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A Retrospective Analysis of Surgeon Estimated Time and Actual Operative Time to Develop an Efficient Operating Room Scheduling System

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Abstract

Problem*:* Surgical departments account for sizable budgets in hospitals. To ensure efficiency, optimal processes need to be maintained. The current practice for posting a surgical case is using surgeon estimated times (SETs), which only includes the reporting points of component 2 (C2) "incision" to "dressing."

Objective: To analyze if there was a significant difference in minutes between actual operative times (AOT) and SET in patients undergoing outpatient general laparoscopic and inpatient orthopedic total joint surgery.

Methods*:* The facility is a level one trauma teaching center, with 371 beds, and a yearly surgical volume of 17,000 cases. This retrospective study used random sampling to compare and analyze the difference between AOT and SET, as well as actual operating room time (AORT): component one (C1) - "patient in OR to before incision" and component 3 (C3) - "after dressing to patient out of OR." With a statistical power level of 0.8%, an alpha of 0.05%, a sample size of 120 surgical patients from each category was included.

Results**:** In hypotheses testing for outpatient general laparoscopic and inpatient orthopedic total joint patients, the results indicated that SET time (mean=105.8, $\pm$ 31.6; mean=147, $\pm$36.4) in minutes was significantly greater than the AOT times (mean=75.5, $\pm$ 30.6; mean=111.5, $\pm$23.4; $p<0.001$ for both analyses) in minutes, respectively.

Conclusions: The results uncovered a significant difference between AOT and SET and suggested over booking; whereas in AORT and SET, results suggested under booking. An interdisciplinary team will be assembled to develop an efficient scheduling system.

A Retrospective Analysis of Surgeon Estimated Time and Actual Operative Time to Develop an Efficient Surgical Scheduling Model

Background

The current practice for posting a surgical case at my hospital is the use of Surgeon Estimated Times (SETs), which only includes the reporting points of "incision" to "dressing." Factors of overestimating or underestimating surgery time can lower utilization or increase staff working overtime and staff/physician dissatisfaction (Larrson, 2013). Since surgeries account for 40% of the hospital's revenue, managing an efficient Operating Room (OR) is critical to maximizing profitability (Lehtonen et al., 2013). Multiple methods used to estimate surgical times, which consist of subjective, surgical case history, or using math formulas have been recommended (Larsson, 2013).

The established definition for the duration for actual operating room time includes the time when the patient enters the OR -- to when the patient leaves the OR (Pandit & Carey, 2006; Dexter, 1996; Sorge, 2001; Eijkemans, et al, 2009), which consists of the following three components: C1 is patient in OR to just before incision, C2 is incision to dressing, and C3 is after dressing to patient out of the OR. The time between when the patient exits the OR to when the next patient enters the OR is known as turnover time (TOT). TOT at my hospital is set at 20 or 30 minutes depending on the subsequent type of case. At my current hospital there is not a consistent practice among surgeons to estimate surgical times to include "patient in OR" to "patient out of OR" time. Cerner, the electronic medical record (EMR) system utilized at my hospital was also used for scheduling surgery. The Cerner scheduling system provides surgical Computer Estimated Times (CETs), which only includes incision to dressing (C2). It was suggested that using CET may partially increase case surgical scheduling accuracy but my organization has not established a policy to utilize CET.

Problem Statement

The current issue with the use of SET surgical times is a cause for case delays, staff overtime, and dissatisfied surgeons. Currently at my hospital there is no method for estimating Actual Operating Room Time (AORT) duration from “patient in OR” to “patient out of OR,” thus a better surgical scheduling time estimate system needs to be developed. The goal was to create an efficient AORT scheduling system for surgical cases. This allowed OR management to competently allocate staffing to support scheduled cases, improves surgeons’ awareness of the correct start time for their procedures, and avoids delaying cases.

Purpose

In addition to Larrson’s (2013) study, our retrospective research study compared and analyzed the difference between AOT (C2), SET (C2), and the other two components of actual operating room time, (C1, C3) of surgery for general outpatient laparoscopic and inpatient orthopedic total joint surgical cases (Table 1). Based on these findings, the long term purpose is to create an interdisciplinary team consisting of a surgeon, anesthesiologist, Director of Surgical Services, Finance Director of Surgical Services, and Surgical Nurse Manager to design an accurate efficient surgical scheduling system model.

Specific Aims

- Assess the average time (in minutes) from when a patient enters the OR to just before the incision is made (C1), as well as the average (in minutes) from after dressing to patient out of OR (C3) in outpatient general laparoscopic and inpatient orthopedic total joint surgery.

- Assess the SET (C2) and AOT (C2) in patients undergoing general outpatient laparoscopic and inpatient orthopedic total joint surgery.
- Calculate the difference between SET and AOT in patients undergoing general outpatient laparoscopic and inpatient orthopedic total joint surgery.

Research Questions

To achieve the study aims, the following research questions will be evaluated:

- What is the average time (in minutes) from patient in OR to just before incision (C1)?
- What is the average time (in minutes) from incision to dressing (C2/AOT)?
- What is the average time (in minutes) from after dressing to patient out of the OR (C3)?
- What is the difference in the average time (in minutes) between SET and AORT?

Hypotheses

To achieve the aims of the study, the following research hypothesis was tested: There is a significant difference in minutes between SET and AOT in patients undergoing outpatient general laparoscopic and inpatient orthopedic total joint surgery.

Significance

With the current shortage of nurses worldwide, and the expected decline in the nursing workforce over the next 20 years, the ability to retain OR nurses becomes critical (Yu, et al., 2015). Aiken, et al., (2002) reports that the nursing shortage was related to impractical workload and 40% of nurses’ reach burnout when compared to other health care workers. Liu et. al., (2012) discussed that to ensure for nurse satisfaction and retention, hospitals needed to be able to provide a balance between nurse work-life and improve the work environment. Inconsistent scheduling due to the unpredictability of an inaccurate OR surgery schedule can lead to nurse burnout, dissatisfaction, and imbalance.

The inability to create an accurate surgery schedule by using incorrect AORT can lead to inefficiency in the OR and less than optimal resource planning, specifically in inappropriate OR staffing. Bross et al., (1995) discussed that inaccurate OR schedules have led to decreased staff productivity, dissatisfaction, and high turnover. Our study has the potential to assist OR managers and surgical scheduling teams with data on two different case acuities levels -- laparoscopic outpatient (low acuity) and inpatient total joints (high acuity), to offer a possible range for AOT estimates. If AORT estimates are utilized, OR managers can plan ahead appropriately for gaps in staffing resources, reduce over or under staffing of ORs (Sorge, 2001), and improve work-life balance for staff.

