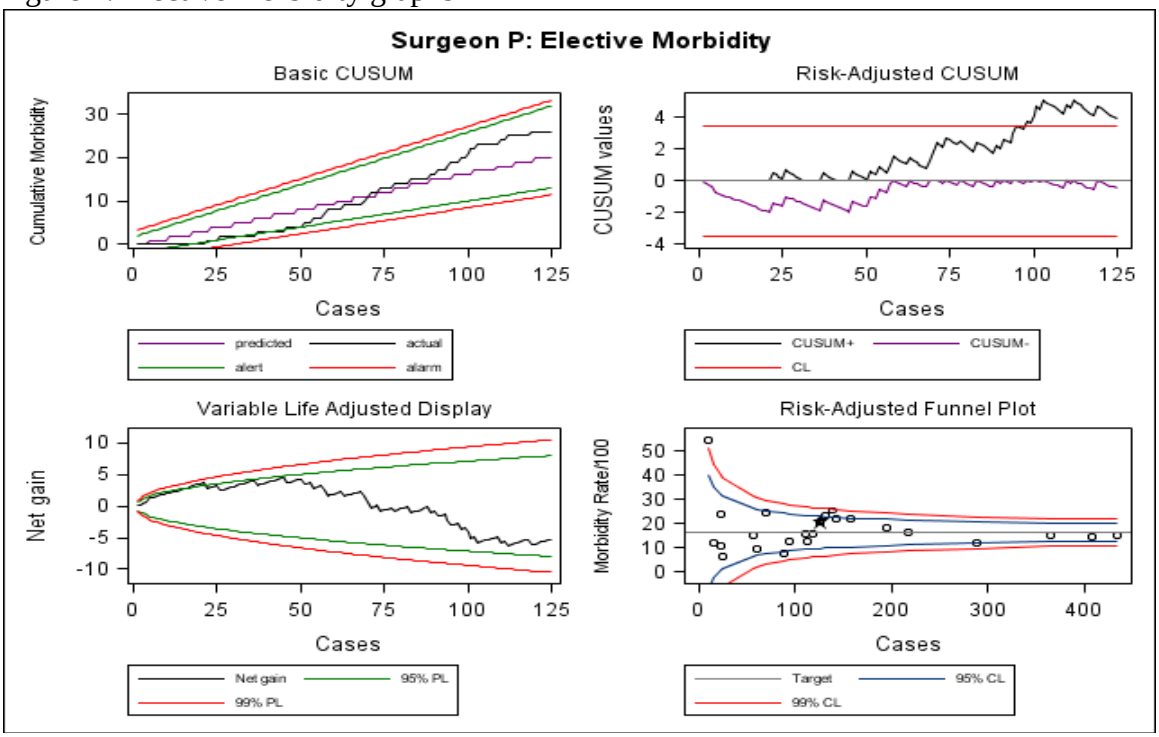


Figure 3: Emergent mortality graphs

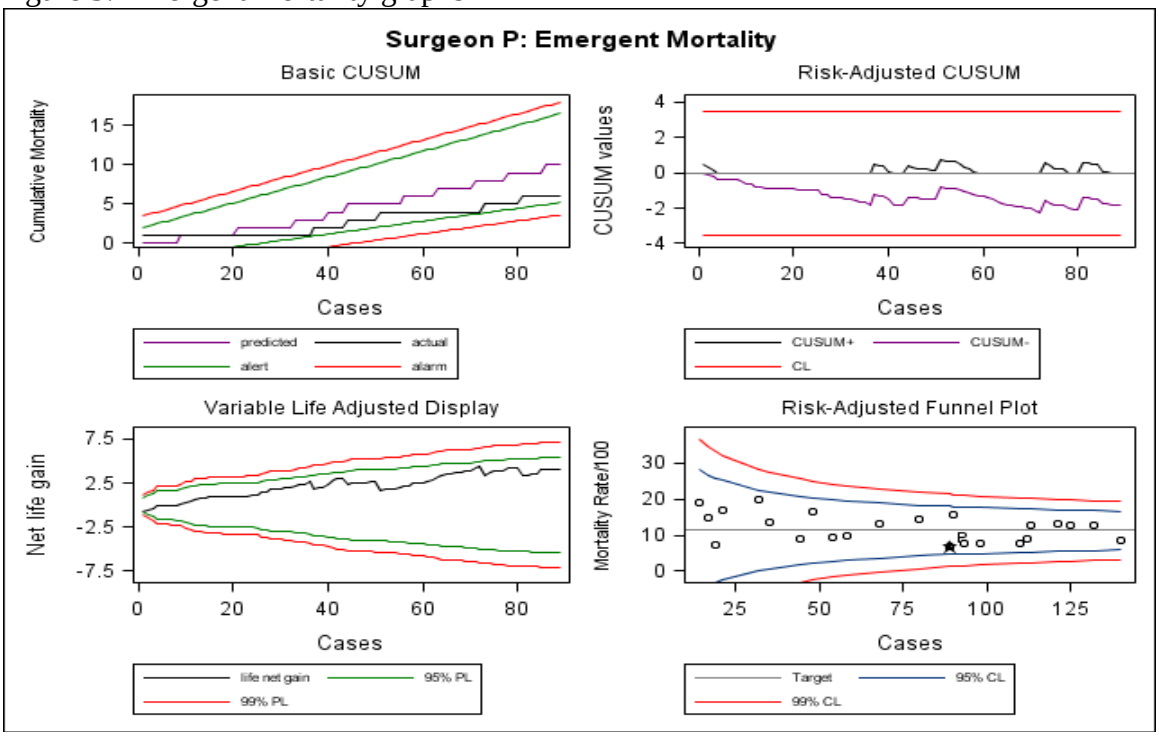



Figure 4: Emergent morbidity graphs

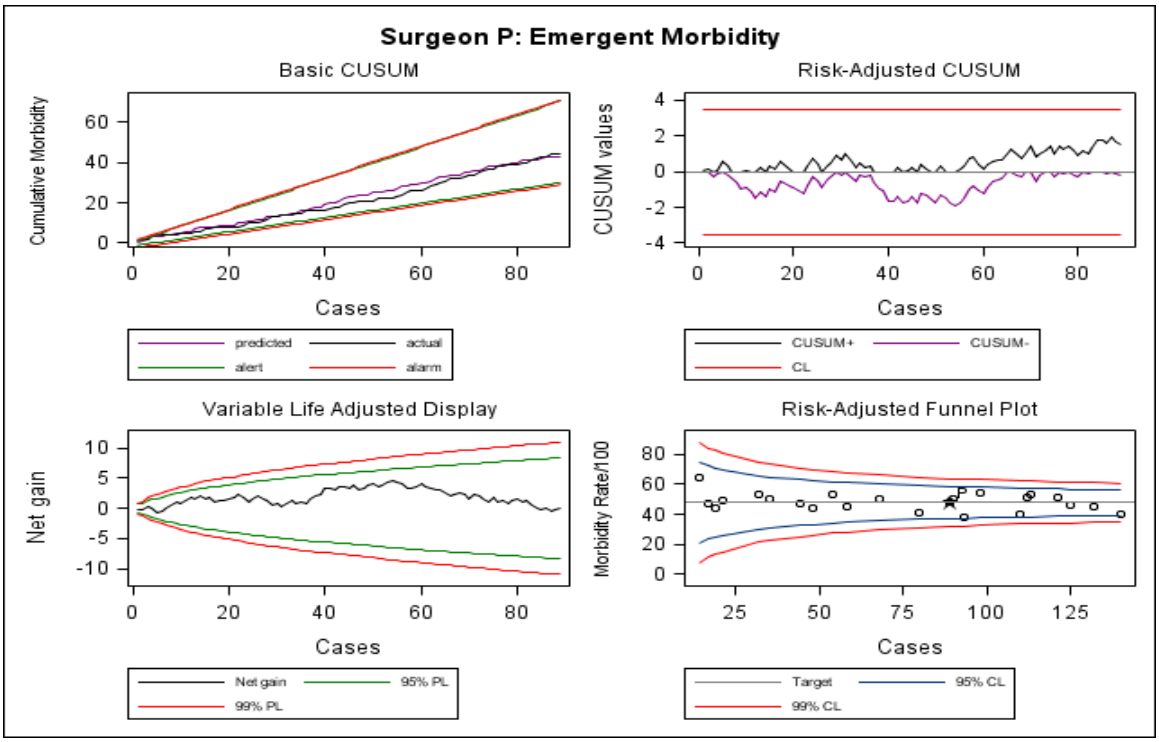


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon Q | Total | Surgeon Q | Total | Surgeon Q | Total |
| | | N=22 | N=3267 | N=48 | N=1713 | N=70 | N=4980 |
| Age | Mean ± SD | 53.36 ± 15.75 | 61.49 ± 15.97 | 62.35 ± 16.89 | 63.33 ± 17.34 | 59.53 ± 16.96 | 62.12 ± 16.47 |
| | Median (IQR) | 55 (44-67) | 64 (52-74) | 66 (54-77) | 66 (52-77) | 60 (52-73) | 64 (52-75) |
| Sex | F | 11 (50.0%) | 1423 (43.6%) | 26 (54.2%) | 888 (51.8%) | 37 (52.9%) | 2311 (46.4%) |
| | M | 11 (50.0%) | 1844 (56.4%) | 22 (45.8%) | 825 (48.2%) | 33 (47.1%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 2.95 ± 4.25 | 5.82 ± 6.53 | 6.88 ± 7.71 | 7.67 ± 7.87 | 5.64 ± 7.03 | 6.46 ± 7.08 |
| | Median (IQR) | 0 (0-6) | 4 (0-9) | 5 (0-13) | 5 (0-16) | 4 (0-10) | 4 (0-11) |
| Diagnosis | Cancer | <=5 (18.2%) | 2038 (62.4%) | 15 (31.3%) | 638 (37.2%) | 19 (27.1%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (13.6%) | 182 (5.6%) | 7 (14.6%) | 241 (14.1%) | 10 (14.3%) | 423 (8.5%) |
| | Crohn's | 0 (0.0%) | 175 (5.4%) | <=5 (6.3%) | 98 (5.7%) | <=5 (4.3%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (4.2%) | 45 (2.6%) | <=5 (2.9%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (10.4%) | 122 (7.1%) | <=5 (7.1%) | 124 (2.5%) |
| | Stoma related | 10 (45.5%) | 522 (16.0%) | 0 (0.0%) | 29 (1.7%) | 10 (14.3%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (4.5%) | 19 (0.6%) | <=5 (6.3%) | 137 (8.0%) | <=5 (5.7%) | 156 (3.1%) |
| | Hernia | 0 (0.0%) | <=5 (0.1%) | <=5 (2.1%) | 10 (0.6%) | <=5 (1.4%) | 13 (0.3%) |
| | Other | <=5 (18.2%) | 160 (4.9%) | 12 (25.0%) | 292 (17.0%) | 16 (22.9%) | 452 (9.1%) |
| Open/lap | Open | 22 (100.0%) | 2355 (72.1%) | 48 (100.0%) | 1570 (91.7%) | 70 (100.0%) | 3925 (78.8%) |
| Resection type | AR | <=5 (4.5%) | 845 (25.9%) | <=5 (4.2%) | 141 (8.2%) | <=5 (4.3%) | 986 (19.8%) |
| | bypass | <=5 (4.5%) | 162 (5.0%) | 10 (20.8%) | 321 (18.7%) | 11 (15.7%) | 483 (9.7%) |
| | reversal | 9 (40.9%) | 495 (15.2%) | <=5 (2.1%) | 20 (1.2%) | 10 (14.3%) | 515 (10.3%) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | segmental | 11 (50.0%) | 1404 (43.0%) | 34 (70.8%) | 1113 (65.0%) | 45 (64.3%) | 2517 (50.5%) |
| | total | 0 (0.0%) | 70 (2.1%) | <=5 (2.1%) | 101 (5.9%) | <=5 (1.4%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 124.82 ± 33.88 | 226.37 ± 96.11 | 109.40 ± 38.58 | 172.77 ± 72.97 | 114.24 ± 37.62 | 207.94 ± 92.40 |
| | Median (IQR) | 125 (105-143) | 213 (160-277) | 109 (76-123) | 160 (125-205) | 110 (89-131) | 191 (143-255) |
| Stoma | | <=5 (18.2%) | 698 (21.4%) | 31 (64.6%) | 869 (50.7%) | 35 (50.0%) | 1567 (31.5%) |
| Surgery | Colon | 21 (95.5%) | 2131 (65.2%) | 46 (95.8%) | 1555 (90.8%) | 67 (95.7%) | 3686 (74.0%) |
| | Rectal | <=5 (4.5%) | 1136 (34.8%) | <=5 (4.2%) | 158 (9.2%) | <=5 (4.3%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon Q | Total | Surgeon Q | Total | Surgeon Q | Total |
| | | N=22 | N=3267 | N=48 | N=1713 | N=70 | N=4980 |
| 30 day postoperative complication index* | 0 | 17 (77.3%) | 2722 (83.3%) | 23 (47.9%) | 864 (50.4%) | 40 (57.1%) | 3586 (72.0%) |
| | 2 | 0 (0.0%) | 140 (4.3%) | <=5 (2.1%) | 201 (11.7%) | <=5 (1.4%) | 341 (6.8%) |
| | 3 | <=5 (18.2%) | 240 (7.3%) | <=5 (8.3%) | 142 (8.3%) | 8 (11.4%) | 382 (7.7%) |
| | 4 | <=5 (4.5%) | 125 (3.8%) | 12 (25.0%) | 312 (18.2%) | 13 (18.6%) | 437 (8.8%) |
| | 5 | 0 (0.0%) | 40 (1.2%) | 8 (16.7%) | 194 (11.3%) | 8 (11.4%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 8.59 ± 4.29 | 9.06 ± 11.67 | 22.08 ± 27.04 | 22.88 ± 28.95 | 17.84 ± 23.31 | 13.81 ± 20.51 |
| | Median (IQR) | 8 (6-9) | 6 (5-9) | 11 (7-26) | 13 (8-26) | 9 (7-18) | 8 (5-14) |
| 30 day readmission | 0 | 22 (100.0%) | 3072 (94.0%) | 45 (93.8%) | 1579 (92.2%) | 67 (95.7%) | 4651 (93.4%) |
| | 1 | 0 (0.0%) | 183 (5.6%) | <=5 (6.3%) | 124 (7.2%) | <=5 (4.3%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

