University of Michigan Health System
Program and Operations Analysis

Recommendations on How to Develop
Suture Right-Size Inventory Model
Final Report

To: Patricia Silverman, Administrative Manager Inter Healthcare
Sam Clark, Industrial Engineer Lead and Lean Coach
Mary Duck, Industrial Engineer Expert and Lean Coach
Mark Van Oyen, University of Michigan IOE Professor

From: IOE 481 Project Team, Program and Operations Analysis
Austin Chrzanowski
Feng Zheng
Wei Zheng

Date: December 14, 2009
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Executive Summary

The University of Michigan Hospital Operating Room Facility has been experiencing inefficiencies with regard to their surgical sutures flow. The hospital has had problems regarding excess inventory, expired sutures, inaccurate usage documentation and an overall lack of standardization.

Project Goals
The goal of this project is to fix the inefficiency issues listed above through a right-sized inventory model that will ensure that the right product is available at the right time, in the right quantity. This right-sized inventory model should also consider the quality of patient care and patient safety.

Observations and Data Collection
The project goals were achieved by collecting usage and purchase data, interviewing many operating room staff members about the process flow of sutures, and completing a room by room physical inventory count. The usage and purchasing data enabled the team to show where the largest inefficiencies were occurring. The interviews gave a general sense of suture flow. A large scale physical inventory count was also performed to have definite knowledge of how much value and quantity was on-hand, in addition to helping locate the areas storing excessive suture inventory.

Findings
After collecting all of the necessary data, extensive analysis was performed to show where the overall inefficiencies were occurring. Usage data was stratified by surgery service type, by operating room, and by core. The overall suture distribution by location was roughly split in thirds between the collective operating rooms, the mobile suture carts, and the main core suture storage wall. The general results also show that many rooms are storing entire boxes of suture which have had little to no usage in the past twelve months.

Conclusions/Recommendations
From the team’s overall findings, a robust suture inventory model based on usage data for the entire operating room facility was created. This model includes par levels for suture walls, operating rooms, and suture carts. The estimated average value of the model inventory is $168,803, which is nearly half of the on hand inventory ($331,501). The following list includes additional recommendations:

- Restocking operating rooms and suture carts
  - Restock on Mondays before weekly reordering (Tuesdays)
  - Suture usage documentations
  - Consistently document and update suture usage
• Suture layout
  o Designate storage location for slow moving sutures
  o Label slow moving sutures
  o Install main dividers on metal storage racks
  o Change suture label color to match suture box color
• Expired Sutures
  o Place older sutures in the bottom combined boxes
  o Avoid storing packages individually in mobile carts
  o Label opened boxes that have a close expiration date
• Suture Flow
  o Use provided OR room and suture cart par levels
  o Still use current par levels for suture walls if implementation not practical
• Clinical Suture Reduction Project
  o Consolidating extremely slow moving suture types
  o 30 suture types, one box will last for more than 5 years
Introduction

Operating room (OR) sutures, which consist of a sterilized needle with an attached thread, are used to hold body tissues together during surgery. The costs of OR sutures range from $0.65 to $50 per package with an average cost of $5.64 per package. Sutures are packaged by the manufacturers into various sizes of boxes with various colors and each type of suture has a unique quantity in the box. At the University of Michigan Hospital, more than 350 types of OR sutures are stored in various locations within the OR facilities. However, due to the lack of standardization of suture inventory and inaccurate documentation of the suture usage, excessive numbers of sutures are being ordered and stored in the OR facilities. As a result, the inefficient suture flow and the expired sutures can potentially deteriorate the patient care quality. The Operating Room management wants to reduce the excessive suture inventory and optimize the suture flow. Therefore, the Administrative Manager asked the Industrial and Operations Engineering 481 team to develop a right-size inventory model that will maintain appropriate levels of suture stock in the OR while improving patient care. To develop the model, the team has observed the current suture inventory layout in the OR facilities, interviewed relevant OR staff, shadowed the suture flow and reorder process, analyzed the usage and purchase data and compared them with the physical inventory, and identified and studied the root cause of excessive inventory. Based on the findings and analysis, the team has developed recommendations for a right-size inventory model that will reduce excessive inventory, improve the inventory layout, and optimize the suture flow and reorder process. This final report presents the background and key issues, the approach and methodology, the finding and analysis, and the conclusions and recommendations for the right-size inventory model.

Background

The OR facilities at the University of Michigan Hospital consist of three cores surrounded by 29 operating rooms that are used by 21 different OR services (surgery types). Out of the 21 OR services, only 14 have designated home core areas where most of their surgeries occur. The remaining 7 service types do not have home cores and are scheduled in different operating rooms throughout the week.

OR Suture Storage Layout

OR sutures are stocked in the main storage suture walls in Core A & C, the designated storage cabinets in each operating room, and on the mobile suture carts. The suture walls in Core A and Core C are the main storage locations for sutures outside of the operating rooms. The Core A suture wall stores every type of suture that is used for OR surgeries; whereas, the Core C suture wall has limited space and only carries the sutures that are needed for the surgeries in Core C. Each operating room has its own designated suture cabinet that is used to
store the most commonly used sutures in the room based on the surgery types. Sutures are also stored on mobile suture carts, which are typically used if the surgery is performed in an operating room that is outside of its home core.

