Second Milestone Report

Fundamentals of Robotic Surgery:
Consensus Conference on Curriculum

Conducted by:
Minimally Invasive Robotics Association*
Florida Hospital Nicholson Center**

Locations:

Florida Hospital Nicholson Center
Celebration, Florida
April 29-30, 2012

University of Minnesota Medical School
Minneapolis, MN
August 17-18, 2012

Principal Investigators:
R.M. Satava, University of Washington School of Medicine, Seattle, WA
R.D. Smith, Florida Hospital Nicholson Center, Celebration, FL
V.R. Patel, Florida Hospital, Global Robotics Institute, Celebration, FL

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* This work was supported by an unrestricted educational grant through the Minimally Invasive Robotics Association from Intuitive Surgical Incorporated.

** This effort was also sponsored by the Department of the Army, Award Number W81XWH-11-2-0158 to the recipient Adventist Health System/Sunbelt, Inc., Florida Hospital Nicholson Center. "The U.S. Army Medical Research Acquisition Activity, 820 Chandler Street, Fort Detrick MD 21702-5014 is the awarding and administering acquisition office." The content of the information does not necessarily reflect the position or the policy of the Government, and no official endorsement should be inferred. For purposes of this article, information includes news releases, articles, manuscripts, brochures, advertisements, still and motion pictures, speeches, trade association proceedings, etc. The U.S. Army Medical Research and Materiel Command (USAMRMC) shall be notified by recipient prior to release to the public of planned news releases, planned publicity, advertising material concerning grant/cooperative agreement work, and planned presentations to scientific meetings.

SECTION 1. COGNITIVE SKILLS AND DIDACTIC INSTRUCTIONS FOR PSYCHOMOTOR SKILLS AND TEAM TRAINING & COMMUNICATION SKILLS

I. INTRODUCTION TO ROBOTIC SYSTEMS AS APPLIED TO SURGERY

A. GENERAL PRINCIPLES

Background: Many randomized trials have demonstrated the benefits of Minimally Invasive or Laparoscopic Surgery over traditional open surgery. The use of laparoscopic techniques has penetrated deeply in some specialties, such as urology, gynecology and cardiac surgery, and only slightly into other specialties, such as gastrointestinal surgery and Otolaryngology. This is because Laparoscopic Surgery is very difficult to perform. Indeed, many Surgeons never overcome the inherent limitations of Laparoscopic Surgery. Specifically, Laparoscopic Surgery poses the following barriers to performing Minimally Invasive Operations:

1) Two Dimensional Imaging - Traditional video laparoscopes project two dimensional images of the operative field onto traditional video monitors. Although Laparoscopic Surgeons learn to interpret monocular cues such as shading, aerial perspective, relative size and occlusion to indirectly appreciate depth perception, This requires great concentration and proves very tiring and anxiety provoking;

2)Motion Reversal ("the fulcrum effect") – the laparoscopic trocar through which instruments are inserted into the operative site, such as abdomen, chest, etc acts as a fulcrum causing reversal of the surgeon's hand motions relative to the motion of the tip of the surgical instruments. Moving the handle of the laparoscopic instrument down causes the tip of the instrument to go up;

3) Motion Amplification - The laparoscopic trocar also acts as a lever arm. Generally, the majority of the laparoscopic instrument is inside the patient and fulcrum. As a result of the lever action, hand motions of the surgeon are amplified generating greater excursion arcs of the instrument tips. A one inch displacement of the laparoscopic instrument's handle might cause a three inch displacement of the instruments effector tip. This also results in tremor of the tip of the instrument

4) Limited Degrees of Freedom (DOF) in Instrument Motion – Laparoscopic Instruments are straight. The surgeon can move the instruments up/down, right/left, in/out and rotate them each of those axes (pitch, yaw and roll), resulting in the classic "six degrees of freedom" (6DOF). Often the trocars force the instruments to assume a parallel orientation. This limits the types of motion and the parallel alignment of the instruments make complex motions that are not in the direct axis of the instrument shaft, such as instrument tying, very difficult;

5) Unstable Camera Platform – Often during Laparoscopic Operations, the Camera Holder stands in uncomfortable positions, becomes tired and permits the camera to wander from the operative field. Moreover, the Surgeon lacks direct control of the camera and may need to frequently let go of one of the laparoscopic instruments to manually adjust the camera position; and

6) Poor ergonomics – With traditional laparoscopic towers holding the monitor and electronics equipment, the surgeon often stands in poor ergonomic positions. Unless the monitor is adjusted to the right height and placed directly in the surgeon's line of vision (i.e., a coherent eye, hand, monitor axis), the surgeon often stands in contorted positions increasing strain on his/her neck, back, shoulders and hips. Similarly, if the table is not adjusted to the proper height, the surgeon's arms are forced to assume tiresome positions. Indeed, these unnatural positions result in the surgeon operating mainly with the awkward motions of their elbows and shoulders (instead of the delicate

motions of their hands and wrists), causing many orthopedic injuries in Laparoscopic Surgeons such as rotator cuff tears.

B. ADVANTAGES OF ROBOTIC SURGICAL SYSTEMS:

Robotic Surgical Systems are computer systems (or information systems) with data input (visually from the monitor, auditorily through the speakers and through haptics (the sense of touch) through the manipulator handles. The surgeon in control then sends information to the team (verbal commands), or data to the instrument(s) by moving the manipulator handles. Because all the data must go through the computer, the robotic system can amplify this information (data) to enhance the surgeon's performance beyond normal human physical limitations. For example, the video image can be increased in size to give the surgeon magnified vision, or can use "false coloring" (infra-red, ultraviolet, etc) to "see" structures, properties (e.g. heat) and functions (e.g. blood flow) not visible to the human eye. Hand motion scaling and tremor elimination allows the surgeon with a precision of less than 100 microns, overcome these inherent limitations of Laparoscopic Surgery and, thereby, facilitate the performance of Minimally Invasive Surgery. Hopefully, this facilitation will encourage more surgeons to offer Minimally Invasive Procedures to their patients.

A Psychomotor skill enhancement of, Robotic Surgical Systems:

1) provide high definition, scalable and the option for three dimensional imaging – the image is transmitted through a telescope contains one or two video cameras. If the camera system is stereoscopic, it will project a true three dimensional video image using a binocular imaging system much like field binoculars. Viewing the operative field in three dimensions increases the accuracy of depth perception, and may result in increased precision; it also has proven to be less tiring and generates less anxiety during the operation;

2) obviate motion reversal (eliminates the "fulcrum effect") – the Robotic Instrument Controllers (Master Controllers) translate with great precision the motions of the surgeon's hands to the tip of the surgical instruments. Moving the surgeon's hand up, for example, moves the surgical instrument up. This returns the natural intuition of hand motion to the surgeon, and greatly simplifies the performance of complex tasks with the surgical instruments;

3) permit favorable motion scaling – the Surgeon can select specific levels of motion scaling for both the instruments and the visual field. The surgeon might select, for example, a one to one translation of his hand motions to motion of the instrument or a 3 to 1 ratio or a 10 to 1 ratio; likewise the visual field can be increased by 2, 3 or even 10 fold.

4) incorporates tremor elimination – the computer interface serves to filter out tremors in the surgeon's hands making very delicate motions of the robotic instruments possible; the limit of human performance for precision and accuracy by the very best of surgeons is approximately 200microns, however with robotic systems this precision can be improved by 5-10 fold for even the average surgeon.

6) provide 7 DOF in motion of the surgical instruments- in addition to the standard 6DOF of laparoscopy, the incorporation of a wrist like joint at the end of the end-effector permits movement of the instrument tip away from the long axis of the instruments. This added freedom of motion overcomes parallax issues and facilitates complex motions such as dissection, suturing and instrument tying;

7) maintain a stable camera platform controlled by the surgeon – The Surgeon moves the camera telescope to the position offering the best visualization of the operative field The operative field of view remains fixed in place without tremor, rotation or migration while the Surgeon manipulates the other surgical instruments to perform the operation. A; . Also the surgeon does not have to continually try to instruct the assistant camera-holder exactly where to center the camera, thereby improving efficiency eliminating communication errors to the assistant;

8) provides excellent ergonomically correct positioning for the surgeon – The surgeon adjusts

the console to the ergonomic positions that are most comfortable, then sits during the. For example on the current systems, the binocular visualization system moves up and down to provide a comfortable sitting position. The Surgeon rests his/her forearms on a padded rest permitting the fore arm, wrists and fingers to move freeing in controlling the motions of the instruments. In an ergonomically advantageous position

B. Inherent advantages of a robotic surgery system: In addition to overcoming the limitations of Laparoscopic Surgery, Surgical Robotic Systems offer the intrinsic features of Robotic Systems such as advanced safety mechanisms. These include:

- 1) redundancy (multiple sensing mechanisms and high precision actuators suitable for surgical use to insure that if one component malfunctions, there are other backup components to continue the operation safely
- 2) fault tolerance (the system recognizes errors and alerts the surgeon, allowing the operator to correct the error or to terminate the procedure before an error patient injury could occur),
- 3) graceful degradation (if a malfunction occurs, the component or the system doesn't totally fail instantly, rather a slow step-wise shutting down of the system occurs (e.g.. an error in one robotic arm does not shut down the whole system; it merely slowly and safely degrades system performance by slowly shutting down the one arm.)