Literature Review

The operating room is a fast paced, high output, consumer dependent department that is supported with 10-15% of an institution's financial budget, thus managing OR resources and productivity is critical (Wright, et al., 1996; Rizk & Arnaout 2012). Since 60% of patients admitted are treated in the OR, it is important to begin their surgeries at the scheduled start time to maintain OR efficiency and satisfaction for patients, surgeons, and staff (Eijkemans et al., 2010; Zhou et at., 1999). The impact of overestimating or underestimating surgical scheduling times has an enormous effect for the OR causing inefficiencies and inaccurate allocation of resources. An overrun surgery schedule can lead to dissatisfied surgeons, disgruntled patients, and unscheduled overtime for staff; while an underrun surgery schedule leads to unused ORs and a decrease in productivity (Pandit & Carey, 2006; Eijkemans et al., 2010; Wright et al., 1996). To assist OR management teams with resource allocation and to maintain an accurate schedule it is essential that ORs identify and establish an efficient surgical scheduling time case model.

The literature presented multiple studies that used computerized scheduling systems to predict accurate surgery times (Zhou et al., 1999; Bross et al, 1995; Pandit & Tavare, 2011), while other studies conducted comparisons between computer estimated time and surgeon estimated time to predict an accurate surgical estimated time (Larsson, 2013; Eijkemans et al., 2010). Most studies identified that time for surgery must be from the time a patient enters the OR to the time the patient leaves the OR (Dexter, 1996; Sorge, 2001; Pandit & Carey, 2006; Eijkemans, et al, 2009).

To help OR management plan and allocate resources, Sorge (2001) focused on creating and implementing a “scheduling component” to predict surgical time for 15,000 surgical cases per year. Their current process for estimating surgical scheduling time was given by surgeons with some adjustment in time from the surgical manager based on the patients’ clinical. Sorge (2001) used data from six different surgical specialties (general, gynecological, orthopedic, peripheral vascular, ENT [ear, nose and throat], and plastic surgeries) and for convincing sampling, they randomly selected 10 cases from each specialty and generated a report from the Operating Room Information System (ORIS) on actual and ORIS given time in minutes. ORIS standard time was the time required to complete the entire procedure - from patient in OR to patient out of OR. Using that data, they created an interval scale using 15-minute blocks and measured any procedures falling within 15-minutes of the end time to be accurate. Using Chi square analysis, with 15-minute frequency distributions, they compared ORIS to the number of inaccurate procedure times. The study started with a sample size of 7,028 for six different surgical specialties, but resulted in a sample size of 437 after applying the Chi square analysis, where 238 (54.46%) cases were accurately booked, leaving 199 (45.54%) cases inaccurately booked. Therefore, Sorge (2001) accepted the null hypothesis that "ORIS time is not an accurate predictor of actual surgical times" (pg. 14).

To maintain staff productivity, satisfaction, and decrease turnover, Bross et al., (1995), conducted a retrospective study with a hypothesis that they could predict the procedure length to within 15 minutes of the accurate procedure length. They used data from the OR schedule and computer records on 14 surgical specialties and identified 10 causes for start time delays. Using descriptive statistics, results demonstrated that out of 1,103 procedures, about 65% (720) of the procedures ended within 15 minutes of the schedule time and 28% (306) of the procedures had an accurate estimated time. Bross et al., (1995) also identified that 22% (248 of 1,103) of the procedures did not start on time, which caused 34% of the surgeons, 25% of prior case overruns, 14% of anesthesia care providers, and 11% of patients being late to the OR. They recognized that with support of the OR committee surgeons, anesthesia delays can be addressed through communication. To address prior case overruns and patients being late to the OR, they identified that utilizing preadmission testing more appropriately to screen and prepare patients can eliminate such delays.

Kayis, et al., (2012), conducted a study that investigated if "operational and temporal factors" can improve surgical time estimates. In a one-year period, a total of 10,305 elective studies were retrieved with case details from the electronic medical record (EMR) system. They used estimations from the last 5 cases by surgery type (13 different specialty categories), if the historical data was available; if not, the case was rejected. Bias (systematic) and mean absolute deviation (MAD) in minutes were used to investigate the range of error, along with "operational and temporal" factors, which were type of month, add on case, inpatient, outpatient, time of day, and sequence. From 10,305 surgeries, 2,820 cases were excluded since historical data was not available. The results showed there were differences when the last 5 case times were analyzed of MAD varying from 13 minutes for gastroenterology to 79 minutes for cardiothoracic surgery. An average coefficient of variation (CV) of 89% was the range for all specialties. They also assessed the “operation and temporal” factors which resulted in cases that were performed as outpatient (14%), add-on case (-11%), or if the case started after 5pm (-7%). Using their regression model, they concluded that MAD improved. Their adjusted model displayed an absolute error of 15 minutes or less in 44% of cases (2957 cases) versus 42% (2821 cases) (Kayis, et. al., 2012).

Eijkemans, et al., (2010), identified that in order to manage an efficient OR, optimal planning and cost containment are essential. They focused on creating a prediction model using surgeon’s estimate time, procedure, surgical team members, and patient characteristics specific to the operation. The prediction model included the “type of operation, surgeon’s estimate, and team and patient characteristics as fixed effects” (pg. 43). The study had a sample size of 17,412 general surgery procedures, with an exclusion criterion of emergency operations. The variables identified had multiple categories; operations were classified into 253 categories with subcategories of single or multiple procedure, and patient characteristics were age, sex, and number of admissions to the hospital before operation and length of current admission. The results displayed the wide gap in operation time with the median ranging from 42.5 to 504 minutes but identified that surgeon estimates had a high impact and influence on estimating accurate surgical case time. They used historical averages, when the prediction model reduced from 2.8 to 6.6 minutes shorter-than and longer-than predicted, reducing 12% and 25% respectively. The study recognized that patient characteristics had a limited influence, but added that the prediction model would benefit with information from a surgeon’s estimated time, patient, procedure, and a surgical team can assist in predicting accurate operation times.