**Suture Flow in the Cores**

Figure 1 shows the current suture flow in the OR facilities. This process flow is based on observations and multiple interviews with OR nurses and other staff.

![Suture Flow Diagram](image)

Figure 1: Current State of Suture Flow

The sutures are delivered from the supplier, Owen’s and Minor, and placed outside of the purchasing office. These sutures are then transported to Core A and Core C and stocked on the suture walls. Sutures on the suture walls are then moved into the operating rooms or suture carts without a standardized process or appropriate documentation. The Patient Technicians (PT), who prepare the OR supplies before the surgeries, pick the requested sutures for OR cases from the suture walls. However, some PTs pick these sutures from the Operating room cabinets. The circulators, who assist the surgeons during the OR cases, pick additionally requested sutures from the suture walls during the OR cases. The service leads or other OR nurses, who are responsible for restocking the supplies in the operating rooms and the suture carts, retrieve the sutures from the suture walls and restock them to the appropriate locations.
Suture Flow in the Operating Rooms
For most OR cases, the pick sheets are used to pre-select sutures, the day before the surgery, from the suture walls by PTs (Patient Technicians). However, during each operation, three situations can affect the suture inventory. First, not all of the sutures requested by the surgeon might be used during the operation. Second, any suture package that is opened must either be used in the surgery or discarded due to the loss of sterility. Third, throughout the operation, additional sutures might be requested. These extra requests might arise because incision sizes can differ, the number of blood vessels that need to be repaired can vary, and some sutures may fail and backups might be needed. If additional requested sutures are not available in the room, the circulator is responsible to retrieve them from the suture walls. In order to minimize the chance of potential infection on patients, the number of trips into and out of the operating room during the surgery needs to be reduced.

Additional sutures requested during an operation are recorded on the suture pick sheet by the circulator. At the end of the operation, this updated pick sheet is sent to the OR billing department to make any necessary changes into the suture usage database. However, the additional requested sutures might not be updated in the suture usage database because the billing department only updates sutures that will be charged to the patient, which exclude sutures costing less than $10.

Restocking Process for the Operating Rooms
Due to the immediate need for additional sutures requested by the surgeon and the need to minimize the frequency of opening doors in the OR during the operation (infection prevention), an appropriate level of inventory for the most commonly used sutures in the room must be maintained based on the suture usage. However, there are no standard procedures for when to replenish the sutures in the OR storage and how many boxes of sutures to be pulled from the suture walls. In addition, the rooms are lacking a standard reference for determining which suture types should be stocked in each room. Nurses usually restock their room based on their own experiences without a standardized plan. Therefore, sutures that are frequently used might not always be available when they are requested during an operation. On the other hand, some sutures that are rarely used in that room might be stocked in the cabinet and might become expired; this can cause the gap between the suture usage and purchase. Using the expired sutures on patients during OR surgeries could cause serious life threatening consequences.

Reordering Process
To place suture orders every Tuesday, the purchasing nurses compare the inventory in Core A and Core C suture walls with the inventory PAR levels that they have set based on their experience. Then they place the suture orders through the supplier at the purchasing office. Most sutures can be delivered the following day; however, a few suture types might have a longer lead time. Also, the supplier has the capacity to deliver the sutures every day. Even though the purchasing nurses place the bulk order for sutures on Tuesdays, they also order sutures throughout the week if any types of sutures are low when they check the inventory on a daily basis.
The OR nurses have different restocking practices for sutures in their rooms and carts since there are no standardized guidelines to follow. As a result of these non-standardized practices and lack of suture inventory documentation, it is difficult for the purchasing nurses to estimate the overall on-hand inventory. Therefore, the purchasing nurses tend to order more than enough sutures to prevent suture shortage.

**Key Issues**
To reduce the excessive suture inventory and improve the suture flow in the OR facilities, the following key issues were addressed in this project:

- Lack of standardization for suture storage
- Lack of standardized practice to pick the sutures for the OR cases
- Lack of standardized process to restock the operating rooms and suture carts
- Lack of documentation on suture inventory
- Inaccurate suture usage documentation
- Expired sutures

**Goals and Objectives**

The primary goal of this project was to develop a right-size inventory model for OR sutures, which will increase efficiency of suture flow and improve patient care. The following are the specific objectives for achieving the overall project:

- Reduce excessive suture inventory
- Improve the organization of sutures in the OR and Cores
- Improve and standardize the suture flow by using lean methodology
- Standardize the restocking process and reordering process
- Standardize suture inventory and usage documentation
- Determine the current on-hand inventory of all OR sutures
- Eliminate waste caused by expired sutures

**Project Scope**

The scope of this project included the following: examining the current layout of suture storage, reorder processes for sutures, and other suture related activities within the OR facility; analyzing suture usage and purchase data and comparing the gap between those data; developing a right-size inventory model that will improve suture inventory flow and reduce excessive sutures.

