University of Michigan Health System
Analysis of Wait Times Through the Patient Preoperative Process

Final Report

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Executive Summary

The General Surgery Section of the University of Michigan Health System contains a Minimally Invasive Surgery Division, in which hernia surgeries are performed. The Ambulatory Care Manager believed that wait times for hernia surgeries in the system were unnecessarily long, about 6 months, and asked the University of Michigan IOE 481 Student Team 2 to perform an analysis to determine what is causing these long wait times.

The team researched the Patient Preoperative Process, which starts when the patient is called to set up a New Patient Appointment (NPA) to determine if hernia surgery is necessary and ends when surgery is actually performed on the patient. The Senior Project Manager of the Ambulatory Care Services, a project coordinator, retrieved the historical data for the team, which allowed the team to perform analyses to determine the major factors causing the long wait times.

Background

The Ambulatory Care Manager reported that there are problems within the Patient Preoperative Process that are causing delays: disconnect between the two systems (MiChart: electronic health system and Optime: surgical information system), lengthy case order creation, and mismatch in hernia surgery supply and demand. There is currently no direct way to determine the patient wait time for hernia surgeries because of the disconnect between the two information systems used at UMHS: MiChart, which is used for clinical visits, and Optime, which is used for surgery information. Case Orders should be entered into Optime at the completion of the New Patient Appointment; however, the Ambulatory Care Manager suspects that this procedure is not being followed. The Ambulatory Care Manager believes that the percent of OR time that is dedicated to hernia patients does not accurately reflect the percent of hernia patient calls coming into the Call Center. These issues are perceived to be creating longer wait times for hernia surgery patients.

Methods and Findings

The team used six methods for the analysis of wait times throughout the Patient Preoperative Process: literature search, interviews, organization of data, current state processing map, data analysis, and linear regression. These methods were used to develop findings.

Literature Search

The team conducted a literature search and found six sources that were used to find possible causes for the delay in the Patient Preoperative Process, both quantitative and qualitative.

Interviews

The team then interviewed the Cardio and Thoracic Call Center Manager, one Call Center Agent, and the OR Scheduler to determine the length of time it takes them to complete their process, the materials required before the patient can move to the next step in the Patient Preoperative
Process, and any causes for the delay in their process. These interviews were used to create the current state Value Stream Map.

Organization of Data
The team retrieved 24 months of historical data from the Senior Project Manager for the Ambulatory Care Services, a project coordinator. The historical data came from two information systems, MiChart and Optime, which the team then combined into one Excel spreadsheet linked by patient Medical Record Number (MRN). The MiChart data is from March 2013 - August 2015, and the Optime data is from June 2014 - August 2015.

Current State Processing Map
The team created a current state Value Stream Map which displays the process steps, the wait times between each step, sources of delay in the process, required materials, patient caused delays, and the overall wait time. Table E-1 displays the wait times between the Patient Preoperative Process steps using a sample size of 254 cases.

Table E-1: Overall Wait Time is Over 4 Months (Sept. 2013-Aug. 2015)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.58 ± 1.18</td>
<td>1.89 ± 3.10</td>
<td>1.23 ± 0.69</td>
<td>4.67 ± 3.4</td>
</tr>
</tbody>
</table>

Table E-1 shows the overall wait time is 4.67 months of which only 184.5 minutes are value added time.

Data Analysis
The team analyzed the historical data from the combined spreadsheet, segmenting it by both surgeon and hernia type. There are three MIS surgeons (Surgeons 1, 2, and 3) and five hernia types (hiatal, inguinal, umbilical, ventral, ventral-incisional). The team discovered the following: Surgeon 2 has the longest overall wait time, Surgeon 1 has the longest wait time for NPA, Surgeon 3 has the shortest wait times for all steps, hiatal has the longest overall time, and umbilical has the longest wait time for NPA and surgery.

The team then compared hernia versus bariatric for the percent breakdowns of the following: supply and demand for NPA, Surgery Time, and number of surgeries. When comparing the supply and demand for hernia versus bariatric patients, the team discovered that demand could not be calculated from the data because the New Patient (NP) type is not being specified for each NPA. The hospital is unable to determine how many patients came in for NPAs for the many different types of surgeries MIS surgeons perform. Hernia patients waited twice as long for an NPA when compared to bariatric patients when all patients went through the Patient Preoperative Process.
Linear Regression
The team performed a multivariable linear regression analysis to determine the validity of the model’s results, and to determine which variables (surgery time in minutes, surgeon, and hernia type) have the biggest impact on the overall patient wait time. The linear regression shows that Surgeon 3 tends to have the shortest overall wait time by almost 2 months. It was also found that Surgeons 1 and 2 are not statistically different from each other in terms of overall wait time. It was found that it is extremely significant that inguinal hernia patients have the shortest wait time followed by ventral hernia patients.

Conclusions and Recommendations
The team determined that the major sources of delay in the Patient Preoperative Process are due to: NPA slot allotment, surgeon preferences, surgical backlog, NPA type classification, and surgery date assignments.

More NPA slots are allotted to bariatric patients than to hernia patients, due to surgeon preference. Hernia patients wait 1.58 months for an NPA while bariatric patients only wait 0.76 months for an NPA. The team calculated the hours of OR time that are needed to complete all of the surgeries in the current backlog which equals about 182 hours of OR time, which is 41.15 full OR days. Surgeons only have three OR days a week; without adding any more patients this backlog would take 13.72 weeks to complete. Future backlog cannot be predicted because the NPA type is not currently being classified. The team calculated that for each additional 20 minutes in length of case, the overall wait time for the entire Patient Preoperative Process increases by almost one day. Currently, a patient is assigned a surgery date based on the date of his/her NPA, and the amount of pain and risk he/she is in is not taken into consideration.