C. COMPONENTS OF ROBOTIC SYSTEMS

Components of the system and their functions:

Definition: A typical robotic surgical system consists of the following elements:

- The Surgeon's Console
- The Remote manipulator arms
- The visualization support system
- Accessories and their controls and cables and connectors

One or more surgeon(s) consoles control the surgical instruments at the operative field by using master manipulators while viewing a monitor presenting the operating environment. The surgeon console also integrates controls to configure the whole system and the ability to communicate with the rest of the operating team. Foot pedals and hand switches are available for system mode changes such as camera control or instrument operation.

A set of patient-side manipulators designed to pivot about the entry ports hold a variety of removable dexterous or flexible surgical instruments. These manipulators may be attached to passive articulating arms allowing their optimal positioning over the patient's body. A wide range of instruments for cutting, suturing, application of energy, and other needs can be attached and replaced during the procedure as required for the surgery.

The input to the surgeon's monitor is generated by a stereo-endoscopic vision system that includes the camera, electronics, and a separate monitor for the operating team and assistants. Additional console(s) may enable training, assistance, collaborative, or remote surgery.

Monitor Interface (including alerts/errors): Operating data and alerts are presented and superimposed on the visual field of the operating surgeon and secondary displays improving information awareness and making error detection easier.

Important events may also generate an audible alarm. For example, icons appear that report expired instruments, non-recognition of the instrument by the robot suggesting either adapter-arm connection issues or instrument-adapter connection issues, or which foot switch is being activated. Picture in picture capabilities also exist to allow the surgeon to simultaneously view additional surgery specific information.

Secondary Consoles: Secondary consoles allow for training, assistance, remote surgery, and surgeon collaboration. These console(s) allow control of the instruments and performance the procedure if delegated by the primary surgeon. A system mode change permits the control of surgical instruments to be transferred between consoles.

On screen annotations allow specific visual instructions such as indicating the planes of dissection or identification of target anatomy

Master-Slave relationship: Current robotic systems are not autonomous and unable to perform any function without the input of the operator; they merely translate surgeon commands into actions.

In the normal operating mode, the surgical instruments reproduce the surgeon's hand motions at a configurable scale. For example, the system could be configured to operate at a "fine" scale where 5mm of master motions produce 1mm of slave motion. The instruments maintain the same hand orientation regardless of motion scaling.

The camera is operated separately and differently from the remaining instruments. A mode switch disconnects the instruments (they will not move until you return to normal operation) and connects the camera to the both masters permitting change in camera position, orientation, and zoom. For example, moving both hands in/out will move the camera out/in, respectively (zoom).

The system will not operate if the masters and slaves relationship is disrupted by overpowering the controls.

Instruments (end-effectors) and accessories: Unlike laparoscopic instruments, robotic instruments allow for wristed motion at the instrument tip. A wide range of instruments exist and are being continuously updated. REFER to PRODUCT CATALOGUE

Energy Sources: There are a variety of thermal/energy sources including monopolar shears/paddles/hooks, bipolar graspers, ultrasonic shears, etc are available for robotic systems and each have their respective activation process.

Simulation and Communication Components: Because the robotic system is a computer-controlled information system, there are extraordinary potential for access, integration and implementation of all forms of information and data to be displayed on the monitor in real time. This includes full situational awareness of the current status of the patient (real-time vital signs, alerts, etc), archived data from the medical record (both text and images), simulation (including pre-operative warm-up exercises, pre-operative planning and surgical rehearsal), and image-guided surgery (with overlay of various pre-operative images such as CT scan, MRI scan, ultrasound, PET, etc).

In addition, the design, mechanism, and visualization of the robotic system can all be simulated. This affords the opportunity of less expensive training platforms and self-directed practice and surgical rehearsal. Simulation training can be performed with reality-based (RB) and virtual reality-based (VR) curricula. Dry lab (RB) training is critical for robot set-up, docking, patient positioning, understanding differences in suture material/size, and recognizing grasp effects of instruments on tissue phantoms. VR platforms exist to accelerate learning curves for instrument manipulation, clutching, camera movements, thermal cautery devices, knot-tying, warm-up, and some procedure-specific rehearsal. Evidence suggests that novices and experienced robotic surgeons derive a technical skills performance boost after simulation warm-up prior to actual surgical performance; thus, imbedding such a protocol before robotic surgery may be beneficial.

D. SYSTEM FUNCTIONALITY

Adjusting the Robotic Console Settings: The surgeon's console(s) provide a wide range of configurable options. Options may include: Console ergonomics, camera type, motion scaling, and haptic feedback, digital zoom, control of any secondary consoles, control of energy and other devices, and communications control.

A secure sign-on procedure may be available to automatically recall your configurable settings. This may be done via a menu in the console touch screen, at the secondary display, or may require operation of controls on the console.

Ergonomics (for surgeon at console). Hyperlink definition to Wikipedia: Prior to operating the instruments, it is essential to establish an operating workspace that permits free hand movement, comfortable body posture, and optimal visualization.

Secondary hand and/ or feet controls may permit reconfiguration of the surgeon's workspace to avoid collisions with console hardware, or with each other.

It is important that these controls are easily accessible and in positions where they are not accidentally activated.

An essential component to maintaining appropriate ergonomics is recognizing fatigue symptoms such as eye fatigue, or body part discomfort and taking immediate steps to alleviate it.

Operating Master Controllers: The master controllers allow control of the instruments and the endoscope. Surgeons obtain control of the instruments by grasping these controllers (i.e. using their thumb and index finger) only if their vision is engaged in the operating field (i.e. by having their forehead inside the view panel).

An inherent property of robotic systems is that when handling errors occur an alarm or message can be displayed and control of the system may be temporarily suspended until the error is resolved. For example, the system will not operate if the masters- slave relationship is disrupted by overpowering the controls. Applying too much pressure on the controllers will generate an error and temporary locking of the instrument. If this happens releasing the pressure and trying to move them gently again will usually fix the problem.

To operate the camera, instrument control must be paused while the field of view is being adjusted. For example camera control is activated through a switching mechanism (i.e. a foot pedal, hand switch, or voice command). Camera focus is also adjustable.

Indexing/clutching: Due to the motion scaling capability of the robotic system and changes in the field of view, operator hand controls may need to be periodically repositioned to the optimal operating position. Clutching is used when the master controllers reach their limits of movement (collide with the console walls or with each other) or the surgeon operating position becomes uncomfortable. During this adjustment the master controls move independently from the instruments while maintaining instrument orientation

Visualization Capabilities: In addition to providing a stable camera platform and navigation robotic systems may integrate advanced capabilities for visualization. This includes imaging beyond visual spectrum (i.e. near infrared), non-visual imaging (i.e. Ultrasound), and integration of pre-operative imaging. For example, the 3D high-definition endoscopes are available in multiple sizes, (for example, 12 mm and 8.5 mm diameters), different angular views (0, and 30 degree up and down), different angel of view (for example, wide-angle 60-degree field of view) and digital zooming (current system provides 5 levels of zoom).

Visualization systems typically have to be white balanced and calibrated for stereo visualization (stereopsis or 3D view) prior to the procedure using the appropriate calibration equipment (i.e. calibration block).

Motion Scaling: The robotic system has the capability of increasing (or decreasing) the distance the tip of an instrument moves relative to the distance the hand controller moves – referred to as motion scaling. This permits translation of large hand motions by the surgeon into small motions by the instrument. For example, a 3:1 scale factor translates 3 cm of movement at the master controllers to 1 cm of movement at the instrument tip.

Collision Avoidance: Because of the fulcrum nature of laparoscopic surgery instruments may collide both inside and outside the patient body and operator hand controls may collide with each other or the console. Collisions can be reduced by optimal trocar placement and robotic arm positioning at the beginning of the procedure.

If a collision is encountered adjustments may need to be made at the bedside by repositioning of the arm manipulators; similarly clutching of the master controllers will mitigate surgeon hand collisions

Arm Switching: Current Robotic systems may contain more than two arms; given that the surgeon can only control two of them at the same time a mechanism exists to exchange control between arms. For example, to swap arm control between the active and inactive arms, the console surgeon must activate the swapping switch. When such swapping occurs the master controllers must first assume the orientation of the new instrument before any motion is permitted. This ability also permits the use of inactive arms for retraction, stable camera platform, or other assistance.

System Operations: System operations begin with setting up the robot.

The different components of the system have to be connected to ensure functionality. This is followed by customization and configuration of the operating interfaces (initialization and preferences)

In order to maintain sterility disposable sterile barriers are required to cover the parts of the system that are within the operating field. Typically the console that controls the instruments is outside the sterile field; thus, the surgeon does not have immediate access to the bedside

Both the surgeon and the bedside assistant have the ability to disable all robotic system motion using stop buttons in the event of an emergency.

D. SPECIFIC PSYCHOMOTOR SKILLS AND TASKS

(see SECTION 2: PSYCHOMOTOR SKILLS and TASKS)

II. DIDACTIC INSTRUCTIONS FOR ROBOTIC SURGERY SYSTEMS

A. PRE-OPERATIVE PHASE

1. **Goals** – Take the necessary steps to conduct a safe, successful robotic operation in a timely manner and to minimize the possibility of errors that may arise at subsequent steps of the operation.

2. **Identifying structure of the robotic console and arms:** The system may have been connected by the operating team and its elements located in appropriate parts of the operating room. This includes:

- The Surgeon's Console
- The Remote manipulator arms
- The visualization support system
- Accessories and their controls and cables and connectors
- The surgeon should identify the components of the system (console, remote manipulator arms, visualization system, accessory control devices and control towers). It is also important to ensure that connections are correct, robotic, and accessory controls are accessible, and that the operating room is configured for safe operation.