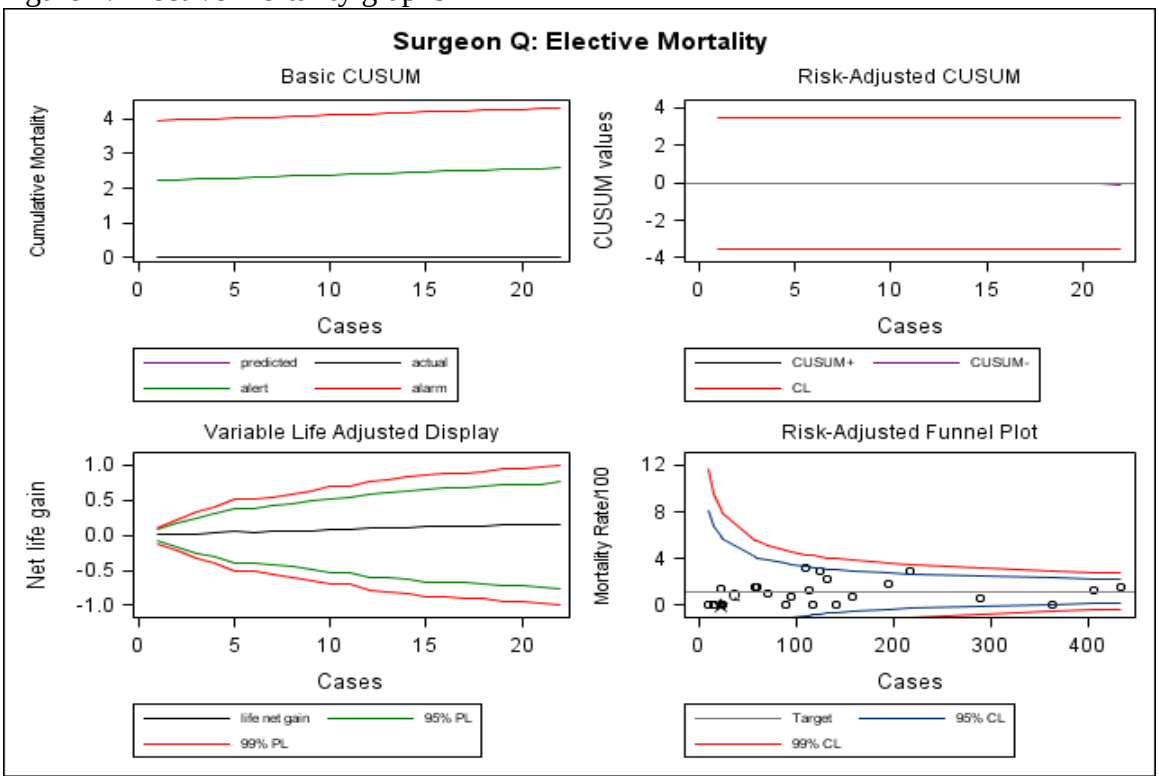



Figure 2: Elective morbidity graphs

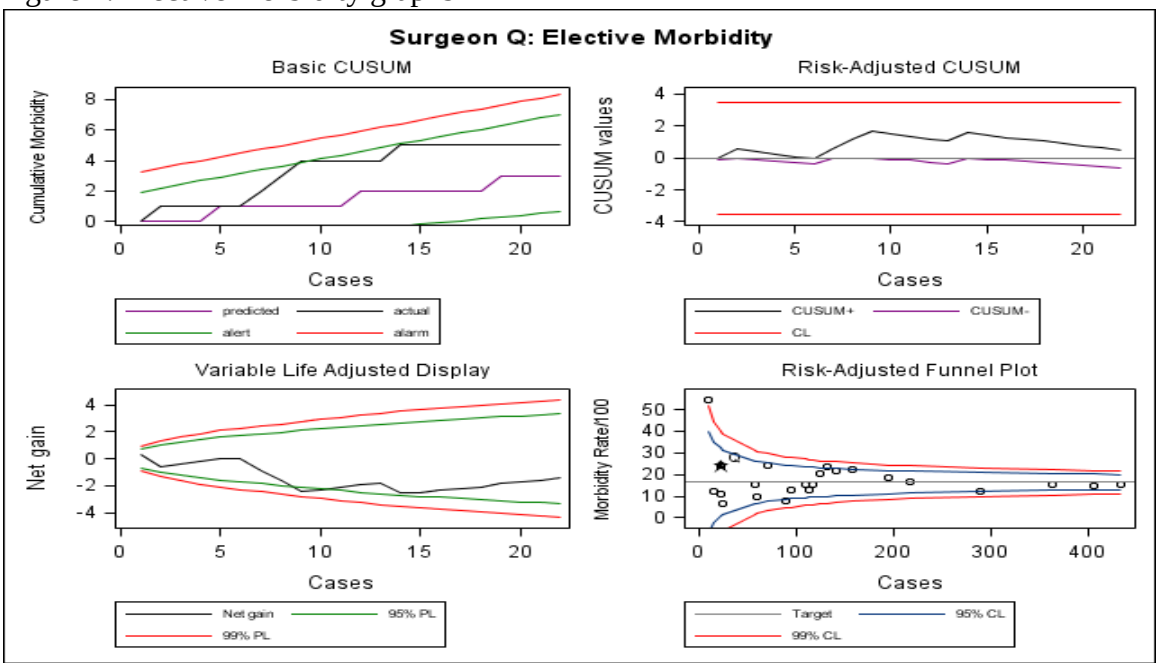


Figure 3: Emergent mortality graphs

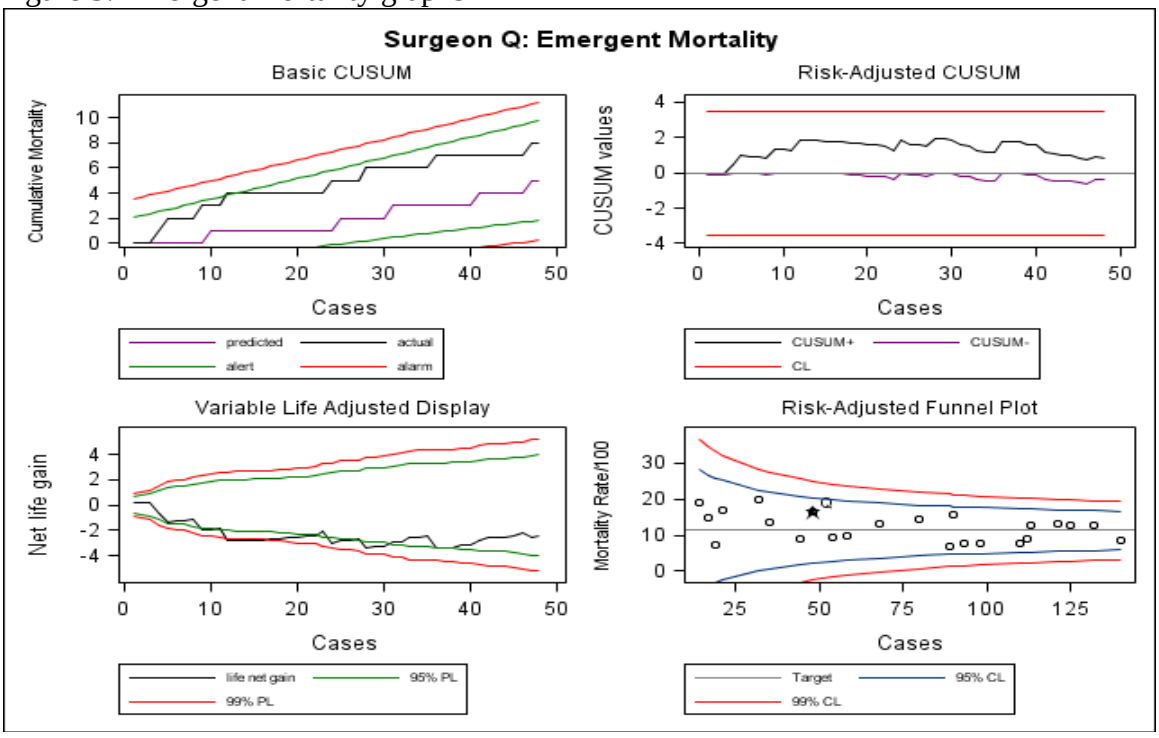



Figure 4: Emergent morbidity graphs

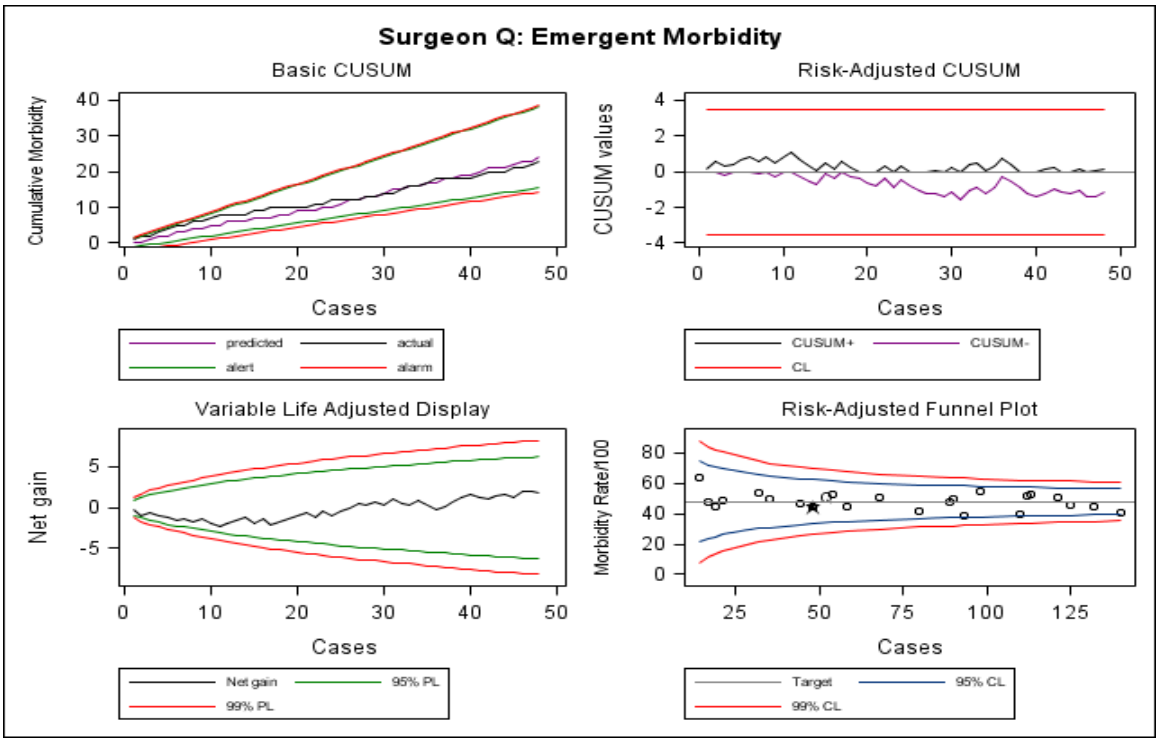


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon R | Total | Surgeon R | Total | Surgeon R | Total |
| | | N=70 | N=3267 | N=110 | N=1713 | N=180 | N=4980 |
| Age | Mean ± SD | 62.09 ± 14.86 | 61.49 ± 15.97 | 61.56 ± 17.26 | 63.33 ± 17.34 | 61.77 ± 16.33 | 62.12 ± 16.47 |
| | Median (IQR) | 65 (51-73) | 64 (52-74) | 64 (51-76) | 66 (52-77) | 64 (51-76) | 64 (52-75) |
| Sex | F | 39 (55.7%) | 1423 (43.6%) | 56 (50.9%) | 888 (51.8%) | 95 (52.8%) | 2311 (46.4%) |
| | M | 31 (44.3%) | 1844 (56.4%) | 54 (49.1%) | 825 (48.2%) | 85 (47.2%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 6.37 ± 6.95 | 5.82 ± 6.53 | 8.14 ± 8.02 | 7.67 ± 7.87 | 7.45 ± 7.65 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-12) | 4 (0-9) | 5 (2-16) | 5 (0-16) | 4 (0-16) | 4 (0-11) |
| Diagnosis | Cancer | 42 (60.0%) | 2038 (62.4%) | 50 (45.5%) | 638 (37.2%) | 92 (51.1%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (4.3%) | 182 (5.6%) | 15 (13.6%) | 241 (14.1%) | 18 (10.0%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (1.4%) | 151 (4.6%) | <=5 (2.7%) | 82 (4.8%) | <=5 (2.2%) | 233 (4.7%) |
| | Crohn's | <=5 (1.4%) | 175 (5.4%) | <=5 (4.5%) | 98 (5.7%) | 6 (3.3%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (2.7%) | 45 (2.6%) | <=5 (1.7%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 9 (8.2%) | 122 (7.1%) | 9 (5.0%) | 124 (2.5%) |
| | Stoma related | 20 (28.6%) | 522 (16.0%) | <=5 (2.7%) | 29 (1.7%) | 23 (12.8%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | 9 (8.2%) | 137 (8.0%) | 9 (5.0%) | 156 (3.1%) |
| | Other | <=5 (4.3%) | 160 (4.9%) | 13 (11.8%) | 292 (17.0%) | 16 (8.9%) | 452 (9.1%) |
| Open/lap | Laparoscopic | <=5 (2.9%) | 912 (27.9%) | <=5 (0.9%) | 143 (8.3%) | <=5 (1.7%) | 1055 (21.2%) |
| | Open | 68 (97.1%) | 2355 (72.1%) | 109 (99.1%) | 1570 (91.7%) | 177 (98.3%) | 3925 (78.8%) |

**Surgeon R Performance**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Resection type | APR | <=5 (4.3%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | <=5 (1.7%) | 308 (6.2%) |
| | AR | 17 (24.3%) | 845 (25.9%) | 15 (13.6%) | 141 (8.2%) | 32 (17.8%) | 986 (19.8%) |
| | bypass | <=5 (7.1%) | 162 (5.0%) | 26 (23.6%) | 321 (18.7%) | 31 (17.2%) | 483 (9.7%) |
| | reversal | 16 (22.9%) | 495 (15.2%) | <=5 (0.9%) | 20 (1.2%) | 17 (9.4%) | 515 (10.3%) |
| | segmental | 29 (41.4%) | 1404 (43.0%) | 67 (60.9%) | 1113 (65.0%) | 96 (53.3%) | 2517 (50.5%) |
| | total | 0 (0.0%) | 70 (2.1%) | <=5 (0.9%) | 101 (5.9%) | <=5 (0.6%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 168.76 ± 72.15 | 226.37 ± 96.11 | 142.73 ± 49.74 | 172.77 ± 72.97 | 152.85 ± 60.62 | 207.94 ± 92.40 |
| | Median (IQR) | 159 (130-188) | 213 (160-277) | 136 (110-167) | 160 (125-205) | 147 (115-175) | 191 (143-255) |
| Stoma | | 13 (18.6%) | 698 (21.4%) | 41 (37.3%) | 869 (50.7%) | 54 (30.0%) | 1567 (31.5%) |
| Surgery | Colon | 50 (71.4%) | 2131 (65.2%) | 95 (86.4%) | 1555 (90.8%) | 145 (80.6%) | 3686 (74.0%) |
| | Rectal | 20 (28.6%) | 1136 (34.8%) | 15 (13.6%) | 158 (9.2%) | 35 (19.4%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

**Surgeon R Performance**

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon R | Total | Surgeon R | Total | Surgeon R | Total |
| | | N=70 | N=3267 | N=110 | N=1713 | N=180 | N=4980 |
| 30 day postoperative complication index* | 0 | 51 (72.9%) | 2722 (83.3%) | 67 (60.9%) | 864 (50.4%) | 118 (65.6%) | 3586 (72.0%) |
| | 2 | <=5 (5.7%) | 140 (4.3%) | 8 (7.3%) | 201 (11.7%) | 12 (6.7%) | 341 (6.8%) |
| | 3 | 8 (11.4%) | 240 (7.3%) | 11 (10.0%) | 142 (8.3%) | 19 (10.6%) | 382 (7.7%) |
| | 4 | 6 (8.6%) | 125 (3.8%) | 16 (14.5%) | 312 (18.2%) | 22 (12.2%) | 437 (8.8%) |
| | 5 | <=5 (1.4%) | 40 (1.2%) | 8 (7.3%) | 194 (11.3%) | 9 (5.0%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 12.21 ± 12.45 | 9.06 ± 11.67 | 19.95 ± 21.25 | 22.88 ± 28.95 | 16.94 ± 18.68 | 13.81 ± 20.51 |
| | Median (IQR) | 8 (7-12) | 6 (5-9) | 12 (8-26) | 13 (8-26) | 11 (7-19) | 8 (5-14) |
| 30 day readmission | 0 | 66 (94.3%) | 3072 (94.0%) | 100 (90.9%) | 1579 (92.2%) | 166 (92.2%) | 4651 (93.4%) |
| | 1 | <=5 (5.7%) | 183 (5.6%) | 10 (9.1%) | 124 (7.2%) | 14 (7.8%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