For the entire Patient Preoperative Process, patients are waiting 4.7 months for a value added process time of 184.5 minutes. When looked at in minutes, the overall process time is 204,552 minutes, the value added time is only 0.09% of the overall time they spend in the Patient Preoperative Process. From the conclusions and the difference between value time added and non-value time added, the team recommends:

- NP should not be an option for classifying MIS patient appointment type
- Appointment type specification should be required for all patients
- Surgery date should be based off of overall wait time, outcome risk of delaying surgery, and severity of pain

The team has developed these conclusions and recommendations to help the MIS Division and the Ambulatory Care Manager, the client, improve the Patient Preoperative Process for hernia patients. The team also suggests that future work be done to meet the hernia surgery demand, which includes investigating various alternatives to meet the demand.
Introduction

The University of Michigan Health System (UMHS) is an academic medical center of the University of Michigan, Ann Arbor. UMHS includes three hospitals, 120 outpatient clinics, and 40 health centers. The Minimally Invasive Surgery (MIS) Division of the General Surgery Section of the Department of Surgery performs bariatric, hernia, colon, gallbladder, and esophageal surgeries. The Ambulatory Care Manager, the client, expressed concern regarding the perceived long patient wait times for hernia surgeries, which are within this division. The Ambulatory Care Manager believes that wait times were over six months for hernia surgeries. This extended wait time is the total of the wait times between five steps in the Patient Preoperative Process from when the patient initially calls in for a New Patient Appointment (NPA), to the time of his or her surgery. The current Patient Preoperative Process includes these five steps:

1. The Cardio and Thoracic Call Center Agent calls the patient to schedule a NPA
2. The patient comes into the Domino’s Farms Plastic Surgery Clinic for his/her NPA
3. The surgeon creates a Case Order for the patient in the surgical information system
4. The Operating Room (OR) scheduler calls the patient to schedule his/her surgery
5. The patient has surgery

The Ambulatory Care Manager believed that a delay in entering the Case Order is causing a backlog of hernia surgeries and an increased wait time for hernia patients. In addition, the wait time had not yet been quantified and there was not a single source that included all of the data to determine the wait times in the Patient Preoperative Process. Therefore, the Ambulatory Care Manager asked Student Project Team 2 from IOE 481 from the University of Michigan (UM) to determine the average wait time between each step in the Patient Preoperative Process. The purpose of this project was to determine the average wait times between the steps in the Patient Preoperative Process (overall, by surgeon, by hernia type), the current hernia surgery supply and demand, and the sources of the extended overall patient wait time. To provide the information requested by the Ambulatory Care Manager, the team did the following: a literature search, interviews, data organization, current state process mapping, data analysis, and a linear regression analysis. This report presents the methods the team used throughout this project, the findings generated, and the conclusions and recommendations drawn from the findings.

Background

The University of Michigan Hospital A. Alfred Taubman Center, which currently houses the General Surgery Department, was founded in 1981. The General Surgery Section is a part of the Department of Surgery and includes Acute Care, Colorectal, Endocrine, Hepatopancreaticobiliary (HPB), MIS, and Oncology divisions. Bariatric and hernia surgeries are a part of the MIS division, which is where the Ambulatory Care Manager believes the longest
wait times in the Patient Preoperative Process are occurring, which is causing patient
dissatisfaction. This project explores the following hernia types: hiatal, inguinal, umbilical,
ventral, ventral-incisional. Within MIS, four surgeons performed both bariatric and hernia
surgeries. In October of 2014, an MIS surgeon who specialized in hernia surgeries left the
division, leaving the division with only three MIS surgeons. Each surgeon is assigned one day a
week (7am-5pm) at the UMHS OR for surgeries. Each surgeon gets one day a month at East Ann
Arbor, and one clinic session a week at Domino’s Farms Plastic Surgery Clinic. Each clinic
session lasts 4 hours and takes place in the morning. The Department of Surgery, a coordinator,
informed the team that ORs are being 100% utilized for MIS.

The Ambulatory Care Manager reported that there is currently no direct way to determine the
patient wait time for hernia surgeries because of the disconnect between the two information
systems used at UMHS: MiChart, an electronic health record, which is used for clinical visits,
and Optime, a surgical system, which is used for surgery information. Case orders are entered
into Optime at the end of the NPA for a surgery to be scheduled. The Ambulatory Care Manager
disclosed that the average process time for entering a case order is three minutes and can take
from one to seven minutes. The Ambulatory Care Manager suspects that there is a delay between
when the NPA occurs and the date that the Case Order is entered into Optime. This delay is
believed by the Ambulatory Care Manager to be causing an increased wait time for hernia
surgery patients.

The Ambulatory Care Manager also believes that the percent of OR time that is dedicated to
hernia patients does not accurately reflect the percent of hernia patient calls coming into the Call
Center. This perceived mismatch in supply and demand is expected to be creating additional wait
time for hernia surgery patients.

Key Issues
The key issues as perceived by the Ambulatory Care Manager created the need for this project:
- Patients are dissatisfied with wait times
- An MIS Surgeon who specialized in hernia surgeries left UMHS last year
- Data does not currently exist in an easily accessible format
- Case Orders are not being entered promptly
- There is a mismatch in surgery supply and demand

Goals and Objectives
To determine the process times, wait times between each step, and possible causes of delays in
the Patient Preoperative Process, the team performed the following tasks:
- Complete a Literature Search
- Interview the Call Center Manager, a Call Center Agent, and the OR Scheduler
- Organize and combine historical MiChart and Optime data
- Develop Current State Process Map
- Analyze historical data
- Conduct a linear regression analysis

With this information, the team developed a detailed summary of the Patient Preoperative Process to develop changes that will:
- Decrease the patient wait time
- Increase overall patient satisfaction
- Decrease the backlog of hernia surgeries
- Increase understanding of current hernia supply and demand

**Project Scope**
This project includes the Patient Preoperative Process for the MIS Division. The MIS Division has been narrowed down to hernia surgeries for the scope of this project. This project includes information from five steps in the current Patient Preoperative Process. These five steps are as follows:

1. The Cardio and Thoracic Call Center Agent calls the patient to schedule a NPA
2. The patient comes into the Domino’s Farms Plastic Surgery Clinic for his/her NPA
3. The surgeon creates a Case Order for the patient in the surgical information system
4. The OR scheduler calls the patient to schedule his/her surgery
5. The patient has surgery

This project excludes hernia patients who did not complete each step in the Patient Preoperative Process within the historical data time frame (September 2013 to August 2015). It also excludes patients who came in for a revisit or postoperative appointment rather than an NPA. This project excludes bariatric patients when looking at the Patient Preoperative Process wait times, but is included in the supply and demand breakdowns for bariatric versus hernia cases.