A walk-around is recommended prior to the procedure to ensure all components are connected and cables are not likely to be disconnected by accident.

3. **Setting up the robotic system:** Setting up the system involves configuring components so that they will have the workspace required for the operation. Operational requirements are dependent on the particular case, surgeon discipline and preferences.

The set up specifically requires:

a. Calibration – of the camera, patient side manipulators and the master manipulators,

b. Configuration of patient arms according to the requirements of the procedure,
c. Selection of remaining user preferences

Upon configuration the appropriate checklist must be completed.

4. **Turning on the robot and calibration :** Surgeons have to ensure that all components of the robotic system they are using are powered on. A power-on self-check is typically performed automatically but its successful completion may have to be verified by the team.

A verification of the calibration process should be included in the checklist prior to positioning the robot arms. The power-on sequences should be completed with no accessories installed on the patient side manipulators.

A calibration failure may render the robot inoperative for surgery and will require maintenance to repair and recertify the robot for human surgery. To prevent conversion during human surgery, it is advisable to schedule system maintenance instead of attempting power-off/recalibration steps.

A robotic surgical system will recognize and interactively guide the user for some errors, but not all possible errors. Failed calibration and disconnected cables are detected and an audio alarm and message is displayed. However, if accessories remain installed on a training robot then calibration step may be "successfully" avoided. This must be manually monitored and indicated/assessed.

After system configuration the appropriate checklist item must be completed

ERRORS*:* The following errors will need to be specified for each particular robotic system

Turning on robot and calibration: no power, data or other cables, failure to calibrate

- Failure to calibrate the system
- Failure to appropriately connect the system components to ensure functionality
- Failure to recognize and address system error notifications

Checklist of the settings on the robot console (check & respond): doesn't perform list

- Failure to set or verify the appropriate console settings
- Failure to use the checklist

Ignoring or failing to recognize error messages

- Failure to recognize and address system error notifications

5. **Positioning of components - console, cart/arms, etc:** The various components of the robotic system must be positioned in a way that prevents collisions with other equipment or the patient. For example, in a cart based manipulator extended arms may interfere with or break floor or ceiling mounted equipment. Care must be taken to orient the arms in the recommended stowing position prior to moving the cart base. Practice and familiarization is needed to safely operate the cart around patients.

Positioning of the cart depends upon the surgical procedure and surgical preference. The visualization system must be positioned where the assistants/operating team can safely view, and interact with it.

The console should be positioned safely outside the sterile field such that the surgeon is able to view the operative field without having to step away from the console.

Poor patient positioning may lead to poor exposure or patient movement during the procedure that may compromise patient safety. The surgeon has to learn to use gravity to maximize exposure while preventing patient sliding on the operating table. A safe approach to prevent patient sliding / moving during surgery includes securing the patient well on the OR table and testing for patient sliding/ movement during table manipulations prior to draping the patient and docking the robot. This may identify the need for additional patient securing or the limits of position manipulations. Given that position changes cannot be made during the procedure when the robot is docked surgeons need to have adequate planning of how they will obtain exposure in the absence of position changes.

Moving the OR table after the robot is docked is an error and could potentially be prevented if the OR table is locked or its power cut (unplug) so that it cannot be moved inadvertently during surgery. If the table nevertheless gets moved the surgeon needs to examine the operative field and outside it to verify no injuries occurred. In addition, inadequate prepping may lead to contaminations of the operating field especially if draping has to be manipulated during the procedure. This can be prevented with wide prepping.

Upon configuration the appropriate checklist item must be completed.

ERRORS*:* Accurate attention to the positioning of personnel and equipment is critical:

- Incorrect positioning of anesthesia, assistants and nurses
- Incorrect positioning of patient bed, OR staff, and equipment that prevents access to needed parts of the patient
- Incorrect positioning of patient bed, OR staff, and equipment that leads to preventable collisions
- Incorrect positioning of patient that can result in patient movement during repositioning.
- Moving the operating table (purposefully or inadvertent) after docking

6**. Checklist of the settings on the robot console (check & respond):** The robot console configuration includes ergonomic positioning of (but not limited to):

- Ergonomic height of 3D viewer,
- Viewing configuration such that the surgeon sees a focused 3D view
- Location/configuration of seating
- Location/reconfiguration of foot controls where appropriate
- Location/reconfiguration of accessory controls,
- Location/reconfiguration of hand controls
- Location/reconfiguration (speaker and microphone volumes) of communication systems
- Motion scaling configuration for master-slave teleoperation
- Camera configuration/selection.

Upon completion of moving and configuring the system components, an appropriate checklist item should be completed.

ERRORS*:*

- Failure to set or verify the appropriate console settings
- Failure to use the checklist
- Wrong procedure or wrong site surgery

7. Draping of robot: Draping of the robotic arms should occur before the start of the case.

Attention should be given to avoid contamination of the draped arms while they are not being used. Drapes and sterile protections should not interfere with arm motions. Upon draping completion the system sterility should be verified (ie. No holes in drapes)

ERRORS:

- contaminating sterile drapes or operative field
- improper drape position which interferes with instruments or camera (e.g., docking and instrument exchanges, etc)
- Inadequate wide-area prepping

8. Patient transfer into operating room: No modifications are needed for the transfer of patients to the operating room; usual process is adequate

9. **Table positioning and patient draping:** Table positioning and draping should follow standard processes and is specific to the operation performed. For example, upper abdominal procedures reverse Trendelenburg position and for pelvic procedures Trendelenburg position provide good exposure.

The OR table should not be adjusted while the robotic arms are engaged in the patient. It is, therefore, important to obtain the table position that provides the best exposure prior to docking of the robot. Sterile patient drapes should cover all exposed surfaces and should not interfere with the positioning of the robotic arms.

10. **Positioning of anesthesia, assistants and nurses:** components in relation to ancillary equipment and OR personnel with the anesthesia team in order to ensure patient safety.

Positioning should take into consideration potential problems that may occur during surgery. For example for cart-based systems clear the pathway that the robotic arms will take during docking. (For ***ERRORS***, see above on positioning of components and patient)

11. **Time Out:** Prior to the start of every robotic procedure a time out of the surgical team should be performed to verify the identity of the patient and the correct procedure

ERRORS:

- Wrong patent or wrong site surgery

12. **Anesthesia administration:** The surgeon should communicate with the anesthesia team at the beginning and during the case to ensure adequate paralysis of the patient throughout the procedure to avoid patient injury by the robotic arms. In addition, to prevents delays in the extubation of the patient the surgeon should notify the anesthesia team in a timely manner about the anticipated procedure completion

B. INTRA-OPERATIVE PHASE

1. **Goals**: The following tasks have been identified :

- Demonstrate the completion of tasks to a benchmark of proficiency without critical error.
- Understand the use and purpose of these individual tasks to future procedures.
- Improve psychomotor, spatial, perceptual, cognitive, communication, leadership, and management skills to the benchmark level of proficiency.
- Learn and become proficient in alert recognition, identification of source and correction of errors.

2. **Trocar placement:** Trocar insertion technique is dependent on surgeon preference. Trocar positioning is specific to the procedure and robotic system.

For abdominal cavity procedures, typical access is initiated at the umbilicus. Many procedures use the umbilicus for the 12mm or 8.5mm camera port and 2-3 additional working 8mm or 5mm robotic ports.

Identification and/or marking of anatomic landmarks helps guide the user for appropriate targeting to the desired operative field. There are varying strategies for positioning including triangulation, diamond, and HIDES positioning.

It is most important is to avoid injuries during trocar insertion. Therefore the type of access technique and the familiarity of the surgeon with this technique are critical. In general all access techniques (open and closed) can be performed safely if appropriately used.

For open cut-down techniques, usually the umbilicus is used in abdominal procedures. For closed techniques an off midline entry location is preferred as it prevents potential injury to the big vessels that can be fatal. The surgeon should be familiar with different entry techniques to be able to switch from one to the other when difficulty is encountered; this approach will likely decrease injury risk.

A general rule is that initial entry should be away from previous scars to prevent injuring any adherent structures underneath. (for example, bowel for abdominal access). It is also of paramount importance that surgeons look for injuries after trocar placement to verify their absence.

Surgeons should also have an appropriate plan for where they will place their trocars to be able to accomplish their procedure safely. While trocar placement is procedure specific common errors such as placing the trocars too close to each other (<10cm apart) is likely to lead to collisions of the robotic arms during the procedure and compromise its feasibility and safety. In addition, appropriate trocar placement in relation to the target anatomy is important. Generally a distance of 10-20 cm between the trocar and target anatomy is considered appropriate. Short or too long distances can be problematic.

In the currently available systems, robotic trocars need to be inserted up until the thick black line can be visualized at the level internal surface of the cavity or space (e.g. in abdomen the peritoneum or chest the pleura). If this is not the case injuries to the port site can occur.

Surgeons need to check for appropriate position of the trocars prior to docking the robot (especially if part of the case up to the use of the robot was done laparoscopically or videoscopically)

EXAMPLES: For abdominal surgery, because insufflation distorts anatomic landmarks in the abdomen marking of working port insertion sites should occur after insufflation is complete. For thoracic surgery, initial access to the chest is dependent on the craniocaudad position of the target anatomy and the camera port is placed between the ribs. For transoral, transorbital, subcutaneous trocar insertion, please review anatomy-specific curricula.