One of the limitations noted was the inability to generalize methods due to multiple variables. Sorge (2001) and Bross et. al. (1995) compared two variables - computer and surgeon estimated times, whereas, Eijkemans, et al., (2010) used five different variables to predict accurate operative time and concluded that surgeon's estimated time was crucial in predicting an accurate surgical schedule. This study identified and analyzed two similar variables (SET & AOT) in surgical scheduling along with comparing two key components of surgery - C1 and C3 to determine variances. Based on the findings and analysis, our study would present which C2 component - AOT, SET, should be utilized. Furthermore, it determined how much time should be calculated to account for C1 and C3 to create an AORT in order to produce accurate surgical scheduling system.

Theoretical Framework

Well developed and properly managed processes of an Operating Room in any hospital that produces optimal results has positive effects on a multitude of areas to include revenue, quality healthcare, and customer satisfaction (Peter et al., 2011). In a department where procedures are so close to one another that one less than optimal activity can have a domino effect on all other procedures, the OR must have the greatest possible output and waste mitigation possible. Measurement of all processes from OR first case starts to subsequent cases and surgical case times can determine the reason for failure to meet OR productivity and efficiency.

"Ultimately, the goal is to produce the greatest possible output using tasks that produce the best results and happiest customers" (Pyzdek Institute, 2016). Optimized operations create the best results. Lean manufacturing effectively removes waste and errors, while Six Sigma implements "measurement-based strategy that focuses on process improvement and variation reduction" (Business Dictionary, 2016; iSixSigma, 2016). Lean Six Sigma is a business strategy that is used in industries to improve quality of the product, reduce waste, and eliminate defects. Lean Six Sigma uses Define-Measure-Analyze-Improve-Control (DMAIC) to improve processes (ASQ, n. d. a). This is a data-driven quality strategy that consists of five phases-DMAIC: "1) *define* the problem, improvement activity, opportunity for improvement, the project goals, and customer (internal and external) requirements, 2) *measure* process performance, 3) *analyze* the process to determine root cause of variation, poor performance (defects), 4) *improve* process performance by addressing and eliminating the root causes, and 5) *control* the improved process and future process performance" (ASQ, n. d. b).

Our hospital's surgery scheduling department identified inaccuracies in scheduling a surgical case when using SETs. The hospital has not identified any interventions to address this scheduling process issue, but yet there is a significant strain for OR management to predict appropriate staffing, maintain customer satisfaction for staff, patients and surgeons, and sustain a productive OR. Based on the forecasted data analysis, the contribution from this study has the potential to create a reliable scheduling system that will reduce over and under booking of cases to maintain an efficient, dependable OR.

Method

Design

We conducted a retrospective study, using a descriptive comparative design with random sampling for outpatient general laparoscopic and inpatient orthopedic total joint surgical cases. This design adequately responded to the research questions and aims to allow comparison of multiple variables appropriately.

Study Population and Sample Size

Our study assumed the sample size to be a total minimum of 128 surgeries (64 surgeries from each category of outpatient general laparoscopic and inpatient orthopedic total joint cases) for a two-tailed t-test, with a moderate effect size (cohen's *d*) of 80%, a statistical power level of 0.8%, and a probability level (alpha) of 0.05%. Since the study involved strict exclusion criteria and to ensure sufficient data were obtained, we added 87.5% to the sample size to account for missing and erroneous data that would likely be encountered in our retrospective review.

With access to a substantial surgical volume, it was estimated that the available pool of sampling per year will be a total of 1,200 cases (840 and 360 for outpatient general laparoscopic and inpatient orthopedic total joint cases respectively). A total of 240 cases were included from March 1st, 2015 to March 31st, 2016 with 120 from outpatient general laparoscopic and 120 from inpatient orthopedic total joint cases. The sampling method used was simple random sampling (SRS) utilizing a table of random digits (see Appendix B). This method decreases biases and ensures proper random selection is attained. After applying the exclusion criteria, each case will be assigned a number beginning at 000 to *n*-1 for each group. From the sampling frame, 120 numbers were pulled for each group utilizing the table of random digits (see Appendix B) entering at a random line. For example, if the sampling frame is from 001 to 133, beginning at line 102 from the table of random digits, the first number is 736 (not pulled because it doesn't exist), the next is 764 (not pulled), then 715 (not pulled), 099 (pulled), 400 (not pulled), 019 (pulled) and so on. In our study, the first 120 numbers (cases) were pulled for outpatient general laparoscopic and then 120 numbers (cases) for inpatient orthopedic total joint cases for a total of 240. If duplicate numbers were pulled they were omitted, as well as numbers not in the sampling frame.

The inclusion criteria consisted of outpatient general laparoscopic and inpatient orthopedic total joint cases from March 1st 2015 to March 31st 2016 between the hours of 0730 to 1700 Monday to Friday (cases scheduled with a "patient in OR" before 1700 were included). Patients included were 18 years of age and older, both male and female, and of all races.

For both groups, patients were excluded if the case was a revision, add-on, emergent and unstable, multiple procedures, any cases between 1700 to 0730, cases on Saturday and Sunday, or if postoperative diagnosis was different from preoperative diagnosis. For outpatient general laparoscopic cases, patients were excluded if a laparoscopic case converted to laparotomy or a robotic outpatient general laparoscopic. For inpatient orthopedic total joint cases, patients were excluded if they had bilateral total joint surgeries.

Setting

Data was collected at a level one trauma teaching center, with 371 beds, 17 ORs, 5 ambulatory surgery ORs, and one hybrid OR with a yearly surgical volume of 17,000 cases in the mid-Atlantic region. The hospital is partnered with a nationally recognized, interdisciplinary academic health center comprising the School of Medicine and Health Sciences and the School of Public Health and Health Services. With clinical expertise in cardiac care, minimally invasive and robotic surgery, neurosurgery, oncology, neurology, women's services, orthopedics, and urology, the hospital offers globally renowned health care. Each surgical case consisted of nurses, a surgical technologist, surgeon, resident, anesthesiologist, anesthesiology resident, and medical students who assisted with patient care during the procedure. The circulating nurse(s) was primarily responsible for all documentation intraoperatively and entered data into patients EMR (Cerner).

Instrument and Measurements

Data was imported from the hospitals' electronic scheduling system, Cerner to a data collection tool, similar to other studies that have extracted data from their electronic scheduling system along with using a developed form for data management (Larsson, 2013; Sorge, 2001). Both studies included data that needed to be manually entered and cleaned before any data analysis was conducted.

