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**14. ABSTRACT**

This term of the grant has been comprised of three main directions. The first primary direction focused on simulation preparation, personnel training, and conducting data collection sessions. Based on recommendations identified from pilot simulations, necessary modifications were made to each of the procedural stations. Next, the entire team traveled to the institutions involved in the study, set up all the simulation stations, interacted with participants, and collected data to bring back to the lab for analysis. Additionally, there was a focus on collecting the same data set from surgeons who had retired from the field at varying levels. The second direction of effort focused on the organization, database and transcription coding, and analysis of this data. Analysis was expedited using participant workbooks, common error checklists, and video recordings made during participant data collections. Additional data such as images of final products were obtained and coded. The third direction focused on the dissemination of findings learned in the initial analyses performed. A set of scores validating our data was developed and will be used for future coding, analysis and reporting methods to participants. Multiple abstracts and posters were created for surgical conferences attended. These works concentrated on data from pre and post participation surveys, perceptions of skill reduction, motor control in robotic tasks, longitudinal comparisons and comparisons between robotic and simulation tasks. Lessons learned from each of the main directions have been incorporated into plans for additional refinements to be made that will ensure continuing study success for our upcoming third year of data collection sessions.

**15. SUBJECT TERMS** Refined development of simulated procedure stations; Training of personnel in human subjects research for data collection; Completion of data collection from participating institutions; Development and execution of Performance Review Tool; Organization, coding, and transcribing of collected data; Analysis of qualitative survey and quantitative procedure simulation data; Dissemination of results at surgical conferences

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# Introduction

The third term of the grant has continued to focus on identifying key differentiating performance factors in the pre-mastery and mastery phases. Identifying these factors was primarily done by evaluating survey results from the first and second round of data collection, and analyzing performance on the six stations including beginning cross analysis between stations. The lab was able to compare performance for current study participants at one station to those whose data was analyzed from previously recorded in both 2014 and in simulation based LVH repairs. Station design has been updated and optimized to allow for the best possible data collection.

# Summary for Statement of Work Progress (Read Progress Detail in each Report)

The following section details each element of the SoW as it has been addressed through our work thus far. For review, the following four objectives guided this work:

**Objective One**: To evaluate mental rehearsal as an intervention for skill decay in the pre-mastery phase.

**Objective Two**: To identify key differentiating performance factors for the pre-mastery and mastery phases.

**Objective Three**: To develop a generalizable, multi-variable, predictive model of skills decay.

**Objective Four**: To develop an efficient and effective set of assessment tools and individualized training recommendations to counteract skills decay.

In its third year, our work has continued to focus on Objectives Two and Four because significant progress on these two objectives is required in order to address Objectives One and Three. Begin granted a no cost extension until 09/2016, we intend to shift our primary towards addressing Objectives One and Three as data analysis continues as this project completes.

### OBJECTIVE ONE

No progress at the time of this report. We plan to address this objective as data collection continues.

### OBJECTIVE TWO

The greatest area of progress for Objective Two has been compiling the data collected in 2014 and 2015 along with conducting analyses. During data collection common error checklists were completed, and the checklists were later used to code and timestamp key events or errors using video collected from each clinical scenario station. Videos from each station were also coded for the major steps that occurred in each participant's procedure. The coding of procedural steps for each participant will allow for comparison between performance level and post-graduate year. To assist in further differentiating performance factors between the pre-mastery and mastery phases, performance data was collected from nine retired general surgeons. These retired surgeons represent complete mastery with varying levels of non-practice, ranging from 2 years out of clinical practice, to 23 years out of clinical practice. Data from retired surgeons will be coded and analyzed in a fashion identical to that of resident participants. The level of performance decay can then be compared between residents in the pre-mastery phase and retired surgeons who achieved complete mastery while in practice.

## Methods of Analyzing Data

### *Needle Angle: Central Line*

Common events and errors have been logged in RedCap during the 2015 data collections regarding the Central Line Catheterization procedure. Time points still need to be incorporated. When this is completed, analysis on performance between 2014 and 2015 participants can be performed.

One area of variation between participants was the needle angle for accessing the vein in the central line. Research assistants analyzed the needle angle and number of attempts to access the vein. Time segments were noted for further analysis of motor movements that might differentiate those who were successful from those who were not.

Because pauses can signify surgical planning, research assistants viewed all the videos of the central line to identify those time points in which the participant was pausing while viewing either the instruments or the simulator and not interacting with the experimenter so that further motion analysis can be performed to assess the length of time taken during each pause.

Participants varied in the technique that they used to access the vein. Analysis of videos of needle insertion evaluated the trajectory and perseveration of tissue disturbance.

Participants varied in ability to trouble shoot central lines. Analysis of technical error rate and ability to troubleshoot central line insertion evaluated for any associated correlation.

A regression of the errors committed while accessing the central line and the motion smoothness as measured by motion monitoring sensors measures the association of categorical and continuous measures of surgical performance.

A survey on critical steps and events for the Central Line Catheterization procedure was developed to create a procedure score. Multiple procedural experts have completed the survey and it is currently in the validation phase.

### *Bowel Anastomosis*

Common events and errors have been logged in RedCap during the 2015 data collections regarding the Bowel Anastomosis procedure. Statistical analysis on performance differences and similarities for 2014 and 2015 participants is starting.

Bowel Anastomosis can be performed in a couple of valid ways. The creation of decision trees for each of these methods helps the categorization of surgical decision making.

Evaluation of critical decisions such as suture type assesses surgical knowledge. Video and final product analysis judged whether participants sutured one or two layers and whether absorbable or non-absorbable sutures were used for the different layers.

A survey on critical steps and events for the Bowel Anastomosis procedure was developed in order to create a procedure score. Multiple procedural experts have completed the survey and it is currently in the validation phase.

***Urinary Catheter***

Common events and errors have been logged in RedCap during the 2015 data collections regarding the Urinary Catheterization procedure. Statistical analysis on performance differences and similarities for 2014 and 2015 participants is starting.

Participant's medical decision trees regarding urinary catheter placement in hypothetical scenarios were transcribed and categorized. Comparison to standard treatment and possible risks will identify gaps in knowledge.

Knowing when to refer to a specialist is a critical decision in medicine. Problem solving in the case of common and unique hypothetical scenarios involving urinary catheterization was analyzed for medical decision tree and the tolerance of ambiguity before making a referral.

A survey on critical steps and events for the Urinary Catheterization procedure was developed in order to create a procedure score. Multiple procedural experts have completed the survey and it is currently in the validation phase.

***LVH Repairs***

Common events and errors have been logged in RedCap during the 2015 data collections regarding the Laparoscopic Ventral Hernia repair procedure. Statistical analysis on performance differences and similarities for 2014 and 2015 participants is starting.

Identification of movement gestures in motion tracked data in laparoscopic simulator: We developed analysis tools to automatically identify segments of goal directed movements during clinical scenario tasks. The method employs a combination of measures, including, speed, frequency, and the spatial extent of movement, in order to determine time points of the total data record that are likely associated with movement initiation, ballistic action, and stabilization of movement.

For all participants that attempted the laparoscopic ventral hernia repair (LVH) from 2014, bimanual and unimanual coordination during the mesh securing phase have been identified using the Transana software. Workers observed video collected from each participant and identified time points when modality changed and are compiling the time points into a spreadsheet for future motion analysis.
Analysis of angle and rotation of hands during use of surgical instruments to grasp suture associate the minimum amount of rotation required to efficiently grasp suture in the course of repairing a hernia on a simulated laparoscopic ventral hernia repair.

A survey on critical steps and events for the Laparoscopic Ventral Hernia repair procedure was developed in order to create a procedure score. Multiple procedural experts have completed the survey. Following one more expert survey completion, validation will begin.

Laparoscopic Ventral Hernia repair skins for 2015 participants were graded using two raters. Inter-rater reliability identified two categories that required additional grading and improvement. New kappa scores reflect statistically sound grading. The next step is to compare repair scores between 2015 and 2014 participants.

### *Matlab*

In order to utilize the motion monitoring data, Matlab code previously developed to capture motion metrics (e.g., path length, working volume, idle time) for another project is currently being adapted for its use with each station on the DoD project. When the Matlab code is finally up and running, time points for each station collected during previous quarters will then be utilized to identify valuable segments for motion analysis and the code will produce meaningful information regarding path length, working volume, and idle time for each segment.

### *Virtual Reality Station*

The 2014 data was analyzed to set up a performance review tool for the force tasks. The just noticeable difference task data was analyzed to give every participant a perspective of the smallest difference in stiffness they could differentiate. Based on the results the tests were altered to have conditions with finer difference in stiffness for the 2015 data collection. The force production with stationary target and the reaction time task was analyzed to compare the path lengths and distance from target of each participant with respect to given trial conditions. The force production with moving target module is being analyzed for the 3D path lengths and accelerations.

Previously developed human error classification systems are currently being used to deconstruct errors at major decision points in the simulated laparoscopic ventral hernia repair (LVH). The taxonomy (see Table 1) distinguishes between cognitive and technical failures that occurred during each participant's performance. Using Transana, time points will be collected which will later parse the large procedure video into more manageable video clips that show useful highlights of each error characteristic.

*Table 1: Error framework for classifying error type and error level*

| Error characteristic | | Definition |
|---|---|---|
| Error type | | |
| Omission | | Failure to perform a step entirely |
| Commission | | Failure to perform a step correctly |
| Error level | | |
| Cognitive | | |
| | Information | Inability to detect cues arising from change in system state |
| | Diagnosis | Inaccurate diagnosis of the system state on the basis of the information available |
| | Strategy | Selection of a strategy that fails to achieve the intended goal |
| Technical | | |
| | Procedural | Execution of a procedure inconsistent with the strategy selected |
| | Action | Failure to properly execute the procedure |
| | Mechanical | Occurrence of structural or mechanical failures that do not provide an opportunity for intervention |

We continued our analysis using MANOVA to determine which metrics were most important in positively identifying the demographic background of each experiment participant. We recently enhanced this work with a stepwise procedure of including contributions from each metric, depending on the probability of type-II error for that individual metric. We also employed a covariance analysis to determine which metrics provided redundant information.

An generalized estimating equation analysis of direction and amount of displacement during a virtual reality manual compensation task shows that different levels of force disrupt manual compensation more when the force is taken away than when it is applied.

### *Sensitivity Analysis*

Individual differences in sensitivity to task factors: We performed a sensitivity analyses of how performance depended on changes in task conditions. We found that surgery residents were sensitive to the starting location of movement, heading angle of movement, the degree of visual distortion, and coping with changes in the force threshold of the puncture task. Interestingly, the changes in movement heading and starting location were significant factors across different tasks.