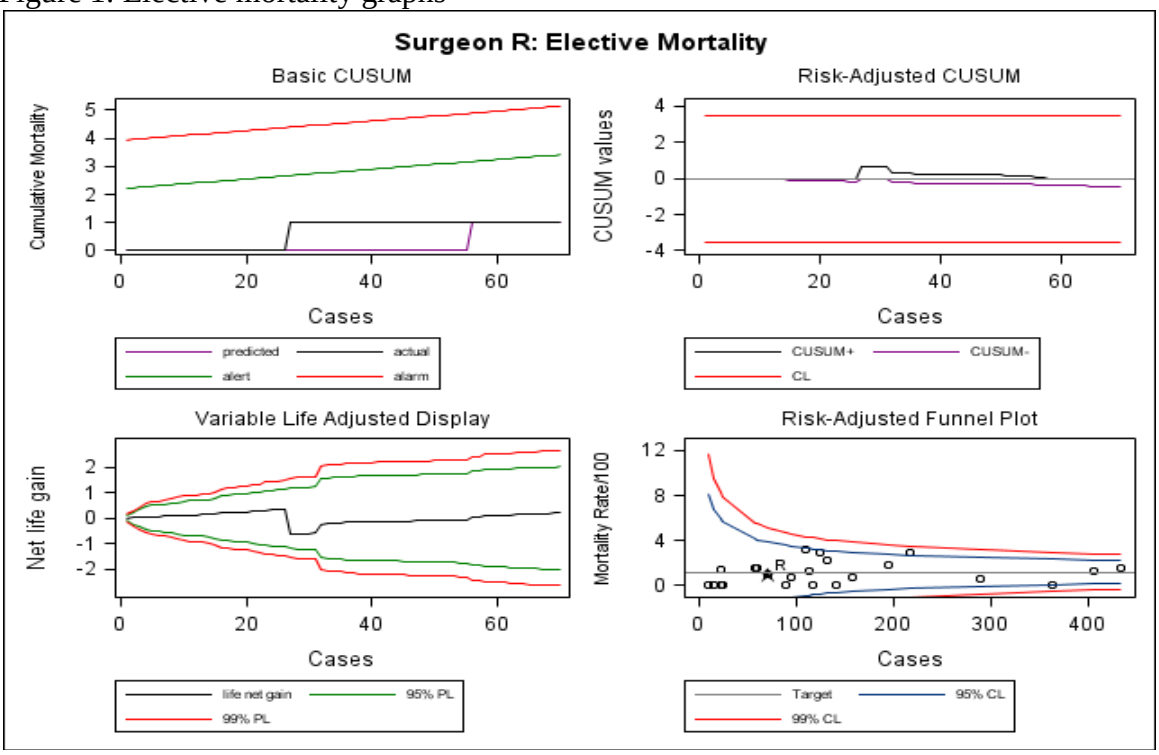



Figure 2: Elective morbidity graphs

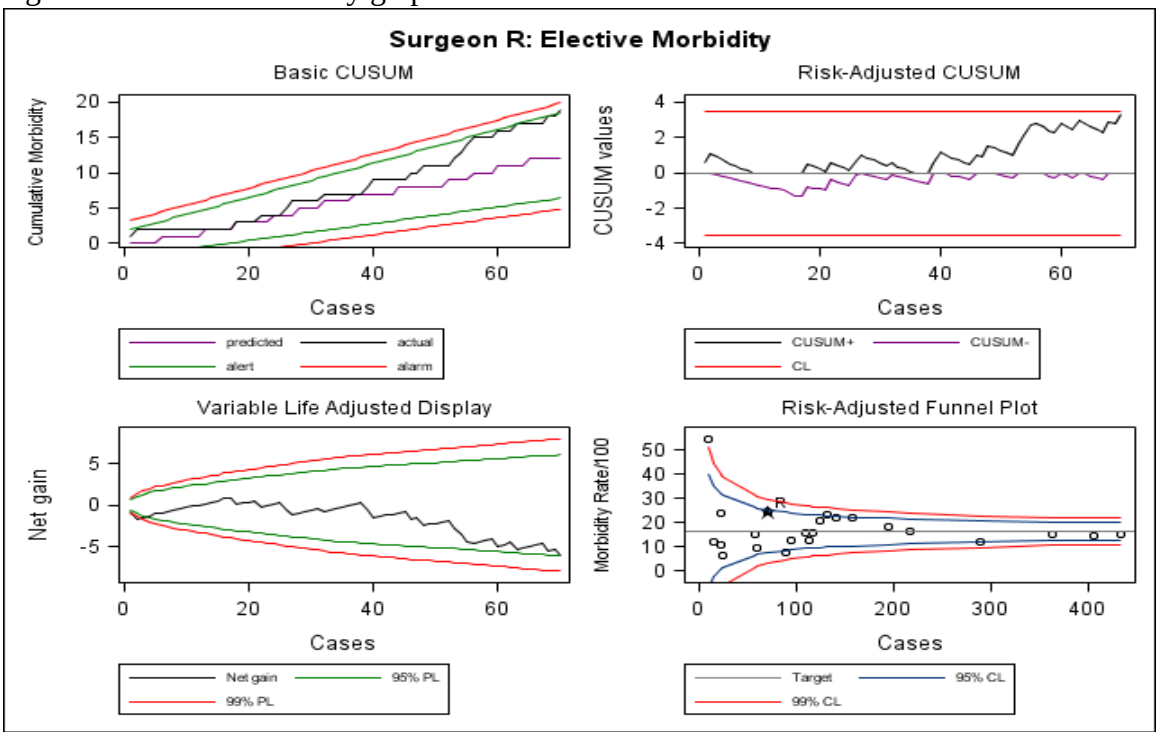


Figure 3: Emergent mortality graphs

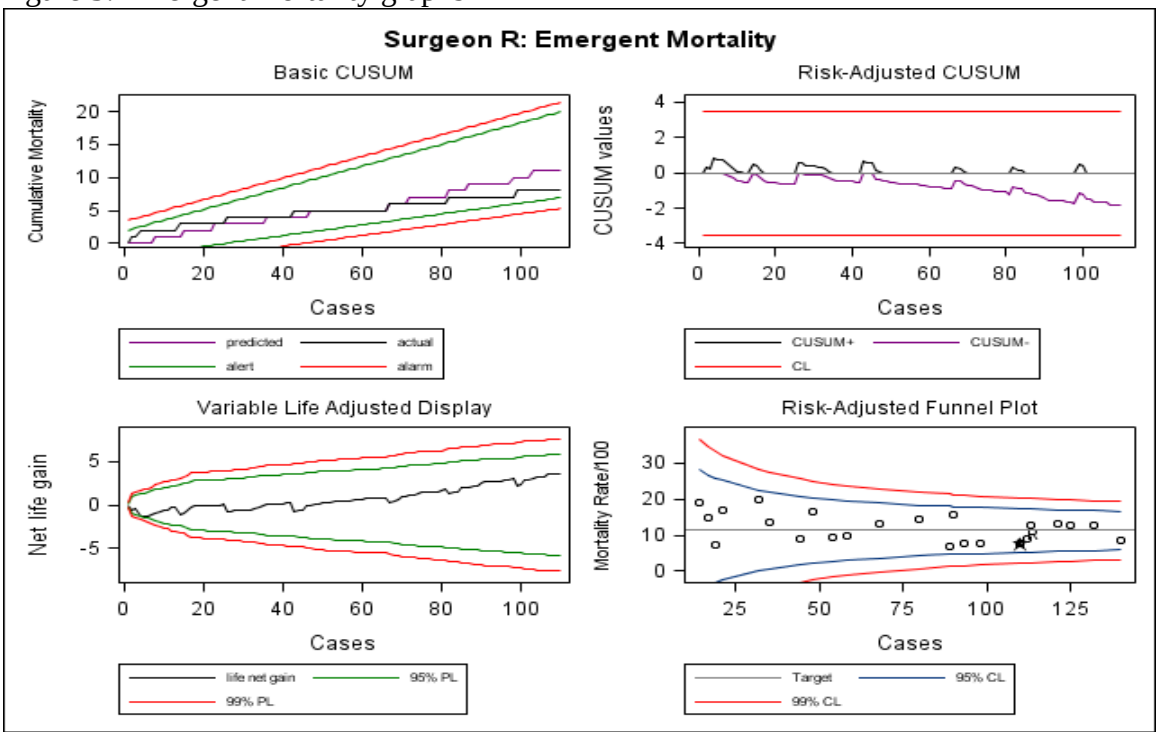



Figure 4: Emergent morbidity graphs

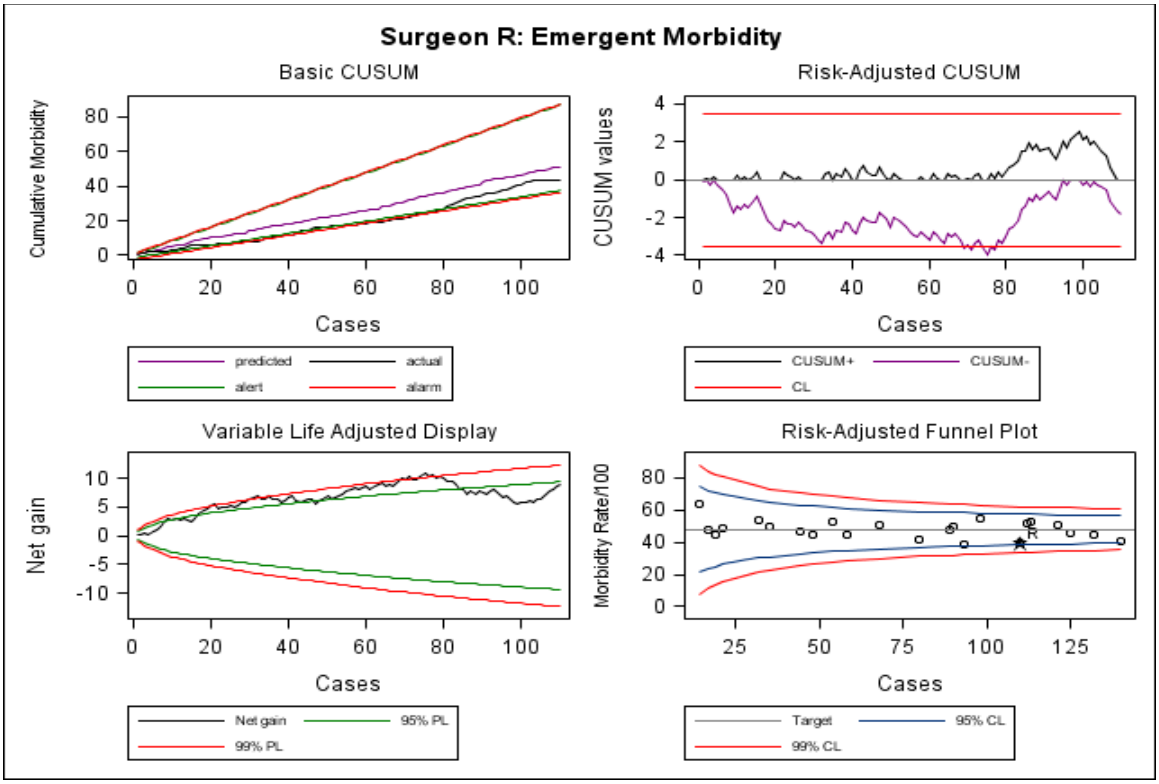


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon S | Total | Surgeon S | Total | Surgeon S | Total |
| | | N=364 | N=3267 | N=112 | N=1713 | N=476 | N=4980 |
| Age | Mean ± SD | 61.43 ± 15.84 | 61.49 ± 15.97 | 59.68 ± 18.46 | 63.33 ± 17.34 | 61.02 ± 16.49 | 62.12 ± 16.47 |
| | Median (IQR) | 64 (51-73) | 64 (52-74) | 60 (47-75) | 66 (52-77) | 63 (51-73) | 64 (52-75) |
| Sex | F | 131 (36.0%) | 1423 (43.6%) | 51 (45.5%) | 888 (51.8%) | 182 (38.2%) | 2311 (46.4%) |
| | M | 233 (64.0%) | 1844 (56.4%) | 61 (54.5%) | 825 (48.2%) | 294 (61.8%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 6.51 ± 6.88 | 5.82 ± 6.53 | 6.72 ± 7.78 | 7.67 ± 7.87 | 6.56 ± 7.09 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-11) | 4 (0-9) | 4 (0-15) | 5 (0-16) | 4 (0-12) | 4 (0-11) |
| Diagnosis | Cancer | 260 (71.4%) | 2038 (62.4%) | 48 (42.9%) | 638 (37.2%) | 308 (64.7%) | 2676 (53.7%) |
| | Diverticular disease | 6 (1.6%) | 182 (5.6%) | 11 (9.8%) | 241 (14.1%) | 17 (3.6%) | 423 (8.5%) |
| | Ulcerative colitis | 23 (6.3%) | 151 (4.6%) | 9 (8.0%) | 82 (4.8%) | 32 (6.7%) | 233 (4.7%) |
| | Crohn's | 13 (3.6%) | 175 (5.4%) | <=5 (4.5%) | 98 (5.7%) | 18 (3.8%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (0.9%) | 45 (2.6%) | <=5 (0.2%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 9 (8.0%) | 122 (7.1%) | 9 (1.9%) | 124 (2.5%) |
| | Stoma related | 50 (13.7%) | 522 (16.0%) | <=5 (1.8%) | 29 (1.7%) | 52 (10.9%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | <=5 (0.3%) | 19 (0.6%) | 11 (9.8%) | 137 (8.0%) | 12 (2.5%) | 156 (3.1%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (1.8%) | 16 (0.9%) | <=5 (0.4%) | 16 (0.3%) |
| | Polyp | <=5 (0.3%) | 8 (0.2%) | 0 (0.0%) | 0 (0.0%) | <=5 (0.2%) | 8 (0.2%) |
| | Other | 10 (2.7%) | 160 (4.9%) | 14 (12.5%) | 292 (17.0%) | 24 (5.0%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 143 (39.3%) | 912 (27.9%) | 20 (17.9%) | 143 (8.3%) | 163 (34.2%) | 1055 (21.2%) |
| | Open | 221 (60.7%) | 2355 (72.1%) | 92 (82.1%) | 1570 (91.7%) | 313 | 3925 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | (65.8%) | (78.8%) |
| Resection type | APR | 71 (19.5%) | 291 (8.9%) | <=5 (3.6%) | 17 (1.0%) | 75 (15.8%) | 308 (6.2%) |
| | AR | 119 (32.7%) | 845 (25.9%) | 16 (14.3%) | 141 (8.2%) | 135 (28.4%) | 986 (19.8%) |
| | bypass | 16 (4.4%) | 162 (5.0%) | 26 (23.2%) | 321 (18.7%) | 42 (8.8%) | 483 (9.7%) |
| | reversal | 45 (12.4%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | 45 (9.5%) | 515 (10.3%) |
| | segmental | 96 (26.4%) | 1404 (43.0%) | 58 (51.8%) | 1113 (65.0%) | 154 (32.4%) | 2517 (50.5%) |
| | total | 17 (4.7%) | 70 (2.1%) | 8 (7.1%) | 101 (5.9%) | 25 (5.3%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 271.41 ± 96.94 | 226.37 ± 96.11 | 192.45 ± 70.36 | 172.77 ± 72.97 | 252.83 ± 97.28 | 207.94 ± 92.40 |
| | Median (IQR) | 270 (207-322) | 213 (160-277) | 186 (148-223) | 160 (125-205) | 252 (179-309) | 191 (143-255) |
| Stoma | | 112 (30.8%) | 698 (21.4%) | 67 (59.8%) | 869 (50.7%) | 179 (37.6%) | 1567 (31.5%) |
| Surgery | Colon | 174 (47.8%) | 2131 (65.2%) | 92 (82.1%) | 1555 (90.8%) | 266 (55.9%) | 3686 (74.0%) |
| | Rectal | 190 (52.2%) | 1136 (34.8%) | 20 (17.9%) | 158 (9.2%) | 210 (44.1%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon S | Total | Surgeon S | Total | Surgeon S | Total |
| | | N=364 | N=3267 | N=112 | N=1713 | N=476 | N=4980 |
| 30 day postoperative complication index* | 0 | 308 (84.6%) | 2722 (83.3%) | 56 (50.0%) | 864 (50.4%) | 364 (76.5%) | 3586 (72.0%) |
| | 2 | 21 (5.8%) | 140 (4.3%) | 26 (23.2%) | 201 (11.7%) | 47 (9.9%) | 341 (6.8%) |
| | 3 | 25 (6.9%) | 240 (7.3%) | 6 (5.4%) | 142 (8.3%) | 31 (6.5%) | 382 (7.7%) |
| | 4 | 10 (2.7%) | 125 (3.8%) | 16 (14.3%) | 312 (18.2%) | 26 (5.5%) | 437 (8.8%) |
| | 5 | 0 (0.0%) | 40 (1.2%) | 8 (7.1%) | 194 (11.3%) | 8 (1.7%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 7.82 ± 5.74 | 9.06 ± 11.67 | 18.47 ± 23.02 | 22.88 ± 28.95 | 10.33 ± 13.02 | 13.81 ± 20.51 |
| | Median (IQR) | 6 (5-8) | 6 (5-9) | 11 (8-19) | 13 (8-26) | 7 (5-10) | 8 (5-14) |
| 30 day readmission | 0 | 339 (93.1%) | 3072 (94.0%) | 103 (92.0%) | 1579 (92.2%) | 442 (92.9%) | 4651 (93.4%) |
| | 1 | 22 (6.0%) | 183 (5.6%) | 7 (6.3%) | 124 (7.2%) | 29 (6.1%) | 307 (6.2%) |
| | 2 | <=5 (0.8%) | 12 (0.4%) | <=5 (1.8%) | 10 (0.6%) | <=5 (1.1%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