The Cerner EMR system "is an integrated database that provides a comprehensive set of capabilities… created it to allow healthcare professionals to electronically store, capture and access patient health information in both the acute and ambulatory care setting" (Cerner, n.d.). Discern Explorer (Discern Analytics) is integrated with Cerner HNA Millennium systems to provide queries and reports regarding clinical process related data (Cerner, 2001).

As the principal investigator for this study, I used the Discern Analytics (see Appendix C) tool from Cerner. I created two reports in Discern Analytics, the results were copied and pasted to two identical data collection excel spreadsheet forms (see Appendix D). The report from Cerner's Discern Analytics consisted of the following data points: date, patient type, patient medical record number (MRN), pre-operative diagnosis, post-operative diagnosis, procedure, patient in OR, surgery start, surgery stop, patient out of OR, SET, the American Society of Anesthesiologist (ASA) physical status classification, patient age, patient sex, wound classification, race/ethnicity, and body mass index (BMI). After data was cleaned, the following data points were extracted manually: race/ethnicity and BMI. Using the codebook (see Appendix E) developed for this study, each variable was coded accordingly to manage and analyze the data on excel sheets and with IBM SPSS software program.

To discuss reliability (trustworthiness), the internal consistency for each of the variables was set by the standard practice of the circulation RNs who entered these data points as they occurred in the OR. The tool (Discern Analytics) utilized directly extracted these data points from patients' records providing applicability. Additionally, the excel data sheets used were identical to provide consistency and maintain reliability. Our study was the first piloted study at this facility to develop an accurate scheduling system. Since this is the first study, validity (truth) would be improved after the results of this study.

Data Collection Procedure and Timeline

Cerner's Discern Analytics report filtered out the following for both groups: add-ons, emergent unstable case, and outpatient and inpatient patient types for general laparoscopic and orthopedic cases, respectively. Once all inclusion and exclusion criteria had been applied, numbering (000 to *n*-1) of the sample frame occurred, as well as extracting data points - race/ethnicity and BMI, that needed to be manually retrieved from the Cerner scheduling system and entered into the data collection forms. MRNs were deleted to de-identify data once all data points were collected and prior to conducting any calculations. Then the following data points from the excel spreadsheet were uploaded to IBM SPSS software for analysis.

The data extraction process took two weeks and was completed by myself, the principal investigator. No additional data collectors were used. A data accuracy check was conducted for 10% of the data, for which I utilized an expert who is familiar with the Cerner EMR application, and is a certified clinical investigator. In addition, I also cross-checked for data accuracies. Data from the spreadsheet were crossed-checked with the patients' EMR beginning with a random number from the table of random digits (see Appendix B). A total minimum of 24 (12 per group) random cases were checked for outpatient general laparoscopic and inpatient orthopedic total joint cases. Once data was collected on the spreadsheet, checked for data accuracy, and cleaned from patient identifiers (MRNs), data was finally transferred to IBM SPSS (version 24). Expedited approval was obtained from the hospital's IRB.

Data Analysis Plan

This study used descriptive analysis where evaluation of individual variables was studied, as well as inferential statistics that analyzed the relationship between variables. Once data collection was completed, the excel file was imported to IBM SPSS software for analysis. IBM SPSS is a statistical software that assists in data mining and analytics.

For all analyses, alpha was set at 0.05%. Descriptive statistics were performed and stratified by surgery types (see Table 3). Descriptive statistics were calculated for ASA, age, gender, wound classification, race/ethnicity, BMI and weight category for both groups. Categorical data was reported as frequency and percentage. Interval/ratio data were reported as mean, standard deviation, minimum, and maximum time ranges.

First, data were assessed to answer the research questions: 1) What is the average time (in minutes) from patient in OR to just before incision (C1)? 2) What is the average time (in minutes) from incision to dressing (C2/AOT)? 3) What is the average time (in minutes) from after dressing to patient out of the OR (C3)? 4) What is the difference in the average time (in minutes) between SET and AORT?

Second, using repeated measures analysis of variance (ANOVA), data were analyzed for difference in time (in minutes) for mean, standard deviation, minimum, and maximum time ranges for SET and AOT (see Table 5 and 6).

Finally, Actual Operating Room Time (AORT) was analyzed using mean and standard deviation from the following: C1, C2 (AOT), and C3 (see Table 7).

Ethical Considerations

Our retrospective study was approved as expedited by our institutional IRB. The only identifiable data was the MRN. To maintain privacy of patient, the MRN was stored on a data worksheet on a password protected computer in a locked office at the hospital with access to only the principal investigator. Once inclusion and exclusion criteria were applied, and 10% data accuracy check was completed, all MRNs were deleted from the worksheet to maintain confidentiality.

Results

Characteristics of the Sample

Using IBM SPSS version 23, analysis was conducted on a total sample size of 120 patients for Outpatient General Laparoscopic and 120 patients for Inpatient Orthopedic Total Joint. (*Table 3*, Appendix F). The majority of the patients in the outpatient general laparoscopic were between the ages of 45-<65 years old (n=47, 39.2%), while nearly all the patients in the inpatient total joint orthopedic group were between 45-<65 years old (n=62, 51.7%). There were 71 (59.2%) females in outpatient general laparoscopic and 78 females (65%) in the total joint orthopedic group. The majority of patients in the outpatient general laparoscopic group were Caucasians (n= 53, 44.2%) or African Americans (n=42, 35%). In inpatient orthopedic total joint group majority of the patients were African Americans (n=52, 43.3%) or Caucasians (n=51, 42.5%).

In the procedures category for outpatient general laparoscopic group, the majority of cases were gall bladder surgery (n= 82, 68.3%), followed by hernias (n=25, 20.9%) that included inguinal, ventral and incisional hernias. For inpatient orthopedic total joint group, the majority of cases were total knee surgery (n=61, 50.8%), followed by total hip surgery (n=48, 40%). In the ASA category the majority were ASA 2 of 78 (65%) and 71 (59.2%) for outpatient general laparoscopic and inpatient orthopedic total joint, respectively. In the category of wound classification majority for outpatient general laparoscopic were 90 (75%) patients with wound class 2, while the inpatient orthopedic total joint group had 118 (98.3%) patients of wound class 1. BMI for the outpatient general laparoscopic group had a mean of 30.4 (±7.4), while the inpatient orthopedic total joint group had a mean of 29.8 (± 6.6). Both groups had the highest percentage of patients in the obese (BMI of 30 or greater) weight category of 60 (50%) and 54 (45%) for outpatient general laparoscopic and inpatient orthopedic total joint, respectively.