### *Transcription*

Three stations have been transcribed using audio/video transcription software Transana. Quantitative and qualitative features from audio and video recorded data from 2014 data collections have been coded and categorized.

Transcription of the focus groups that were conducted in early 2015 has been completed and analyzed to better understand our recruitment efforts and enhancements that are necessary for our Performance Review Tool.

### *Moonlighting*

An analysis was performed on the effect of moonlighting or on-call work in addition to lab time on skill decay in the performance of the LVH. While the model was not significant at baseline, this analysis suggests that with similar data skill decay could be seen as decrease in the final products (the LVH skin) score of the LVH by as much as 1.4 points per year. This analysis also demonstrated that post simulation confidence and difficulty ratings were far more indicative of performance as judged by the final product than pre simulation ratings.

## OBJECTIVE THREE

No progress at the time of this report. We plan to address this objective as data collection and analysis continues.

## OBJECTIVE FOUR

### *Data Collection Efforts*

The primary focus of the study team's efforts surrounded acting on lessons learned from previous pilot studies, training lab personnel, and streamlining current study protocols all in an effort to maximize the quality of the data collected from our participants. Most notably, this process included three distinct features:

1) Redesigning the clinical procedure stations;
2) Improving existing study protocols/instructions; and
3) Providing standardized training ***and*** assessment for all lab personnel who will be involved in data collection.

### *Redesigning the Clinical Procedure Stations*

Based on feedback from previous pilots, expert reviews of each station, and internal evaluation, each of the clinical procedure stations underwent a significant improvement over the course of quarter 1.

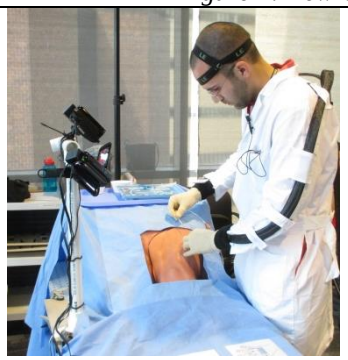
First, noted "experts" on each of the four clinical procedure stations (Central Line, Bowel Anastomosis, Urinary Catheterization, and Laparoscopic Ventral Hernia) were asked to provide their feedback and suggestions for how each station may be improved. For each review, the expert was asked a series of semi-formal interview questions by project management both before *and* after performing the procedure (Figures below for examples). The audio and video from these expert reviews were transcribed and coded to generate a list of possible improvements or changes to the four stations.

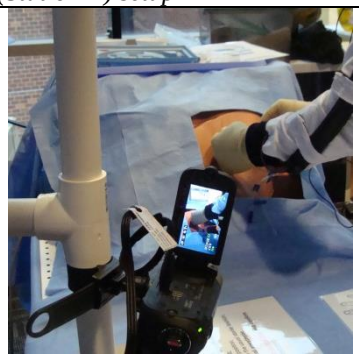
The second major improvement to the clinical procedure stations was consolidating and simplifying the setup of each station. The following examples show some of the improvements made to each station.

***Station A: Subclavian Central Line.***

The general setup for this station remained the same; however, a new task was added to the time rotation for this station's effort. An additional camera was affixed to a post mounted to this station's table to capture a close-up view of the participant's placement of needles on the simulation model. This assists greatly in the post-processing video analysis of correct needle placement.

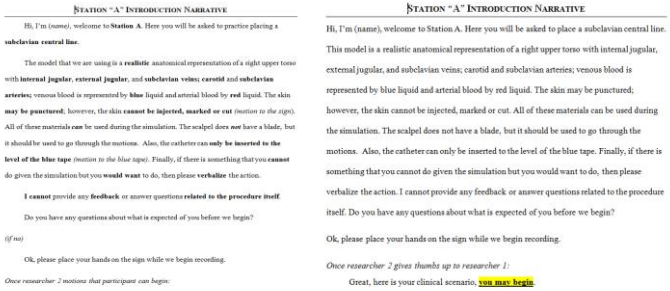
*Figure 1: New Central Line Simulation (Station A) setup*





***Station Narrative***

The introduction narrative that is read aloud by researchers at Station A was shortened. This was done because participants were getting confused from all of the information presented to them in the beginning of the station. Information that was not considered pertinent was eliminated from the narrative in order to keep residents present in the situation.



**STATION "A" INTRODUCTION NARRATIVE**

Hi, I'm (*name*), welcome to **Station A**. Here you will be asked to practice placing a **subclavian central line**.

The model that we are using is a **realistic** anatomical representation of a right upper torso with **internal jugular**, **external jugular**, and **subclavian veins; carotid** and **subclavian arteries;** venous blood is represented by **blue** liquid and arterial blood by **red** liquid. The skin **may be punctured**; however, the skin **cannot be injected, marked or cut** *(motion to the sign)*. All of these materials **can** be used during the simulation. The scalpel does **not** have a blade, but it should be used to go through the motions. Also, the catheter can **only be inserted to the level of the blue tape** *(motion to the blue tape)*. Finally, if there is something that you **cannot** do given the simulation but you **would want** to do, then please **verbalize** the action.

**I cannot** provide any **feedback** or answer questions **related to the procedure itself**.

Do you have any questions about what is expected of you before we begin?

*(if no)*

Ok, please place your hands on the sign while we begin recording.

*Once researcher 2 motions that participant can begin:*

Great, here is your clinical scenario.

**STATION "A" INTRODUCTION NARRATIVE**

Hi, I'm (name), welcome to Station A. Here you will be asked to place a subclavian central line. This model is a realistic anatomical representation of a right upper torso with internal jugular, external jugular, and subclavian veins; carotid and subclavian arteries; venous blood is represented by blue liquid and arterial blood by red liquid. The skin may be punctured; however, the skin cannot be injected, marked or cut. All of these materials can be used during the simulation. The scalpel does not have a blade, but it should be used to go through the motions. Also, the catheter can only be inserted to the level of the blue tape. Finally, if there is something that you cannot do given the simulation but you would want to do, then please verbalize the action. I cannot provide any feedback or answer questions related to the procedure itself. Do you have any questions about what is expected of you before we begin?

Ok, please place your hands on the sign while we begin recording.

*Once researcher 2 gives thumbs up to researcher 1:*

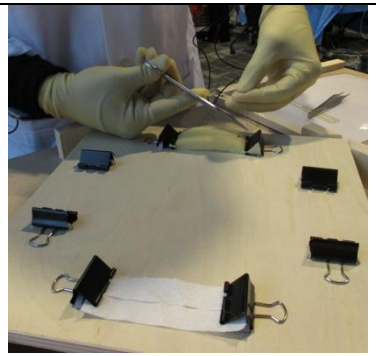
Great, here is your clinical scenario, **you may begin**.

*Figure 2: Old (Left) and New (Right) Central Line Placement (Station A) Introduction Narrative*

***Suturing Task***

An additional task was added to the clinical procedural scenarios. This task is an isolated and constrained task of placing 3 interrupted sutures into body tissue mimics using an instrument tying technique. This work is based off of a task developed and refined in Anne-Lise D'Angelo's NIH F32 training grant project using the Variable Tissue Simulator. The task simulates differing levels of task complexity by presenting two different materials to suture: rubber balloon (dense connective tissue), tissue paper (friable tissue). The addition of this station is highly useful in establishing a baseline of motor performance in suturing while in an isolated contextual environment. This can then be used as a comparison to identify differences in performance when suturing is investigated in the performance of the Bowel Anastomosis station. Another benefit offered by this station comes from the data analysis methods refined for D'Angelo's experimental results. The suture board presented here is identical to that of her project, so the analysis of the motion capture data matches very well. The analysis programs written for her project can be directly applied to data collected with this additional station task.

*Figure 3: Setup of simple suture task that was added to Station A*



The performance of this Suturing Task was added to Station A because the Central Line placement task performance is typically fast for a participant. The spare time compared to other stations was a good place to add a second task, since participants are already wired into the motion capture system. The Suturing Task fixture was fabricated to be placed directly on top of the Central Line fixture, facilitating rapid change-overs. The workspace provides participants with a suture board containing materials and trays that hold necessary instruments. Additionally, a camera mounted to a support post captures a close-up view of the participant's suturing actions.

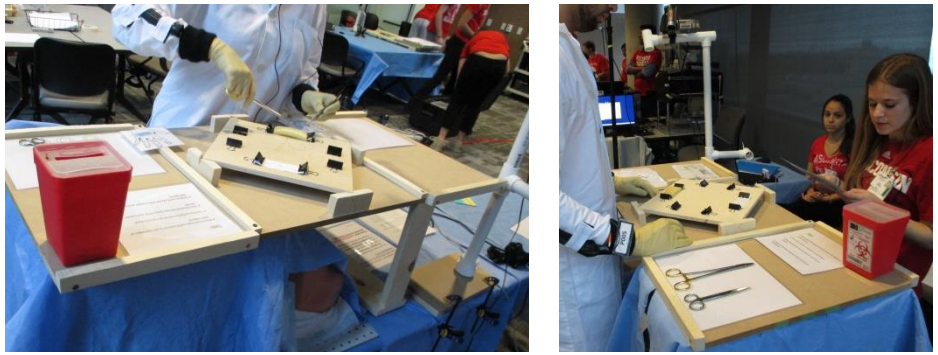


*Figure 4: Novice researchers instructing a **2015** participant on completing the suture task*

***Station B: Bowel Anastomosis***

An additional camera was placed into this station's workspace to capture close-up views of the participant's hand movements as they perform the anastomosis task. This helps to provide greater detail of the bowel exploration and specific suturing methods participants choose to use during the task execution. The camera is affixed to a post mounted to the station's table. This is located near the right shoulder of the experimenter assistant that interacts with the subject.

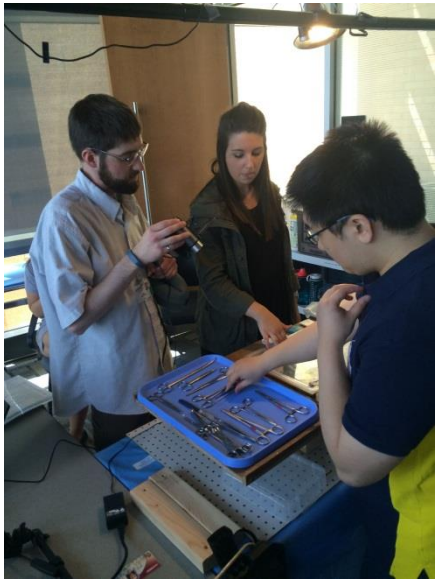


*Figure 5: New Bowel Anastomosis Simulation (Station B) setup*

Originally the station involved residents using clips to hold the bowel as they performed resections and anastomoses. For the purposes of understanding resident performance more through guiding and instructing a researcher, an assistant researcher was placed at the Bowel Anastamosis station. By introducing the role of an assistant to the resident at this station, the resident could interact with them and provide more of their knowledge verbally through direction.