**Methods and Findings**

The team used six methods for the analysis of wait times throughout the Patient Preoperative Process: literature search, interviews, organization of data, current state processing map, data analysis, and linear regression. These methods were used to develop findings to substantiate changes that will decrease the patient wait time throughout the Patient Preoperative Process and, as a result, improve patient satisfaction.

**Literature Search**
The team performed a literature search and identified six sources about how best to approach the project. The team looked at a past IOE 481 project from 1993, *Mott Children’s Hospital Operating Room Scheduling Project*, which details many qualitative reasons delays in the Patient Preoperative Process may be occurring [2]. Throughout the project, the team investigated if any
of the same reasons may be causing delays in the Patient Preoperative Process for hernia patients as well.

The team did additional research on hernia patient wait times in other parts of the world. In the article: *Why are men being refused surgery for their hernias?* Lambert details that hospitals in the United Kingdom are adopting a process known as “watchful waiting” [1]. Watchful waiting is a process where a person with a hernia waits until his/her symptoms grow or his/her pain becomes unbearable before receiving a diagnosis for surgery. This new process has been developed following American research that shows that waiting does not increase the chance of developing a strangulated surgery. In 2012, the average wait time for hernia surgeries in the UK was 78 days long [3]. This allowed the team to develop a recommendation related to prioritizing patient surgery date.

The additional sources the team found detail quantitative methods for analyzing patient wait times, which the team looked to when selecting engineering approaches for data analysis. These sources include, *A Two-Stage Approach for Surgery Scheduling* by Zhong, Luo, and Wu [6], *A simulation study of scheduling clinic appointments in surgical care: individual surgeon versus pooled list* [4], and *Use of VNS heuristics for scheduling of patients in hospital* [5].

**Interviews**

The team interviewed the Cardio and Thoracic Call Center Manager and Agent, as well as the OR Scheduler. The six Call Center Agent schedule NPAs at the Domino’s Farms Plastic Surgery Clinic and the OR Scheduler schedules surgeries at either the UMHS’s ORs or East Ann Arbor’s ORs. The purpose of the interviews was to better understand the process at each step in the Patient Preoperative Process, to gather estimates from the interviewees of the length of time certain steps in their process take them to complete (shortest possible time, average, and longest time), and to understand what needs to happen (insurance checks, additional appointments, etc.) before the patient can move to the next step in the Patient Preoperative Process and any causes for the delays in their process. Appendix 1 details the initial list of questions the team used when interviewing the Call Center Manager.

*The Cardio and Thoracic Call Center Manager*

The Cardio and Thoracic Call Center Manager described the high level Call Center Process which is related to step 1 in the Patient Preoperative Process. The Manager said the Minimally Invasive Surgery Division is scheduling NPAs four months in advance. Each of the three surgeons in Minimally Invasive Surgery determine how many appointment slots for their clinic days are allotted for each type of appointment (i.e. NPA hernia, NPA bariatric, Return Visit hernia, Return Visit bariatric). Surgeon 1, Surgeon 2, and Surgeon 3 have three, five, and four new hernia patient appointments per clinic day, respectively. On average four new hernia patients are seen per day, and 12 new hernia patients are seen per week. The Cardio and Thoracic Call Center Agent explained their NPA Process to the team. The process begins when a
physician refers a patient for a hernia appointment. These referrals are deposited in each of the six Agent’s queues in MiChart to be scheduled. For an appointment to be scheduled, the patient must already have a confirmed hernia diagnosis, which includes the hernia type, in MiChart.

*The Cardio and Thoracic Call Center Agent*

The Cardio and Thoracic Call Center Agent explained the specific details of the Call Center scheduling process. The Agent starts each day with about 22 appointment requests in his queue. For each appointment request, the Agent uses the Schedule Matrix to determine which surgeons perform the type of surgery the patient requires. The Agent then uses MiChart to find out the earliest appointment date available and calls the patient to schedule an appointment. A phone call takes on average two and a half minutes and can last from one to five minutes. The Agent attempts to contact the patient, by phone, up to three times to schedule an appointment and if the Agent is unable to contact the patient, the patient is removed from the queue. The average number of days it takes to reach a patient is seven days with one day being the shortest and 21 days being the longest. Each Agent schedules about 40 patients a day. The materials required before a patient can move to process step 2 are a confirmed hernia diagnosis from another physician, current medical records, and insurance verification.

*The OR Scheduler*

The OR Scheduler explained the surgery scheduling process, which is related to step 4 in the Patient Preoperative Process. The process starts when the patient’s Case Order (created by the surgeon at the end of an appointment) is deposited in the Scheduler’s Optime queue. The materials required before a patient can move to process step 4 are the OR schedule and the Case Order. The Case Order includes:

- The date the patient was seen for the NPA
- The location of surgery
- The length of the surgery in hours
- The tests that need to be completed before surgery