Research Questions

To respond to the research questions, results are displayed in *Table 4* (Appendix G). The first three questions displayed the mean, standard deviation, minimum and maximum times (in minutes) for the three components (C1, C2, and C3) of patients in the OR to patients out of the OR. C1 resulted in a mean 23.8 (±5.9) minutes for outpatient general laparoscopic cases, while inpatient orthopedic total joint had a mean of 45.7 (±8.7) minutes. For outpatient general laparoscopic cases, C2 had a mean of 75.5 (± 30.6) minutes and 111.5 minutes (± 23.4) for inpatient orthopedic total joint respectively. C3 resulted in a mean of 11.1 minutes (± 7.2) for outpatient general laparoscopic cases, with a mean of 11.8 minutes (± 6.4) for inpatient orthopedic total joint. The last research question reviewed for the difference between SET and AORT, which resulted in a mean difference of 4.6 minutes (± 34.8) for outpatient general laparoscopic cases and a mean difference of 22.0 minutes (± 38.8) for inpatient orthopedic total joint.

Hypothesis Testing

In hypotheses testing for outpatient general laparoscopic patients, the results indicated that SET time (mean=105.8, ± 31.6) in minutes was significantly greater than the AOT times (mean=75.5, ± 30.6; $p<0.001$) in minutes (*Table 5*, Appendix H). For inpatient orthopedic total joint patient, the results reveal that SET time (mean=147, ±36.4) in minutes was significantly greater than AOT times (mean=111.5, ±23.4; $p<=0.001$) in minutes (Table 5, Appendix H). With the SD of 30+ for total mean in each group, utilizing the mean times that actually occurred for AOT would allow for the creation of a more accurate surgical schedule, but accounting for C1 and C3 was still needed.

In analyzing the AORT which combines C1, C2, and C3 for outpatient general laparoscopic patient, the mean AORT time was 110.3 (± 33.8) minutes and 169.0 (± 26.3) minutes for inpatient orthopedic total joint (*Table 6*, Appendix I).

Discussion

The current practice at my institution is the use of SET for surgical cases, but after reviewing the results of this study, there is evidence to support the argument that the practice needs to be changed to accurately schedule surgical cases. The characteristics of the sample revealed that the majority of patients for both groups were ASA 2. According to American Society of Anesthesiologists (ASA, 2017), ASA 2 is defined as "a patient with mild systemic disease", indicating that patients in both groups were moderately healthy. In the category of wound classification majority of outpatient general laparoscopic patients were in wound class 2, while in inpatient orthopedic total joint group majority of the patients were in wound class 1. According to the Centers for Disease Control and Prevention (CDC, 2001), wound class 1 is "clean" in which the wound is "uninfected operative wound in which no inflammation is encountered". Wound class 2 is "clean/contaminated" in which the wound is "an operative wound in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination”. In both groups, the wound classes accurately matched the type of procedure performed.

The hypothesis testing results indicated that the SET was significantly higher than the AOT (C2) (Table 6) in the outpatient general laparoscopic and inpatient orthopedic total joint groups, which suggests that the surgeons were over booking the amount of time for their cases, but in reality using the SET to schedule surgical cases did not account for C1 and C3 (Table 4). SET to AOT comparison indicated that not all surgeons were necessarily scheduling cases from “incision to dressing,” but were scheduling as “patient in OR to patient out of OR.”

Multiple studies indicate that AORT accuracy up to 15 minutes is satisfactory (Larrson, 2013; Bross, et al., 1995). AORT results in *Table 6* accurately indicate the real time of “patient in to patient out of OR” surgical times. When SET and AORT (research question #4) were compared, the results indicated surgeons under booking their cases. Although the mean for outpatient general laparoscopic was closer to accurate time, the mean for inpatient orthopedic total joint was greater than 15 minutes to accurate time. The range of mean averages between SET, AOT, and AORT was from approximately four to 30 minutes, indicating the gaps in the OR schedule. Both over booking and under booking cases have an impact on OR efficiency; it can mean the difference for scheduling additional cases and planning important resources accordingly. If surgical cases are to be accurate, surgeons need to include C1 and C3 in their case times.

Limitations

The critical limitation in our study was the inability to obtain data on Computer Estimated Times (CETs). CET is the computer estimated time recorded by Cerner using the last 10 cases for that procedure done by a specific surgeon. This study originally included comparing the CET variable with AOT and SET. The Cerner scheduling system does provide surgical Computer Estimated Times, which only includes incision to dressing (C2). It has been suggested that using CET may partially increase case surgical scheduling accuracy but my organization has not established a policy for utilizing CET. During a data quality check, we identified that retrospective CET data defaulted to the current CET averages. Since accurate CET data could not be obtained for the date of the actual operative procedure, the variable was unusable and discarded. Although CET was omitted, realistically this would be a key data point to consider using when creating an accurate scheduling system. This data point is readily available with current averages when scheduling a case and surgical schedulers and managers can immediately identify if a surgeon is over or under booking a case.

Recommendations and Implications

Our results demonstrate that an accurate surgical system needs to be developed at our institution. Based on our data and the current capabilities of the scheduling system available, we will recommend to the OR committee that we implementing the following steps: 1) create a surgical procedure list across all specialties using their mean times for C1, AOT, and C3, 2) update the OR policy by declaring that surgical cases will utilize AORT time (in minutes) based on the last 10 case averages for each surgeon, and 3) develop a model algorithm for the surgical posting department to include C1, AOT, and C3 times by procedures that would be updated on a monthly basis. An ideal setting would be the use of CET for surgical scheduling. Thus, a short term goal for the interdisciplinary team should be to request that Cerner scheduling system update the CET times to reflect from “patient in OR to patient out of OR,” then conduct a preliminary data analysis of CET to AOT and SET, and if preliminary results support it, develop a process to use CET for surgical scheduling.

Efficiencies in the OR can have a positive or negative impact on an organization. A hospital that is focused on providing quality service and care for staff, surgeons, and patients will benefit from this initiative to improve actual surgical times because of the gains in timely and efficient execution of surgical procedures. Utilizing the key elements of Lean Six Sigma model of “Define-Measure-Analyze-Improve-Control” as a foundation for this process improvement project, we expect to eliminate waste and improve efficiencies (McKenzie, 2009; ASQ, n. d. a). The goal of this system is to utilize C1, AOT, and C3 mean averages to schedule surgical cases to ensure the OR schedule is as close as possible to being accurate. While identifying that the organizational setting is a teaching institution and utilizing mean averages allows the schedule to account for flexibility.