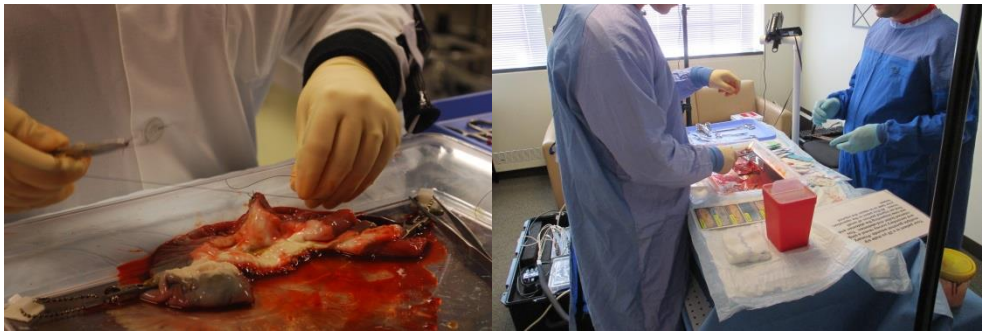
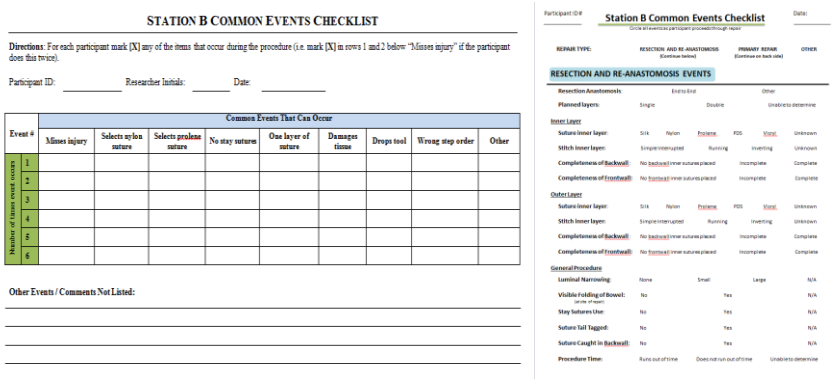


*Figure 6: Old (Left) and New (Right) Procedure for Bowel Anastomosis (Station B)*

In order to improve post-performance analysis of bowel repairs, the station's common events checklist was revamped to consider the different choices residents made, including planned layers, suture type, stitch type, completeness, and general procedure steps. This level of detail will also expedite statistical analyses performed within the station and across stations.



STATION B COMMON EVENTS CHECKLIST

**Directions**: For each participant mark [X] any of the items that occur during the procedure (i.e. mark [X] in rows 1 and 2 below "Misses injury" if the participant does this twice).

Participant ID: _____ Researcher Initials: _____ Date: _____

| Event # | | Common Events That Can Occur | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Misses injury | Selects nylon suture | Selects prolene suture | No stay sutures | One layer of suture | Damages tissue | Drops tool | Wrong step order | Other |
| Number of times event occurs | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| | 3 | | | | | | | | | |
| | 4 | | | | | | | | | |
| | 5 | | | | | | | | | |
| | 6 | | | | | | | | | |

**Other Events / Comments Not Listed:**

Participant ID#: _____ Station B Common Events Checklist Date: _____

Circle all events as participant proceeds through repair

REPAIR TYPE: RESECTION AND RE-ANASTOMOSIS (Continue below) PRIMARY REPAIR (Continue on back side) OTHER

RESECTION AND RE-ANASTOMOSIS EVENTS

Resection Anastomosis: End to End Other

Planned layers: Single Double Unable to determine

Inner Layer

Suture inner layer: Silk Nylon Prolene PDS Vicryl Unknown

Stitch inner layer: Simple interrupted Running Inverting Unknown

Completeness of Backwall: No backwall inner sutures placed Incomplete Complete

Completeness of Frontwall: No frontwall inner sutures placed Incomplete Complete

Outer Layer

Suture inner layer: Silk Nylon Prolene PDS Vicryl Unknown

Stitch inner layer: Simple interrupted Running Inverting Unknown

Completeness of Backwall: No backwall inner sutures placed Incomplete Complete

Completeness of Frontwall: No frontwall inner sutures placed Incomplete Complete

General Procedure

Luminal Narrowing: None Small Large N/A

Visible Folding of Bowel: (circle # of times) No Yes N/A

Stay Sutures Use: No Yes N/A

Suture Tail Tagged: No Yes N/A

Suture Caught in Backwall: No Yes N/A

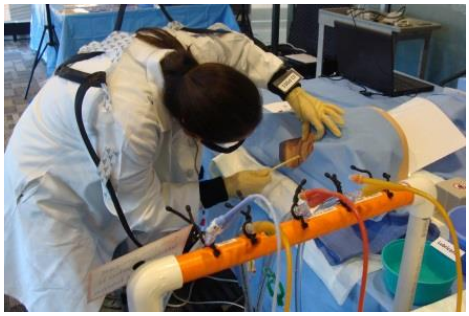
Procedure Time: Runs out of time Does not run out of time Unable to determine

*Figure 7: Old (Left) and New (Right) Bowel Anastomosis (Station B) Common Events Checklists*

***Station C: Urinary Catheter***

Based on feedback obtained from focus group interviews with past participants, this station underwent a major redesign in model positioning and equipment placement. First, the orientation of the pelvic model was placed on the table in a fashion to mimic the positioning of a patient lying on a bed. This better simulated the leaned over position the participant would have to do if in a patient's room. Second, a new catheter kit was made to better match the way a clinician would place a Foley kit between a patient's legs prior to starting a urinary catheterization. The kit approximates the purchased kit and also facilitates rapid changeovers because it can be picked up and switched out with matching kits that contain different size catheters that can be requested. Additionally, a close-up camera and mount was added to this station to better capture the detail in the participant's catheter insertion.

*Figures 8-9: Station C: Urinary Catheter*

| **Before** | **After** |
|---|---|
|    |    |

Addition of Close up Cameras to three of the four clinical stations. These allow for a more detailed, focused view of the scene and assist in coding errors and events. They each have a standardized position/view and are manually focused so that participant movement does not blur the view of the simulation.

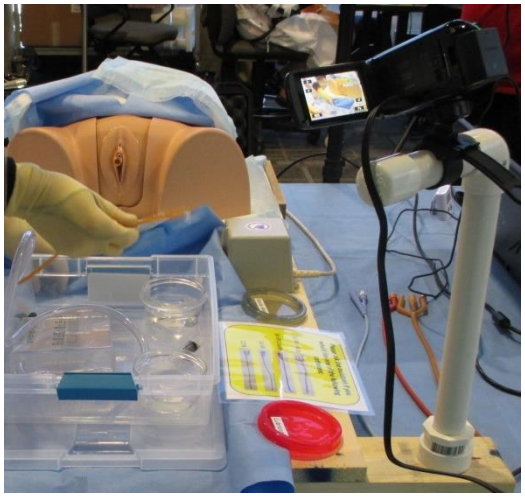


*Figure 10: New close up cameras*

***Additional Updates to Urinary Catheter Station:***

a. Simulation models turned sideways (no longer facing edge of table) to mimic position of actual patient awaiting catheter insertion.
b. Two models used for catheterization instead of three due to time constraints.
c. Vaginal ring added to female simulator to restrict access to urethra; previously sutures were used to restric access, however these were unrealistic and prone to breaking.
d. Yellow and red colored water instead of clear water used to represent normal and bloody urine return, respectively.
e. Drainage bags removed from ports to increase participant turn-over and facilitate station clean-up.
f. Catheter boxes/kits created to replace catheter stand.

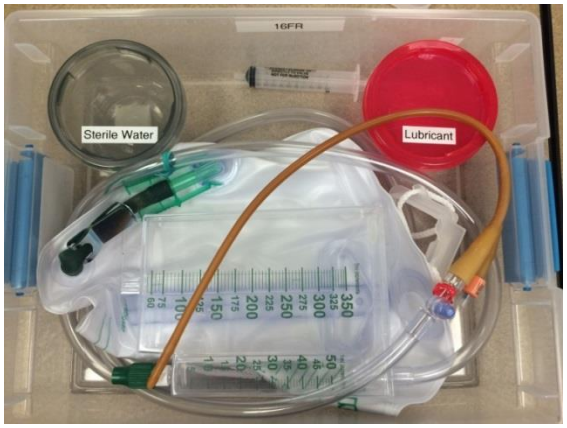



*Figure 11: Example of new catheter box*

In order to better assess resident decision making, this station underwent a redesign in equipment placement. In 2014, residents were able to see all catheter options available to them. This year residents were required to vocalize their catheter choice without visualization of the catheters ahead of time. Only if residents were unable to articulate their decision did we provide a list of catheter options.

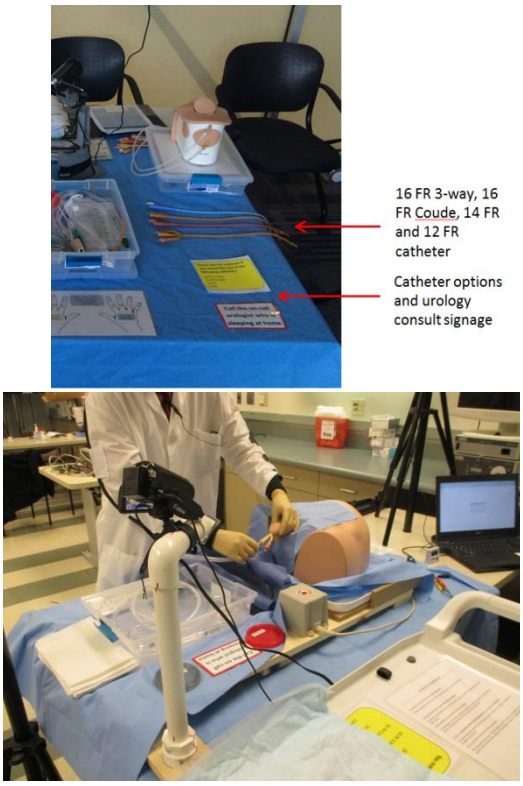



*Figure 12: Old (Left) and New (Right) Equipment Layout for Urinary Catheterization (Station C)*

Based on experiences researchers have had with residents in previous data collections on Station C, a Frequently Asked Questions document was created to include questions that participants frequently ask about the models and urine output. By making this document, researchers would have standard response options when prompted with these frequent questions.