ERRORS: Several errors can occur during trocar placement and vary with the cavity (abdominal or thoracic) being entered. The following generic errors are identified:

- Injury to a major organ (bowel, liver, kidney, lung, etc)
- Inability to undock quickly enough in an emergency to achieve open access to operative site
- Trocar site too close to scar or previous incision
- Not visualizing the tip of the trocar during insertion
- Not checking port site and operative site for bleeding, injury, etc after insertion
- Not checking port site for proper level of trocar insertion (current version of robotic trocars need to be inserted until the thick black line can be visualized at the level of the internal surface of the cavity or space)
- Trocars placed too close together that inhibits reaching operative site (usually <10cm apart)
- Trocars placed too close resulting in robotic arm collisions
- Not checking for appropriate position of the trocars prior to docking robotic arms

3. Position of patient and robot cart - orientation of all arms: The orientation of the surgical cart (robot) to the patient is dictated by the target compartment.

- Pelvis – at the feet, between the legs, or side-docked.
- Flanks – along side of patient.
- Upper abdomen – position cart over the shoulder.
- Chest – alongside chest.
- The working arms are typically positioned on either side of the camera arm.

4. **Docking of robot cart and arms:** The robotic arms can be docked in varying sequences to ensure minimizing likelihood of arm collisions.

- Docking from right or left arm first and going in sequence across the camera port than one or two other opposite working ports.
- Camera port first.
- Camera port last.

Once the arms are all docked, attention must be taken to separate the elbows of the working arms from the camera arm to avoid arm collisions once docked. To avoid bruising on the skin, each port should be manipulated (burped) to slightly evert the skin as opposed to depressing the skin into the patient. This also increases the distance of the trocars to the target anatomy which is especially important for the camera port in small spaces.

ERRORS:

- Insufficient separation of working arms from camera
- Injury (bruising, etc) to the patient
- Collision of robotic arms
- Insecure seating of the trocar within the clasping/attaching mechanism due to inadequate/incorrect positioning of the arm prevents secure seating of the trocar within the clasping/attaching mechanism.
- Trocar not securely attached/locked.
- Trocar motion due to incorrect positioning of the fulcrum point.
- Bed rotation/patient repositioning after docking.
- Port damage/patient injury during docking.
- Bed rotation/patient repositioning after docking.
- Port damage/patient injury during docking.

5. **Instrument Insertion:** When inserting the instruments, the instrument end effectors should be straightened before insertion to avoid puncture of trocar seals. (The following is an example of a current robotic surgery system; however the basic principles remain the same)

First engage the tip of the instrument into the diaphragm of the trocar seal, and then seat the housing of the instrument against the sterile adapter above the sterile adapter tracks. The instrument is then slid down into the sterile adapter tracks until the four spindles engage the instrument.

If the insertion is the first one of the case, the clutch button will need to be depressed to slide the instrument in and position the arm. If the insertion is a tool change, the clutch button does not need to be depressed to insert the new tool to the existing position (guided tool change).

The instrument tip will be 2-3mm proximal to the tip position of the previous instrument tip as a result of this software safety mechanism.

Instruments should be inserted under direct vision and guidance. In the absence of this safety measure collisions of the instruments with tissue can occur that may lead to preventable injuries. To avoid this risk it is advisable to unzoom the camera during instrument exchanges to widen the view field (the majority of the time it is not easy to visualize the internal tip of the robotic trocars during surgery). In addition, instrument insertion should occur slowly to have time to react if the instrument is not visualized as anticipated.

Importantly, a safety mechanism exists in that during instrument exchange the robotic system remembers the instrument position and will allow for the new instrument to go back to the location of the removed instrument. This mechanism is canceled if the robotic arm is clutched during the exchange; the OR team should therefore know to avoid clutching the arms during instrument exchanges. If this has to happen significant more attention needs to be given to instrument insertion

ERRORS:

- Clutching the arms during instrument exchanges (this deactivates the safety mechanism that the robotic system uses to remember the instrument position and allow for the new instrument to go back to the exact location of the removed instrument).
- Instrument not completely through trocar,
- Not maintaining view of instrument during the insertion,
- Collision of instrument with tissue upon insertion (automatic insertion mode)
- Wrist not visible past the cannula (instrument not ready for surgical control) – This is done by the assistant, not the console surgeon).
- Overpowering the master controls prevents master/slave alignment and instrument activation.
- Attempting to remove the instruments when they are still attached on tissue or crossing inside the patient

- Clutching the robotic arm during instrument exchange without monitoring the new instrument tip during reinsertion
- Surgeon does not specify and communicate to the team which instrument arm has to be exchanged
- Surgeon or bedside assistants do not communicate clearly requests (for instrument exchange, suture insertion, energy activation etc)
- Poor guidance / communication with of the bedside surgical assistant

6. **Final review of set up**: Surgeon must perform a final review of robot arms, instrument/trocar position to insure all connections are correct, that the position of the patient is correct and the patient is not impinged by the robotic arms. Should there be an incorrect position of an arm or trocar, the surgeon should remove instrument before repositioning the arm and reinserting the instrument. When this review is complete, the surgeon may safely go to the console.

ERRORS: The surgeon does not perform the final review to detect these errors

- Patient positioning not verified
- Incorrect position of robot arms,
- Incorrect position of instrument/trocar
- Change position of arm or trocar without removing instrument.

7. **Surgeon Transition to Console:** The surgical procedure is conducted from the console, with assistance at the patient side. To insure the safest, most efficient and comfortable (least stressful for the surgeon), there are four fundamental principles to follow:

- Establish the ergonomics of the console
- Set up visual field and operative field
- Activate the instruments
- Prevention of injury to patients

8. **Establish ergonomics of the console:** Prior to operating the robot, surgeon ergonomic positioning should be established for the duration of the procedure (please refer also to the ergonomics section in the introduction) . Appropriate ergonomic are important to minimize surgeon fatigue during the procedure which may jeopardize patient safety and/ or to avoid chronic musculoskeletal injuries.

Ergonomic settings can usually be established manually or recalled from stored system memory. For example, in existing systems surgeons have the ability to place the viewer, level of hand rest, and foot controls in a comfortable position and configure the 3D stereo vision.

The initial set up begins when the surgeon puts their head in surgeon's console, their hands on the master controls. (Input devices handles) and configures the viewer & hand/foot controls in a comfortable position.

9. **Set up visual field and operative field**: Once the surgeon has established an ergonomically comfortable field. The visual field determines how much of the operative field is visualized and is determined my multiple factors such as type of videoscope (0, 30, 45 or 90 degree), magnification of the scope, focus, the distance from the center of the operative field, etc. Also included are the various icons that are along the periphery – the field has to be adjusted so there is no obstruction from the icons.

To set up the visual field, the surgeon has to activate the visualization system and obtain the appropriate field of view for the respective procedure. The focus and level of zoom can be adjusted as needed. To increase safety, the surgeon should strive to maintain the widest field of view possible for the task performed, and to keep the operating instruments in the operative field (usually the center of the visual field that contains the organs/structures to be operated upon). Frequent readjustments of the view field may be necessary during a procedure. Caution must be observed to insure that instruments (initially and during instrument changes) are not inserted outside the field of view, which could result in undetected injury to vital structures.

10. **Activate instruments:** To activate the robotic instruments the surgeon has to place their head inside the console and touch the forehead rest.
Next the surgeon has to place their fingers inside the controllers and gently move them to obtain control of the instruments. Applying too much pressure on the controllers will generate an error and temporary locking of the instrument. If this happens releasing the pressure and trying to move them gently again will usually fix the problem. It is also important to understand that if the forehead sensor is activated and the surgeon takes his fingers off the controllers after they have activated the instruments, the instruments could move uncontrollably, potentially leading to an injury. This should be avoided

11. **Prevention of injury to the patient or assistant:** When positioning the robot to the patient, docking the instrument manipulators, and installing/exchanging instruments, specific procedures (see manufacturer protocol) must be followed to enhance safety and prevent patient injury. Insure that all the arms are free of collision with the patient. It may be difficult to visually appreciate whether the arms are pressing on the anatomy under the drapes; for example the legs (for pelvic surgery), the head or chest (for over the shoulder positioning – upper abdominal surgery), or patient arms on arm boards/at side (for flank surgery). The bedside assistant may need to verify appropriate positioning of the robot by sweeping the open space with their hands by enabling manual motion of the instrument manipulators (clutching) and moving them to the steepest and shallowest positions.

During surgery, each inserted instrument must be visually monitored (manually by the assistant for first insertion or by the surgeon for exchanges) with the camera to its operating position. While some systems may provide assistive modes for instrument exchanges, these are only aids and do not excuse visual monitoring of instrument insertion.

It is also critical to insure the safety of the surgical assistant. This is done by monitoring the assistant through frequent communication between the surgeon and assistant and establishing a safe working space for the bedside assistant when placing assistant ports. The surgeon must make sure that the console speaker is on so that the assistant can hear intentions of the console surgeon and make sure room noise is minimized so that the console surgeon can hear the bedside assistant.

The bedside assistant should avoid/minimize placing hands/arms in between two moving arms to prevent pinching or crushing. Especially for shorter bedside assistants, care must be taken to avoid positioning head near robot arms.

ERRORS: Safety must be observed for both the patient and the bedside surgical assistant.