Additionally, with the shortage of nurses nationwide, the implementation of the new accurate scheduling system has the potential to improve OR staff satisfaction by allowing staff to plan their workday as the OR schedule is displayed and focus on patient care This in turn allows the ORs to operate with less effort and has the potential to enhance surgeon satisfaction and optimize patient care. Also, by improving efficiency, staff will be able to better plan their personal schedules accordingly, which has the potential to reduce burn out or requests from manager to work overtime. Moreover, satisfied OR staff are likely to lead to employee retention and decreased spending for recruitment.

Finally, the impact of scheduling surgical cases accurately allows for an increase in the number of cases that can be performed daily and decreases potential waste of resources. These factors allow the ORs to perform on time and cost-effectively, with opportunity to add last minute cases, which in turn is likely to improve surgeon and patient satisfaction and throughput.

Any surgical department that can increase case volume could substantially increase the organizations financial gains with an opportunity to improve overall.

Conclusion

Accurate prediction of the duration of surgical procedure is critical to meet the needs of the stakeholders. Our results exposed that SET was significantly higher than AOT suggesting surgical cases were being overbooked; but when SET was compared to AORT the difference indicated that surgeons were under booking surgical cases. These variances in either direction can negatively affect the OR and mandates that improvements be made. The significance of our study was to provide the hospital's surgical scheduling department and the OR with the critical data to revise the current failing surgical scheduling system. Utilizing our recommendations, an interdisciplinary team will be assembled consisting of a surgeon, anesthesiologist, Director of Surgical Services, Finance Director of Surgical Services and Surgical Nurse Manager to develop a new accurate surgical scheduling system. We believe this new surgical scheduling system has the potential to benefit the OR by 1) assisting surgical managers to generate more accurate surgical schedules, 2) allowing OR managers to plan for better staffing and resources, 3) improving patient, surgeon, and staff satisfaction by starting cases on time as scheduled, and 4) reviving the surgical scheduling process to maintain efficient productivity for the surgery department.

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Appendix A

Table 1. Identifying and Defining Variables Affecting Surgical Scheduling

Variables	Type of Variable	Theoretical Definition	Operational Definition
Patient Type	Demographic	Based on the operative procedure, patients will either admitted to be inpatients or discharged within 23 hours to be outpatients.	As scheduled by the surgeon's office when the case is posted: 1=Outpatient 2=Inpatient
Medical Record Number (MRN)	Demographic	A systematic unique number assigned to that patient by the hospital.	A 7-digit number unique to the patient.
Pre-Operative Diagnosis	Demographic	The nature and identification of a disease/illness process and a conclusion reached before surgery.	Diagnosis of a patient before surgery, as given by the surgeon's office to surgical posting when the case is posted.
Post-Operative Diagnosis	Demographic	The nature and identification of a disease/illness process and a conclusion reached after surgery.	Diagnosis of a patient after surgery given by the surgeon, as recorded by OR nurse in the patient's EMR.
Operative Procedure: General Laparoscopic Surgery	Demographic	Surgery that focuses on abdominal organs using small incision known as "minimally invasive technique," where patients are hospitalized for less than 24 hours.	Laparoscopic surgery performed on: esophagus, stomach, small bowel, colon, liver, pancreas, spleen, gallbladder, and bile ducts.
Operative Procedure: Orthopedic Surgery	Demographic	Surgery that focuses on skeleton and its attachments, the ligaments and tendons, where patients are hospitalized for more than 24 hours.	Orthopedic surgery performed on total joints: knee, hip, and shoulders.
Component 1 (C1)	Dependent	Surgical time from patient in OR to just before incision.	Time (in minutes) from patient in OR to just before incision, as recorded by OR nurse in the patients' electronic

			medical record.
Component 2 (C2-SET and AOT)	Dependent	Surgical time from incision to dressing.	SET- Time (in minutes) from incision to dressing, as given by the surgeon's office to surgical posting when the case is posted. AOT- Time (in minutes) from incision to dressing, as recorded by OR nurse in the patients' EMR.
Component 3 (C3)	Dependent	Surgical time from after dressing to patient out of OR.	Time (in minutes) after dressing to patient out of OR, as recorded by OR nurse in the patients' electronic medical record.
The American Society of Anesthesiologist (ASA)	Demographic	Classification system issued by The American Society of Anesthesiologists to determine the "physical state" before selecting the anesthetic or before performing surgery.	ASA categories as recorded by the Anesthesiologist in EMR: 1=ASA 1 2=ASA 2 3=ASA 3 4=ASA 4 5=ASA 5 6=ASA 6
Patient Age	Demographic	Chronological age in number of years.	Age as recorded in EMR by the nurse. 1=18 to < 30 2=30 to < 45 3=45 to < 65 4=65 or more
Patient Gender	Demographic	Patient's biological sex.	Patient's gender from EMR.
Wound Classification	Demographic	Wound classification is a grading system used for the assessment of microbial contamination for the surgical site.	As recorded by the OR nurse: 1=Wound Class 1 2=Wound Class 2 3=Wound Class 3 4=Wound Class 4
Race/Ethnicity	Demographic	A person's genetic or biological characteristics.	As recorded by Admitting in the EMR:

			1=Caucasian 2=African American 3=Other
Body Mass Index (BMI)	Demographic	Height and weight calculated to obtain BMI.	BMI as recorded in EMR.
Weight Categories	Demographic	Classifications based on BMI categories.	Based on the BMI, the following categories will be recorded: 0=Underweight <18.5 1=Normal 18.5 to 24.9 2=Overweight 25 to 29.9 3=Obese 30 and over
Actual Operating Room Time (AORT)	Dependent	Surgical time from when the patient enters the OR to when the patient leaves the OR.	Time (in minutes) when patient enters OR to when patient leaves the OR, which is the total of C1, AOT (C2), and C3, as recorded by OR nurse in the patients' electronic medical record.