The OR Scheduler’s process starts when the Case Order appears in her queue and ends when the surgery has been scheduled. After receiving the Case Order, the Scheduler views the patient’s MiChart history to determine the date he/she came in for the NPA to avoid the problem that arises when surgeons do not enter the Case Order immediately following the appointment. This procedure aligns scheduling surgery dates with the order patients came in for their NPA. With this information, the scheduler calls each patient to inform him/her that there are currently no surgery slots available, what month his/her surgery will most likely be, and that he/she will be contacted when the schedule for that month is available. The patient is then called again to schedule his/her appointment during the month that was given to him/her by the Scheduler. After each day, the Scheduler reorganizes and reprioritizes the waiting patients to make sure that scheduling aligns with the order patients came in for their NPA. The OR Scheduler then discussed with the team the high level OR Scheduling Process.
The team discovered the following facts from the interview with the OR Scheduler: process time for phone call, materials required, backlog, and OR scheduling priorities. A phone call takes on average 20 minutes and can last from 15 to 30 minutes. It takes an average of three days to reach a patient when scheduling surgery. The materials required before a patient can move to process step 5 are: complete history and physical, complete testing, scheduled OR date and postoperative checkup. The Scheduler told the team that there was a backlog of 114 hernia patients waiting for surgery on 10/6/15 and the current backlog is 124 hernia patients as of 11/19/15. The number of OR rooms assigned for Minimally Invasive Surgeries is limited; however, increasing the number of OR rooms is not feasible at this time so it is outside of the scope of this project. Two of the three Minimally Invasive Surgery surgeons will complete additional surgeries if other ORs are available. The surgeons have requested that their surgery schedule first be given to the Bariatric Schedulers before the OR Scheduler, as this is where there individual preferences lie.

**Data Organization**

Data Organization was completed in 3 steps: combining the data, eliminating irrelevant data points, and eliminating data that was outside of the Patient Preoperative Process. The team retrieved 24 months of historical MiChart and Optime data in four separate Excel spreadsheets from the Senior Project Manager for the Ambulatory Care Services, a project coordinator. The MiChart data is from March 2013 - August 2015, and the Optime data is from June 2014 - August 2015.

The team used many Excel function to combine the data into one linear Excel spreadsheet. VLOOKUPs were used to link the spreadsheets by patient Medical Record Number (MRN), and surgical Case ID number. The team realized that the historical data was not in a format that could be analyzed, because it was not a linear comparison for one patient having one data point for each step in the Patient Preoperative Process. To combine the spreadsheets into one linear Excel spreadsheet, the team manually eliminated patients who met the following criteria:

- Patients coming for a re-visit or postoperative appointment
- Patients who do not have a NPA within the historical data time frame
- Patients who do not have a surgery within the historical data time frame
- Patients who have multiple NPAs within the historical data time frame
- Patients who have multiple surgeries within the historical data time frame
- Patients who do not have a case order within the historical data time frame
- Patients who have multiple case orders
  - If there are two within a month remove the second case order
  - If there are two within more than a month remove the patient
- Patients who have different surgeons for the NPA and their surgery

After the team manually eliminated all of the patients who meet the above criteria, the team was left with 254 cases to analyze. These cases had the following hernia surgery types: hiatal, inguinal, umbilical, ventral, and ventral-incisional with a sample size of: 15, 109, 12, 12, and 106
patients, respectively. Of the three surgeons Surgeon 1 had a sample size of 78 patients, Surgeon 2 had a sample size of 105 patients, and Surgeon 3 had a sample size of 74 patients. Each of these patients had only one NPA, one Case Order, and one surgery with a single surgeon, which allowed the team to create a combined linear Excel spreadsheet.

This spreadsheet was used to determine the process times for Step 2: NPA and Step 5: Surgery, and the wait times between all five steps in the Patient Preoperative Process. The team removed Step 3 when determining the overall wait time for the patient preoperative process because the OR scheduler explained that she reprioritizes all patients for surgery scheduling by their NPA date, out of fairness to the patient. The team analyzed and drew conclusions from the wait times between Step 1: Call Center Agent calls the patient and Step 2, Step 2 and Step 4: OR Schedule calls the patient, and Step 4 and Step 5. The average overall wait time for the Patient Preoperative Process is 4.67 months with a standard deviation of 3.4 months. Figure 1 below shows the non-value added wait times between the four steps:

Figure 1: Wait Time for Surgery Scheduling is the Longest
(n=254, Sept. 2013-Aug. 2015)

Figure 1 displays the average wait times between each of the four steps. It can be seen that the average wait time for surgery scheduling is the longest at 1.89 months with a standard deviation of 1.18 months followed by wait time for NPA at 1.57 months with a standard deviation of 3.10 months, and wait time for surgery at 1.22 months with a standard deviation of 0.69 months.

Current State Process Mapping
The team used the information obtained during interviews to create a SIPOC (Supplier, Input, Process, Output, Customer) diagram that helped the team understand the relevant elements of the Patient Preoperative process, which include the high level process, the project scope, and the key...
stakeholders. The SIPOC represents the process including the flow from the key suppliers and their inputs, through the process with the resulting outputs, to the key customers from beginning to end. The team used the SIPOC diagram (Appendix 2) to create a Current State Value Stream Map (VSM) (Appendix 3).

The VSM details the five steps of the Patient Preoperative Process and the number of people involved in each step. The average process time for each step was determined. Three of the steps required process time estimates from interviews to determine their value time added. These steps are: **Step 1: Call Center Agent calls the patient**, **Step 3: Case order is created** and **Step 4: OR scheduler calls the patient**. For these steps, the team created a triangular distribution (average, shortest and longest) for the process time. The average and standard deviation of the process times for **Step 2: NPA Appointment** and **Step 5: Surgery** were calculated from the combined linear Excel spreadsheet. The process times for these steps are value added time, which is the total time that benefits the patient. The total value added time for a hernia patient through the Patient Preoperative Process is 184.5 minutes.

The VSM also includes the average and standard deviation of wait times between each of the five steps, which were determined from the combined linear Excel spreadsheet. These wait times include the wait time between Step 2 and Step 3 and the wait time between Step 2 and Step 4, but the wait time between Step 3 and Step 4 is not included because this time is arbitrary. The wait times between these steps are non-value added time, which is the total time that does not benefit the patient. The total non-value added time for a hernia patient through the Patient Preoperative Process is 4.7 months. Each step in the process includes a description of the materials required before the patient can move to the next step in the process. Step 1 and Step 3 include interaction with the patient and therefore include the average time for patient caused delays. In addition, the VSM includes sources of delay, which note the issues that were described to the team during interviews.