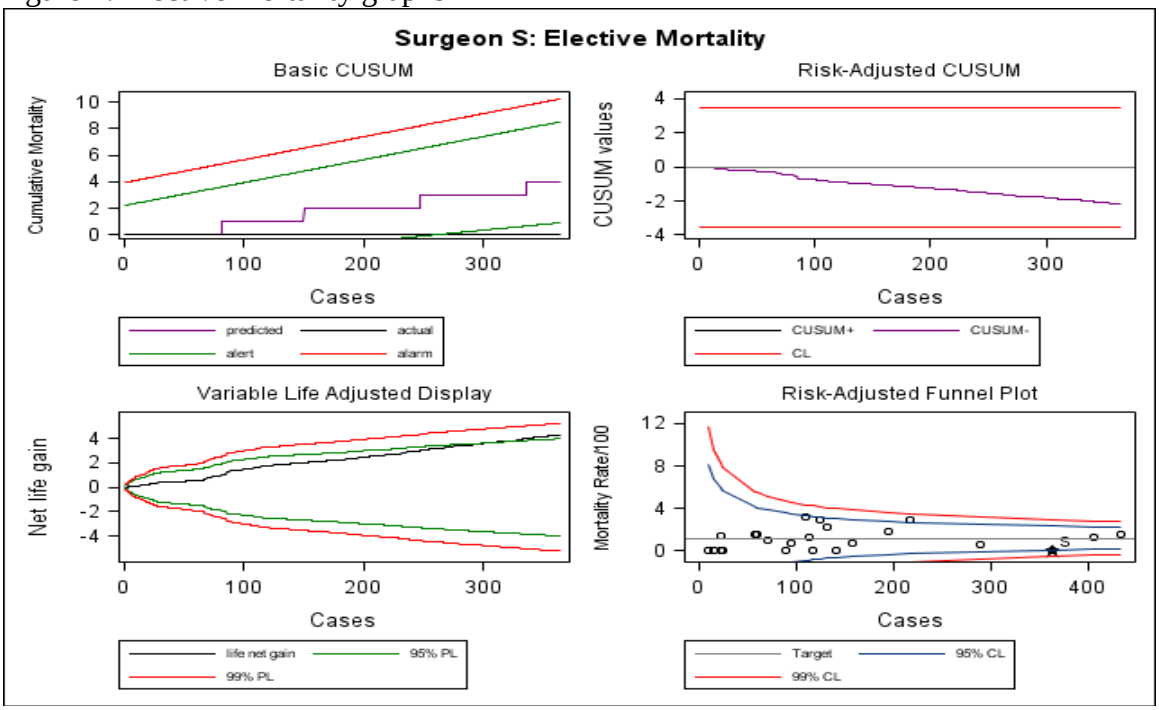



Figure 2: Elective morbidity graphs

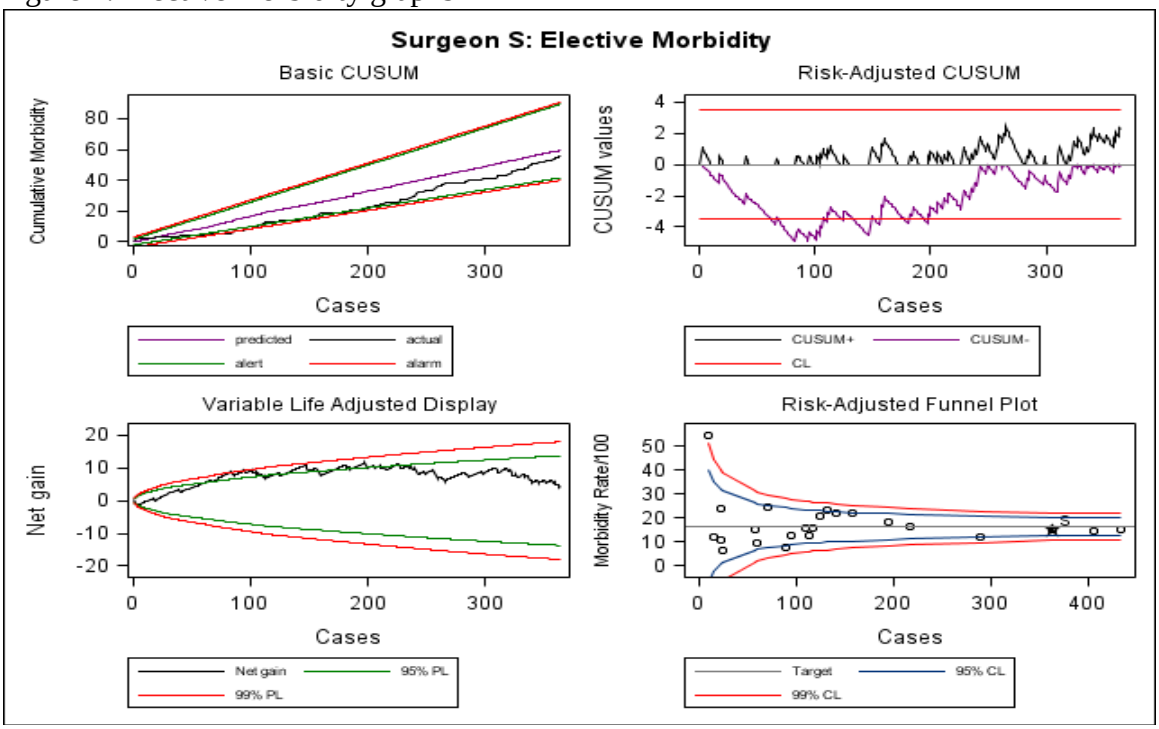


Figure 3: Emergent mortality graphs

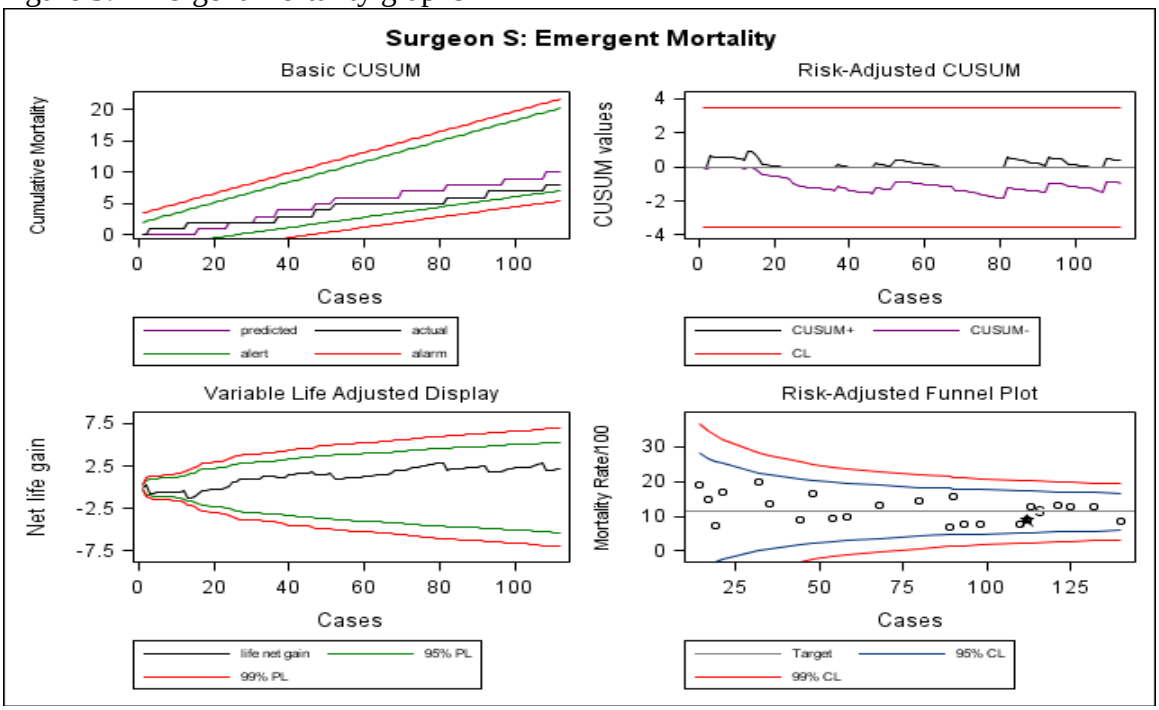



Figure 4: Emergent morbidity graphs

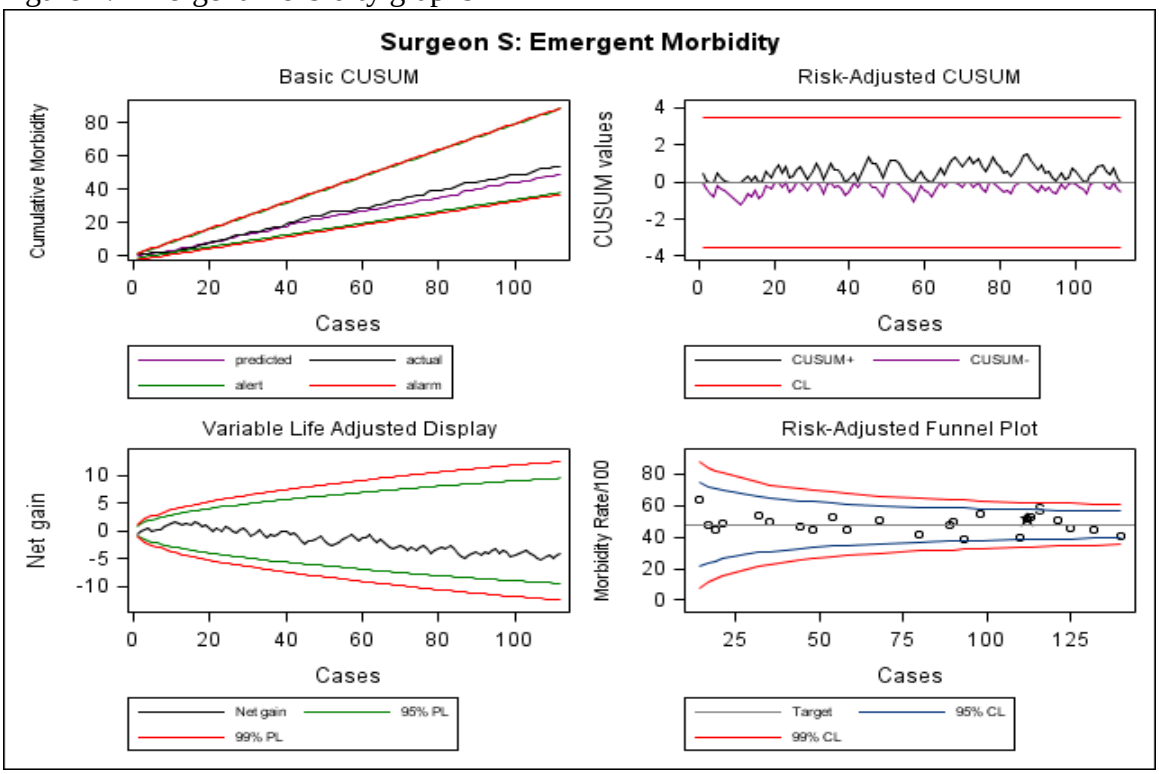


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon T | Total | Surgeon T | Total | Surgeon T | Total |
| | | N=60 | N=3267 | N=121 | N=1713 | N=181 | N=4980 |
| Age | Mean ± SD | 62.30 ± 13.86 | 61.49 ± 15.97 | 64.28 ± 15.82 | 63.33 ± 17.34 | 63.62 ± 15.19 | 62.12 ± 16.47 |
| | Median (IQR) | 62 (54-73) | 64 (52-74) | 65 (53-77) | 66 (52-77) | 64 (53-75) | 64 (52-75) |
| Sex | F | 24 (40.0%) | 1423 (43.6%) | 63 (52.1%) | 888 (51.8%) | 87 (48.1%) | 2311 (46.4%) |
| | M | 36 (60.0%) | 1844 (56.4%) | 58 (47.9%) | 825 (48.2%) | 94 (51.9%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 4.05 ± 5.33 | 5.82 ± 6.53 | 8.31 ± 8.22 | 7.67 ± 7.87 | 6.90 ± 7.64 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (0-5) | 4 (0-9) | 6 (2-16) | 5 (0-16) | 4 (0-12) | 4 (0-11) |
| Diagnosis | Cancer | 20 (33.3%) | 2038 (62.4%) | 40 (33.1%) | 638 (37.2%) | 60 (33.1%) | 2676 (53.7%) |
| | Diverticular disease | 9 (15.0%) | 182 (5.6%) | 24 (19.8%) | 241 (14.1%) | 33 (18.2%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (1.7%) | 151 (4.6%) | <=5 (0.8%) | 82 (4.8%) | <=5 (1.1%) | 233 (4.7%) |
| | Crohn's | <=5 (1.7%) | 175 (5.4%) | <=5 (2.5%) | 98 (5.7%) | <=5 (2.2%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (3.3%) | 45 (2.6%) | <=5 (2.2%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | 9 (7.4%) | 122 (7.1%) | 9 (5.0%) | 124 (2.5%) |
| | Other colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (0.8%) | <=5 (0.2%) | <=5 (0.6%) | 6 (0.1%) |
| | Stoma related | 27 (45.0%) | 522 (16.0%) | <=5 (2.5%) | 29 (1.7%) | 30 (16.6%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | 8 (6.6%) | 137 (8.0%) | 8 (4.4%) | 156 (3.1%) |
| | Bleeding | 0 (0.0%) | 0 (0.0%) | <=5 (0.8%) | 16 (0.9%) | <=5 (0.6%) | 16 (0.3%) |
| | Other | <=5 (3.3%) | 160 (4.9%) | 27 (22.3%) | 292 (17.0%) | 29 (16.0%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 25 (41.7%) | 912 (27.9%) | 12 (9.9%) | 143 (8.3%) | 37 (20.4%) | 1055 (21.2%) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Open | 35 (58.3%) | 2355 (72.1%) | 109 (90.1%) | 1570 (91.7%) | 144 (79.6%) | 3925 (78.8%) |
| Resection type | APR | <=5 (5.0%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | <=5 (1.7%) | 308 (6.2%) |
| | AR | 7 (11.7%) | 845 (25.9%) | 10 (8.3%) | 141 (8.2%) | 17 (9.4%) | 986 (19.8%) |
| | bypass | <=5 (8.3%) | 162 (5.0%) | 23 (19.0%) | 321 (18.7%) | 28 (15.5%) | 483 (9.7%) |
| | reversal | 24 (40.0%) | 495 (15.2%) | <=5 (0.8%) | 20 (1.2%) | 25 (13.8%) | 515 (10.3%) |
| | segmental | 20 (33.3%) | 1404 (43.0%) | 82 (67.8%) | 1113 (65.0%) | 102 (56.4%) | 2517 (50.5%) |
| | total | <=5 (1.7%) | 70 (2.1%) | <=5 (4.1%) | 101 (5.9%) | 6 (3.3%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 173.42 ± 63.33 | 226.37 ± 96.11 | 148.09 ± 62.67 | 172.77 ± 72.97 | 156.49 ± 63.84 | 207.94 ± 92.40 |
| | Median (IQR) | 178 (129-208) | 213 (160-277) | 138 (112-165) | 160 (125-205) | 149 (113-187) | 191 (143-255) |
| Stoma | | 11 (18.3%) | 698 (21.4%) | 58 (47.9%) | 869 (50.7%) | 69 (38.1%) | 1567 (31.5%) |
| Surgery | Colon | 50 (83.3%) | 2131 (65.2%) | 111 (91.7%) | 1555 (90.8%) | 161 (89.0%) | 3686 (74.0%) |
| | Rectal | 10 (16.7%) | 1136 (34.8%) | 10 (8.3%) | 158 (9.2%) | 20 (11.0%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon T | Total | Surgeon T | Total | Surgeon T | Total |
| | | N=60 | N=3267 | N=121 | N=1713 | N=181 | N=4980 |
| 30 day postoperative complication index* | 0 | 54 (90.0%) | 2722 (83.3%) | 52 (43.0%) | 864 (50.4%) | 106 (58.6%) | 3586 (72.0%) |
| | 2 | <=5 (1.7%) | 140 (4.3%) | 11 (9.1%) | 201 (11.7%) | 12 (6.6%) | 341 (6.8%) |
| | 3 | <=5 (5.0%) | 240 (7.3%) | 8 (6.6%) | 142 (8.3%) | 11 (6.1%) | 382 (7.7%) |
| | 4 | <=5 (1.7%) | 125 (3.8%) | 32 (26.4%) | 312 (18.2%) | 33 (18.2%) | 437 (8.8%) |
| | 5 | <=5 (1.7%) | 40 (1.2%) | 18 (14.9%) | 194 (11.3%) | 19 (10.5%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 7.18 ± 5.63 | 9.06 ± 11.67 | 17.89 ± 14.30 | 22.88 ± 28.95 | 14.34 ± 13.13 | 13.81 ± 20.51 |
| | Median (IQR) | 5 (4-9) | 6 (5-9) | 13 (8-24) | 13 (8-26) | 10 (5-18) | 8 (5-14) |
| 30 day readmission | 0 | 57 (95.0%) | 3072 (94.0%) | 114 (94.2%) | 1579 (92.2%) | 171 (94.5%) | 4651 (93.4%) |
| | 1 | <=5 (5.0%) | 183 (5.6%) | 6 (5.0%) | 124 (7.2%) | 9 (5.0%) | 307 (6.2%) |
| | 2 | 0 (0.0%) | 12 (0.4%) | <=5 (0.8%) | 10 (0.6%) | <=5 (0.6%) | 22 (0.4%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