- Failure to insure that all the arms are free of collision with the patient
- Failure to monitor the instrument insertion into the patient
- Failure to monitoring assistant (e.g.: injury from assistant holding suction, etc)
- Failure to establish a safe working space for the bedside assistant when placing assistant ports.
- Not turning on the console speaker is on so that the assistant can hear intentions of the console surgeon
- Not insisting that room noise is minimized so that the console surgeon can hear the bedside assistant.
- Bedside assistant places hands/arms/head in between two moving arms

12. **Performing Basic Skills and Tasks**

(see SECTION 2: PSYCHOMOTOR SKILLS and TASKS)

C. POST-OPERATIVE PHASE

1. **Goals:** To insure all instruments/supplies are removed while checking there are no intra-operative injuries and to safely undock robot and transfer patient.

2. **Checklist:** At the end of each procedure the surgeon should ensure that all foreign bodies and specimens have been removed from the patient and no undetected injuries have occurred. To accomplish this it is important to re-inspect the operating field and all areas outside the operating field where an injury to tissues could have occurred (ie. Near trocar insertion sites). A checklist that verifies that foreign bodies introduced in the operative field or specimens have been removed and a check for injuries has been performed can be very valuable. Failure to complete this step may lead to adverse patient outcomes and constitutes a serious error.

ERRORS:

- Not performing the checklist
- Retained foreign body or specimen
- Unrecognized patient injury

3. **Safe removal of all instruments, supplies, trocars**: All instruments, supplies, and trocars used in a procedure should be removed carefully. In addition, they should be inspected to verify that no damage occurred during the procedure that could have resulted in foreign body retention in the patient.

Dropping of instruments or equipment during removal can lead to patient/staff injury or damage the system. It may also lead to costly repairs. (i.e. dropping and breaking the camera)

ERRORS:

- Attempting to remove instruments when they are still attached on tissue or crossing inside the patient
- Crossing of instruments furing removal (prevents removal)
- Undocking the ports before the instruments are removed
- Advancing the instruments towards the patient during removal (instead of just pulling them out; this could happen especially if the arm is clutched during removal)
- Clutching the robotic arm before instruments are removed
- Dropping instruments or other equipment during removal
- Discarding camera mount while removing drapes (mount is reusable)

4. **Undocking robot and moving away from patient**: Prior to undocking all instruments must be removed first from the patient. Prior to instrument removal all instruments need to be free of patient tissues.

During undocking of the robot the OR table position has to be maintained and patient repositioning avoided. Moving the OR table before undocking constitutes a significant error that can lead to patient injury and should be avoided at all cost. When moving the robot away care should be paid at avoiding collisions with the patient or damage of the robot by crashing onto other OR equipment. The path the robot will follow during undocking must be cleared from obstruction by other equipment. Particular attention should also be given to the robotic cables and cords so they are not damaged during repositioning of the robot (robot cart running over cables)

To undock the arms

- Release the locking mechanism
- The arms must be disconnected from the trocars.
- The arms are elevated away from the trocars
- The robotic cart moved away from the patient making sure to clear its path (avoid arm collision with patient or other equipment

ERRORS**:** Errors can occur to either the patient or to the equipment.

- Moving table before robot undocked
- Patient injury by robot due to reposition of patient before docking
- Collision with patient or other OR equipment

- Robot cart running over cables and crushing them
- Damage bed, or table or gurney when repositioning OR table

5. Reposition patient for incision closure and transfer. After the robotic cart has been removed from the patient the OR table is usually brought back to its neutral position for incision closure and patient transfer to the stretcher

ERRORS: Failure to level OR table before repositioning patient for incision closure

6. Closing incisions: Standard recommendations apply in a method similar to laparoscopic port closure. Generally fascial incisions related to ports >10cm should be approximated with suture. For smaller incisions fascial closure may not be needed as the risk of port site hernia is very low

It is good practice to inspect the trocar sites laparoscopically after trocar removal. This will allow recognition of bleeding from a potential inadvertent injury of an abdominal wall vessel by the trocar. If this check is not performed unrecognized bleeding may continue and require reoperation or blood transfusion.

In the event of pooling blood, halt surgery and inspect the pool for active bleeding. Make sure suction is available to clear the field. Inspection of the ports sites as the patients wakes up and coughs may provide evidence of incomplete fascial closure with a distinct bulge under the closure.

If illumination within the abdominal or chest cavity decreases without any change in the light settings, one should look for active bleeding as pooling blood absorbs light.

ERRORS:

- Failure to inspect the trocar sites laparoscopically after trocar removal
- Failure to recognize bleeding from a potential inadvertent injury of an abdominal wall vessel by the trocar

7. **Transfer patient from OR table to gurney**: Upon expiration of anesthesia, patients may move erratically without balance. Assistants should monitor the patient on the OR table until the gurney is beside the bed. Standardized safe transfer practices must be followed. Safe transfer may involve a roller board or slide board placed underneath the patient to utilize low friction transfer to the gurney.

ERRORS:

- Safe repositioning protocol not followed
- Collisions between or damage to OR equipment, bed, table or gurney.
- Table rails or table not lowered
- Patient injury during repositioning

8. **Transport to recovery room:** Standard safe practices for transport must be followed. A member of the primary surgical team should accompany the patient to recovery to facilitate adequate handoff of the patient to the recovery nursing staff.

Any drains should be double checked for security because of the recent moves from the OR table and the awakening patient.

ERRORS: Transfer from bed to gurney, transport to recovery room

- Safe transfer protocol not followed
- Patient condition not verified
- Staff not identified/directed to accompany patient to recovery room
- Drains, catheters, etc not checked after stabilization in recovery room

SECTION 2: PSYCHOMOTOR SKILLS CURRICULUM

DESCRIPTION AND INSTRUCTIONS FOR PSYCHOMOTOR SKILLS and TASKS

A. GENERAL PRICIPLES:

1. Background Robotic surgery systems are true tele-operation systems – that is, they only respond to input from the surgeon – without input from the hand controllers, voice input or other actions, the robotic system is not able to initiate any actions independently. There is a one-to-one mimicking of the surgeon's hand motions such that whatever DIRECTION the surgeon moves he hand controller, the instrument moves in precisely the same direction (when performing minimally invasive surgery through a trocar, the reversal or fulcrum effect at the abdominal wall is automatically compensated by the robotic system to maintain the one-to-one directionality). While direction remains identical, there are adjustments on the robotic system that can be used to increase or decrease the amount of DISTANCE the tip moves, referred to as SCALING, such that large motions can be 'scaled down' for precise positioning of the instrument tip. For example a scaling of two times (2X) results in a one –half motion of the instrument tip (ie, a one centimeter motion results in a 5 millimeter motion of the instrument trip). Another common capability of a robotic system is TREMOR FILTERING; any involuntary oscillating hand motion (tremor) to the hand controller is smoothed out by removing the oscillating motion. Finally, dexterity is determined by the number of degrees of freedom (DOF) that the instrument tip is capable of performing. There is a standard of 6 DOF of a rigid instrument

Translation:

1. Moving left and right (swaying)
2. Moving up and down (heaving)
3. Moving forward and backward (surging)

Rotation

1. Tilting forward and backward (pitching)
2. Turning left and right (yawing)
3. Tilting side to side (rolling)

Most instruments (open surgery and laparoscopic surgery) are straight, so they are only capable of 6 DOF, however if a 'joint' is added to the instrument, and additional DOF occurs – this is the 'wrist' on robotic instruments which permits greater dexterity in moving behind structures, or more complex motions, such as for knot tying. Thus these and other sophisticated augmentations by the robotic system permits the surgeon unprecedented control and accuracy of the instrument, and permits hand motions in a very 'natural' or 'intuitive' manner.

B. GOALS and OBJECTIVES

The goals and objectives of the basic skills and tasks for robotic surgery are to train and assess the proficiency of the psychomotor robotic skills of the surgeon. This will ensure that only the surgeons who are skilled and well trained in robotic surgery perform such complex procedures, making the patient the ultimate benefactor. In order to perform these tasks, the following principles of the exercises should be followed:

1. The tasks should be 3 dimensional in nature.
2. The tasks designed for testing should be such that they have multiple learning objectives that incorporate multiple tasks from the first conference report. The tasks designed for training will have more focused learning objectives.
3. Implementation of the tasks and the resultant method for teaching should be cost effective.
4. The tasks are designed on the physical models for the purpose of assessment. However, the VR based models derived from these tasks can be eventually used for training as well.
5. The physical models will be so designed that they are agnostic to any particular robotic surgical system.

6. Tasks should be easy to administer to ensure Inter-Rater Reliability (IRR).
7. Preference should be given to tasks that have existing evidence of validity

In line with these seven principles of exercise design, all the tasks listed below are performed on physical models with the real robot.

C. PHYSICAL MODEL:

The physical model is an 'abdomen' box with a metallic dome positioned inside; the dome has a disposable skin covering. The outer diameter of the dome is 24 cms. The 'abdomen' box has 4 ports attached: 12 mm camera port and three 8 mm ports for the instruments. The ports are 9 cm from each other. The box has a timer that will be used for all exercises.