**Data Analysis**

The Ambulatory Care Manager, the client, asked the team to look at the frequency that the percent of NPAs are occurring within the standard time, Access, which is two weeks from when the Call Center Agent contacts the patient. Figure 2 below shows the breakdown of NPAs that are within the standard time and those that are not:
Figure 2 shows that only 25% of patients are seen within two weeks of scheduling their NPA with the Call Center Agent. The Ambulatory Care Manager, the client, then asked the team to look at the frequency that case orders are occurring within the standard time, which is 24 hours. Figure 3 below shows the breakdown of case order creations that are less than one day, within one day, and more than one day:

Figure 3 shows that 80% of the case orders are completed within the standard time of 24 hours. However, this is after the team eliminated the top 5% of case order entry lengths, as they were strong outliers.
**Surgeon Analysis**

The Ambulatory Care Manager, the client, asked the project team to analyze the historical data by surgeon. There are three MIS surgeons who perform hernia surgeries: Surgeon 1, Surgeon 2 and Surgeon 3. To do this, the team used filters on the combined linear Excel spreadsheet to view the data one surgeon at a time, or one hernia type at a time. Once the data was filtered, the team calculated the average value added wait time (in minutes) and their standard deviations by surgeon, which can be seen in Table 1.

**Table 1: Value Added Time for Surgeon 2 is the Longest (Sept. 2013 - August 2015)**

<table>
<thead>
<tr>
<th>Surgeon (Sample Size)</th>
<th>Surgeon 1 (n=77)</th>
<th>Surgeon 2 (n=104)</th>
<th>Surgeon 3 (n=73)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of NPA (minutes)</td>
<td>46.14 ± 19.89</td>
<td>60.91 ± 29.98</td>
<td>29.89 ± 19.04</td>
</tr>
<tr>
<td>Length of Case (minutes)</td>
<td>97.66 ± 35.05</td>
<td>135.5 ± 73.36</td>
<td>94.56 ± 52.74</td>
</tr>
<tr>
<td>Overall Time (minutes)</td>
<td>143.81 ± 42.96</td>
<td>196.41 ± 84.45</td>
<td>124.45 ± 54.57</td>
</tr>
</tbody>
</table>

Table 1 shows that Surgeon 3 has the shortest value added time of 88.12 minutes, followed by Surgeon 1 at 103.65 minutes and finally Surgeon 2 has the longest value added time at 155.33.

The team then looked at the average non-value added wait time (in both months and days) and their standard deviations by surgeon, which can be seen in Table 2,

**Table 2: Non-Value Added Time for Surgeon 2 is the Longest (Sept. 2013-August 2015)**

<table>
<thead>
<tr>
<th>Surgeon (Sample Size)</th>
<th>Surgeon 1 (n=77)</th>
<th>Surgeon 2 (n=104)</th>
<th>Surgeon 3 (n=73)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wait Time For NPA (months)</td>
<td>1.79 ± 1.42</td>
<td>1.56 ± 1.20</td>
<td>1.37 ± 0.76</td>
</tr>
<tr>
<td>Wait Time for SurgSched from NPA (months)</td>
<td>1.69 ± 2.12</td>
<td>2.31 ± 3.35</td>
<td>1.50 ± 3.52</td>
</tr>
<tr>
<td>Wait Time for Surg (months)</td>
<td>1.24 ± 0.71</td>
<td>1.27 ± 0.66</td>
<td>1.16 ± 0.71</td>
</tr>
<tr>
<td>Overall Wait Time (months)</td>
<td>4.72 ± 2.63</td>
<td>5.15 ± 3.58</td>
<td>4.10 ± 3.91</td>
</tr>
</tbody>
</table>

Table 2 shows that Surgeon 3 has the shortest non-value added time of 4.10 months, followed by Surgeon 1 at 4.72 months and finally Surgeon 2 has the longest non-value added time at 5.15 months. The Surgeons rankings for both value added time and non-value added time are the same with Surgeon 2 always being the longest and Surgeon 3 always being the shortest. This is confirmed in Figure 4 below:
Figure 4: Surgeon 2 has the longest Overall Wait Time (n=254, Sept. 2013 - Aug. 2015)

Figure 4 shows the comparison of wait times for NPA, for Surgical Scheduling, and for Surgery for each of the three surgeons. Although Surgeon 2 has the longest Overall Time, Surgeon 1 has the longest wait time for NPA. Surgeon 3 has the lowest wait times for all steps.

Hernia Type Analysis

The team then filtered the data by hernia type. This project includes: hiatal, inguinal, umbilical, ventral, and ventral-incisional. Again, the team calculated the average value added time (in minutes) and their standard deviations, by hernia type which is displayed in Table 3.

Table 3: Value Added Time for Hiatal Hernias is the Longest (Sept. 2013-Aug. 2015)

<table>
<thead>
<tr>
<th>Hernia Type (Sample Size)</th>
<th>Hiatal (n=15)</th>
<th>Inguinal (n=109)</th>
<th>Umbilical (n=12)</th>
<th>Ventral (n=12)</th>
<th>Ventral-Incisional (n=106)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of NPA (minutes)</td>
<td>61.07 ± 22.61</td>
<td>50.70 ± 26.91</td>
<td>49.33 ± 31.98</td>
<td>66.67 ± 24.81</td>
<td>39.96 ± 26.28</td>
</tr>
<tr>
<td>Length of Case (minutes)</td>
<td>239.73 ± 58.25</td>
<td>95.16 ± 30.07</td>
<td>78.33 ± 17.07</td>
<td>167.25 ± 83.98</td>
<td>109.43 ± 61.02</td>
</tr>
<tr>
<td>Overall Time (minutes)</td>
<td>300.80 ± 61.26</td>
<td>145.85 ± 41.98</td>
<td>127.67 ± 36.50</td>
<td>233.92 ± 103.10</td>
<td>149.40 ± 72.76</td>
</tr>
</tbody>
</table>