This project did not include studying suture inventory at other University of Michigan hospital sites. Recommending how surgeons should pre-select the sutures for an operation was also out of project scope.
Project Deliverables

To develop the right-sized suture inventory model within the project scope, the client and the team decided on the following project deliverables:

- Right-size suture inventory model including recommending formulas for appropriate PAR levels that are used to maintain the suture inventory
- Recommendations for future storage solutions and suture related practices
- A3 document as a general guidance for addressing the key issues of the project
- Current and future process flow charts that describe the suture storage and suture flow in the OR facilities
- Findings and observations on the current on-hand inventory
- Findings of the 12-month purchase and usage data from Operating Room Management Information System (ORMIS)
- Root cause analysis of the gap between suture usage and purchase
- Percentage of OR cases that are performed in their designated home cores
- Relevant information to assist the OR nurse, who is currently taking another suture project that is focused on reducing excessive suture types from the clinical perspective, to evaluate sutures types needed in the OR facilities

Approach and Methodology

To develop a right-size suture inventory model, the team used the Six Sigma DMAIC methodology which includes Define, Measure, Analyze, Improve, and Control phases. In the define phase, the team interviewed the OR key personnel and observed OR storage layout and suture-related activities. In the measure phase, the team reorganized and consolidated the suture purchase and usage data. The team also assisted the OR staff to count the physical inventory of sutures in the OR facilities. In the analyze phase, the team analyzed the suture usage & purchase data and physical inventory results. Then in the improve phase, based on the findings from the observations and data analysis, the team developed a robust model that meets the “Right-sized” goals including right products, right time, right quantity, and right place. Finally in the control phase, the team made recommendations for improving suture flow and optimizing the suture inventory in the OR facilities.

Observations and Interviews

At the beginning of the project, the team performed the following tasks in order to observe the current suture storage layout and the suture-related activities in the OR facilities:

- Interviewed the relevant OR personnel, which included the inventory manager, the purchasing manager, and three OR nurses, to look at the project from their
perspectives and to identify the problems that they had observed

- Observed the general layout in the OR facilities and the various suture storage locations including the suture walls, the operating room suture cabinets, and the suture carts
- Shadowed suture reordering process with the purchasing nurse for three hours and observed the processes to move the delivered sutures from the purchasing office to the suture walls for two hours
- Viewed suture purchasing process with the purchasing manager
- Interviewed two OR nurses to determine the suture picking process and restocking process
- Observed three OR Surgical Cases individually to understand the suture flow and related suture practices during the operation
- Interviewed the circulator to determine the general practices to pick the additionally requested sutures during the operation and to updates the suture pick sheets

### Data Collection and Inventory Count

After observing the current processes and layout in the OR facilities, the team received the suture usage and purchase data for fiscal year 2009 (July 2008-June 2009). This data was from the ORMIS database and included the suture name, the manufacture catalog number, the resource number, the quantity in box, the unit (box) cost, the OR case number, the surgery type, the operating room number related to the case, the monthly usage, and the monthly purchase for each suture type.

In addition to the suture usage and purchase data, the team and the OR staff counted the physical inventory of sutures on November 7, 2009 from 7 am to 3 pm to determine the on-hand inventory in the OR facilities. The participants counted and documented the quantities of the suture types for all the suture storage locations including the sutures walls, the Operating rooms, and the mobile suture carts. The expired sutures for each location were counted, documented, and removed. The inventory data was then entered into a single Excel file. Based on the suture physical inventory and the related unit price, the total value of the suture inventory for each location and the combined total suture inventory value were determined. The expired sutures values for each storage location were also calculated.

### Data Analysis and Findings

There were more than 350 suture types in each of the purchase and usage raw data from ORMIS. However, not all the sutures types appeared in both the purchase and usage data because of the incomplete documentations. The relevant suture data were first reorganized and consolidated according to the related suture ID numbers. Then these data were stratified by 29 Operating rooms, 21 OR services, and 3 cores in order to thoroughly analyze the data at different levels.
**Suture Purchase/Usage and Physical Inventory Summary**

The team calculated the total purchase and usage for a 12-month period, and compared the two sets of data. To determine the root causes for excessive suture inventory, the team first evaluated the gap between the suture purchase and usage. Based on the suture usage and purchase data from July 2008 to June 2009, the total cost of the 12-month suture purchase was $855,498 whereas the total cost of the 12-month usage was $655,747 and the difference between the purchase and the usage was $215,131 (Figure 2). However, the total on-hand inventory was estimated to be $331,501 according to the results of the OR physical inventory count. The total on-hand suture inventory was approximately half of the 12-month suture usage. In other words, there were about six months of suture inventory on hand assuming the usage data were accurate and on-hand inventory results closely represented the average inventory.

![Figure 2: 12-month Suture Purchase and Usage vs. On-hand Inventory](image)

**Suture Purchase/Usage Gap**

It was difficult to determine the exact cause of the large gap between suture purchase and usage due to the following reasons:

- Lack of suture inventory documentations at the beginning (July 2008) and the end (June 2009) of the 12-month period
- Current inventory may not be a good representation of previous inventory levels

Although the exact causes for the gap could not be determined, nine potential causes were identified based on the observations, the interviews, and the purchase/usage data analysis; these causes are grouped into four categories - inventory, documentations, processes, and others - in the following cause-effect diagram.
Figure 3: Potential Causes for Suture Purchase/Usage Gap

By using the cause-effect diagram, the team further analyzed the suture purchase/usage gap for all suture types. Because there are more than 350 sutures types in the purchase and usage data, these sutures types were sorted into three different groups based on the purchase quantities in the 12-month period. In the 12-month period, the quantities purchased for individual suture type range from 0 to 13,824 packages. The following three groups of suture represent the high purchase, the medium purchase, and the low purchase group respectively.