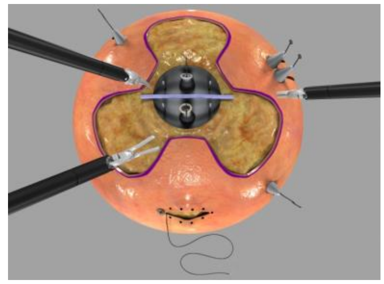

Figure 1. Tasks performed on dome

D. TASKS:

TASK 1: DOCKING AND INSTRUMENT INSERTION

Instructions:

Once the port placement is complete (described above) on the 'abdomen' box, the circulating nurse drives the robot and parks it close to the patient (box) such that the arms can be extended to within the operative field (abdomen box). At this point, the robotic arms will need to be docked to the ports. The arms are passively moved to within range of the port sites, the arms are attached to the ports, and the instruments are inserted through the ports into the 'abdomen' box through these ports. It is important that docking is done correctly otherwise the robot will not "read" the instruments. Furthermore, if the robotic arms are not placed properly, the arms will keep colliding during the surgery or the instruments might not be able to reach the operative field during the surgery. The cables for the camera must be organized and secured behind the camera to ensure a clear field. Finally, the instruments should be inserted carefully under vision and the memory clutch pressed. If not done properly, the instruments may cause serious injury to the surrounding tissues at the port site.

Learning Objective:

By the end of this task, the learner will be able to safely dock the robotic arms and insert the instruments through the ports into the 'abdomen' box and bring the instrument tips into the operative field of view without error.

Psychomotor skills assessed:

Primary:

- Docking.
- Instrument insertion.
- Safety of operative field.

Secondary:

- Eye-hand instrument coordination.

Task set-up - Objects and Conditions:

- 12 mm camera port.
- Three 8 mm instrument ports.
- All instruments ports 9 cm from the camera port.
- Arms at the neutral position and at maximum height in the beginning of the task.

Task:

- Dock the robotic camera arm to the 12 mm camera port.
- Dock other 3 arms to 8 mm instrument ports.
- Insert 30 degree scope into the camera port and secure the cable behind the arm.
- Insert the long needle drivers in the two arms (#1 and #2) and monopolar scissors in the 4th arm.
- Confirm that all 3 instruments are in the field of view such that the entire dome and all instruments are completely visualized.

Metrics:

- Total time (minutes) until all three instruments are in view.
- Pathway (Optional)

Errors:

- Collision of an instrument or camera with the dome
- Camera arm not in the “sweet” spot (full visual field of the dome and test objects)
- Failure to secure the camera cable behind the camera arm.
- Inserting instruments/camera into the wrong ports.
- Incorrectly inserting the instrument.
- Instrument-instrument collision following insertion of the instruments.
- Non-visualization of an instrument tip during insertion.
- Failure to press the clutch (memory) button in the end of the setup.

Standards: (To be determined in validation studies).

- Total time to completion of docking and setting the memory button.
- Number of errors as listed above

TASK 2: RING TOWER TRANSFER

Instructions:

Learning to navigate the camera and the surgical instruments using a robotic system is both completely different from open surgery (and laparoscopic surgery), but also designed to be totally natural and mimicking the same motions that are used in open surgery (but opposite those motions of laparoscopic surgery).

One of the most basic rules of surgery is - Do not cut what you do not see. For visualization of the operative field, the camera is the only source of visual feedback in robotic surgery, and maneuvering the camera is very different from laparoscopic surgery – there is no fulcrum effect in robotic surgery (that is, in laparoscopic surgery, moving the hand on the camera head upward causes the laparoscopic camera tip to move down, etc, - whereas with robotic surgery, moving the hands upward causes the camera tip to move upwards). One technique that is unique to robotic surgery is that the surgeon must press the foot pedal while moving both hands in order to navigate (properly move and position) the camera.

In addition, one of the major advantages of a robotic system is the wristed motion (the ability to move the tip of the instrument up to 90 degrees perpendicular to the shaft of the instrument), which is especially helpful in complex motions such as reaching behind a structure or suturing. In order to assist the surgeon in precise manipulation of tissues and objects, tremor filtration (removal of tremor while positioning of the instruments), scaling (large hand motions are converted to precise, small instrument tip motions) and 10x visual magnification of the operative field compliment the wristed motions of the instruments. In order to safely and effectively use the robot, it is necessary to learn and practice both camera navigation and instrument manipulation in simple and complex tasks.

Learning Objectives:
By the end of this task, the learner will be able to able to navigate the camera and use the camera clutch effectively. They will also be able to maneuver the instruments such that the potential of wristed instrumentation is utilized maximally for precise instrument tip positioning.

Psychomotor skill assessed:
Primary
- Eye hand instrument coordination
- Camera navigation
- Clutching
- Atraumatic handling
- Precise instrument tip positioning

Secondary
- Wrist articulation

Task set-up - Objects and Conditions:
- Instruments used: 2 large needle drivers.
- Dome on 30-degree incline.
- 2 towers in the middle of the dome with “S” wire on top.
- 2 similar towers (with “S” wires) on each side.
- The “S” shaped wires perpendicular to the dome plane.
- Side towers are in different planes.
- Towers are insulated but wires are not.

Task:
- Pick up and remove the ring from the middle tower with one hand without touching the “S” wire.
- Transfer the ring to opposite hand in mid air.
- Place the ring on the side tower without touching the “S” wire.

Metrics:
- Total time to transfer rings from middle to side towers (seconds)
- Total time for instrument-wire collisions (seconds).
- Instrument-instrument collisions. (number of times)
- Number of ring drops.
- Number of errors

Errors:
- Dropping the ring
- Breaking the ring
- Breaking the wire

- Instrument-instrument collision
- Instrument-wire collision

Standards: (To be determined in validation studies).

- Transferring rings from middle to side towers without error

TASK 3: KNOT TYING

Insrtuctions

Any complex surgical procedure requires knot tying. However in robotic surgery there are no haptics (the sense of touch) and the surgeon does not have direct handling of the needle, suture or tissues and therefore has the complete loss of the sense of touch (force feedback). This means that while tying a knot, a surgeon must totally rely on the visual cues and experience to handle the suture carefully and not break the suture nor cause tissue tearing with the suture. If the suture breaks during knot tying (especially after the task of a continuous suturing during anastomosis), this will require repeating the suturing and knot tying, increasing the possibility of complications and resulting in prolonged operating time and frustration levels of the team.

Learning Objective:

By the end of this task, the learner will be able to successfully place a suture and tie a square knot.

Psychomotor skill assessed:

Primary:

- Needle and suture handling
- Knot tying

Secondary:

- Wrist articulation
- Eye hand instrument coordination

Task set-up - Objects and Conditions:

- Instruments: two large needle holders.
- The dual parallel towers on one side of the dome with 7 mm diameter eyelets on top.
- 10 cm 2-0 silk sutures (to be passed through both the eyelets).

Task:

- Tie a surgeon's knot to approximate the two eyelets such that they touch each other.
- Back up the knot with two more throws. (Total 3 knots)

Metrics:

- Time to complete the knots (under tension)
- Approximation of the eyelets
- Security of the knot

Errors:

- Islets do not touch each other.
- Air knot
- Knot slippage
- Insecure knot
- Suture breakage

- Instrument-instrument collision.

Standards: (To be determined in validation studies).
- A securely tied knot that completely approximates the eyelets of the two towers without breaking the suture or other errors.

TASK 4: RAILROAD TRACK

Instructions:

Precision is one of the major advantages of the robot, and is particularly important in needle holding and suturing. Suture/needle handling is a basic surgical skill, however, due to the lack of force feedback, novices frequently break not only the sutures during a continuous suture but also the needle (which is unique to robotic surgery). If suture or needle breakage occurs in the middle of a complex suturing task, this can be lead to complications and/or prolonged operating time. This task will teach the learner appropriate needle handling and suturing technique using the robot.

Learning Objectives:

By the end of this task, the learner will be able to precisely control the needle and perform suturing task using the robot.

Psychomotor skill assessed:

Primary:
- Needle holding and manipulation
- Wrist articulation
- Atraumatic tissue handling

Secondary:
- Eye hand instrument coordination
- Suture handling

Task set-up - Objects and Conditions:
- Instruments: Two large needle holders
- 5 cms incision on one side of the dome.
- 4 dots (target points) stamped on each side of the incision in the skin, 1 cm apart from each other.
- 10 cms 2-0 silk on SH needle, pre-secured in the skin.
- BLAST grids to assess amount of eversion.

Task:
- Perform horizontal mattress suturing through the target points to approximate the tissue
- Tie a knot at the completion of the suturing.

Metrics:
- Time to complete closure of incision and tie knot (seconds)
- Complete wound approximation
- Precision of needle placement onto dots along the incision (mm distance from center of dot)
- Amount of eversion (mm)
- Wound tension (no gap of wound edges)
- Secure knot at completion of suturing (no slipping)

Errors:

- Wound separation (mm)
- Excessive eversion (mm)
- Tearing of tissue (mm of tears)
- Inaccurate targeting (mm from dots)
- Inaccurate suture technique (number of needle placements that are not mattress suture)
- Suture breakage (number of times)
- Needle breakage (number of times)

Standards: (To be determined in validation studies).

- Accurate approximation of wound edges with accurately placed continuous mattress suture

TASK 5: 4TH ARM CUTTING

Instructions:

In open and laparoscopic surgery, the surgeon uses an assistant to retract, position and hold specific instruments. In robotic surgery, the presence of the fourth arm allows the surgeon to have direct control of both the camera and an additional arm. However, controlling four arms (with only two hands) poses some challenges. As in clutching for camera navigation, the surgeon must 'place on hold' one hand and activate the other arm. This is accomplished when the surgeon presses one of the 'pedals', which activates the 4th arm while inactivating one of the other instruments. Since the 4th arm is usually used for retraction, after appropriate repositioning of the retraction, the surgeon switches back to the primary instrument after repositioning the camera, since the 4th arm and retractor is usually outside the field of view. If the surgeon activates the 4th arm by mistake, this can cause serious injury. The purpose of this task to is make the learner proficient in switching back and forth between a primary instrument and the 4th arm.