**STATION "C" FAQ RESPONSES**

In regards to questions about the **color of the urine**:

"Please assume the color of the urine is intentional and is a part of the simulation."

If the participant asks to **remove the ring on model 2**:

"It will be recorded that you have asked to remove the ring, however please proceed with the ring in place."

If this continues to be a problem for the participant:

"Unfortunately our simulators cannot be modified, we will record that you'd like the ring removed, but please proceed as if the ring were non-removable."

If there is a **potential problem with the simulator** (i.e. air bubble in the bladder):

"We understand that simulators can at times have issues. Please try to re-insert the catheter, or re-adjust its placement."

If this continues to be a problem for the participant:

"We apologize for any issues with the simulator; it will be noted in your records. If you are unable to proceed due to these issues, we will continue on to the next scenario/station."

*Figure 13: Frequently Asked Questions and Responses for Urinary Catheterization (Station C)*

## *Station D: Laparoscopic Ventral Hernia (LVH)*

### *Updated LVH Pretest Instructions*

To gather more information and clear information on hernia port placement, the LVH pretest instructions were updated. The pretest now differentiates between ports for instruments and ports for cameras. It also asks participants to assign the order in which they would place the ports used.

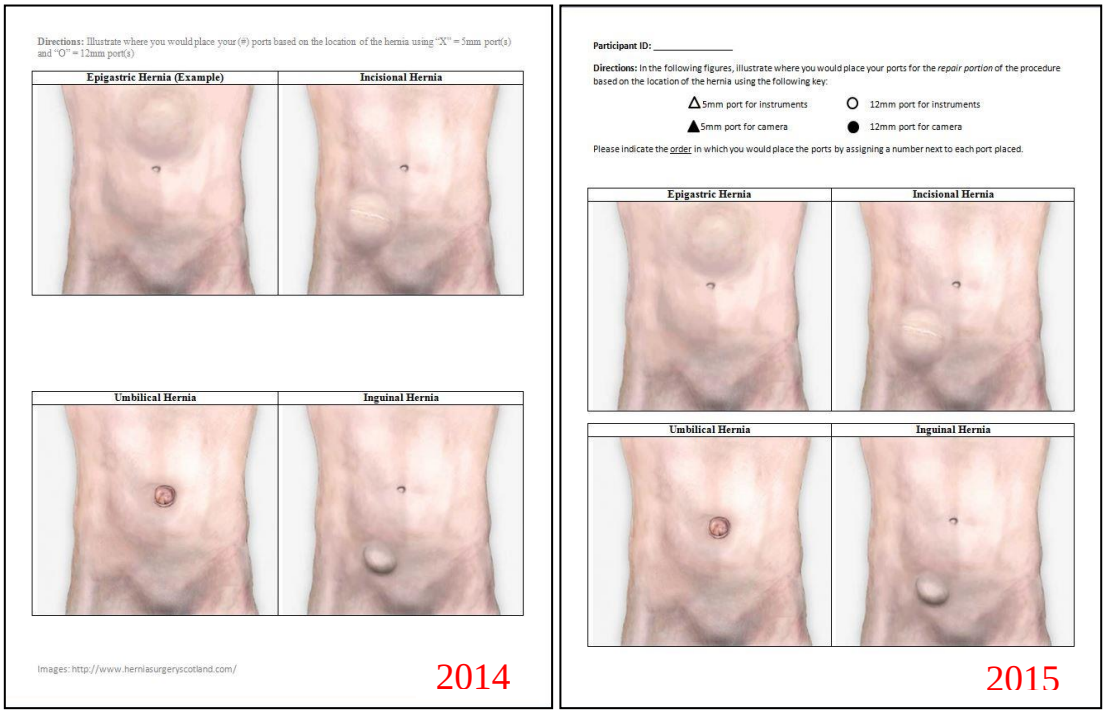



*Figure 14:* ***2014*** *and* ***2015*** *LVH pretests showing the greater detail of the instructions*

### *Improving Existing Study Protocols/Instructions*

The second area where the research team focused their efforts was streamlining and improving the protocols and instructions for how data were to be collected at each station. These improvements included creating dedicated *Station Manager Binders*, establishing dedicated researcher responsibilities for each station, and finalizing the *Participant Survey Workbook*.

### *Modified Protocol to Standardize POV Cameras*

Video glasses with low image quality were retired and replaced by additional head-mounted cameras. These cameras were set up to have a better focus and better image quality than previously recorded point-of-view video data.

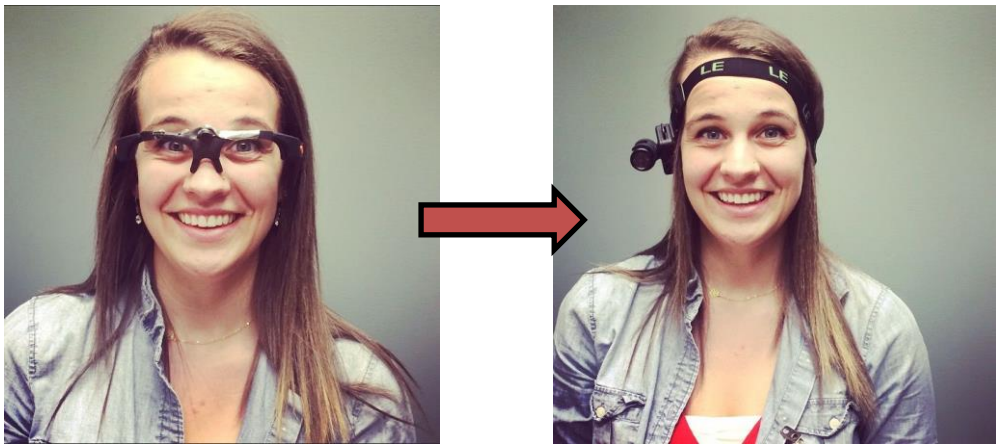


*Figure 15: Old POV glasses from **2014** and new POV headbands for **2015***

### *Documentation of Technological Protocols*

With the addition of new equipment such as the close-up cameras, and standardization of protocols with head cameras and camera mounting, a number of new training documents were created. These cover in detail the physical setup of technology devices, placement in the operating workspace, software configurations, and use during data collections. Each of the station personnel responsible for setup has been trained in equipment using these instructions. Highlighted below are portions of documents concerning head and close-up camera setup.

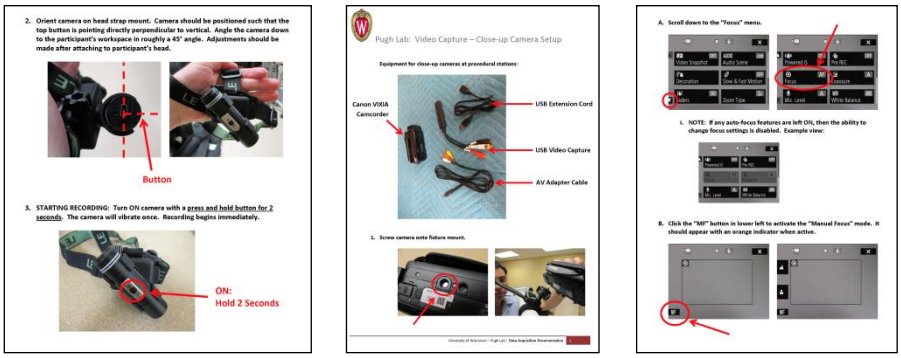



*Figure 16: Examples of documentation for technology setup used in study*

### *Lucas-Kanade Template Matching Tracking Algorithm*

Because we have a significant amount of data in video format, we have started using the Lucas-Kanade algorithm to automate the identification of instruments. It is based on template matching between two consecutive frames and uses multiple parameters to identify transformation of feature frames. We were able to test this algorithm on Station A with the scalpel used to perform the central line catheterization (Figure 17).

*Figure 17: Example of instrument tracking at Station A. The scalpel has been identified by the algorithm by the blue rectangular box and green dot*

### *Providing Training and Assessment for All Lab Personnel Who will be Involved in Data Collection*

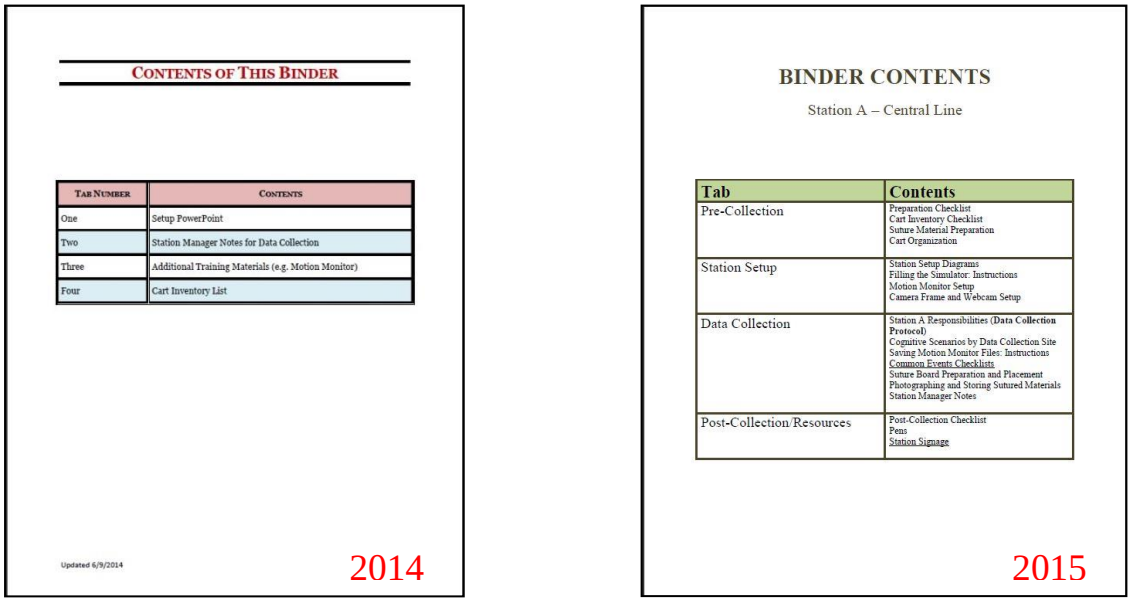
The third area of work on which the team focused was in providing organized training for any of the lab personnel who will be involved with collecting data. The individuals who had been responsible for managing each of the four clinical procedure stations at the previous two pilots were selected as "Station Team Leaders." Together with the project and lab managers, these team leaders developed a set of structured learning objectives and training activities to prepare other lab personnel (i.e. "Station Team Members") to fill the role as *primary* or *secondary* researcher for the stations.