- Group 1 – Sutures with 12-month purchase between 3000 and 14000 packages
- Group 2 – Sutures with 12-month purchase between 1000 and 3000 packages
- Group 3 – Sutures with 12-month purchase less than 1000 packages

Figure 4 shows the differences between number of sutures purchased and the number of sutures used for Group 1.
Figure 4: Purchase/Usage difference for Group 1 Sutures with 12-month Purchase between 3,000 and 14,000 Packages

Each bar represents a suture type and the corresponding suture ID number is labeled on the X-axis. The total height of the bar represents the total number purchased for the suture during the 12-month period; the blue section of the bar represents the total number used during the 12-month period; the red section of the bar represents the gap between the purchase and usage. Some sutures have higher gaps than other sutures and the gaps vary significantly for difference sutures. For suture ID 125272, the total number of sutures purchased was 13,824 packages and the total number of suture used was 10,361 packages. The purchase/usage gap was 3,463 packages (288 boxes). The gap suggests that there should be at least 288 boxes of this suture in stock. However, there were only 31 boxes from the physical inventory count. The high gap is most likely due to the inaccurate usage documentation.
Figure 5 shows the purchase/usage differences for sutures in Group 2 with medium purchase.

For suture ID 125989, the purchase/usage gap is negative since this type of sutures was used more than their total purchase during the 12-month period. This negative gap is either because the purchase documentation for this suture type was inaccurate or the original inventory for this suture type at the beginning of the 12-month period was high so that the purchasing nurses ordered fewer sutures than expected. For suture ID 641239, the documented suture usage was only 15% of the total purchase in the same period. This high gap is again most likely due to the inaccurate usage documentation.
Figure 6 shows purchase/usage differences for sutures in Group 3 with low purchase. The gaps between suture purchase and usage vary significantly for different types of sutures in this group.

Figure 6: Purchase/Usage difference for Group 3 Sutures with 12-month Purchase Less than 1,000 Packages
Figure 7 shows a scatter plot of the purchase/usage difference and the 12-month purchase with each dot representing one suture type. The further the dot deviates above the regression line, the higher the gap between suture purchase and usage comparing with its 12-month purchase.

Source: ORMIS (July 2008 – June 2009)

Figure 7: Scatter Plot of Purchase/Usage Difference VS. 12-month Purchase
OR Cases within the Home Cores
The operating rooms are used by 21 different service types. Overall, 14 out of the 21 service types have designated home cores. To find out how often an OR case occurred outside of its home core, the 12-month usage data was stratified by services, and the total number of cases occurring in and out of the home core were determined for each service. As seen in Table 1, the average percentage of OR cases being performed in their home cores was approximately 84%.

Table 1: Percentage of OR Cases being performed in Home Core for Each OR Service

<table>
<thead>
<tr>
<th>OR Service</th>
<th>Home Core</th>
<th>Total Case Counts in 12 months</th>
<th>Percentage Performed in Home Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPTH</td>
<td>None</td>
<td>16</td>
<td>N/A</td>
</tr>
<tr>
<td>ANES</td>
<td>None</td>
<td>6</td>
<td>N/A</td>
</tr>
<tr>
<td>THOR</td>
<td>None</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td>CARD</td>
<td>None</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>OTHE</td>
<td>None</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>PESU</td>
<td>None</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>SVA</td>
<td>None</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>OTO</td>
<td>A</td>
<td>650</td>
<td>100%</td>
</tr>
<tr>
<td>DENT</td>
<td>A</td>
<td>2</td>
<td>100%</td>
</tr>
<tr>
<td>NSA</td>
<td>A</td>
<td>801</td>
<td>98%</td>
</tr>
<tr>
<td>UROL</td>
<td>C</td>
<td>695</td>
<td>98%</td>
</tr>
<tr>
<td>GYN</td>
<td>C</td>
<td>683</td>
<td>98%</td>
</tr>
<tr>
<td>PLA</td>
<td>B</td>
<td>534</td>
<td>90%</td>
</tr>
<tr>
<td>MIS</td>
<td>C</td>
<td>276</td>
<td>89%</td>
</tr>
<tr>
<td>STX</td>
<td>B</td>
<td>260</td>
<td>87%</td>
</tr>
<tr>
<td>ORTH</td>
<td>B</td>
<td>1620</td>
<td>82%</td>
</tr>
<tr>
<td>TBE</td>
<td>C</td>
<td>335</td>
<td>70%</td>
</tr>
<tr>
<td>GSE</td>
<td>B</td>
<td>500</td>
<td>67%</td>
</tr>
<tr>
<td>SON</td>
<td>B</td>
<td>404</td>
<td>60%</td>
</tr>
<tr>
<td>SGI</td>
<td>B</td>
<td>264</td>
<td>60%</td>
</tr>
<tr>
<td>ORAL</td>
<td>A</td>
<td>286</td>
<td>36%</td>
</tr>
</tbody>
</table>

Average Percentage 84%

Source: ORMIS (July 2008 – June 2009)

OTO and DENT are the only OR services that had 100% of their cases being performed in the respective home cores. NSA, UROL, and GYN services have 98% of their cases being performed in the respective home cores. ORTH service has the highest number of cases and
about 82% of the 1,620 cases were performed in its home core.