Table 3 shows that the value added times by hernia type from longest to shortest are as follows: hiatal, ventral, ventral-incisional, umbilical, inguinal. The team then looked at the average non-value added wait time (in both months and days) and their standard deviations by hernia type, which can be seen in Table 4.
Table 4: Non-Value Added Time for Hiatal Hernias is the Longest (Sept. 2013-Aug. 2015)

<table>
<thead>
<tr>
<th>Hernia Type (Sample Size)</th>
<th>Hiatal (n=15)</th>
<th>Inguinal (n=109)</th>
<th>Umbilical (n=12)</th>
<th>Ventral (n=12)</th>
<th>Ventral-Incisional (n=106)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wait Time For NPA (months)</td>
<td>0.66 ± 0.33</td>
<td>1.65 ± 1.43</td>
<td>2.04 ± 0.71</td>
<td>1.44 ± 1.16</td>
<td>1.59 ± 0.94</td>
</tr>
<tr>
<td>Wait Time for SurgSched (months)</td>
<td>4.56 ± 3.99</td>
<td>1.24 ± 2.20</td>
<td>2.37 ± 6.18</td>
<td>2.42 ± 2.03</td>
<td>2.06 ± 3.17</td>
</tr>
<tr>
<td>Wait Time For Surg (months)</td>
<td>1.34 ± 0.52</td>
<td>1.21 ± 0.71</td>
<td>1.75 ± 0.64</td>
<td>1.26 ± 0.59</td>
<td>1.18 ± 0.68</td>
</tr>
<tr>
<td>Overall Wait Time</td>
<td>6.57 ± 3.92</td>
<td>4.09 ± 2.82</td>
<td>6.16 ± 5.61</td>
<td>5.12 ± 2.60</td>
<td>4.83 ± 3.57</td>
</tr>
</tbody>
</table>

Table 4 shows that the non-value added times by hernia type from longest to shortest are as follows: hiatal, umbilical, ventral, ventral-incisional, inguinal. The ranking differs for value time added versus non-value time added. These changes in ranking can be seen in Figure 5 below:

![Figure 5: Hiatal Hernias have the longest Overall Wait Time](image)

Figure 5 shows the comparison of wait times for NPA, for Surgical Scheduling, and for Surgery for each of the five hernia types. Although Hiatal has the longest Overall Time, Umbilical has the longest wait time for NPA and Surgery, while Hiatal only has the longest time for surgery scheduling.
Supply and Demand Analysis
There are three surgeons in MIS who perform both hernia surgeries and bariatric surgeries. The number of bariatric patients the surgeon sees impacts the wait time for hernia patients, because the same surgeons perform both hernia and bariatric surgeries. The Ambulatory Care Manager, the client, informed the team that the surgeon’s research interests are in bariatrics and therefore they prefer to do bariatric versus hernia surgeries.

The team compared hernia versus bariatric for the percent breakdowns of the following: supply and demand for NPA, Surgery Time, and number of surgeries. The team created a combined linear Excel spreadsheet for bariatric patients in the same manner as for hernia patients, which created an even comparison of the two data sets. The team analyzed the supply of hernia versus bariatric surgeries using Excel Pivot Tables. The team calculated the volume of hernia and bariatric surgeries performed in each month (by volume and by OR time in minutes), and then determined the average of the 15 months. This comparison can be seen in Figure 6:

![Figure 6: Demand for Surgeries determined by volume and time are approximately even (n=254, Sept. 2013-Aug. 2015)](image)

Figure 6 shows that the supply for hernia surgeries in volume is much larger than bariatric surgeries. More time is spent in the OR for bariatric cases when compared to the actual volume of cases. The team discovered a problem with determining the demand for hernia patients versus bariatric patients. Without the NPA type classification there is currently no way to determine if a patient came into the clinic for a hernia NPA or a bariatric NPA. The breakdown of NPA types is shown below in Figure 7:
Figure 7: 75% of NPAs are labeled NP without a description
(n=254, Sept. 2013-Aug. 2015)

Figure 7 shows the breakdown of NPAs by the visit type assigned to them. NP stands for New Patient. Only 25% of the data has a specified NP type, which makes it impossible to determine the demand for either hernia or bariatric surgeries. The team was told that in previous years there was not an option to specify the type of NP. The percentage breakdown, however, does not change significantly from 2013 to 2015. Finally, the team analyzed the wait time for NPA after the initial call for both hernia and bariatric patients. Figure 8 compared bariatric versus hernia patients wait time for NPA after the Call Center Agent’s initial call.

Figure 8: Access for bariatric patients is half as long as Access for hernia patients
(n=254, Sept. 2013-Aug. 2015)
It can be seen in Figure 8 that the Access time for a hernia patient is about 6 weeks, whereas the Access time for a bariatric patient is almost half of that, about 3 weeks. More NPA slots allotted to bariatric patients than hernia patients causing a source of delay for hernia patients.

**Linear Regression Analysis**

The next method that the team utilized was a multivariable linear regression. The independent variable used in this analysis was the overall patient wait time. The dependent variables that the team explored were surgery length (in minutes), surgeon, and hernia type. The linear regression holds all other variables constant when performing analysis (for example, the number of surgeries each surgeon performs, the type of surgery that each surgeon performs most often, etc). The Ambulatory Care Manager, the client, requested that the team analyze which of these dependent variables affect the overall patient wait time the most. Because the surgeon and hernia type variables are categorical, the team assigned new variables for whether the patient had Surgeon 1 (0 meaning he/she did not have Surgeon 1, 1 meaning that he/she did).