Appendix B

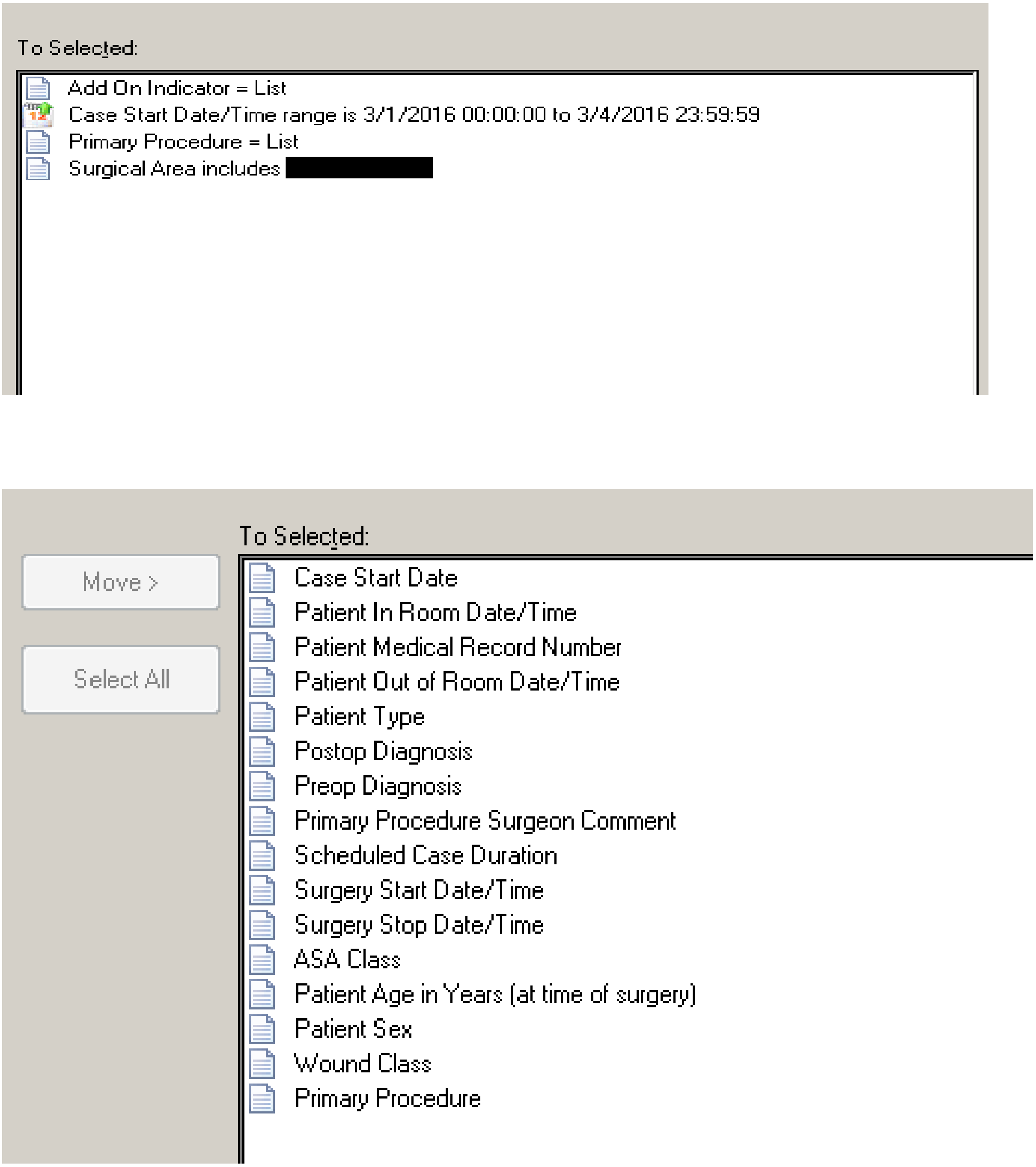
Figure 1. Table of Random Digits

Random digits

Line								
101	19223	95034	05756	28713	96409	12531	42544	82853
102	73676	47150	99400	01927	27754	42648	82425	36290
103	45467	71709	77558	00095	32863	29485	82226	90056
104	52711	38889	93074	60227	40011	85848	48767	52573
105	95592	94007	69971	91481	60779	53791	17297	59335
106	68417	35013	15529	72765	85089	57067	50211	47487
107	82739	57890	20807	47511	81676	55300	94383	14893
108	60940	72024	17868	24943	61790	90656	87964	18883
109	36009	19365	15412	39638	85453	46816	83485	41979
110	38448	48789	18338	24697	39364	42006	76688	08708
111	81486	69487	60513	09297	00412	71238	27649	39950
112	59636	88804	04634	71197	19352	73089	84898	45785
113	62568	70206	40325	03699	71080	22553	11486	11776
114	45149	32992	75730	66280	03819	56202	02938	70915
115	61041	77684	94322	24709	73698	14526	31893	32592
116	14459	26056	31424	80371	65103	62253	50490	61181
117	38167	98532	62183	70632	23417	26185	41448	75532
118	73190	32533	04470	29669	84407	90785	65956	86382
119	95857	07118	87664	92099	58806	66979	98624	84826
120	35476	55972	39421	65850	04266	35435	43742	11937
121	71487	09984	29077	14863	61683	47052	62224	51025
122	13873	81598	95052	90908	73592	75186	87136	95761
123	54580	81507	27102	56027	55892	33063	41842	81868
124	71035	09001	43367	49497	72719	96758	27611	91596
125	96746	12149	37823	71868	18442	35119	62103	39244
126	96927	19931	36089	74192	77567	88741	48409	41903
127	43909	99477	25330	64359	40085	16925	85117	36071
128	15689	14227	06565	14374	13352	49367	81982	87209
129	36759	58984	68288	22913	18638	54303	00795	08727
130	69051	64817	87174	09517	84534	06489	87201	97245
131	05007	16632	81194	14873	04197	85576	45195	96565
132	68732	55259	84292	08796	43165	93739	31685	97150
133	45740	41807	65561	33302	07051	93623	18132	09547
134	27816	78416	18329	21337	35213	37741	04312	68508
135	66925	55658	39100	78458	11206	19876	87151	31260
136	08421	44753	77377	28744	75592	08563	79140	92454
137	53645	66812	61421	47836	12609	15373	98481	14592
138	66831	68908	40772	21558	47781	33586	79177	06928
139	55588	99404	70708	41098	43563	56934	48394	51719
140	12975	13258	13048	45144	72321	81940	00360	02428
141	96767	35964	23822	96012	94591	65194	50842	53372
142	72829	50232	97892	63408	77919	44575	24870	04178
143	88565	42628	17797	49376	61762	16953	88604	12724
144	62964	88145	83083	69453	46109	59505	69680	00900
145	19687	12633	57857	95806	09931	02150	43163	58636
146	37609	59057	66967	83401	60705	02384	90597	93600
147	54973	86278	88737	74351	47500	84552	19909	67181
148	00694	05977	19664	65441	20903	62371	22725	53340
149	71546	05233	53946	68743	72460	27601	45403	88692
150	07511	88915	41267	16853	84569	79367	32337	03316