**On-Hand Suture Inventory**

The results from the on-hand suture inventory count, which was done in the OR facilities on November 7, 2009, were analyzed to determine the causes for excessive suture inventory. The results might not accurately represent the average on-hand inventory for the following reasons:

- The inventory count was performed on a Saturday. But since suture usage varies from time to time, the inventory on a Saturday was not a good representation of the average inventory.
- The OR nurses might have stocked their Operating rooms differently because they were informed about the upcoming inventory count.

Figure 8 summaries the suture inventory distributions by the storage types. The suture walls in Core A and Core C stocked 37% of the total suture inventory by value; the Operating rooms stocked 33% of the total suture inventory; the suture carts stocked 29% of the total suture inventory.

![Figure 8: Suture Inventory Summary by storage types](image)

Figure 8: Suture Inventory Summary by storage types

Table 2 lists the five operating rooms with the most suture inventory by value. Operating room 9 has $9,753 worth of sutures, which is more than double the average suture inventory value ($4,100) of all the operating rooms.
Table 2: Operating rooms with Most Suture Inventory

<table>
<thead>
<tr>
<th>Operating room</th>
<th>Inventory Value ($)</th>
<th>Percentage of Total Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR 9</td>
<td>$9,753</td>
<td>2.94%</td>
</tr>
<tr>
<td>OR 17</td>
<td>$6,919</td>
<td>2.09%</td>
</tr>
<tr>
<td>OR 28</td>
<td>$6,264</td>
<td>1.89%</td>
</tr>
<tr>
<td>OR 12</td>
<td>$6,152</td>
<td>1.86%</td>
</tr>
<tr>
<td>OR 1</td>
<td>$5,388</td>
<td>1.63%</td>
</tr>
</tbody>
</table>

Source: Suture inventory count (Nov 7, 2009)

Table 3 lists the five operating rooms with the least suture inventory. The total value of suture inventory in these operating rooms was $9,078, which accounted for 2.74% of the total inventory. A comparison of Table 2 and 3 showed that the suture inventory levels in the operating rooms vary significantly.

Table 3: Operating rooms with Least Suture Inventory

<table>
<thead>
<tr>
<th>Operating room</th>
<th>Inventory Value ($)</th>
<th>Percentage of Total Inventory</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR 26</td>
<td>$0</td>
<td>0%</td>
</tr>
<tr>
<td>OR 13</td>
<td>$1,084</td>
<td>0.33%</td>
</tr>
<tr>
<td>OR 22</td>
<td>$2,476</td>
<td>0.75%</td>
</tr>
<tr>
<td>OR 20</td>
<td>$2,753</td>
<td>0.83%</td>
</tr>
<tr>
<td>OR 14</td>
<td>$2,765</td>
<td>0.83%</td>
</tr>
</tbody>
</table>

Source: Suture inventory count (Nov 7, 2009)

Expired Sutures

The total value of on-hand suture inventory was $331,501 and the total value of expired sutures was $7,989, which accounted for 2.35% of the total inventory value. The total quantity of the on-hand suture inventory was 77,802 packages; approximately 1,825 packages (2.29% of the total inventory) were expired and removed. This expired suture amount is unacceptable considering that sutures are ordered at least once a week and most sutures do not expire in 5 years. In addition, the expired sutures amount did not account for the expired sutures that were found and discarded routinely prior to the inventory count.

Although Operating room 13 had the second to lowest suture inventory (Table 3), it had the most expired sutures among all the suture storage locations. Operating room 13 had 70% of all the expired sutures in the OR facilities. Table 4 lists the five OR locations with the most expired sutures by value. These five storage locations account for almost 90% of the expired sutures.
Table 4: OR Locations with Most Expired Sutures

<table>
<thead>
<tr>
<th>OR Location</th>
<th>Expired Suture ($)</th>
<th>Percentage of all Expired</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR 13</td>
<td>$5,566</td>
<td>70%</td>
</tr>
<tr>
<td>Core A Suture Wall</td>
<td>$607</td>
<td>7.6%</td>
</tr>
<tr>
<td>ENT Workroom</td>
<td>$381</td>
<td>4.8%</td>
</tr>
<tr>
<td>OR Plastic Suture Cart C430</td>
<td>$274</td>
<td>3.4%</td>
</tr>
<tr>
<td>OR 11</td>
<td>$237</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

Source: Suture inventory count (Nov 7, 2009)

Table 5 shows the five suture types that had the highest expired value. Two of the suture types had high expired value despite having regular use; which might be explained by the excessive inventory for these suture types.