The generated output from the multivariable linear regression analysis can be seen in Appendix 4. First looking at the F statistic, the variable that measures the significance of the model’s results, it can be seen that this model is significant because the p-value is so low (0.0013). The significant findings that can be drawn from this output are as follows:

- Surgeon 3 tends to have the shortest overall wait time by about 2 months, and that holds constant when controlling for other variables
- Surgeons 1 and 2 are not statistically significantly different from each other in terms of overall wait time
- It is extremely significant that inguinal hernia patients have the shortest wait time and ventral hernia patients have the second shortest

The team then created a conditional probability chart to visualize all of the combinations of surgeon, hernia type, and length of surgery. This type of chart uses color (red meaning longer overall wait time and green meaning shorter overall waiting time) to highlight where the problem areas are. This chart can be seen in Appendix 5. Going from left to right is the length of surgery (in minutes), and the values in the cells of the chart are the overall wait time in days for that combination of surgeon, hernia type, and length of surgery.

The conditionally formatted data shows that the hernia types with the shortest wait times are inguinal and ventral, and the longest wait time is for umbilical hernias, followed by hiatal hernias. It can also be seen that Surgeon 3 has the shortest wait times on average, as more of his/her combinations are darker green.
Conclusions and Recommendations

The conclusions that the team has generated from this project are ordered by the order they appear in the Patient Preoperative Process.

**Step 1: NPA**

One of the biggest causes of delay in Patient Access from initial call to NPA is that there are more NPA slots allotted to bariatric patients than for hernia patients. Hernia patients wait 1.58 months for an NPA while bariatric patients only wait 0.76 months for an NPA. The difference in Access is due to the surgeon’s preference to have more NPA slots for bariatric patients.

Determining the demand for surgeries was found to be impossible. To more accurately evaluate the root causes and determine demand for surgeries, the NP type needs to classify NP hernia and NP bariatric. Once the NP appointment types are classified, the analysis of percent of patients by new patient appointment type can be performed to accurately reflect hernia and bariatric demand volume. The team recommends that NP not be an option for classifying MIS patients. The specific NP type should be required so that this information can be looked at in the future.

**Step 2 and Step 4: Wait time between NPA and Surgery Scheduling**

Using the number of hernia patients in the backlog, given to the team during interviews, and the average surgery time by surgeon, the team calculated the hours of OR time that are needed to complete all of the hernia surgeries in the current backlog, which equals about 41.15 full OR days. Surgeons only have three OR days a week; without adding any more patients this backlog would take 13.72 weeks to complete.

**Step 4 and Step 5: OR Scheduling and Surgery**

The team learned through interviews that the number of operating rooms available for hernia operations is a key source of delay in the process and is therefore increasing the overall wait time for hernia patients. Increasing the number of ORs would need a large amount of resources, so it is not a feasible recommendation at this time. The team initially believed that the utilization of the ORs was uneven (more for bariatric); however, after analysis, the team now knows that the supply and demand for patients and surgeries performed is about even, so the utilization of the ORs is not the bottleneck.

**Step 5: Surgery**

From the linear regression analysis, the team calculated that for each additional 20 minutes in length of case, the overall wait time increases by almost one day. Patients who have more complex hernia cases require more OR time and are having to wait much longer for surgery than the simpler hernia cases. Currently, patients are assigned a surgery date based on the date of their NPA, and the amount of pain they are in is not considered. Moving forward, the team
recommends that the surgery date that a patient is assigned should be based off of a weighting of these three factors: overall wait time, outcome risk of delaying surgery, and severity of pain.

**Total Cycle Time**

Another conclusion the team has determined is that the value added time of the Patient Preoperative Process is almost inconsequential to the total process time, as the value added time is in minutes and the non-value added time is in months. Patients are waiting 4.7 months for a process time of 184.5 minutes. When looked at in minutes the overall process time is 204,552 minutes, the value added time is 0.09% of the overall time they spend in the Patient Preoperative Process.

**Expected Impact**

In conducting this study, the team analyzed the overall patient wait time, the wait time by surgeon, and the wait time by hernia type. With these results, the team has developed a detailed summary of the Patient Preoperative Process that will be used to substantiate changes that will lead to:

- Decreased the patient wait time
- Increased overall patient satisfaction
- Increased understanding of hernia surgery backlog
- Increased understanding of current hernia supply and demand

The team hopes that the information provided in this report will help the MIS division of General Surgery and the Ambulatory Care Manager, the client, improve the wait times for the hernia patients throughout the Patient Preoperative Process.

**Future Work**

To meet the hernia surgery demand, the team suggests that following the conclusion of this project, many alternatives be investigated. These alternatives include:

- Expanding the use of the East Ann Arbor Clinic (surgical short stay)
- Adding additional surgical time on Saturdays
- Extending current OR weekday hours
- Hiring additional staff members
- Creating a partnership with other hospitals to refer patients to
- Utilizing alternative clinic locations for NPA

The team also suggests that the hospital staff looks at the connection between the two systems, MiChart and Optime, to optimize the communication between them. Additionally, the team suggests that the hernia backlog is quantified to investigate the negative impact the wait times have on the hospital financially.
Appendix A: Interview Questions

Call Center Manager Interview Questions:

1. Do you schedule a call when the call originally comes in, or do you need to call back?
2. How many months out do you schedule?
3. Reasons for not giving an appointment to a patient?
4. Do you consider patient or surgeon preferences on dates of appointments?
5. What do you estimate the current delay for MIS patients is?
6. What is the process that the agents follow?
7. How many agents are there?
8. Do you ever not fill the clinic days with appointments?
9. Do you fill cancelled appointment slots?
10. Are there any rules/regulations that interfere and need to be considered?

Call Center Agent Questions:

1. How many patients do you have in your queue at the beginning of each day?
2. How many patients do you schedule per day?
3. How long does the average phone call take you?
4. How long does it take to finally reach the patient and how many attempts do you make to reach them?
5. What needs to occur before the patient can be scheduled for a NPA? (Insurance checks, diagnosis from referring physician)
6. How do you determine which surgeon can see which patient?