New student personnel engaged in ***two*** structured training periods: 1) initial training, and 2) follow-up review and discussion. Initial training was conducted by research specialists in the lab in a setting where each individual received one-on-one training for their designated station. Follow-up review and discussion was conducted during retired surgeon data collections throughout the spring, where new researchers and students were able to practice their roles. Additional training was provided when necessary. All in all, six students were trained to serve as primary and/or secondary researchers for each of the clinical scenario and virtual reality stations.

Continued training and cross training of new personnel into station teams will occur throughout the months of April and May.

### *Continued updating "Station Manager Binders"*

To reflect best practices including more detailed inventory and organization to the mobile units, the station manager binders were continually updated. New protocols were documented for how to set up and run each of the four clinical stations. Pre- and post- collection checklists were also added to ensure thoroughness and organization. Binder contents were specialized and further detailed for each specific station.



CONTENTS OF THIS BINDER

| TAB NUMBER | CONTENTS |
|---|---|
| One | Setup PowerPoint |
| Two | Station Manager Notes for Data Collection |
| Three | Additional Training Materials (e.g. Motion Monitor) |
| Four | Cart Inventory List |

Updated 6/9/2014

2014

BINDER CONTENTS

Station A – Central Line

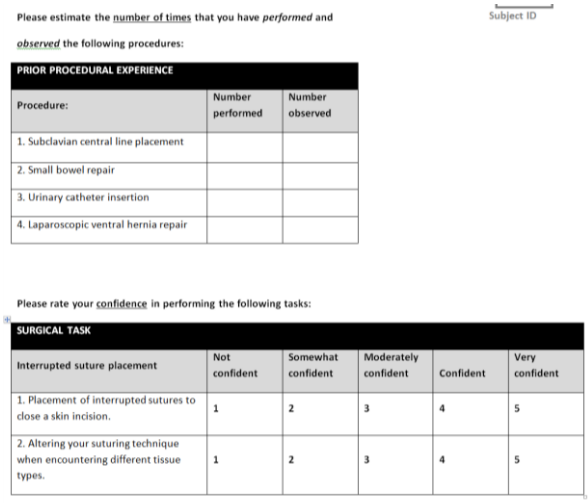
| Tab | Contents |
|---|---|
| Pre-Collection | Preparation Checklist<br>Cart Inventory Checklist<br>Suture Material Preparation<br>Cart Organization |
| Station Setup | Station Setup Diagrams<br>Filling the Simulator: Instructions<br>Motion Monitor Setup<br>Camera Frame and Webcam Setup |
| Data Collection | Station A Responsibilities (**Data Collection Protocol**)<br>Cognitive Scenarios by Data Collection Site<br>Saving Motion Monitor Files: Instructions<br>Common Events Checklists<br>Suture Board Preparation and Placement<br>Photographing and Storing Sutured Materials<br>Station Manager Notes |
| Post-Collection/Resources | Post-Collection Checklist<br>Pens<br>Station Signage |

2015

*Figure 18: **2014** and **2015** binder contents page describing in greater detail what all station training binders contain*

### *Resident Participant Workbook Addition*

The resident workbook was supplemented this year with questions regarding the number of procedures performed and observed by each resident. This allows for a clearer understanding of the experience level each resident has and what previous experience they have with each station. Additionally, the residents were asked to rate their confidence in different suturing techniques and with different tissue types.



Please estimate the number of times that you have *performed* and *observed* the following procedures:

Subject ID

| PRIOR PROCEDURAL EXPERIENCE | | |
|---|---|---|
| Procedure: | Number performed | Number observed |
| 1. Subclavian central line placement | | |
| 2. Small bowel repair | | |
| 3. Urinary catheter insertion | | |
| 4. Laparoscopic ventral hernia repair | | |

Please rate your confidence in performing the following tasks:

| SURGICAL TASK | | | | | |
|---|---|---|---|---|---|
| Interrupted suture placement | Not confident | Somewhat confident | Moderately confident | Confident | Very confident |
| 1. Placement of interrupted sutures to close a skin incision. | 1 | 2 | 3 | 4 | 5 |
| 2. Altering your suturing technique when encountering different tissue types. | 1 | 2 | 3 | 4 | 5 |

*Figure 19: Workbook Addition to Resident Participant Workbooks*

### *Retired Surgeon Workbooks*

The retired surgeon workbooks were developed based on the resident participant workbooks; however, the survey questions were modified to match a retired surgeon's experience and lifestyle. The goal was to keep as much information in the retired surgeon workbooks the same as the resident participant ones so that analyses could be performed across groups. The workbook and its modifications were submitted and approved by the University of Wisconsin Institutional Review Board.

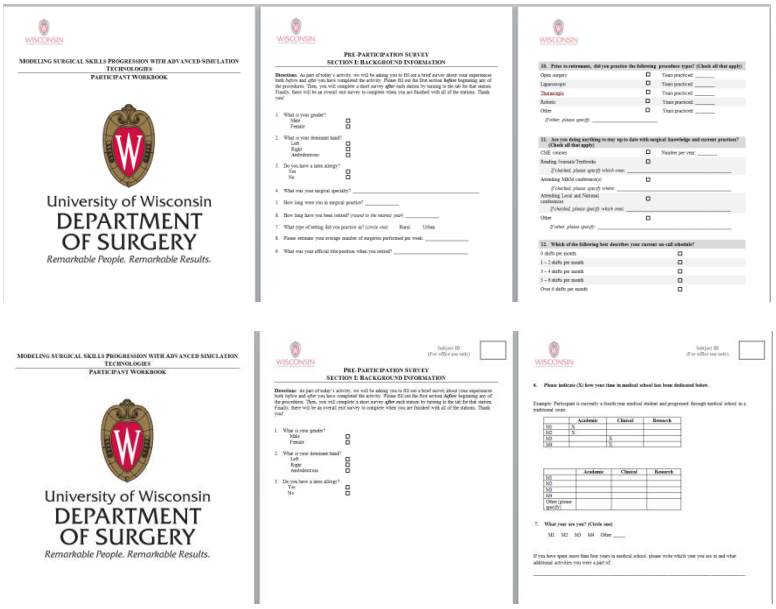



*Figure 20. Development of Retired Surgeon Workbook (Top) Modeled After Resident Participant Workbook (Bottom).*

### *Station Set-up and Pre-Collection Checklist*

In order to improve data collections and ensure each source of data (sensors, cameras, etc.) is working correctly prior to participant collection, a pre-collection checklist was created for each station (Figure X). It is currently still under review by the research team, and includes but is not limited to: working sensors, close-up cameras, scene cameras, and presence of narratives.

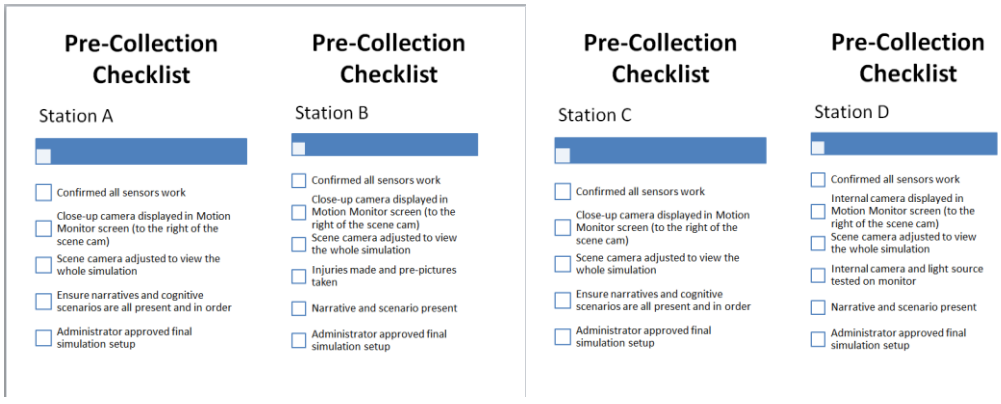
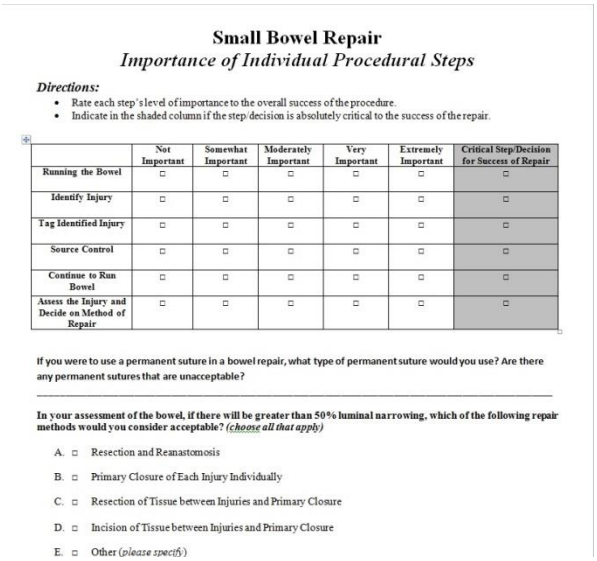



*Figure 21: Pre-Collection checklist for Stations A and B (Left) and Stations C and D (Right)*

### *Point System*

In order to explore skills decay through multiple avenues, a point system is in development by use Cognitive Task Analysis. Essential portions of clinical procedures were placed on a Likert scale and board certified general surgeons of various specialty were asked to rate the importance of each step on a survey. Once data collection is complete, we will validate the scores statistically and work to assign points for performance of each procedure. Participants will then be assigned a point value based on their performance and scores will be compared.