Table 5: Expired Suture Items with Highest Total Value VS Their Usage

<table>
<thead>
<tr>
<th>Suture Name</th>
<th>Expired Value ($)</th>
<th>Expired Quantity</th>
<th>12-month Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>GORE TEX CV-0 TH-26 36IN</td>
<td>$322</td>
<td>17</td>
<td>47</td>
</tr>
<tr>
<td>NOVAFIL 1 GS-26 60IN BLUE</td>
<td>$284</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>PDS 5-0 C-1 C-1 30IN VIOLET</td>
<td>$275</td>
<td>30</td>
<td>222</td>
</tr>
<tr>
<td>ETHILON 10-0 BV75-4 5IN BLACK</td>
<td>$264</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>NYLON SHARPOINT 9-0 DRM 5 NEEDLE</td>
<td>$171</td>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Suture inventory count (Nov 7, 2009) & ORMIS (July 2009 – June 2009)

**Right-Sized Suture Model**

To reduce the excessive suture inventory, the team built a right-sized inventory model that will meet the project goals of Right Product, Right Quantity, Right Place, and Right Time. The model consisted of individual par levels for three different suture inventory locations – (1) suture walls (Cores A & C), (2) operating rooms, and (3) suture carts. The team created a robust model by recommending par level for the suture walls based on overall usage data, and recommending par levels for operating rooms and suture carts based on usage data for each
specific service type. This robust inventory model can be easily modified and reflect potential changes in suture usage, order lead-time, suture usage variability, and assigned service rooms. In addition, this robust model will make rebalancing inventory easier between cores, operating rooms and suture carts.

**Model Assumptions**
The followings are the general model assumptions:

- Detailed 6-month usage data is accurate
- Minimum one week of supply at any given time (ie. safety stock lasts one week)
- Consistent suture order lead-time
- Full boxes must be used to restock the rooms and suture carts, no partial boxes

**Model Formulas for Suture Wall**
The safety stock, reorder level and max par level were based on the following formulas. Figure 9 shows the model formulas in graphical form.

- Safety Stock = Average weekly usage + 3 * Standard Deviation
  - 99.73% of time having enough sutures to supply one week of usage
- Reorder Level = Safety Stock + consumption during lead time
  - Convert unit quantity to boxes (roundup)
- Max Par = Reorder Level + average weekly usage
  - Convert unit quantity to boxes (roundup)

![Figure 9: Graphical Representation of Inventory Model](image-url)
**Model Adjustments for Slow Moving Suture Types**
The team defined slow moving sutures as suture types with a max par of one box. According to this definition, out of 352 suture types, there are 249 slow moving suture types. This group was further divided into— low usage sutures and extreme low usages sutures.

- **Low usage group (195 types)**
  - Suture types with a single box lasting from one month to two years
  - Adjust par level from one box to two boxes
    - Time consuming to count quantity in each box for 195 suture types when reordering
    - Creates buffers for reordering
    - Matches current practices of purchasing nurse
    - High probability of suture expiration if more than two boxes is stocked

- **Extreme low usage group (54 types)**
  - Suture types with a single box lasting more than two years
    - Maintain one box for max par
    - High probability of suture expiration if more than one box is stocked

**Operating Rooms and Suture Cart Par Levels**
The recommended par levels determined for each of 13 different services were based on the following considerations. Only these 13 service types had significant suture usage during the past year.

- **Maximum one box for any suture type (even if need more than one boxes per week)**
  - Nurse recommendation, because restock from the main inventory (suture walls) can be consider as instantaneous

- **Two month usage cut off**
  - Stock if one box will last less than two month
  - Nurse recommendation, covers 70% to 80% of usages for most rooms

Based on the par levels for each service, the team recommended par levels for each operating room and suture cart based on the corresponding service each room or suture cart was assigned for. For operating rooms with multiple services assigned throughout the week, the team recommends using suture carts instead of stocking suture in the room. The specific par levels are included as excel files in the submitted project folder. The summary of the service types, the corresponding operating rooms number, and the number of recommended sutures carts are shown in Table 6.
### Table 6: Recommended Storage Area by Service

<table>
<thead>
<tr>
<th>Service</th>
<th>Recommended Storage Location</th>
<th>Recommended Suture Carts</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTO</td>
<td>OR 1, OR 2, OR 3</td>
<td>None</td>
</tr>
<tr>
<td>PLA</td>
<td>OR 12</td>
<td>2 Suture Carts</td>
</tr>
<tr>
<td>URO</td>
<td>OR 19, OR 22, OR 26</td>
<td>2 Suture Carts</td>
</tr>
<tr>
<td>ORTH</td>
<td>OR 5, OR 10, OR 14, OR 15, OR 16</td>
<td>None</td>
</tr>
<tr>
<td>NSA</td>
<td>OR 6, OR 7, OR 8</td>
<td>1 Suture Carts</td>
</tr>
<tr>
<td>GYN</td>
<td>OR 18, OR 21</td>
<td>1 Suture Carts</td>
</tr>
<tr>
<td>GSE</td>
<td>None</td>
<td>3 Suture Carts</td>
</tr>
<tr>
<td>ORAL</td>
<td>None</td>
<td>2 Suture Carts</td>
</tr>
<tr>
<td>SON</td>
<td>None</td>
<td>2 Suture Carts</td>
</tr>
<tr>
<td>STX</td>
<td>None</td>
<td>2 Suture Carts</td>
</tr>
<tr>
<td>SGI</td>
<td>None</td>
<td>1 Suture Carts</td>
</tr>
<tr>
<td>TBE</td>
<td>OR 27</td>
<td>None</td>
</tr>
<tr>
<td>MIS</td>
<td>None</td>
<td>1 Suture Carts</td>
</tr>
</tbody>
</table>

**Model Summary**

The distribution of the suture inventory by location is summarized in Figure 10.