OR Scheduler Questions:

1. What do you do with a case order once you receive it from the surgeon?
2. What information does a case order contain?
3. How does the case order turn into an appointment for surgery?
4. What does the backlog for hernia patients waiting for surgery?
5. When do you begin to interact with the patient?
6. How far out are you scheduling surgeries?
7. What do you think are the source of some of the delays in the process?
8. Is there ever a difference between the scheduled appointment and the date of the actual surgery?
## Analysis of Wait Times Through the Patient Preoperative Process - SIPOC

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Input</th>
<th>Process</th>
<th>Output</th>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Michart Referral</td>
<td>Patient hernia diagnosis and information in system queue</td>
<td>Call the patient to schedule New Patient Appointment</td>
<td>Date of New Patient Appointment</td>
<td>Patient MiChart Surgeon</td>
</tr>
<tr>
<td></td>
<td>Call Center Agent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient MiChart</td>
<td>Patient information and hernia Date of Appointment Surgeon</td>
<td>New Patient Appointment Occurs</td>
<td>Decision on whether or not surgery is needed</td>
<td>Surgeon Patient MiChart</td>
</tr>
<tr>
<td>Surgeon</td>
<td>Surgery decision MiChart Surgeon</td>
<td>Case Order Created</td>
<td>Case Order</td>
<td>OR Scheduler Optime</td>
</tr>
<tr>
<td>Optime</td>
<td>Case Order OR Scheduler</td>
<td>Call the patient to schedule Surgery time</td>
<td>Date of Surgery</td>
<td>Optime Patient Surgeon</td>
</tr>
<tr>
<td>Patient Optime</td>
<td>Patient Hernia Injury Date of Surgery Surgeon</td>
<td>Perform surgery on patient</td>
<td>Hernia is fixed</td>
<td>Patient</td>
</tr>
</tbody>
</table>
Appendix 3: Value Stream Map

**INPUT**
Patient in Pain
Referring Physician's Diagnosis

**Source of Delay:**
Not enough NPA times allotted, more for bariatric

**Process Step 1**
*Start:* Call Center Agent calls the patient.
*End:* NPA is scheduled.

People: 2
Process Time*: A: 2.5 min S: 1 min L: 5 min

2.5 minutes*

**Required Material before Step 2**
Confirmed Hernia Medical Records Insurance Verification

**Patient Caused Delays:**
A: 7 days S: 1 Day L: 21 Days

**Process Step 2**
*Start:* NPA begins.
*End:* NPA is completed.

People: 2
Process Time:
A: 47 min S: 1 min L: 5 min

47 ± 27 minutes

**Required Material before Step 3**
Appointment Occurs Surgery Required

**Patient Caused Delays:**
A: 7 days S: 1 Day L: 21 Days

**Value Added Time:** 184.5 minutes
**Non-Value Added Time:** 4.7 months
**Total Cycle Time:** 4.67 ± 3.4 months
**Total Sub Cycle Time:** 3.12 months

**Process Step 3**
*Start:* Surgeon begins case order
*End:* Case order is entered

People: 1
Process Time*: A: 3 min S: 1 min L: 7 min

0.23 ± 0.83 months

**Source of Delay:**
Not enough ORs. Bariatric surgeries get schedule first

**Process Step 4**
*Start:* OR Scheduler calls the patient.
*End:* Surgery time is scheduled.

People: 2
Process Time*:
A: 20 min S: 15 min L: 30 min

20 minutes*

**Required Material before Step 4**
Date of NPA Location of Surgery Length of Surgery Testing Required OR Calendar

**Patient Caused Delays:**
A: 7 days S: 1 Day L: 21 Days

**Process Step 5**
*Start:* Patient comes in for surgery.
*End:* Surgery is completed.

People: 2
Process Time:
A: 73 min S: 55 min

112 ± 61 minutes

**Required Material before Step 5**
H&P Required Testing OR Date Post-Op Checkup

**Patient Caused Delays:**
A: 3 Days

124 Patients in queue = 41.15 OR Days

1.89 ± 3.10 months

1.23 ± 0.69 months

**Key**
*Times based on employee estimates S: Shortest L: Longest Dates: September 2013 - August 2015 Sample Size: 254 cases
## Linear Regression

### Regression Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>$R$</td>
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</tr>
<tr>
<td>R-square</td>
<td>0.0909</td>
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<td>Adjusted R-square</td>
<td>0.06503</td>
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<td>$S$</td>
<td>100.61206</td>
</tr>
<tr>
<td>$N$</td>
<td>254</td>
</tr>
</tbody>
</table>

Overall Wait Time = $118.57644 + 0.05085 \times \text{Length of Case} + 22.61182 \times \text{Hiatal} - 53.90161 \times \text{Inguinal} + 30.53236 \times \text{Umbilical} - 20.68282 \times \text{Ventral} + 51.3597 \times \text{Surgeon1} + 60.8507 \times \text{Surgeon2}

### ANOVA

<table>
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<tr>
<th></th>
<th>d.f.</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
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<td>Total</td>
<td>253</td>
<td>2,739,200.42425</td>
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</table>

### Coefficient Table

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Standard Error</th>
<th>LCL</th>
<th>UCL</th>
<th>t Stat</th>
<th>p-level</th>
<th>H0 (5%)</th>
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<tr>
<td>Intercept</td>
<td>118.57644</td>
<td>16.6838</td>
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<td>Length of Case</td>
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<td>0.10693</td>
<td>-0.15976</td>
<td>0.26146</td>
<td>0.47555</td>
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<td>Hiatal</td>
<td>22.61182</td>
<td>30.9405</td>
<td>-38.33027</td>
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<td>0.73082</td>
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<td>Inguinal</td>
<td>-53.90161</td>
<td>16.53639</td>
<td>-86.47259</td>
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<td>Umbilical</td>
<td>30.53236</td>
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<td>Surgeon 1</td>
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<td>Surgeon 2</td>
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<td>24.38197</td>
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<td>3.28651</td>
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T (5%) = 1.96965

LCL - Lower value of a reliable interval (LCL)
UCL - Upper value of a reliable interval (UCL)
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<td>Surgeon 1</td>
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*Values in cells represent overall wait time in days*
Appendix 6: References