**Small Bowel Repair**

*Importance of Individual Procedural Steps*

***Directions:***

- Rate each step's level of importance to the overall success of the procedure.
- Indicate in the shaded column if the step/decision is absolutely critical to the success of the repair.

| | Not Important | Somewhat Important | Moderately Important | Very Important | Extremely Important | Critical Step/Decision for Success of Repair |
|---|---|---|---|---|---|---|
| Running the Bowel | □ | □ | □ | □ | □ | □ |
| Identify Injury | □ | □ | □ | □ | □ | □ |
| Tag Identified Injury | □ | □ | □ | □ | □ | □ |
| Source Control | □ | □ | □ | □ | □ | □ |
| Continue to Run Bowel | □ | □ | □ | □ | □ | □ |
| Assess the Injury and Decide on Method of Repair | □ | □ | □ | □ | □ | □ |

**If you were to use a permanent suture in a bowel repair, what type of permanent suture would you use? Are there any permanent sutures that are unacceptable?**

_____

**In your assessment of the bowel, if there will be greater than 50% luminal narrowing, which of the following repair methods would you consider acceptable?** ***(choose all that apply)***

A. □ Resection and Reanastomosis

B. □ Primary Closure of Each Injury Individually

C. □ Resection of Tissue between Injuries and Primary Closure

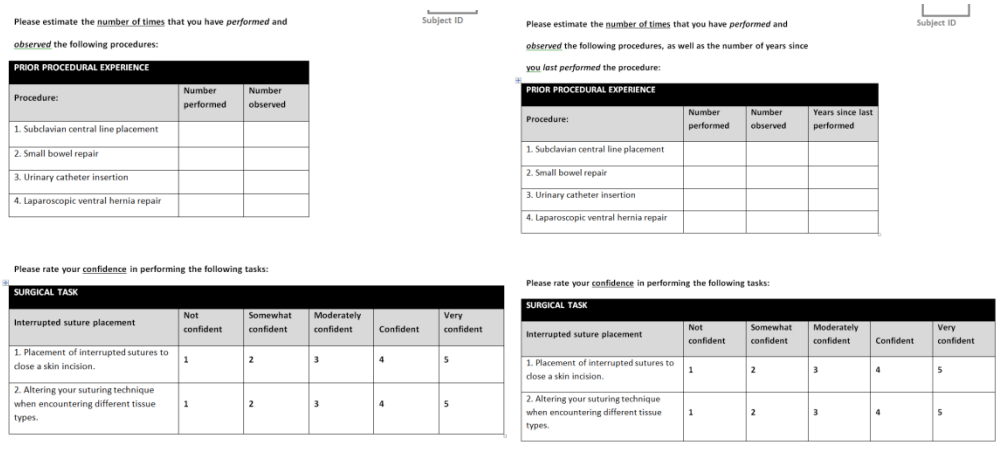
D. □ Incision of Tissue between Injuries and Primary Closure

E. □ Other (*please specify*)

*Figure 22: Example of survey given to general surgeons to develop scoring system*

### *Minor changes to Retired Surgeons' Workbook*

The retired surgeons' workbook was modified to include questions regarding the number of years since each retired surgeon has performed each procedure (Figure X). This allows for a clearer understanding of the experience level each retired surgeon has and how long it has been since they have had any exposure to that procedure type.



Please estimate the number of times that you have *performed* and *observed* the following procedures:

Subject ID

| PRIOR PROCEDURAL EXPERIENCE | | |
|---|---|---|
| Procedure: | Number performed | Number observed |
| 1. Subclavian central line placement | | |
| 2. Small bowel repair | | |
| 3. Urinary catheter insertion | | |
| 4. Laparoscopic ventral hernia repair | | |

Please rate your confidence in performing the following tasks:

| SURGICAL TASK | | | | | |
|---|---|---|---|---|---|
| Interrupted suture placement | Not confident | Somewhat confident | Moderately confident | Confident | Very confident |
| 1. Placement of interrupted sutures to close a skin incision. | 1 | 2 | 3 | 4 | 5 |
| 2. Altering your suturing technique when encountering different tissue types. | 1 | 2 | 3 | 4 | 5 |

Please estimate the number of times that you have *performed* and *observed* the following procedures, as well as the number of years since you *last performed* the procedure:

Subject ID

| PRIOR PROCEDURAL EXPERIENCE | | | |
|---|---|---|---|
| Procedure: | Number performed | Number observed | Years since last performed |
| 1. Subclavian central line placement | | | |
| 2. Small bowel repair | | | |
| 3. Urinary catheter insertion | | | |
| 4. Laparoscopic ventral hernia repair | | | |

Please rate your confidence in performing the following tasks:

| SURGICAL TASK | | | | | |
|---|---|---|---|---|---|
| Interrupted suture placement | Not confident | Somewhat confident | Moderately confident | Confident | Very confident |
| 1. Placement of interrupted sutures to close a skin incision. | 1 | 2 | 3 | 4 | 5 |
| 2. Altering your suturing technique when encountering different tissue types. | 1 | 2 | 3 | 4 | 5 |

*Figure 23: Modification to Retired Surgeons' Participant Workbooks. An additional column was added to the original workbook (Left) to include the number of years since each procedure was performed (Right)*

***Retired Surgeon Post-Collection Survey***

Retired surgeon participants will receive a post-collection survey approximately one week after their participation to understand what surgical knowledge came back to them in the days following the data collection. This document will be loosely modeled after the Retired Surgeon Workbook. We are currently developing what the survey should look like and what areas it should address. We will be submitting the document for IRB approval shortly after the New Year.

***Retired Surgeon Post-Collection Survey***

Retired surgeon participants will receive a post-collection phone survey approximately five days after their participation to understand what surgical knowledge came back to them in the days following the data collection. This document was originally modeled after the Retired surgeon workbook. After much discussion we realized it did not achieve the intended goal of investigating the clinical knowledge that returned to a surgeon. We have developed a new survey that is now IRB approved.

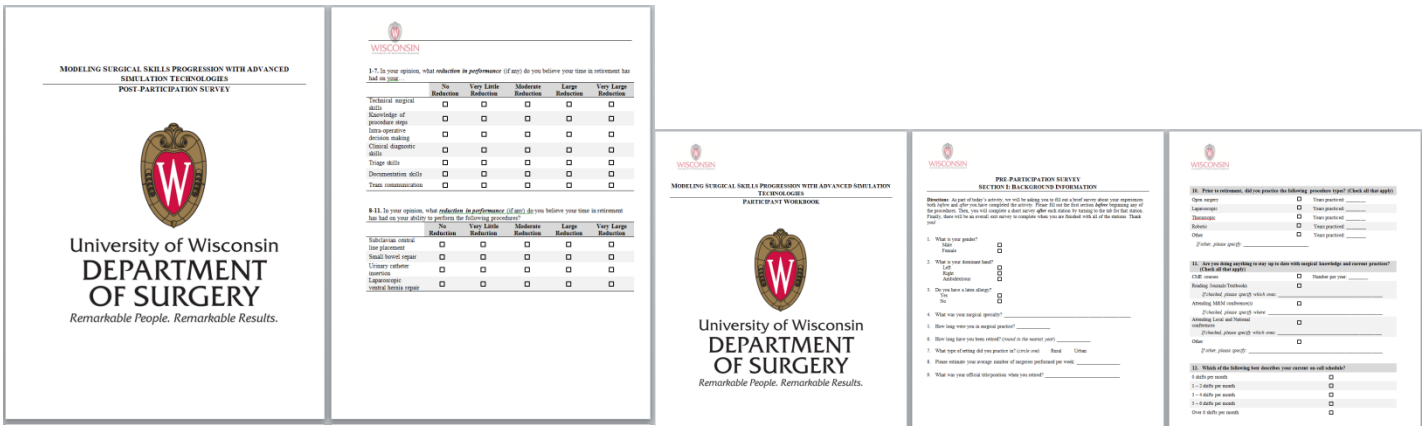



*Figure 24: Development of Retired Surgeon Workbook (Top) Modeled After Retired Surgeon Workbook (Bottom)*

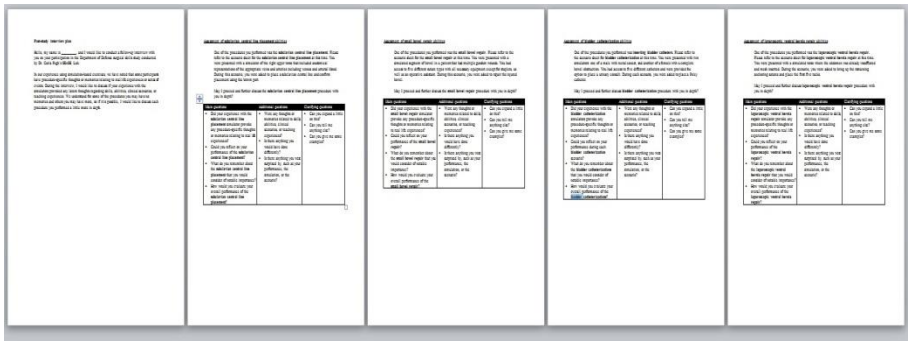


*Figure 25: Shown above is the post procedure interview performed on retired surgeons to better understand what knowledge returns one to three days after a procedure*

***New Data Collection Method***

For the central line station, we realize the value of attaining needle angle used to access the subclavian venous system. Proper needle angle is essential as using too large of an angle can lead to significant patient morbidity. As such, we have sensitized the syringe attached to the needle and the simulator so that we may accurately measure this needle angle.

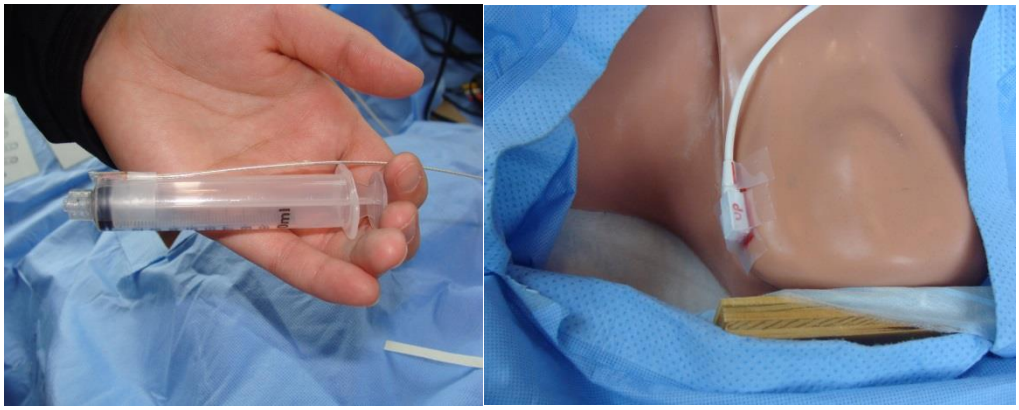


*Figure 26: New sensorization of syringe and simulator to acquire needle angles*

***Additional Staffing***

One additional staff member has been added to the research team over the course of the last year. He brings a specific background and expertise to the team, which will overall assist with addressing the grant's objectives.