Learning Objectives:

By the end of this task, the learner will be able to safely and effectively switch back and forth between the second and the fourth arm of the robot.

Psychomotor skill assessed:

Primary:

- Multiple arm control
- Cutting

Secondary:

- Atraumatic handling
- Eye hand coordination

Task set-up - Objects and Conditions:

- The 'vein' which lies at the center of the dome.
- The 'vein', which is 8 cms long with 3 hash marks 2 cms apart.

Task:

- Pick up the vein with one hand and use the other hand to provide retraction.
- Switch to the 4th arm and use the monopolar scissors to cut the vein transversely at the hash mark.
- Switch back to the retracting instrument and readjust to provide adequate retraction.

- Repeat switching to 4th arm, cutting and retraction till the entire vein' is cut at all the hash marks.

Metrics:
- Time to cut all the hash marks (sec).
- Accuracy of cutting on hash marks (mm distance from center of hash mark)
- Retraction (adequate exposure of vein)
- Stretching of the vein (adequate tension on vein).

Errors:
- Inadequate tension of the vein
- Tearing of vein.
- Failure to switch arm.
- Inaccurate cut.
- Dropping the vein.
- Instrument – instrument collision

Standards: (To be determined in validation studies).
- All hash marks accurately cut (time and without error)

TASK 6: CLOVERLEAF DISSECTION

Instructions:

Fine dissection and tissue plane separation are important surgical skills. However injury to surrounding structures or tissue tearing can have serious clinical implications. This task trains for precise fine dissection such that the skin is incised on the marked lines while not injuring or tearing the underlying tissue.

Learning Objectives:

By the end of this task, the learner will be able to safely and precisely perform fine dissection without damaging the surrounding or the underlying structures.

Psychomotor skill assessed:

Primary:
- Dissection
- Cutting
- Atraumatic tissue handling

Secondary:
- Eye hand coordination
- Wrist articulation

Task set-up - Objects and Conditions:
- Instruments: Maryland Bipolar forceps, Monopolar scissors.
- Cloverleaf pattern in the middle of the dome.
- Lines 2 mm apart.
-

Task:
- Cut the cloverleaf pattern between the lines without incising the underlying tissue or cutting outside of the lines.

Metrics:

- Time to completely dissect the cloverleaf (sec)
- Accuracy of remaining within the lines (mm)
- Tissue handling

Errors:

- Tearing of tissue
- Cutting outside the lines
- Incision of underlying tissue
- Instrument-instrument collision

Standards: (To be determined in validation studies).

- Complete removal of cloverleaf without cutting outside of the lines or injury to underlying tissue

TASK 7: VESSEL ENERGY DISSECTION

Instructions:

Any surgical procedure deals with a combination of fine, blunt and energy dissection. In open and laparoscopic surgery, the activation switches for electrocoagulation are located on the handle of the electrocoagulator, however in robotic electrocoagulation, activation is accomplished by the use of the foot pedals. Thus in robotic surgery if the incorrect pedal is pressed during electrocoagulation of a vessel, serious hemorrhage could occur. It is important to use the correct pedals. This task trains for the correct use of the pedals for electrocoagulation.

Learning Objectives:

By the end of this task, the learner will be able to identify the unipolar and bipolar pedals correctly and use the energy to precisely seal and divide the vessels.

Psychomotor skill assessed:

Primary:

- Accurate activation and use of energy sources (electrocoagulation)
- Dissection of vessels and tissues
- Cutting and coagulation of vessels
- Multiple arm control

Secondary:

- Atraumatic handling
- Eye hand instrument coordination

Task set-up - Objects and Conditions:

- Instruments: Maryland bipolar dissector
- Flap on one side of the dome.
- Pulsating vessel beneath the fat layer.

Task:

- Incision and retraction of the flap upwards with the 4th arm.
- Dissection through the fat to expose the pulsating vessel
- Seal the vessel using Maryland bipolar at the solid hash marks

- Cut the vessel at the dotted hash mark.

Metrics:
- Time to complete dissection, vessel sealing and vessel cutting (sec)
- Accuracy (mm)
- Quality of vessel seal (leaking)
- Blood loss (cc)

Errors:
- Injury to vessel
- Tearing the flap
- Instrument-instrument collision
- Cutting/Energy applied outside the marks

Standards: (To be determined in validation studies).
- Complete dissection, coagulation and cutting of vessel

SECTION 3: TRAINING & COMMUNICATION SKILLS

DESCRIPTION AND INSTRUCTIONS FOR TEAM TRAINING & COMMUNICATION SKILLS

A. GENERAL PRINCIPLES

1. Background: The use of a robotic system creates unique demands which are beyond those demands in open and laparoscopic surgery. The principle difference is the physical separation of the primary surgeon from the patient, the operative team members and operative site. The result is that the surgeon must rely even more upon team participation and clear, unambiguous communication with team members.

Current robotic surgery systems use telemaniplation, image guided and/or stereotactic surgical techniques which require the use of a surgical console – a computer workstation at which the surgeon sits and controls the remote manipulator arms that hold the surgical instruments. This requires intense focus on the monitor(s) of the workstation, increasing the attention on the very limited view of the operative field and a sacrifice of attention to the rest of the operating team and a global view of the patient, the team and the operating room. The result is a significant decrease in situational awareness of the personnel and activity around the patient.

The solution is to increase communication among team members, and a special communication between the surgeon at the console and the first assistant at the patient's side. Because the first assistant is in the immediate vicinity of the robotic arms, the assistant is in particular jeopardy for injury – the surgeon who is controlling the robotic arms is unable to see the assistant, and therefore must have very clear communication in order to avoid injury to the assistant by the robotic arms.

Other industries, such as nuclear industry and aviation, have developed rigorous communication protocols among the team members (e.g., crew resource management in aviation), which include unambiguous commands or queries, confirmation by the receiving person of the communication (closed-loop communication performed by repeating the command/question as part of the answer) and confirmation of the completion of the task. In addition, a culture of safety is developed by empowering all members of the team and including every member as responsible for safety. This process has been formalized in the "... Teams EPPS® (Team Strategies and Tools to Enhance Performance and Patient Safety) methodology ... which has been developed by the Department of Defense (Dodd) and the Agency for Healthcare Policy and Research (AHRQ) ..." and adopted nearly universally for "... communication other teamwork skills are which are essential for the provision of quality healthcare and for the prevention and mitigation of medical errors ... [It]is an evidence-based system aimed at optimizing performance among teams of healthcare professionals — enabling them to respond quickly and effectively to whatever situations arise." (accessed 15 Nov, 2012 from the ARHQ webpage http://www.ahrq.gov/teamsteppstools/instructor/introduction.htm).This is a comprehensive training system for simulation-based skills education which addresses the non-technical critical issues for a holistic approach to the surgeon's responsibility in performing a surgical procedure: team structure, leadership, situation monitoring, mutual support and communication skills. Space does not permit addressing the full breadth of Teams EPPS®, however there are two essential parts that must be emphasized regarding teamwork and communication skills – SBAR and "call-out".

SBAR addresses how to communicate during an urgent and/or critical situation and includes both the identification of the emergency and the action to mitigate error or complication ." (accessed 15 Nov, 2012 from the ARHQ webpage http://www.ahrq.gov/teamsteppstools/instructor/introduction.htm)

Situation	informs the importance of the communication - ie what is going on
Background	informs what the situation is in the context of the event
Assessment	identifies unambiguously what the problem is
Recommendation	indicates accurately what action should be performed

This process is iterative – that is, the team must complete the entire SBAR cycle, by insuring that the communication is heard, understood and acknowledged (see call out below), and then there must be closed-loop feedback to reevaluate the *situation* to insure there is no change in the overall status (ie is it deteriorating in spite of the action, improving, completed, etc), determine the *background* is the same (ie, that no new events have occurred during the interval), conduct a *reassessment* that the problem has not changed, and *recommend* the next step in the action (rarely is a single action sufficient to complete the action for resolution.)

"Call out" is the process for unambiguously clarifying whatever the communication is about so the intended persons are addressed specifically, the questions, commands, answers are repeated by the recipient of the action acknowledges receiving the communication and responds in by repeating the question and then specifically performs and completes the activity, which is then is acknowledged and communicated back to the person who initiated the communication. For example

Surgeon Dr. Davis: Dr Jones (1st Assist), please change the grasper on arm #2 for a scalpel
Its Assist Dr Jones: Dr. Davis, I am changing the grasper on arm #2 for a scalpel (pause)
Dr. Davis the scalpel is now on arm #2
Surgeon Dr. Davis: Acknowledge, the scalpel is now on arm #2.

While his may seem superfluous and melodramatic, it is standard operating procedure in all high risk, high safety environments (nuclear reactor, airplane cockpit, etc) and is a major contribution to the remarkable safety record in these complex environment

This need for team communication and training has been recognized in healthcare and simple, unequivocal procedures and processes (such as checklists, Team STEPPS, etc) have been developed to train teams for routine, urgent and crisis management in the emergency room, ICU, delivery room and operating room. Yet none have the challenges of robotic surgery as listed above, mainly because of the physical isolation of the surgeon at the console and the surgeon's inability to see the patient and the operating site – the surgeon's view is limited to the video monitor inside a console.