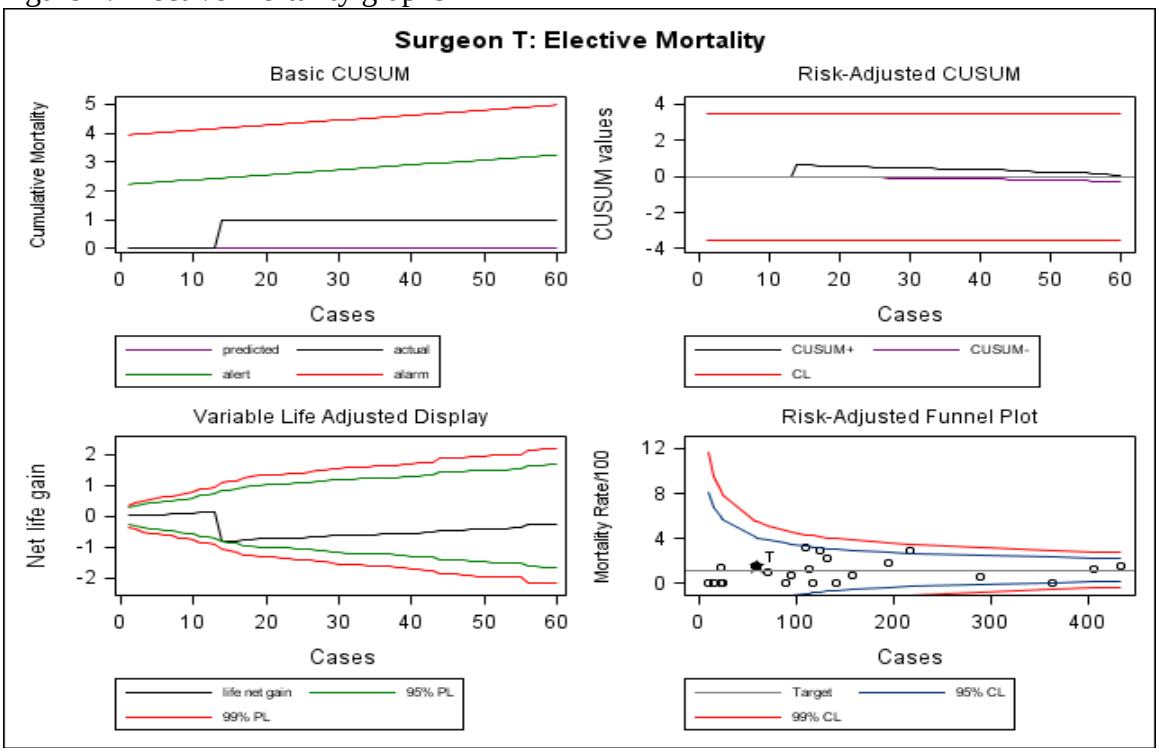



Figure 2: Elective morbidity graphs

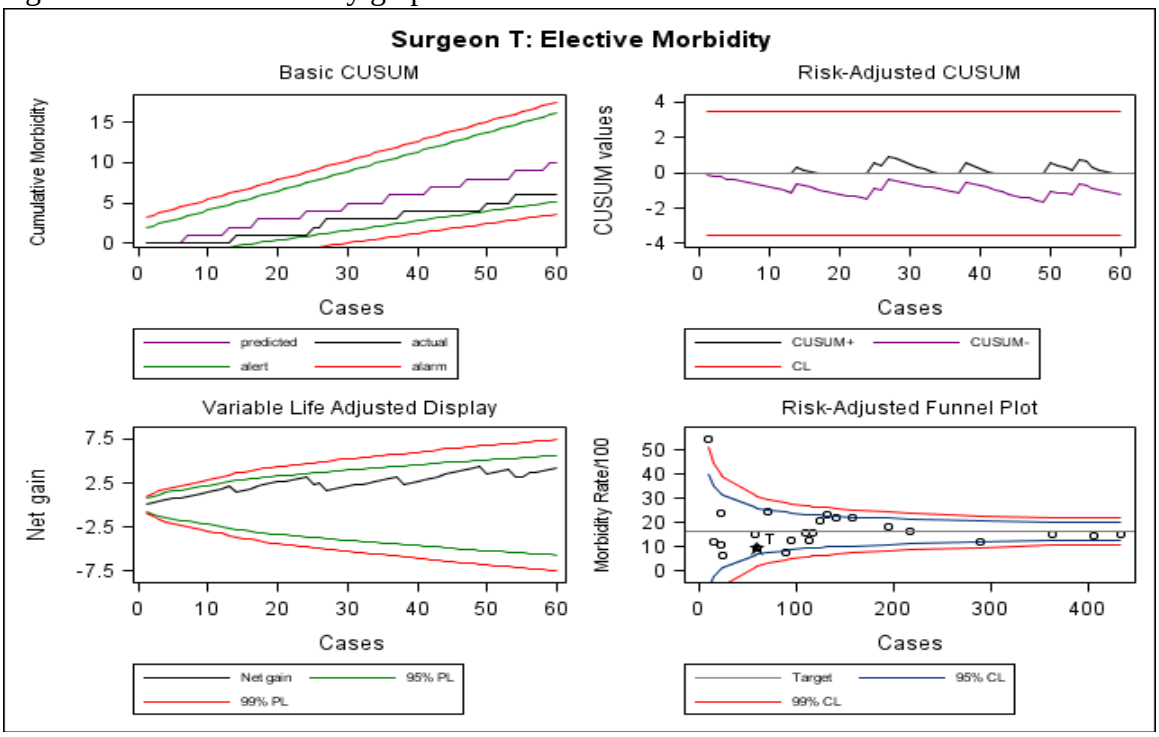


Figure 3: Emergent mortality graphs

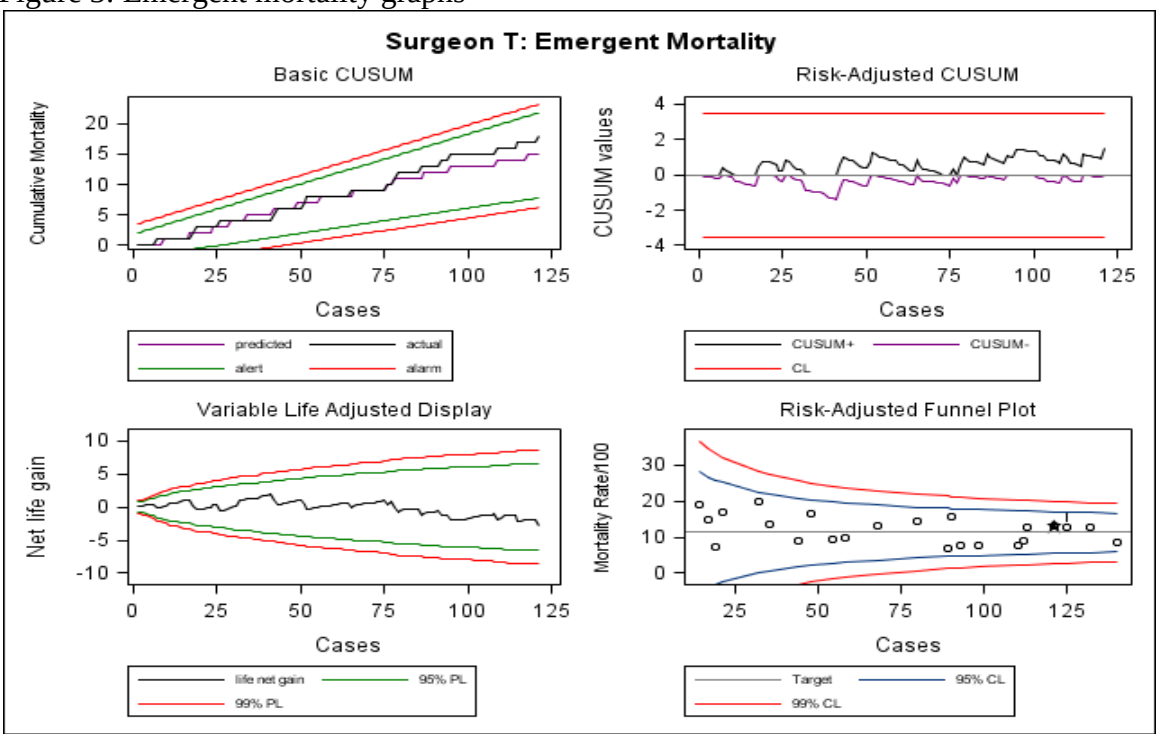



Figure 4: Emergent morbidity graphs

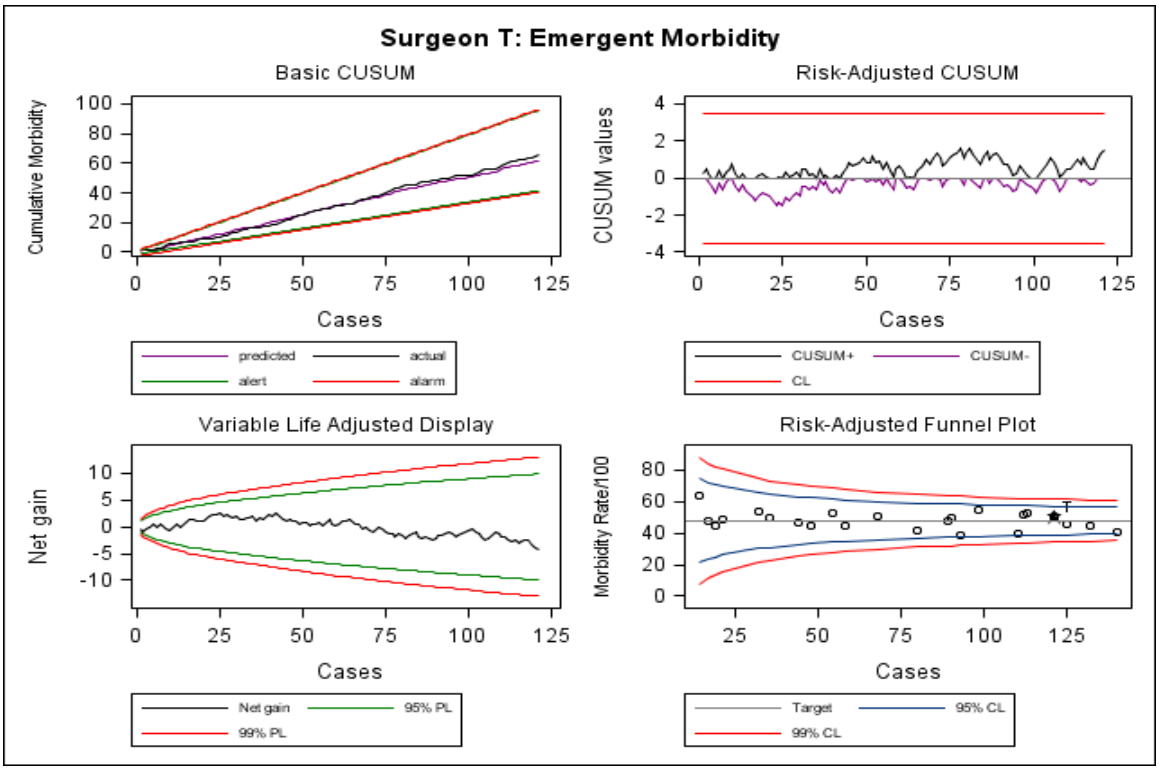


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon U | Total | Surgeon U | Total | Surgeon U | Total |
| | | N=10 | N=3267 | N=21 | N=1713 | N=31 | N=4980 |
| Age | Mean ± SD | 61.40 ± 7.38 | 61.49 ± 15.97 | 69.29 ± 12.57 | 63.33 ± 17.34 | 66.74 ± 11.65 | 62.12 ± 16.47 |
| | Median (IQR) | 62 (56-67) | 64 (52-74) | 70 (60-80) | 66 (52-77) | 67 (57-76) | 64 (52-75) |
| Sex | F | <=5 (20.0%) | 1423 (43.6%) | 14 (66.7%) | 888 (51.8%) | 16 (51.6%) | 2311 (46.4%) |
| | M | 8 (80.0%) | 1844 (56.4%) | 7 (33.3%) | 825 (48.2%) | 15 (48.4%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 11.70 ± 8.00 | 5.82 ± 6.53 | 6.43 ± 7.13 | 7.67 ± 7.87 | 8.13 ± 7.71 | 6.46 ± 7.08 |
| | Median (IQR) | 16 (4-16) | 4 (0-9) | 5 (0-16) | 5 (0-16) | 6 (0-16) | 4 (0-11) |
| Diagnosis | Cancer | 8 (80.0%) | 2038 (62.4%) | 8 (38.1%) | 638 (37.2%) | 16 (51.6%) | 2676 (53.7%) |
| | Diverticular disease | 0 (0.0%) | 182 (5.6%) | <=5 (9.5%) | 241 (14.1%) | <=5 (6.5%) | 423 (8.5%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (14.3%) | 122 (7.1%) | <=5 (9.7%) | 124 (2.5%) |
| | Stoma related | <=5 (20.0%) | 522 (16.0%) | <=5 (4.8%) | 29 (1.7%) | <=5 (9.7%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | <=5 (9.5%) | 137 (8.0%) | <=5 (6.5%) | 156 (3.1%) |
| | Other | 0 (0.0%) | 160 (4.9%) | <=5 (23.8%) | 292 (17.0%) | <=5 (16.1%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 0 (0.0%) | 912 (27.9%) | <=5 (4.8%) | 143 (8.3%) | <=5 (3.2%) | 1055 (21.2%) |
| | Open | 10 (100.0%) | 2355 (72.1%) | 20 (95.2%) | 1570 (91.7%) | 30 (96.8%) | 3925 (78.8%) |
| Resection type | AR | <=5 (30.0%) | 845 (25.9%) | 0 (0.0%) | 141 (8.2%) | <=5 (9.7%) | 986 (19.8%) |
| | bypass | 0 (0.0%) | 162 (5.0%) | <=5 (9.5%) | 321 (18.7%) | <=5 (6.5%) | 483 (9.7%) |
| | reversal | <=5 (20.0%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | <=5 (6.5%) | 515 (10.3%) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | segmental | <=5 (50.0%) | 1404 (43.0%) | 19 (90.5%) | 1113 (65.0%) | 24 (77.4%) | 2517 (50.5%) |
| OR time, minutes | Mean ± SD | 420.70 ± 174.12 | 226.37 ± 96.11 | 224.43 ± 64.84 | 172.77 ± 72.97 | 287.74 ± 143.51 | 207.94 ± 92.40 |
| | Median (IQR) | 409 (238-528) | 213 (160-277) | 219 (178-251) | 160 (125-205) | 238 (197-338) | 191 (143-255) |
| Stoma | | <=5 (20.0%) | 698 (21.4%) | 10 (47.6%) | 869 (50.7%) | 12 (38.7%) | 1567 (31.5%) |
| Surgery | Colon | 7 (70.0%) | 2131 (65.2%) | 21 (100.0%) | 1555 (90.8%) | 28 (90.3%) | 3686 (74.0%) |
| | Rectal | <=5 (30.0%) | 1136 (34.8%) | 0 (0.0%) | 158 (9.2%) | <=5 (9.7%) | 1294 (26.0%) |