![Model Suture Inventory](image)

![Current Suture Inventory](image)

**Figure 10: Model vs. Current Suture Inventory**

Figure 10 shows a shift in the proportionate distribution of suture inventory.
Figure 11 gives the breakdown of suture value for each storage location. For each storage location, the model inventory value decreases resulting in an overall reduction in on-hand inventory by half.

Figure 11: Comparisons of Model Inventory VS On-Hand Inventory
Table 7 shows that the total suture inventory in operating rooms was reduced from $95,581 to $52,652. The team recommended that the operating rooms with multiple services should use suture carts instead of stocking suture in the operating room.

Table 7: Recommended Par Level vs. Original

<table>
<thead>
<tr>
<th>SUTURE LOCATION</th>
<th>NUMBER OF SUTURE TYPES FOR MODEL</th>
<th>TOTAL VALUE FOR MODEL ($)</th>
<th>NUMBER OF SUTURE TYPES FOR CURRENT LEVEL</th>
<th>TOTAL VALUE FOR CURRENT LEVEL ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OR 1</td>
<td>30</td>
<td>$ 2,519</td>
<td>82</td>
<td>$ 5,388</td>
</tr>
<tr>
<td>OR 2</td>
<td>30</td>
<td>$ 2,519</td>
<td>79</td>
<td>$ 4,576</td>
</tr>
<tr>
<td>OR 3</td>
<td>30</td>
<td>$ 2,519</td>
<td>74</td>
<td>$ 3,937</td>
</tr>
<tr>
<td>OR 4</td>
<td>Use carts</td>
<td>Use carts</td>
<td>76</td>
<td>$ 4,037</td>
</tr>
<tr>
<td>OR 5</td>
<td>28</td>
<td>$ 3,519</td>
<td>32</td>
<td>$ 2,814</td>
</tr>
<tr>
<td>OR 6</td>
<td>21</td>
<td>$ 1,591</td>
<td>56</td>
<td>$ 4,511</td>
</tr>
<tr>
<td>OR 7</td>
<td>21</td>
<td>$ 1,591</td>
<td>43</td>
<td>$ 2,974</td>
</tr>
<tr>
<td>OR 8</td>
<td>21</td>
<td>$ 1,591</td>
<td>52</td>
<td>$ 2,986</td>
</tr>
<tr>
<td>OR 9</td>
<td>Use carts</td>
<td>Use carts</td>
<td>123</td>
<td>$ 9,753</td>
</tr>
<tr>
<td>OR 10</td>
<td>28</td>
<td>$ 3,519</td>
<td>49</td>
<td>$ 3,647</td>
</tr>
<tr>
<td>OR 11</td>
<td>Use carts</td>
<td>Use carts</td>
<td>75</td>
<td>$ 4,234</td>
</tr>
<tr>
<td>OR 12</td>
<td>23</td>
<td>$ 1,843</td>
<td>82</td>
<td>$ 6,152</td>
</tr>
<tr>
<td>OR 13</td>
<td>Use carts</td>
<td>Use carts</td>
<td>18</td>
<td>$ 1,084</td>
</tr>
<tr>
<td>OR 14</td>
<td>28</td>
<td>$ 3,519</td>
<td>30</td>
<td>$ 2,765</td>
</tr>
<tr>
<td>OR 15</td>
<td>28</td>
<td>$ 3,519</td>
<td>34</td>
<td>$ 3,371</td>
</tr>
<tr>
<td>OR 16</td>
<td>28</td>
<td>$ 3,519</td>
<td>42</td>
<td>$ 4,008</td>
</tr>
<tr>
<td>OR 17</td>
<td>Use carts</td>
<td>Use carts</td>
<td>73</td>
<td>$ 6,919</td>
</tr>
<tr>
<td>OR 18</td>
<td>23</td>
<td>$ 5,926</td>
<td>63</td>
<td>$ 3,944</td>
</tr>
<tr>
<td>OR 19</td>
<td>34</td>
<td>$ 2,616</td>
<td>80</td>
<td>$ 5,015</td>
</tr>
<tr>
<td>OR 20</td>
<td>Use carts</td>
<td>Use carts</td>
<td>56</td>
<td>$ 2,753</td>
</tr>
<tr>
<td>OR 21</td>
<td>23</td>
<td>$ 5,926</td>
<td>70</td>
<td>$ 4,720</td>
</tr>
<tr>
<td>OR 22</td>
<td>34</td>
<td>$ 2,616</td>
<td>38</td>
<td>$ 2,476</td>
</tr>
<tr>
<td>OR 26</td>
<td>34</td>
<td>$ 2,616</td>
<td>0</td>
<td>$ 0</td>
</tr>
<tr>
<td>OR 27</td>
<td>14</td>
<td>$ 1,184</td>
<td>58</td>
<td>$ 3,516</td>
</tr>
<tr>
<td>OR 28</td>
<td>Use carts</td>
<td>Use carts</td>
<td>93</td>
<td>$ 6,264</td>
</tr>
<tr>
<td>OR 29</td>
<td>Use carts</td>
<td>Use carts</td>
<td>69</td>
<td>$ 4,769</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$ 52,652</strong></td>
<td></td>
<td><strong>$ 95,581</strong></td>
</tr>
</tbody>
</table>
Recommendations

In addition to the implementation of the recommended right-sized suture inventory model, the team has also developed other recommendations based on the interviews, the observations, and the data analysis.