Appendix C

Figure 2. Cerner - Discern Analytics Interface



Appendix D

Figure 3. Data Collection Form

No. (after exclusion criteria applied)	Date	Patient Type	Patient Medical Record Number	Preop Diagnosis	Postop Diagnosis	Procedure	Patient In Room	Surgery Start	Surgery Stop	Patient Out of Room	Surgical Scheduling Duration (SET-inc to before dress)	AORT (C1+AOT+C3)	ASA	Patient Age	Patient Sex	Wound Classification (manually pulled)	CET (manually pulled)	Race/Ethinicity (manually pulled)	BMI (manually pulled)	Weight Categories

Worksheet - Gen OP Lap | Worksheet - Ortho IP Joint | +

Appendix E

Table 2. Data Codebook

Variables	**Codes**
Patient Type	1=Outpatient 2=Inpatient
Medical Record Number (MRN)	A 7-digit unique number.
Pre-Operative Diagnosis	As recorded in patient EMR.
Post-Operative Diagnosis	As recorded in patient record 1 diagnosis=recorded >1 diagnosis=rejected
Procedure	10=gallbladder 11=appendix 12=inguinal hernia 13=ventral hernia 14=incisional hernia 15=colon 16=liver 17=pancreas 18=esophagus 19=small bowel 30=shoulder 31=knee 32=hip
Component 1 (C1)	In minutes, as recorded in patient EMR.
Component 2 (C2- SET & AOT)	SET- In minutes, from incision to dressing, as given by the surgeon's office to surgical posting when the case is posted. AOT- To be calculated in minutes.
Component 3 (C3)	In minutes, as recorded in patient EMR.
ASA	1=ASA 1 2=ASA 2 3=ASA 3 4=ASA 4 5=ASA 5 6=ASA 6
Patient Age Range	1=18 to < 30 2=30 to <45 3=45 to < 65 4= 65 or more

Patient Gender	1=Male 2=Female
Wound Classification	1=Wound Class 1 2=Wound Class 2 3=Wound Class 3 4=Wound Class 4 5=not documented
Race/Ethnicity	1=Caucasian 2=African American 3=Other 4=Unknown
BMI	As recorded in patient EMR.
Weight Categories	Based on the BMI, the following categories will be recorded: 0=Underweight <18.5 1=Normal 18.5 to 24.9 2=Overweight 25 to 29.9 3=Obese 30 and over
Actual Operating Room Time (AORT)	C1+AOT+C3 in minutes

Appendix F

Table 3. Characteristics of the Sample

	Outpatient General Laparoscopic N=120	**Inpatient Total Joint Orthopedic N=120**
Variables	Frequency (%)	Frequency (%)
Age (yrs.)		
18 to <30	14 (11.7%)	0
30 to <45	44 (36.7%)	1 (0.8%)
45 to <65	47 (39.2%)	62 (51.7%)
65 or more	15 (12.5%)	57 (47.5%)
Gender		
Male	49 (40.8%)	42 (35%)
Female	71 (59.2%)	78 (65%)
Race/Ethnicity		
Caucasian	53 (44.2%)	51 (42.5%)
African Americans	42 (35%)	52 (43.3%)
Other	20 (16.7%)	16 (13.3%)
Unknown	5 (4.2%)	1 (0.8%)
Procedure		
Gallbladder	82 (68.3%)	-
Appendix	1 (0.8%)	-
Hernias (includes Inguinal, Ventral and Incisional)	25 (20.9%)	-
Colon	1 (0.8%)	-
Liver	1 (0.8%)	-
Esophagus	10 (8.3%)	-
Shoulder	-	11 (9.2%)
Knee	-	61 (50.8%)
Hip	-	48 (40%)
ASA		
ASA 1	16 (13.3%)	0
ASA 2	78 (65%)	71 (59.2%)
ASA 3	26 (21.7%)	49 (40.8%)
Wound Classification		
Wound Class 1	29 (24.2%)	118 (98.3%)
Wound Class 2	90 (75.0%)	0
Wound Class 3	1 (0.8%)	0
not documented	0	2 (1.7%)
BMI (mean, SD, range)	30.4 (7.4), 16.6-66.5	29.8 (6.6), 15.2-53.3
Weight Categories		

Underweight= <18.5	2 (1.7%)	4 (3.3%)
Normal=18.5 to 24.9	22 (18.3%)	19 (15.8%)
Overweight=25 to 29.9	36 (30%)	43 (35.8%)
Obese=30 or greater	60 (50%)	54 (45.0%)

Appendix G

Table 4. Research Questions Analysis

	Outpatient General Laparoscopic (mean, SD, min, max)	**Inpatient Orthopedic Total Joint (mean, SD, min, max)**
Research question #1 - What is the average time (in minutes) from patient in OR to just before incision (C1)?	23.8, (5.9), 15.0, 56.0	45.7, (8.7), 30.0, 83.0
Research question #2 - What is the average time (in minutes) from incision to dressing (C2/AOT)?	75.5, (30.6), 33.0, 198.0	111.5, (23.4), 74.0, 189.0
Research question #3 - What is the average time (in minutes) from after dressing to patient out of OR (C3)?	11.1, (7.2), 0, 57.0	11.8, (6.4), 3.0, 37.0
Research question #4 - What is the difference in the average time (in minutes) between SET and AORT?	4.6, (34.8), -64.0, 125.0	22.0, (38.8), -82.0, 123.0

Appendix H

Table 5. Outcomes of Hypotheses Testing

	SET Mean (SD)	AOT Mean (SD)	***p* value**
Outpatient General Laparoscopic	105.8 (31.6)	75.5 (30.6)	t=9.49, $p<0.001$
Inpatient Orthopedic Total Joint	147.0 (36.4)	111.5 (23.4)	t=10.59, $p<0.001$

Appendix I

Table 6. Actual Operating Room Time Analysis

	Outpatient General Laparoscopic (mean, SD)	**Inpatient Orthopedic Total Joint (mean, SD)**
C1	23.8 (5.9)	45.7 (8.7)
C2 (AOT)	75.5 (30.6)	111.5 (23.4)
C3	11.1 (7.2)	11.8 (6.4)
AORT	110.3 (33.8)	169.0 (26.3)