*using Elixhauser comorbidity score*

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon U | Total | Surgeon U | Total | Surgeon U | Total |
| | | N=10 | N=3267 | N=21 | N=1713 | N=31 | N=4980 |
| 30 day postoperative complication index* | 0 | <=5 (40.0%) | 2722 (83.3%) | 10 (47.6%) | 864 (50.4%) | 14 (45.2%) | 3586 (72.0%) |
| | 2 | <=5 (10.0%) | 140 (4.3%) | <=5 (19.0%) | 201 (11.7%) | <=5 (16.1%) | 341 (6.8%) |
| | 3 | <=5 (40.0%) | 240 (7.3%) | <=5 (9.5%) | 142 (8.3%) | 6 (19.4%) | 382 (7.7%) |
| | 4 | <=5 (10.0%) | 125 (3.8%) | <=5 (9.5%) | 312 (18.2%) | <=5 (9.7%) | 437 (8.8%) |
| | 5 | 0 (0.0%) | 40 (1.2%) | <=5 (14.3%) | 194 (11.3%) | <=5 (9.7%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 12.80 ± 7.52 | 9.06 ± 11.67 | 18.48 ± 19.60 | 22.88 ± 28.95 | 16.65 ± 16.75 | 13.81 ± 20.51 |
| | Median (IQR) | 12 (7-20) | 6 (5-9) | 12 (7-21) | 13 (8-26) | 12 (7-21) | 8 (5-14) |
| 30 day readmission | 0 | 6 (60.0%) | 3072 (94.0%) | 18 (85.7%) | 1579 (92.2%) | 24 (77.4%) | 4651 (93.4%) |
| | 1 | <=5 (40.0%) | 183 (5.6%) | <=5 (14.3%) | 124 (7.2%) | 7 (22.6%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