Figure 12: Future State Map

Recommendations for Restocking Operating Rooms
The Nurse in charge of placing the orders for the OR sutures checks the inventory levels at the core every week on Wednesdays. Since the nurse only has time to check the inventory levels at the core, the flow of sutures to the operating rooms must be consistent. Nurses and circulators will still go to the core throughout the week to replenish boxes of sutures that are empty. Weekly restocking of all ORs must occur on Mondays in order to offer a reliable total inventory picture for the nurse in charge of suture purchases. The process of restocking the rooms on Monday’s should be fairly simple once the par levels for the rooms are implemented. The individual who restocks the operating room will look for empty spots in the OR suture shelf and replenish from the core inventory. This visual Kanban system will be quick and give a more consistent weekly level of suture inventory at the core which the purchasing is based upon.

Recommendations for Suture Layouts
Listed below are the three major recommendations related to the physical suture layout in the main storage locations.
- Label slow moving sutures
- Install dividers on metal storage racks
- Change suture label color to correspond to the box colors

When the team observed the main suture storage locations in core A & C, the boxes of suture were organized according to by manufacturer and then by the needle/thread code. This system of organization enables the slow moving suture types to hide amongst the high usage sutures. Labeling every slow moving suture box with a simple colored sticker would inform the staff of these infrequently used sutures, therefore; indicating that individual packages should be removed instead of taking the entire box to the OR.

This project’s inventory model will decrease the number of sutures that are kept on the metal racks. With the extra space on the storage racks, dividers should be added to help organized the different suture types. The dividers will help with organization by preventing boxes from being mixed together.

Finally, the small labels that describe the sutures should have their background colors changed to match the color of the suture boxes they represent. This simple change will enable any one to quickly recognize which boxes are in the wrong location. The color correlation is a simple yet effective way to reinforce the method of organization that is already in place.

**Recommendations for Expired Suture**

After performing the physical inventory count, the OR staff pulled out almost $8,000 worth of expired suture. While this does not represent a major loss when compared to the total suture value, the risk of impacting patient safety is high. Many of the tasks below can be implemented with minimal overall effort while dramatically reducing the risk of using expired sutures.

- Place older sutures in the bottom of combined boxes
- Avoid storing packages individually in suture carts
- Label opened boxes that have a pending expiration date

When a box of sutures is almost empty, a new box may be retrieved and the old sutures shoved into the new suture box. This should be avoided by waiting to retrieve a new box until the old one has been used up. However, this may not always be practical. A simple alternative is to place the old sutures in the bottom of the new suture box so that they are the next packages to be used. Since the suture boxes have an opening on the bottom, the nurses always pull sutures from the bottom of the box.

The OR staff should avoid storing loose packages of sutures on the mobile carts. This is often done and results in high disorganization and a higher likelihood of suture becoming expired. If individual sutures must be stored without their boxes, they should have a certain level of organization that is sustainable and easy to locate.
Finally, boxes that are open but contain sutures that have an expiration date within the next year should be marked and placed in the suture wall. This will serve as a visual cue to be the next suture box of that type to be used first. Placing a sticker on these boxes will help prevent sutures from expiring due to poor organization.

**Recommendations for Suture Flow**

A smooth flow of sutures through the OR is important to maintain the appropriate levels of inventory. A weekly check of the inventory for each room will ensure that the high usage sutures are maintained in the room while the slow moving sutures are kept in the suture wall storage locations. The supplemental excel files will provide the analysis results that dictate which sutures should be kept in certain rooms. Only the rooms with a single service have this data provided. The sutures that will be stored in each room will cover over 70% of each room’s usage. This will decrease the number of times that OR staff will need to leave the room to retrieve needed sutures.

For Operating Rooms with a mix of service types, a deliverable will be included to address the stocking recommendations for the mobile suture carts. These suture carts are meant to supply the services that are spread between multiple rooms. These recommendations will ensure that the necessary sutures are kept on the cart. These mixed service type rooms had the highest inventory levels. These high inventory levels are caused by each service stocking to their needs as an individual group and collectively overstocking their rooms.

**Recommendations for Clinical Suture Reduction Project**

A compiled list of the slow moving sutures is provided for the Clinical Suture Reduction project that is currently occurring. This list represents the suture types that should be reduced and/or eliminated from the inventory. A clinical background into these sutures should be analyzed to determine whether they can legitimately be removed from the inventory. This determination should be based on whether the suture type in question can be substituted with another similar type and whether the surgeon preference of that suture can be modified.