**Hossein Mohamadipanah:**
Hossein Mohamadipanah received his PhD in Mechanical and Aerospace Engineering from Oklahoma State University. His main interests include machine learning and medical robotics in the training and assessment of surgical skills. With his background, he will have a critical role in the extensive and high-level analyses of motion data collected from participants in this study. In addition, he will continue cross-analyses of clinical simulation performance and virtual reality performance.

# Key Research Accomplishments

Table 1 below provides a bulleted list of the project accomplishments as organized by the quarter they were achieved. Additional information such as research citations and specific achievement dates have been provided whenever they were available.

**Table 1.** ***List of Project Accomplishments per Quarter***

| # | Task | Quarter |
|---|---|---|
| 1 | Continued updating "Station Manager Binders" to reflect best practices including more detailed inventory and organization to the mobile units. New protocols were documented for how to set up and run each of the four clinical stations. Pre- and post- collection checklists were also added to ensure thoroughness and organization. Binder contents were specialized and further detailed for each specific station. | One |
| 2 | Updated Survey Workbook to make clear resident Post-Graduate Year, clinical and research years completed, as well as past procedural experience. | One |
| 3 | Updated REDCap Data Base for 2015 data coding. Data variables clarified to reflect station changes, new relevant time points, and significant common events. All modules re-organized for enhanced ease of data import and export by researchers. | One |
| 4 | Updated LVH Pretest Instructions to gather more informative and clear information on hernia port placement. The pretest now differentiates between ports for instruments and ports for cameras.<br>It also asks participants to assign the order in which they would place the ports used. | One |
| 5 | Hired 4 new undergraduate students to assist in 2015 data collection and data coding. | One |
| 6 | Continued training and cross training new personnel into Clinical Station Teams as the needs for scheduling the data collections changed based on location and dates. These teams were organized to include station leaders, experienced and novice researchers. | One |
| 7 | Continued to Train Staff on Using Audio/Video transcription software Transana. Software has been used for coding and categorizing quantitative and qualitative features from verbal and video recorded data. Three undergraduate students have been fully trained on using software and have completed transcribing audio data from three of the four clinical stations from 2014. | One |
| 8 | Submitted IRB update for approval to add retired and practicing surgeons as well as medical students. | One |
| 9 | Continued ongoing data analysis for further conference abstract and manuscript submissions. | One |
| 10 | Conducted pilot on April 30, 2015. Goals of this pilot were to familiarize new personnel to stations, test station enhancements and test new suture task which was incorporated into Station A. | One |
| 11 | Began second year data collection on May 26, 2015. Collected from 7 residents from UW Madison; all of which were returning participants. | One |
| 12 | Recruitment efforts for summer 2015 include capturing as many returning residents as possible as well as recruiting new, incoming research residents. | One |
| 13 | Updates to Common Events Checklist for Station B to account for the different types of repairs possible. Researchers are directed to a list of questions dependent on whether the participant performed a bowel anastomosis or a primary enterorrhaphy to repair the injured portion of small bowel. | One |
| 14 | Collected Data from 46 General Surgery Residents from 7 different residency programs across the Midwest. 16 of these participants completed the data collection for the 2nd year in a row, while 30 of these participants were new to the study. | Two |

**Table 1.** ***List of Project Accomplishments per Quarter***

| # | Task | Quarter |
|---|---|---|
| 15 | Added 2 New Programs to Our Study. Washington University in St. Louis, MO and the Medical College of Wisconsin (MCW) both participated for the first time in our study and expressed great interest in continuing participation in the study next year. | Two |
| 16 | Began Planning for Retired Surgeons Data Collection beginning this November at the Wisconsin Surgical Society (WSS) conference. We have created marketing packets to recruit participants, booked a venue and began planning for these participants. | Two |
| 17 | Hired and Trained 1 New Undergraduate Worker to assist in the transcription of the audio and video data collected from 2015 data collections. | Two |
| 18 | Hired and Trained 1 New Researcher who assisted in the summer data collections and helped run our simulation stations. | Two |
| 19 | Hired a New Post Doctorate Researcher to take leadership positions in the upper level organization and analysis of the data collected from 2014 and 2015 data collections. Hossein Mohamadipanah is in the process of being fully trained on the central line catheterization station, the LVH repair station, and the virtual reality station | Two |
| 20 | Engaged in a New Collaboration with Parmesh Ramanathan, an ECE professor in signal processing from the Department of Computer Sciences. Him and his student will be assisting us in organizing and analyzing the vast amount of motion data collected from our small bowel repair station. | Two |
| 21 | Updated Transana Transcription Software with new and improved features to assist our undergraduate students in the transcription and coding of 2015 audio and video data. | Two |
| 22 | Redefined the Clinical Station Teams for the analysis of station data. These teams incorporated experienced members of the lab with new members of the lab. These teams will meet individually once a month to discuss progress made and future plans for analyses. | Two |
| 23 | Redefined the Virtual Reality Station Teams for the analysis of station E and F data. These teams, like the clinical station teams, incorporate experienced and new members of the lab. They will also meet once a month to discuss progress made and future plans for analyses. | Two |
| 24 | Submitted and Received Approval on an IRB change of protocol to add retired and practicing surgeons as well as medical students to our study. This includes the approval of our new survey materials that are directed towards retired surgeons and medical students. | Two |
| 25 | Continued ongoing data analysis for further conference abstract and manuscript submissions. | Two |
| 26 | Collected Expert Data from the Urinary Catheterization station as well as the Central Line Catheterization station. This expert feedback and data will help us compare pre-mastery performance data collected from residents to post-mastery performance data. It will also help us further refine stations to be as realistic as possible for retired surgeon data collections and for future resident data collections. | Two |
| 27 | Recruited Experts to Participate in the Small Bowel Repair station as well as the LVH Repair station. These collections will take place in September and October of 2015. We will continue to recruit experts from UW Madison to perform our stations. | Two |
| 28 | Collected Data from 4 Retired General Surgeons here at UW Madison. Data from retired surgeons will be used as a comparison of pre- vs. post-mastery skills decay. | Three |
| 29 | Created a Retired Surgeons' RedCAP database for the coding of all retired surgeon data-separate from the database where resident data is coded. | Three |
| 30 | Recruited Retired Participants from Wisconsin Surgical Society (WSS) Conference in Kohler, WI. Succeeded in getting the names and email addresses of 7 potential retired general surgeons who are interested in participating in the study. | Three |
| 31 | Continued Recruiting for Retired Surgeons Data Collection with individuals interested from the WSS Conference, as well as referrals from past participants. | Three |

**Table 1.** ***List of Project Accomplishments per Quarter***

| # | Task | Quarter |
|---|---|---|
| 32 | Hired and Trained 1 New Undergraduate Worker to assist in the transcription of the audio and video data collected from 2015 data collections as well as the coding of 2015 Urinary Catheterization data. | Three |
| 33 | Discussed future plans and analyses related to this study at an all-day "DoD Retreat". Data was presented to the group in regards to our resident demographics, clinical stations, as well as virtual reality stations. Collaborators Felix Huang and Sandro Mussa-Ivaldi from Northwestern joined in the discussion with our lab in planning future analyses and the overall future of the study. | Three |
| 34 | Trained New Undergraduate Students on Transana software to assist in the transcription and coding of 2015 audio and video data | Three |
| 35 | Continued ongoing data analysis for further conference abstract and manuscript submissions. | Three |
| 36 | Collected Expert Data from the Laparoscopic Ventral Hernia Repair station. This expert feedback and data will help us compare pre-mastery performance data collected from residents to post-mastery performance data. It will also help us further refine stations to be as realistic as possible for retired surgeon data collections and for future resident data collections. | Three |
| 37 | Recruited Expert to Participate in the Small Bowel Repair station. This collection will take place in January of 2016. We will continue to recruit experts from UW Madison to perform our stations. | Three |
| 38 | Recruited Experts to Validate scoring algorithms for performance on the Subclavian Central Line Insertion, Small Bowel Repair, and Urinary Catheter Insertion. Validation of these scoring algorithms will continue into Spring of 2016. | Three |
| 39 | Collected Data from 4 Retired General Surgeons here at UW Madison. Data from retired surgeons will be used as a comparison of pre- vs. post-mastery skills decay. | Four |
| 40 | Created a 2016 RedCAP database for the coding of all 2016 resident data. | Four |
| 41 | Recruited Retired Participants from the Wisconsin Medical Society and the American College of Surgeons. Succeeded in getting the names and addresses of over 200 potential retired general surgeons in Wisconsin and Illinois. | Four |
| 42 | Hired and Trained 3 New Undergraduate Workers to assist in the collection and coding of retired surgeon data, as well as 2016 resident data. | Four |
| 43 | Trained Undergraduate Students on running clinical simulation stations as well as motion monitor software. | Four |
| 44 | Continued ongoing data analysis for further conference abstract and manuscript submissions. | Four |
| 45 | Recruited Experts to Participate in the full data collection this upcoming summer. | Four |
| 46 | Recruited Experts to Validate scoring algorithms for performance on the Subclavian Central Line Insertion, Small Bowel Repair, Urinary Catheter Insertion, and Laparoscopic Ventral Hernia Repair. Analyses of these scoring algorithms will continue into Summer of 2016. | Four |
| 47 | Presented: 4 abstracts to the American Surgical Congress in 2016 | Four |

# Reportable Outcomes

Table 2 provides a bulleted summary of the reportable outcomes achieved over the past year. These outcomes include specific methodological improvements, new prototypes such as the…, and also specific products such as conference presentations, research papers, assessment instruments, and research protocols. Specific citations have been provided when appropriate.