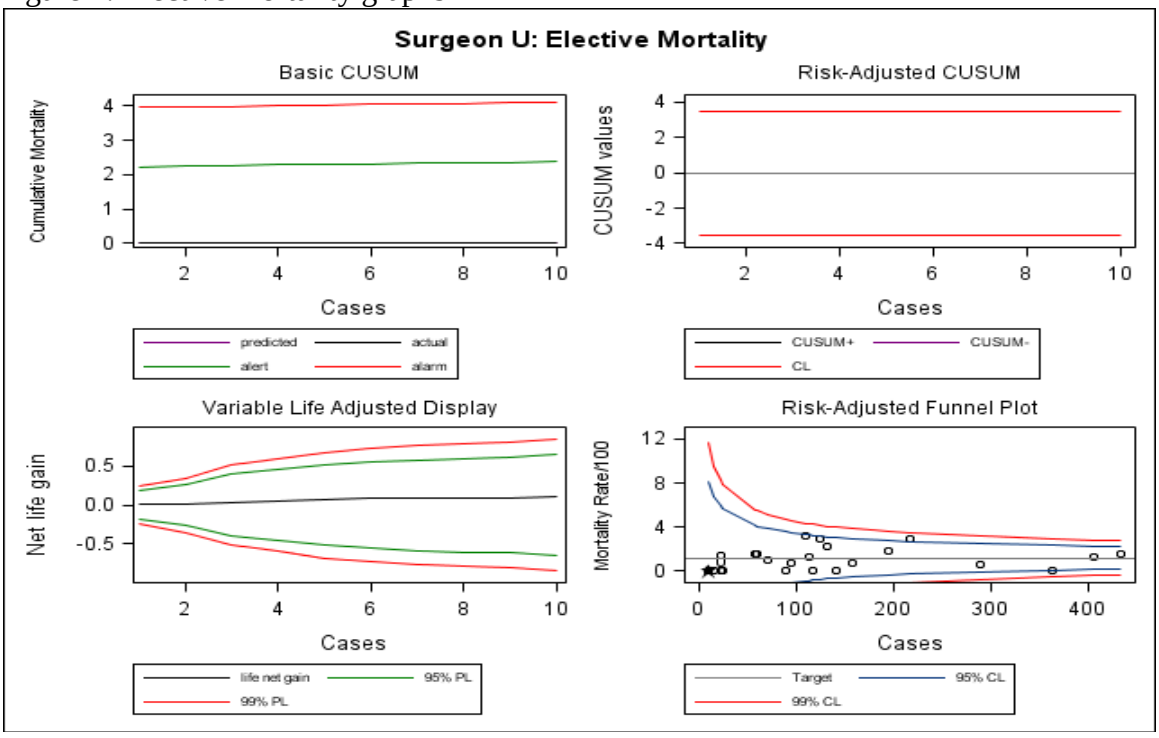



Figure 2: Elective morbidity graphs

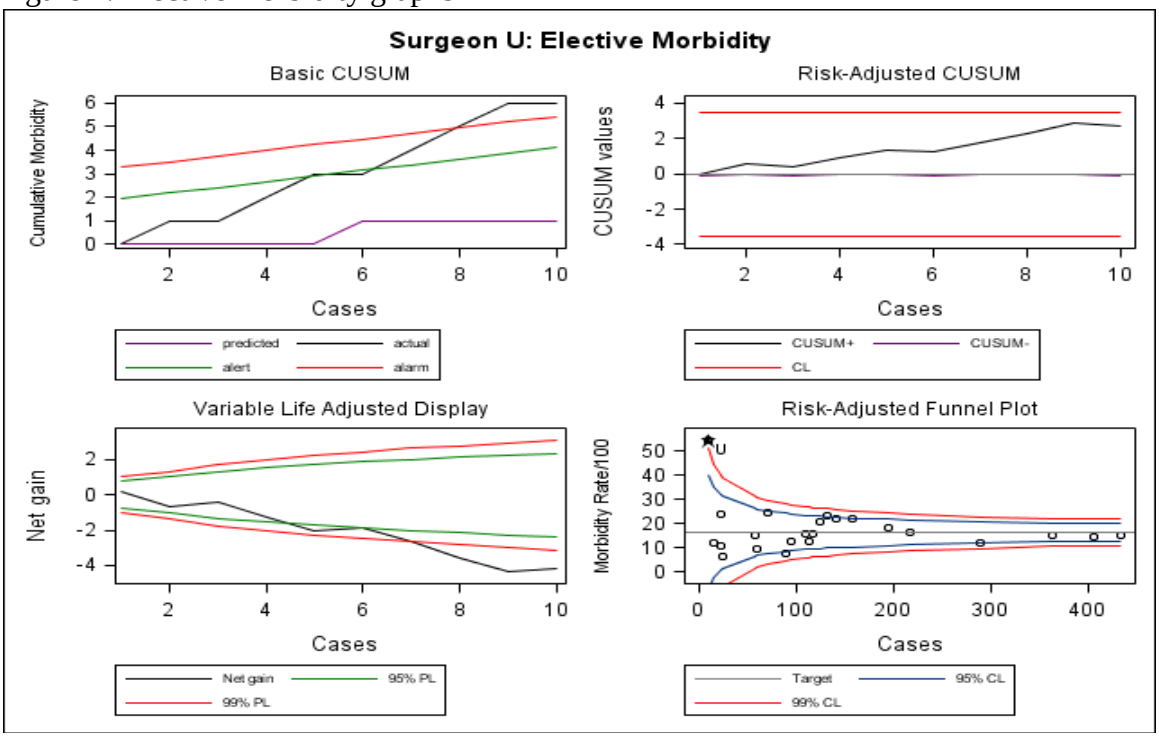


Figure 3: Emergent mortality graphs

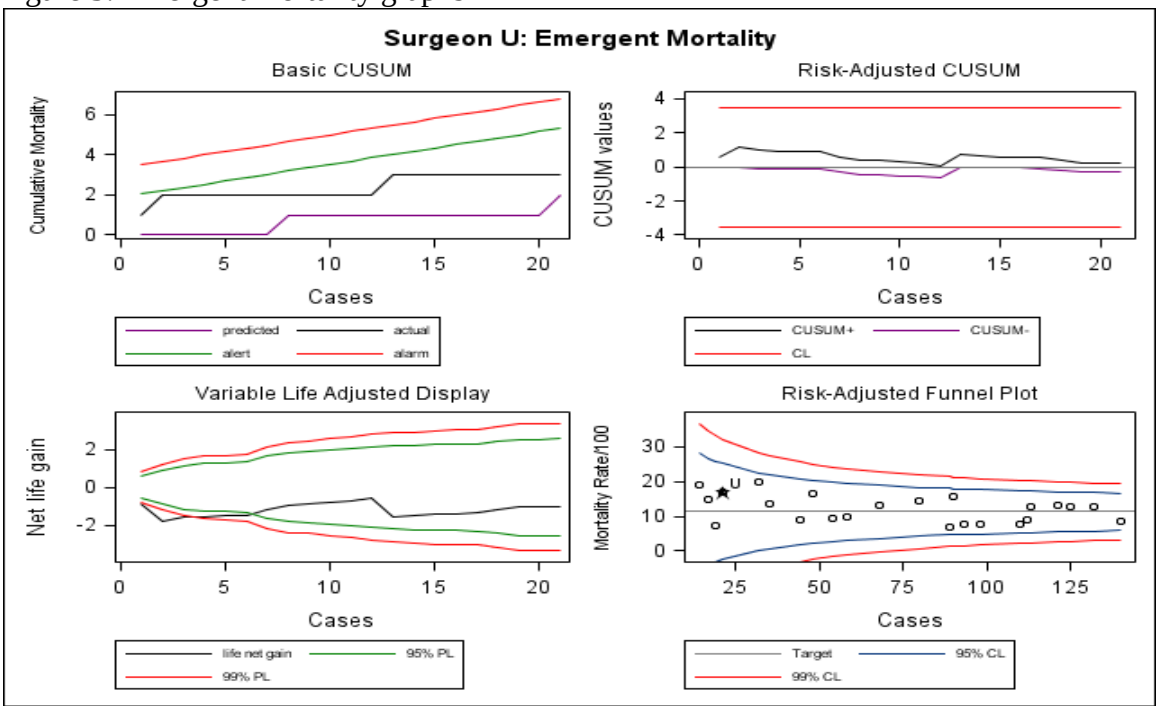



Figure 4: Emergent morbidity graphs

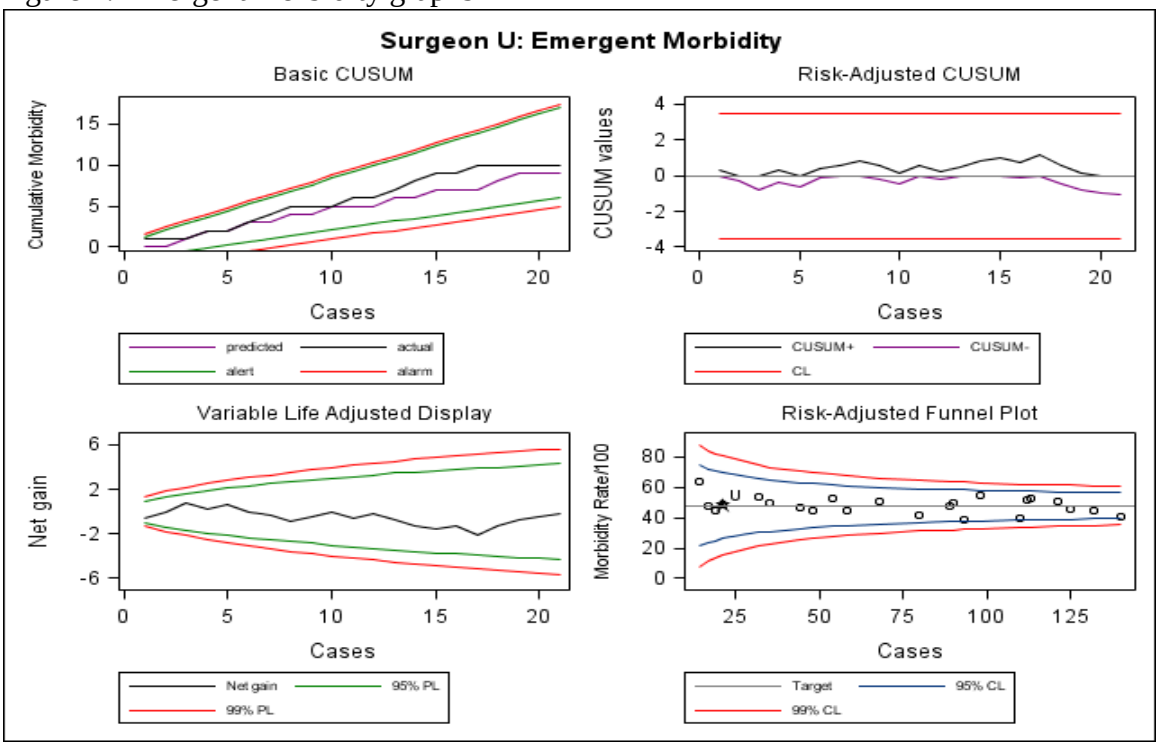


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon V | Total | Surgeon V | Total | Surgeon V | Total |
| | | N=57 | N=3267 | N=14 | N=1713 | N=71 | N=4980 |
| Age | Mean ± SD | 67.28 ± 13.04 | 61.49 ± 15.97 | 60.07 ± 14.53 | 63.33 ± 17.34 | 65.86 ± 13.54 | 62.12 ± 16.47 |
| | Median (IQR) | 70 (61-77) | 64 (52-74) | 61 (50-70) | 66 (52-77) | 69 (57-76) | 64 (52-75) |
| Sex | F | 25 (43.9%) | 1423 (43.6%) | 6 (42.9%) | 888 (51.8%) | 31 (43.7%) | 2311 (46.4%) |
| | M | 32 (56.1%) | 1844 (56.4%) | 8 (57.1%) | 825 (48.2%) | 40 (56.3%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 6.70 ± 6.64 | 5.82 ± 6.53 | 5.43 ± 5.23 | 7.67 ± 7.87 | 6.45 ± 6.37 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (4-10) | 4 (0-9) | 4 (0-10) | 5 (0-16) | 4 (2-10) | 4 (0-11) |
| Diagnosis | Cancer | 43 (75.4%) | 2038 (62.4%) | <=5 (28.6%) | 638 (37.2%) | 47 (66.2%) | 2676 (53.7%) |
| | Diverticular disease | <=5 (5.3%) | 182 (5.6%) | <=5 (14.3%) | 241 (14.1%) | <=5 (7.0%) | 423 (8.5%) |
| | Ulcerative colitis | <=5 (1.8%) | 151 (4.6%) | 0 (0.0%) | 82 (4.8%) | <=5 (1.4%) | 233 (4.7%) |
| | Crohn's | 0 (0.0%) | 175 (5.4%) | <=5 (14.3%) | 98 (5.7%) | <=5 (2.8%) | 273 (5.5%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (7.1%) | 122 (7.1%) | <=5 (1.4%) | 124 (2.5%) |
| | Stoma related | <=5 (5.3%) | 522 (16.0%) | <=5 (7.1%) | 29 (1.7%) | <=5 (5.6%) | 551 (11.1%) |
| | Hernia | 0 (0.0%) | <=5 (0.1%) | <=5 (7.1%) | 10 (0.6%) | <=5 (1.4%) | 13 (0.3%) |
| | Other | 7 (12.3%) | 160 (4.9%) | <=5 (21.4%) | 292 (17.0%) | 10 (14.1%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 36 (63.2%) | 912 (27.9%) | <=5 (21.4%) | 143 (8.3%) | 39 (54.9%) | 1055 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | (21.2%) |
| | Open | 21 (36.8%) | 2355 (72.1%) | 11 (78.6%) | 1570 (91.7%) | 32 (45.1%) | 3925 (78.8%) |
| Resection type | APR | <=5 (8.8%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | <=5 (7.0%) | 308 (6.2%) |
| | AR | 17 (29.8%) | 845 (25.9%) | <=5 (35.7%) | 141 (8.2%) | 22 (31.0%) | 986 (19.8%) |
| | bypass | 7 (12.3%) | 162 (5.0%) | <=5 (7.1%) | 321 (18.7%) | 8 (11.3%) | 483 (9.7%) |
| | reversal | <=5 (7.0%) | 495 (15.2%) | <=5 (7.1%) | 20 (1.2%) | <=5 (7.0%) | 515 (10.3%) |
| | segmental | 22 (38.6%) | 1404 (43.0%) | 7 (50.0%) | 1113 (65.0%) | 29 (40.8%) | 2517 (50.5%) |
| | total | <=5 (3.5%) | 70 (2.1%) | 0 (0.0%) | 101 (5.9%) | <=5 (2.8%) | 171 (3.4%) |
| OR time, minutes | Mean ± SD | 328.47 ± 104.17 | 226.37 ± 96.11 | 265.14 ± 149.50 | 172.77 ± 72.97 | 315.99 ± 116.08 | 207.94 ± 92.40 |
| | Median (IQR) | 322 (259-417) | 213 (160-277) | 243 (192-321) | 160 (125-205) | 314 (229-412) | 191 (143-255) |
| Stoma | | 20 (35.1%) | 698 (21.4%) | 9 (64.3%) | 869 (50.7%) | 29 (40.8%) | 1567 (31.5%) |
| Surgery | Colon | 35 (61.4%) | 2131 (65.2%) | 9 (64.3%) | 1555 (90.8%) | 44 (62.0%) | 3686 (74.0%) |
| | Rectal | 22 (38.6%) | 1136 (34.8%) | <=5 (35.7%) | 158 (9.2%) | 27 (38.0%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

**Surgeon V Performance**

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon V | Total | Surgeon V | Total | Surgeon V | Total |
| | | N=57 | N=3267 | N=14 | N=1713 | N=71 | N=4980 |
| 30 day postoperative complication index* | 0 | 48 (84.2%) | 2722 (83.3%) | 6 (42.9%) | 864 (50.4%) | 54 (76.1%) | 3586 (72.0%) |
| | 2 | <=5 (1.8%) | 140 (4.3%) | 0 (0.0%) | 201 (11.7%) | <=5 (1.4%) | 341 (6.8%) |
| | 3 | <=5 (8.8%) | 240 (7.3%) | <=5 (21.4%) | 142 (8.3%) | 8 (11.3%) | 382 (7.7%) |
| | 4 | <=5 (3.5%) | 125 (3.8%) | <=5 (21.4%) | 312 (18.2%) | <=5 (7.0%) | 437 (8.8%) |
| | 5 | <=5 (1.8%) | 40 (1.2%) | <=5 (14.3%) | 194 (11.3%) | <=5 (4.2%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 7.75 ± 9.56 | 9.06 ± 11.67 | 25.07 ± 26.42 | 22.88 ± 28.95 | 11.17 ± 15.84 | 13.81 ± 20.51 |
| | Median (IQR) | 5 (3-7) | 6 (5-9) | 12 (4-45) | 13 (8-26) | 5 (3-9) | 8 (5-14) |
| 30 day readmission | 0 | 53 (93.0%) | 3072 (94.0%) | 12 (85.7%) | 1579 (92.2%) | 65 (91.5%) | 4651 (93.4%) |
| | 1 | <=5 (7.0%) | 183 (5.6%) | <=5 (14.3%) | 124 (7.2%) | 6 (8.5%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

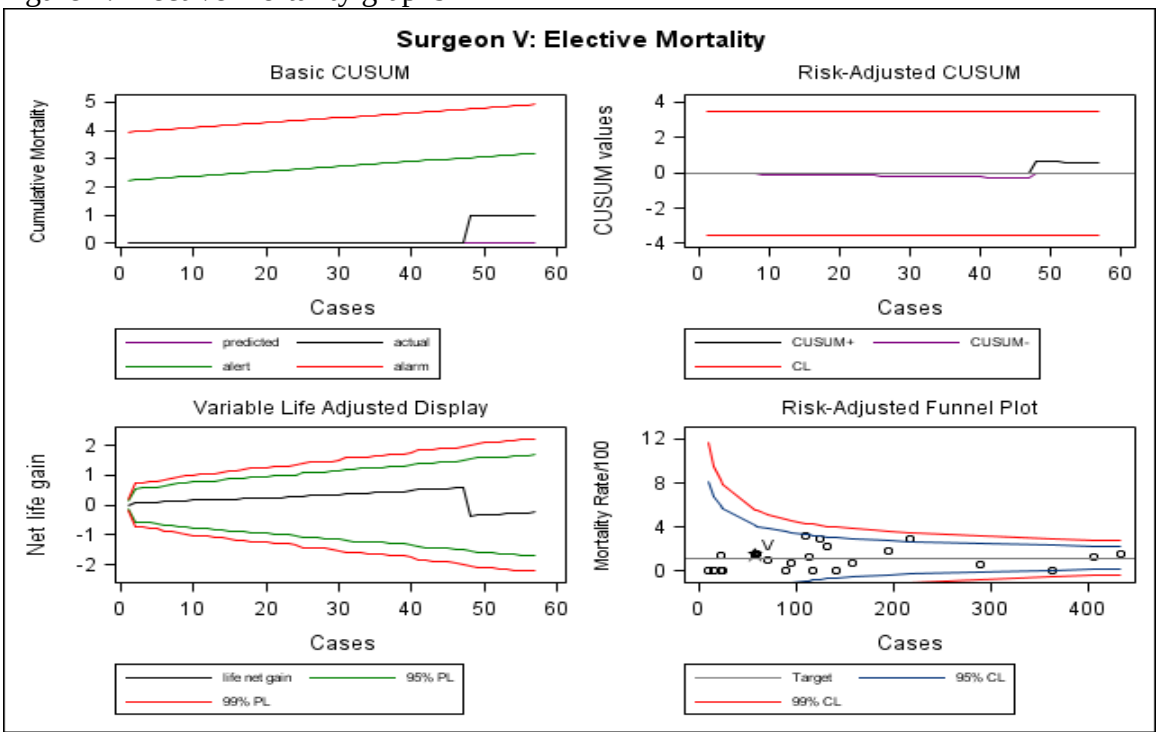



Figure 2: Elective morbidity graphs

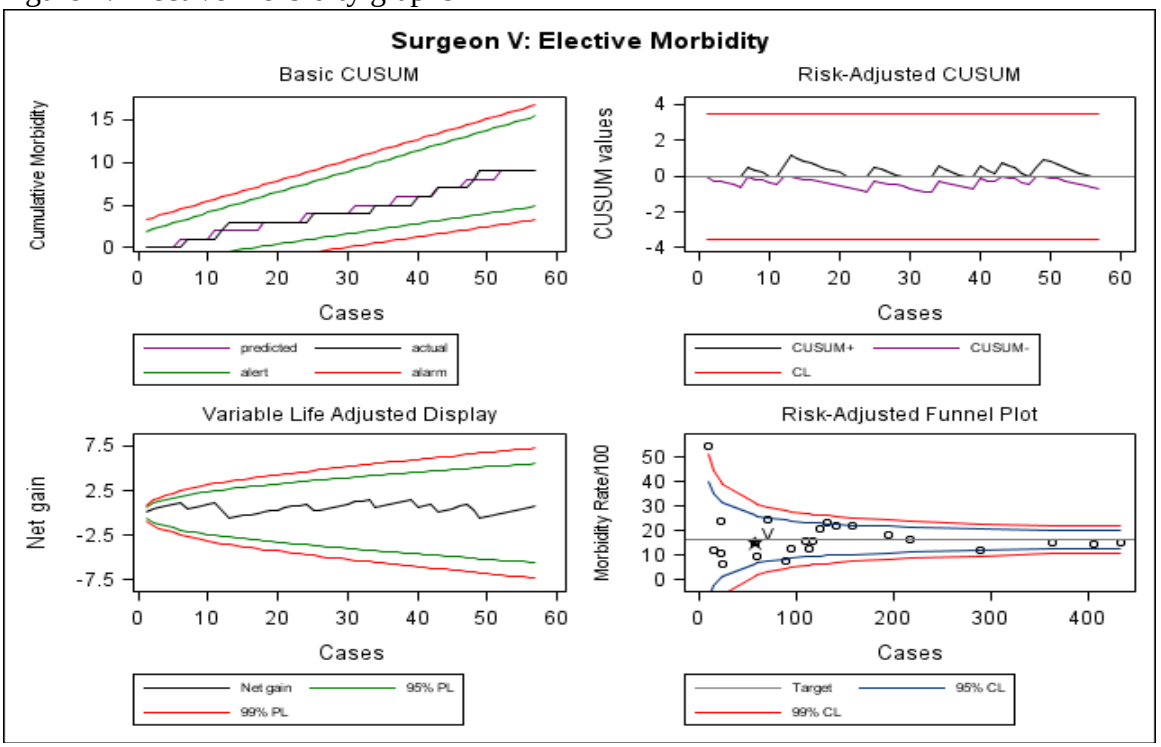


Figure 3: Emergent mortality graphs

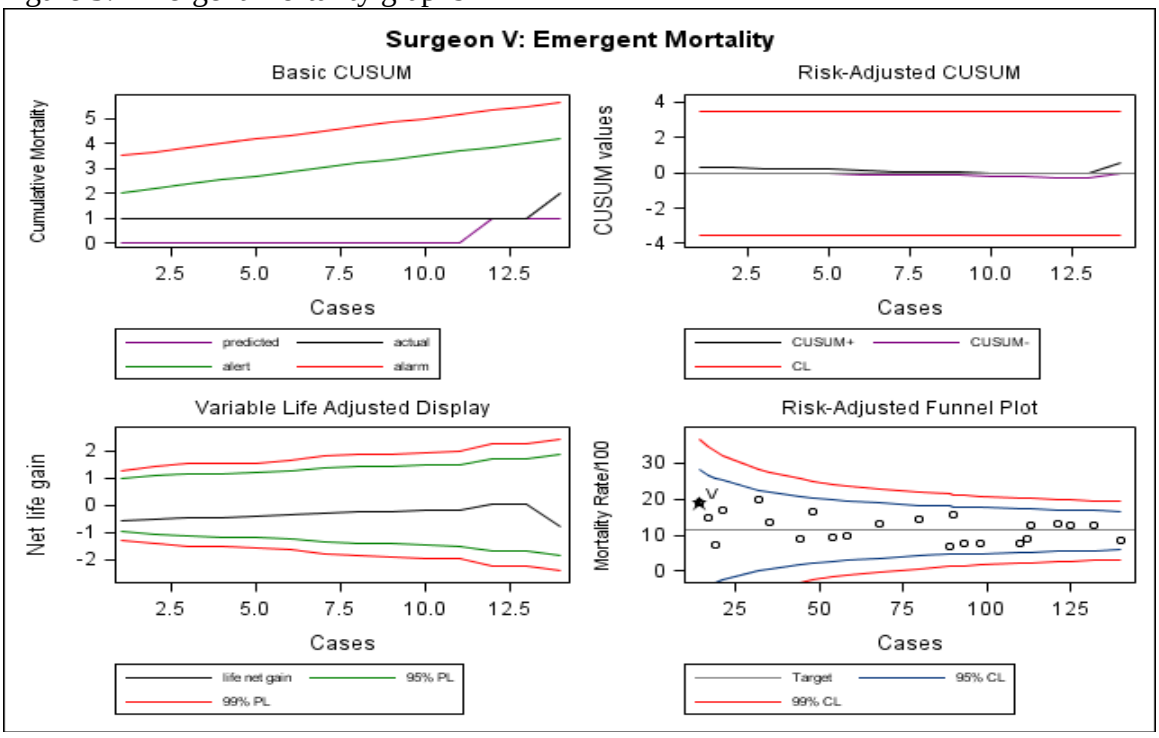



Figure 4: Emergent morbidity graphs

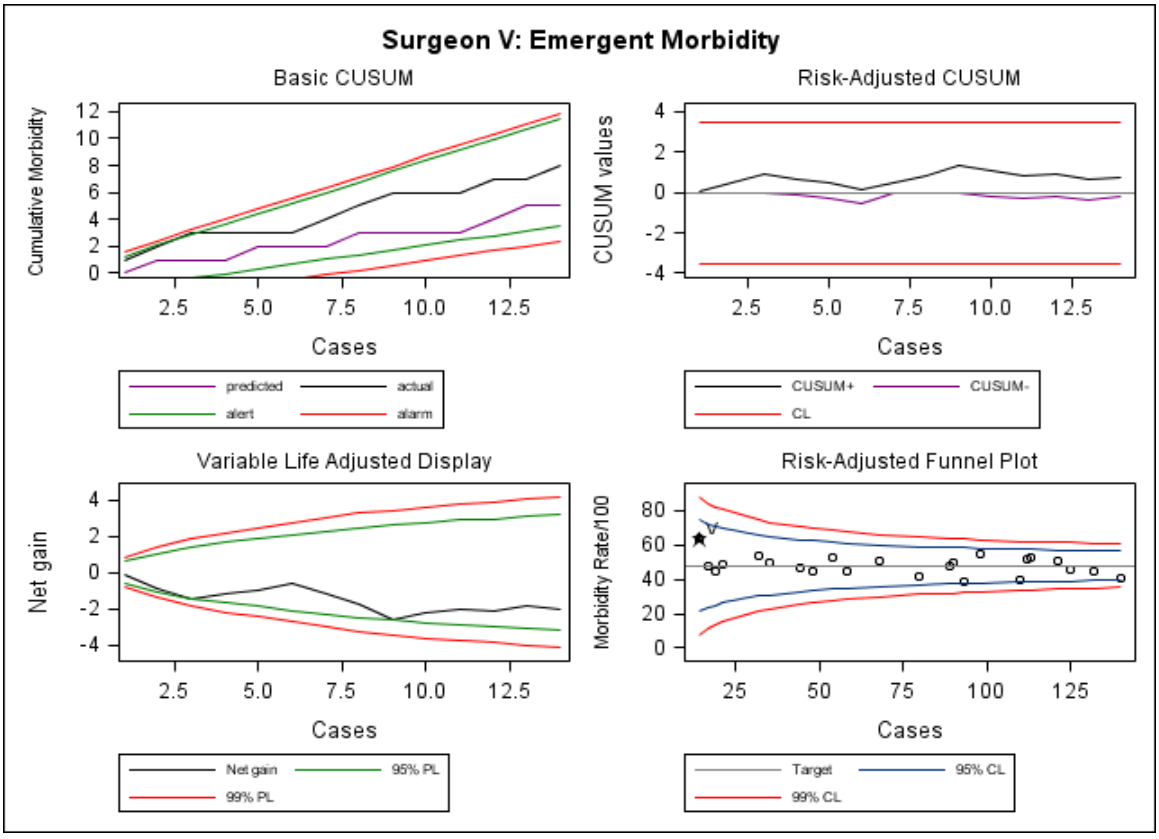


Table 1: Patient Demographics

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon W | Total | Surgeon W | Total | Surgeon W | Total |
| | | N=142 | N=3267 | N=32 | N=1713 | N=174 | N=4980 |
| Age | Mean ± SD | 65.44 ± 13.91 | 61.49 ± 15.97 | 64.22 ± 16.83 | 63.33 ± 17.34 | 65.22 ± 14.44 | 62.12 ± 16.47 |
| | Median (IQR) | 67 (55-76) | 64 (52-74) | 70 (53-75) | 66 (52-77) | 68 (54-75) | 64 (52-75) |
| Sex | F | 61 (43.0%) | 1423 (43.6%) | 14 (43.8%) | 888 (51.8%) | 75 (43.1%) | 2311 (46.4%) |
| | M | 81 (57.0%) | 1844 (56.4%) | 18 (56.3%) | 825 (48.2%) | 99 (56.9%) | 2669 (53.6%) |
| Comorbidity score* | Mean ± SD | 8.58 ± 6.75 | 5.82 ± 6.53 | 10.34 ± 7.26 | 7.67 ± 7.87 | 8.90 ± 6.86 | 6.46 ± 7.08 |
| | Median (IQR) | 4 (4-16) | 4 (0-9) | 13 (4-16) | 5 (0-16) | 5 (4-16) | 4 (0-11) |
| Diagnosis | Cancer | 117 (82.4%) | 2038 (62.4%) | 19 (59.4%) | 638 (37.2%) | 136 (78.2%) | 2676 (53.7%) |
| | Crohn's | 0 (0.0%) | 175 (5.4%) | <=5 (3.1%) | 98 (5.7%) | <=5 (0.6%) | 273 (5.5%) |
| | Infectious colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (9.4%) | 45 (2.6%) | <=5 (1.7%) | 49 (1.0%) |
| | Ischemic colitis | 0 (0.0%) | <=5 (0.1%) | <=5 (6.3%) | 122 (7.1%) | <=5 (1.1%) | 124 (2.5%) |
| | Stoma related | 25 (17.6%) | 522 (16.0%) | <=5 (3.1%) | 29 (1.7%) | 26 (14.9%) | 551 (11.1%) |
| | Volvulus/bowel obstruction | 0 (0.0%) | 19 (0.6%) | <=5 (9.4%) | 137 (8.0%) | <=5 (1.7%) | 156 (3.1%) |
| | Other | 0 (0.0%) | 160 (4.9%) | <=5 (9.4%) | 292 (17.0%) | <=5 (1.7%) | 452 (9.1%) |
| Open/lap | Laparoscopic | 34 (23.9%) | 912 (27.9%) | 6 (18.8%) | 143 (8.3%) | 40 (23.0%) | 1055 (21.2%) |
| | Open | 108 (76.1%) | 2355 (72.1%) | 26 (81.3%) | 1570 (91.7%) | 134 (77.0%) | 3925 (78.8%) |
| Resection type | APR | 15 (10.6%) | 291 (8.9%) | 0 (0.0%) | 17 (1.0%) | 15 (8.6%) | 308 (6.2%) |
| | AR | 45 (31.7%) | 845 (25.9%) | <=5 (6.3%) | 141 (8.2%) | 47 (27.0%) | 986 (19.8%) |
| | bypass | 6 (4.2%) | 162 (5.0%) | 11 (34.4%) | 321 (18.7%) | 17 (9.8%) | 483 (9.7%) |
| | reversal | 25 (17.6%) | 495 (15.2%) | 0 (0.0%) | 20 (1.2%) | 25 (14.4%) | 515 (10.3%) |
| | segmental | 51 (35.9%) | 1404 (43.0%) | 19 (59.4%) | 1113 (65.0%) | 70 (40.2%) | 2517 (50.5%) |
| OR time, minutes | Mean ± SD | 296.84 ± 134.21 | 226.37 ± 96.11 | 223.72 ± 73.20 | 172.77 ± 72.97 | 283.39 ± 128.25 | 207.94 ± 92.40 |
| | Median (IQR) | 284 (211-351) | 213 (160-277) | 215 (184-271) | 160 (125-205) | 272 (199-340) | 191 (143-255) |
| Stoma | | 32 (22.5%) | 698 (21.4%) | 16 (50.0%) | 869 (50.7%) | 48 (27.6%) | 1567 (31.5%) |
| Surgery | Colon | 82 (57.7%) | 2131 (65.2%) | 30 (93.8%) | 1555 (90.8%) | 112 (64.4%) | 3686 (74.0%) |
| | Rectal | 60 (42.3%) | 1136 (34.8%) | <=5 (6.3%) | 158 (9.2%) | 62 (35.6%) | 1294 (26.0%) |

*using Elixhauser comorbidity score

Table 2: Outcomes

| VARIABLE | VALUE | Elective | | Emergent | | Overall | |
|---|---|---|---|---|---|---|---|
| | | Surgeon W | Total | Surgeon W | Total | Surgeon W | Total |
| | | N=142 | N=3267 | N=32 | N=1713 | N=174 | N=4980 |
| 30 day postoperative complication index* | 0 | 108 (76.1%) | 2722 (83.3%) | 14 (43.8%) | 864 (50.4%) | 122 (70.1%) | 3586 (72.0%) |
| | 2 | 16 (11.3%) | 140 (4.3%) | 9 (28.1%) | 201 (11.7%) | 25 (14.4%) | 341 (6.8%) |
| | 3 | 10 (7.0%) | 240 (7.3%) | <=5 (3.1%) | 142 (8.3%) | 11 (6.3%) | 382 (7.7%) |
| | 4 | 8 (5.6%) | 125 (3.8%) | <=5 (6.3%) | 312 (18.2%) | 10 (5.7%) | 437 (8.8%) |
| | 5 | 0 (0.0%) | 40 (1.2%) | 6 (18.8%) | 194 (11.3%) | 6 (3.4%) | 234 (4.7%) |
| Length of stay, days | Mean ± SD | 9.26 ± 10.91 | 9.06 ± 11.67 | 19.69 ± 25.46 | 22.88 ± 28.95 | 11.18 ± 15.15 | 13.81 ± 20.51 |
| | Median (IQR) | 6 (5-10) | 6 (5-9) | 13 (9-20) | 13 (8-26) | 7 (5-11) | 8 (5-14) |
| 30 day readmission | 0 | 131 (92.3%) | 3072 (94.0%) | 29 (90.6%) | 1579 (92.2%) | 160 (92.0%) | 4651 (93.4%) |
| | 1 | 11 (7.7%) | 183 (5.6%) | <=5 (9.4%) | 124 (7.2%) | 14 (8.0%) | 307 (6.2%) |

* Highest complication based on the modified Clavien-Dindo Classification system

| | |
|---|---|
| 0 | No complication |
| 2 | TPN or blood transfusion |
| 3 | Return to OR/Endoscopic/Radiologic intervention |
| 4 | Stepdown/ICU stay |
| 5 | In-hospital mortality |

Figure 1: Elective mortality graphs

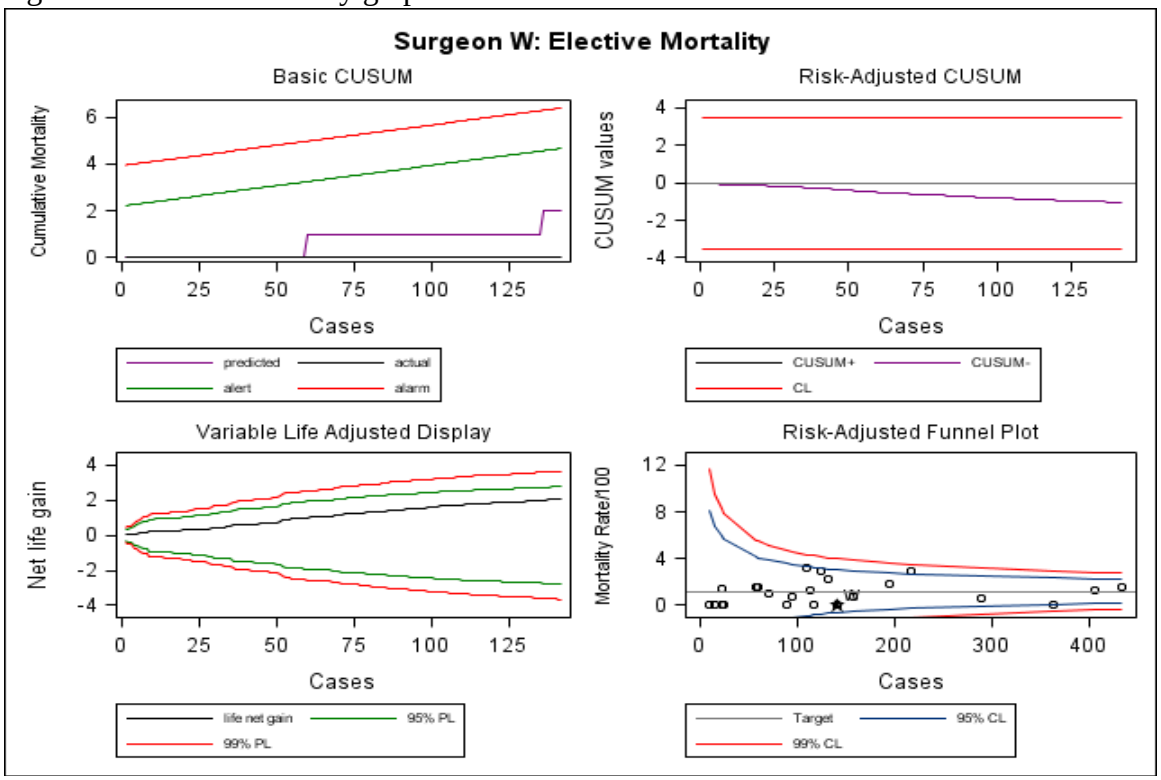



Figure 2: Elective morbidity graphs

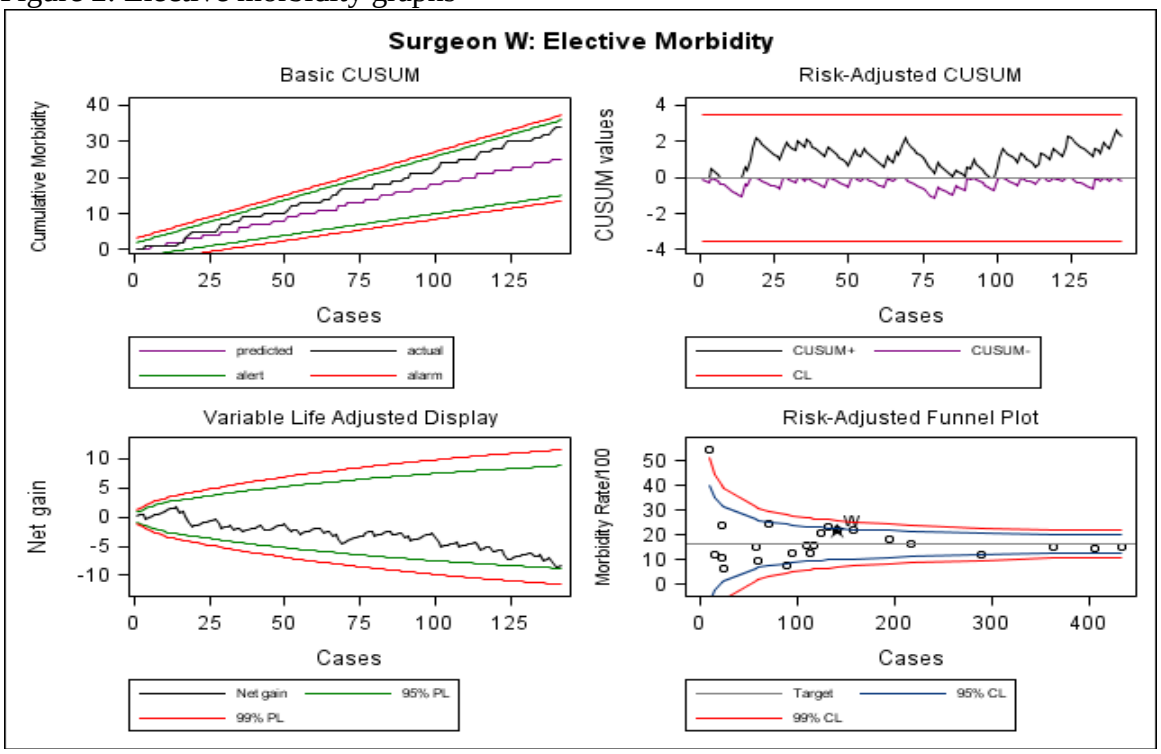


Figure 3: Emergent mortality graphs

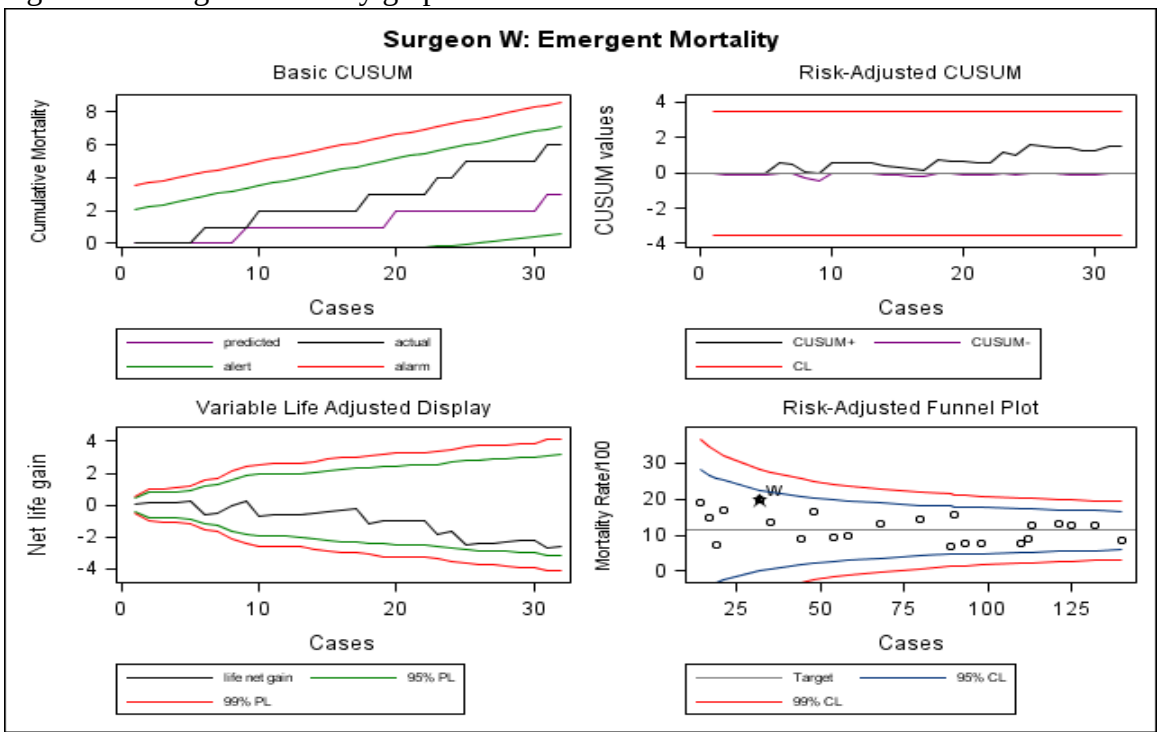



Figure 4: Emergent morbidity graphs