**Table 2.** ***List of Reportable Outcomes per Quarter (Type: Product or Methodology)***

| # | Type | Outcome | Quarter |
|---|---|---|---|
| 1 | Methodology | Station A: Subclavian Central Line. The general setup for this station remained the same; however, a new task was added to the time rotation for this station's effort. An additional camera was affixed to a post mounted to this station's table to capture a close-up view of the participant's placement of needles on the simulation model. This assists greatly in the post-processing video analysis of correct needle placement. | One |
| 2 | Product | Suturing Task. An additional task was added to the clinical procedural scenarios. This task is an isolated and constrained task of placing 3 interrupted sutures into body tissue mimics using an instrument tying technique. This work is based off of a task developed and refined in Anne-Lise D'Angelo's NIH F32 training grant project using the Variable Tissue Simulator. The task simulates differing levels of task complexity by presenting two different materials to suture: rubber balloon (dense connective tissue), tissue paper (friable tissue). The addition of this station is highly useful in establishing a baseline of motor performance in suturing while in an isolated contextual environment. This can then be used as a comparison to identify differences in performance when suturing is investigated in the performance of the Bowel Anastomosis station. Another benefit offered by this station comes from the data analysis methods refined for D'Angelo's experimental results. The suture board presented here is identical to that of her project, so the analysis of the motion capture data matches very well. The analysis programs written for her project can be directly applied to data collected with this additional station task.<br>The performance of this Suturing Task was added to Station A because the Central Line placement task performance is typically fast for a participant. The spare time compared to other stations was a good place to add a second task, since participants are already wired into the motion capture system. The Suturing Task fixture was fabricated to be placed directly on top of the Central Line fixture, facilitating rapid change-overs. The workspace provides participants with a suture board containing materials and trays that hold necessary instruments. Additionally, a camera mounted to a support post captures a close-up view of the participant's suturing actions. | One |
| 3 | Methodology | Station B: Bowel Anastomosis. An additional camera was placed into this station's workspace to capture close-up views of the participant's hand movements as they perform the anastomosis task. This helps to provide greater detail of the bowel exploration and specific suturing methods participants choose to use during the task execution. The camera is affixed to a post mounted to the station's table. This is located near the right shoulder of the experimenter assistant that interacts with the subject. | One |
| 4 | Product | Station C: Urinary Catheterization. Based on feedback obtained from focus group interviews with past participants, this station underwent a major redesign | One |

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| | | in model positioning and equipment placement. First, the orientation of the pelvic model was placed on the table in a fashion to mimic the positioning of a patient lying on a bed. This better simulated the leaned over position the participant would have to do if in a patient's room. Second, a new catheter kit was made to better match the way a clinician would place a Foley kit between a patient's legs prior to starting a urinary catheterization. The kit approximates the purchased kit and also facilitates rapid changeovers because it can be picked up and switched out with matching kits that contain different size catheters that can be requested. Additionally, a close-up camera and mount was added to this station to better capture the detail in the participant's catheter insertion. | |
| 5 | Product | Addition of Suture Task In order to further examine the components of some of the more complicated manual procedures such as the bowel anastomosis, we have added a short suture task in which participants will suture together two pieces of material that simulate frail tissue and firmer skin tissue. The hand technique, efficiency and pauses will be analyzed. | One |
| 6 | Product | Addition of Close up Cameras to three of the four clinical stations. These allow for a more detailed, focused view of the scene and assist in coding errors and events. They each have a standardized position/view and are manually focused so that participant movement does not blur the view of the simulation. | One |
| 7 | Product | Updates to the Urinary Catheterization Station<br>a. Simulation models turned sideways (no longer facing edge of table) to mimic position of actual patient awaiting catheter insertion.<br>b. Two models used for catheterization instead of three due to time constraints.<br>c. Vaginal ring added to female simulator to restrict access to urethra; previously sutures were used to restric access, however these were unrealistic and prone to breaking.<br>d. Yellow and red colored water instead of clear water used to represent normal and bloody urine return, respectively.<br>e. Drainage bags removed from ports to increase participant turn-over and facilitate station clean-up.<br>f. Catheter boxes/kits created to replace catheter stand. | One |
| 8 | Product | Modified Protocol to Standardize POV Cameras Video glasses with low image quality were retired and replaced by additional head-mounted cameras. These cameras were set up to have a better focus and better image quality than previously recorded point-of-view video data. | One |
| 9 | Product | Documentation of Technological Protocols<br>With the addition of new equipment such as the close-up cameras, and standardization of protocols with head cameras and camera mounting, a number of new training documents were created. These cover in detail the physical setup of technology devices, placement in the operating workspace, software configurations, and use during data collections. Each of the station personnel responsible for setup has been trained in equipment using these instructions. Highlighted below are portions of documents concerning head and close-up camera setup. | One |
| 10 | Product | Station C: Urinary Catheterization. One of the scenarios at this station involves a patient with Benign Prostatic Hypertrophy (BPH). Because current market bladder catheterization models do not account for this variation in patient anatomy, we are currently developing a model that improves on our current BPH one that would evaluate catheter insertion technique and procedural decision | Two |

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| | | making. The current BPH model was originally developed as a modification to an available market bladder. We are interested in improving the realism of the model, so that the struggles healthcare providers face when placing a catheter in a patient with BPH are more accurate in feel and location when using our BPH model. Recently, 8 urology residents tested out the model to see if the model replicated a real experience with a patient experiencing BPH. We are hoping that this model replaces the current one during 2016 data collection. | |
| 11 | Product | Station Narratives Station A: Central Line Placement. The introduction narrative that is read aloud by researchers at Station A was shortened. This was done because participants were getting confused from all of the information presented to them in the beginning of the station. Information that was not considered pertinent was eliminated from the narrative in order to keep residents present in the situation. | Two |
| 12 | Methodology | Station B: Bowel Anastomosis. Originally the station involved residents using clips to hold the bowel as they performed resections and anastomoses. For the purposes of understanding resident performance more through guiding and instructing a researcher, an assistant researcher was placed at the Bowel Anastamosis station. By introducing the role of an assistant to the resident at this station, the resident could interact with them and provide more of their knowledge verbally through direction. | Two |
| 13 | Methodology | Station C: Urinary Catheterization. In order to better assess resident decision making, this station underwent a redesign in equipment placement. In 2014, residents were able to see all catheter options available to them. This year residents were required to vocalize their catheter choice without visualization of the catheters ahead of time. Only if residents were unable to articulate their decision did we provide a list of catheter options. | Two |
| 14 | Product | Documentation Station B: Bowel Anastomosis. In order to improve post-performance analysis of bowel repairs, the station's common events checklist was revamped to consider the different choices residents made, including planned layers, suture type, stitch type, completeness, and general procedure steps. This level of detail will also expedite statistical analyses performed within the station and across stations. | Two |
| 15 | Product | Station C. Urinary Catheterization. Based on experiences researchers have had with residents in previous data collections on Station C, a Frequently Asked Questions document was created to include questions that participants frequently ask about the models and urine output. By making this document, researchers would have standard response options when prompted with these frequent questions. | Two |
| 16 | Product | Resident Participant Workbook Addition. The resident workbook was supplemented this year with questions regarding the number of procedures performed and observed by each resident. This allows for a clearer understanding of the experience level each resident has and what previous experience they have with each station. Additionally, the residents were asked to rate their confidence in different suturing techniques and with different tissue types. | Two |
| 17 | Product | Minor Changes to Resident Participant Workbooks.<br>• Resident participant workbook pre-surveys were reorganized and reworded so that questions were clearer and also to clarify follow-up questions.<br>• Resident participant final exit surveys were modified to include questions regarding whether or not they would use training materials while they were | Two |

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| 18 | Product | Retired Surgeon Workbooks. The retired surgeon workbooks were developed based on the resident participant workbooks; however, the survey questions were modified to match a retired surgeon's experience and lifestyle. The goal was to keep as much information in the retired surgeon workbooks the same as the resident participant ones so that analyses could be performed across groups. The workbook and its modifications were submitted and approved by the University of Wisconsin Institutional Review Board. | Two |
| 19 | Product | Station A: Central Line Catheterization. In a retired surgeon data collection, we tried adding an extra camera to the overhead frame for additional methods of analysis. This additional camera was not linked to motion monitor but provided a better quality overhead view of the participant and surrounding scene. The recordings from this camera were used to test a new data analysis methodology for instrument tracking. | Three |
| 20 | Methodology | Lucas-Kanade Template Matching Tracking Algorithm. Because we have a significant amount of data in video format, we have started using the Lucas-Kanade algorithm to automate the identification of instruments. It is based on template matching between two consecutive frames and uses multiple parameters to identify transformation of feature frames. We were able to test this algorithm on Station A with the scalpel used to perform the central line catheterization (Figure X). | Three |
| 21 | Methodology | Station Set-up and Pre-Collection Checklist. In order to improve data collections and ensure each source of data (sensors, cameras, etc.) is working correctly prior to participant collection, a pre-collection checklist was created for each station (Figure X). It is currently still under review by the research team, and includes but is not limited to: working sensors, close-up cameras, scene cameras, and presence of narratives. | Three |
| 22 | Product | The retired surgeons' workbook was modified to include questions regarding the number of years since each retired surgeon has performed each procedure. This allows for a clearer understanding of the experience level each retired surgeon has and how long it has been since they have had any exposure to that procedure type. | Three |
| 23 | Methodology | Retired surgeon participants will receive a post-collection survey approximately one week after their participation to understand what surgical knowledge came back to them in the days following the data collection. This document will be loosely modeled after the Retired Surgeon Workbook. We are currently developing what the survey should look like and what areas it should address. We will be submitting the document for IRB approval shortly after the new year. | Three |
| 24 | Methodology | Point system: Clinical Stations. In order to explore skills decay through multiple avenues, a point system is in development by use Cognitive Task Analysis. Essential portions of clinical procedures were placed on a Likert scale and board certified general surgeons of various specialty were asked to rate the importance of each step on a survey. Once data collection is complete, we will validate the scores statistically and work to assign points for performance of each procedure. Participants will then be assigned a point value based on their performance and scores will be compared. | Four |
| 25 | Methodology | Retired Surgeon Post-Collection Survey. Retired surgeon participants will receive a post-collection phone survey approximately seven days after their participation to understand what surgical knowledge came back to them in the days following the data collection. This document was originally modeled after | Four |

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| | | the Retired surgeon workbook. After much discussion we realized it did not achieve the intended goal of investigating the clinical knowledge that returned to a surgeon. We have developed a new survey that is now IRB approved. | |
| 26 | Methodology | New Data Collection Method For the central line station, we realize the value of attaining needle angle used to access the subclavian venous system. Proper needle angle is essential as using too large of an angle can lead to significant patient morbidity. As such, we have sensitized the syringe attached to the needle and the simulator so that we may accurately measure this needle angle. | Four |

# Final Conclusions

Year three of the project has included a number of significant steps towards meeting the four key study objectives outlined by our original SoW. Specifically, the team has successfully completed the second year of data collection; refined the simulation stations for the initial and future data collections; analyzed performance on multiple stations; and disseminated our preliminary work in the form of several papers and presentations. We have moved towards collecting data from retired surgeons and completing our final year of data collections with research residents. Using the no cost extension to finalize our data analysis and move towards completing work on all four areas of our SoW will be imperative to the final portion of our research.

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