The training in communication skills must include all aspects of the operative procedure, from the moment the patient enters into the operating room until the patient is safely returned and checked in the recovery room – all three phases must be addressed: pre-operative (from entering the room until surgeon begins operating from the surgical console), intra-operative (from "incision to closure") and post-operative (from disengaging the robot from the operative field to final check in the recovery room)

2. Framing Statement and Goals: There are unique demands of robotic surgery, so team development and communication skills are essential to ensure patient safety and successful robotic surgery. The basic principles of team functioning and communication skills include:

a. Team alignment with common objectives (shared mental model)
   i Surgeon acknowledges the need for each team member's role and limitations
   ii Emphasize situation awareness limitations inherent in robotic surgery
b. Inclusion of all members of the team
   i Enhanced importance of every team member's role
   ii Be the eyes and ears of the surgeon
c. Empowerment to speak up and act
   i Surgeon must rely on team member recognition of flow of procedure & danger
   ii Anyone can say "stop" if there is a problem, or potential problem
d. Shared ownership and responsibility
   i Encourage open multidirectional communication
   ii Shared vigilance
   iii Surgeon reliance on team
   iv Team reliance on each other
e. Person specific directives which clearly articulate to whom communications are addressed, which equipment/instrument is to be addressed, etc (SBAR)
   i Reduced visual cues
   ii Require more descriptive and detailed instructions
f. Task management and completion
   i. Confirm completion of task
g. Reiterative/'Just in time' – immediate acknowledgement and response
   i. Front load and repeat key steps of the procedure
   ii. Reiterative instructions and responses to acknowledge exactly what the activity is to be performed (call out)
   iii. Periodic team realignment
h. Risk management/ quality improvement- closed loop communications and post debriefing to improve the team functioning
   i. Overview (big picture) of the entire process
   ii. Opportunities to improve
   iii. Robot-specific and general debriefing

a. Resources and references
   i. Additional readings
      1. Patterns of Communication Breakdowns Resulting in Injury to Surgical Patients
      2. Didactic and Simulation Nontechnical Skills Team Training to Improve Perinatal Patient Outcomes in a Community Hospital
   ii. Link to TeamSTEPPS (accessed 15 Nov, 2012 from the ARHQ webpage http://www.ahrq.gov/teamsteppstools/instructor/introduction.htm).

Institutions committed to robotic surgery must be committed to developing and training all members of robotic surgical team(s) to ensure optimal team development, communication, and proficiency to ensure patient safety and successful robotic surgery.

There has been an enormous investment in developing team training curricula and checklists. The WHO checklist will be leveraged and expanded with robotic specific, team building checklists. Since goals are intentionally generic in order to allow for cross-specialty use, they should incorporate established team training procedures like TeamSTEPPS, or other similar programs. The curriculum must be flexible to allow for procedure/specialty specific variance.

B. PRE-OPERATIVE PHASE

1. Goals: For the purpose of 'surgical' or 'procedural' communication skills, the pre-operative period is defined specifically as from the moment the patient enters the operating room until the surgeon sits down at the console to begin operating. Trocars (or retractors) are inserted as part of the pre-operative procedure (see Psychomotor Skills and Tasks also). Once the general and robot-specific checklists (below) are completed, the critical communication skills revolve around situational awareness (the shared mental model of what is expected to occur during the procedure), continuous monitoring of the team members and environment, and timely feedback of both progress of the procedure and potential untoward events (errors, mistakes, etc). The SBAR and "call-out portions of Team STEPPS are especially critical:

a. Checklist 1: Pre-Operative Checklist (WHO Checklist)

General

- ☐ Has the patient confirmed his/her identity, site, procedure and consent?
- ☐ Is the surgical site marked?
- ☐ Are the anesthesia machine and medication checks complete?
- ☐ Does the patient have a known allergy?
- ☐ Does the patient have a difficult airway/aspiration risk?
- ☐ Does the patient have a risk of >500ml blood loss (7ml/kg in children)?
- ☐ Have all team members introduced themselves by name and role?
- ☐ Have the Surgeon, Anesthetist and Registered Practitioner verbally confirmed the patient's name?
- ☐ Have the Surgeon, Anesthetist and Registered Practitioner verbally confirmed the procedure, site and position that are planned?

Anticipated critical events: Surgeon

- ☐ How much blood loss is anticipated?
- ☐ Are there are specific equipment requirements or special investigations?
- ☐ Are there any critical or unexpected steps you want the team to know about?
- ☐ Has VTE prophylaxis been undertaken (if applicable)?
- ☐ Is essential imaging displayed (if applicable)?

Anticipated critical events: Anesthetist

- ☐ Are there any patient specific concerns?
- ☐ What is the patient's ASA grade?
- ☐ What monitoring equipment and other specific levels of support are required? (e.g. blood)

Anticipated critical events: Nurse/ODP

- ☐ Has the sterility of the instrumentation been confirmed (including indicator results)?
- ☐ Are there equipment issues or concerns?
- ☐ Are back-up instruments available?
- ☐ Is an emergency tray available?

- ☐ Are cables in appropriate position?

Has the surgical site infection (SSI) bundle been undertaken (if applicable)?
- ☐ Antibiotic prophylaxis within the last 60 minutes?
- ☐ Patient warming?
- ☐ Hair removal?
- ☐ Glycemic control?

b. Checklist 2: Robotic Docking Checklist
Anesthesia related
- ☐ Is the airway accessible?
- ☐ Are anesthesia lines accessible?
- ☐ Is the bed locked?

Patient related
- ☐ Is the patient positioned properly?
- ☐ Is the patient appropriately secured?

Robot related
- ☐ Are the robotic arms in appropriate positions?
- ☐ Has the robotic arm range of motion been tested?
- ☐ Does the video need to be saved? Is the video equipment configured?

Bedside assistant
- ☐ Is there accessibility to the patient?
- ☐ Are the monitors readily visible?
- ☐ Is the energy source accessible?
- ☐ Has communication with the surgeon and team been established?

Procedure specific
- ☐ Have specific needs of the procedure been recognized, discussed, and appropriately addressed?
- ☐ Has the level of risk of the procedure and high risk components of the procedure been discussed?

Trouble shooting – empower team for patient safety
- ☐ Is there a plan to account for foreign objects during the procedure and their removal (i.e. white boarding)?
- ☐ Has the team discussed how often periodic checks will be conducted to determine case progression, team member continuity, and other issues that need to be addressed?
- ☐ Has the team reinforced a protocol of regular communication with anesthesia?

Checklist complete
- ☐ Has the team acknowledged that the checklist is complete and they are ready to begin the procedure?

C. INTRA-OPERATIVE PHASE

1. Goals: The lack of visual and physical proximity of the surgeon to the rest of the team demands stringent communication among team members. Once the surgeon sits at the console which controls the robotic manipulators (or imaging device, xray source, etc), the field of view is now constrained to that of the monitor. Although this greatly enhances the feeling of 'being in the operative site' (called telepresence), the remainder of the operating room is now longer visible. Thus, the role of communication during the surgical procedure becomes even more emphasized. The TeamSTEPPS approach becomes even more critical under these circumstances. Examples include instrument change, camera adjustment, repositioning of trocar or arms, etc. The goal is to insure that all team members share the same mental model about the procedure, and communicate frequently. Most important is to have the surgeon updated on a regular basis to insure that there is ‘progress’ with the operation – procrastinating and lack of progress is an error that leads to complications further along in the procedure. When instruments are changed, it must be done efficiently and correctly, when specimens are removed they must be labeled and checked for accuracy, and the operative site must be reviewed to insure there were no missed errors or residual bleeding.

a. Checklist 3: Intraoperative Checklist

- ☐ Is there good team communication concerning instrument usage and transfer?
- ☐ Are all foreign objects accounted for (i.e. white boarding) and removed?
- ☐ Are the periodic checks occurring to discuss case progression, team member continuity, and other issues?
- ☐ Has there been regular communication with anesthesia?

D. POST-OPERATIVE PHASE

1. Goals: Upon completion of the procedure the surgeon must notify the team that a time-out must be taken before ‘closing’. All instruments must be checked, specimens reviewed again, and the intra abdominal (intra thoracic, subcutaneous, etc operative site must be checked, especially paying attention to the site where the trocars were inserted for tissue tearing, bleeding, retained foreign bodies, etc. The anesthesiologist must be informed that they will be “closing” and the surgeon and/or first assistant will close.

The undocking of the robot will be the reverse of the setup, and included safe removal of all instruments from the operative site, powering the robot down, undocking of the robot from the vicinity of the patient, moving all ancillary equipment (towers, energy sources, etc) away from the patient. Only then would it be safe to reposition the patient and transfer to a gurney. A debriefing is needed as the completion event of the procedure

b. Post-operative communication

It is essential to adhere to the SBAR and call out during the time after the major portion of the procedure is completed – this is the time when team members let their guard down, are anxious to finish and leave (or start the next case) and find that colleagues are simultaneously busy (e.g., the anesthesiologist is extubating the patient, the scrub nurse is completing the instrument check and ‘back table cleanup’ and the circulating nurse is gathering instruments, equipment and supplies to be returned to central supply. All members have important and very time consuming activities – this is a time or inattention to the overall situation which leads to slips and eventually errors. The value of the Team STEPPS is having a routine and check lists, which all team members know and adhere to. Specifically calling for the final time out provides the focus to stop what each member is doing, and pay attention to the final check and debriefing.

c. **Checklist 5: Undocking**

- ☐ Did the surgeon check all instruments?
- ☐ Have the instruments been cleared?
- ☐ Have the instruments been removed?
- ☐ Were all foreign bodies removed?
- ☐ Have the trocars been disconnected from the robot arms?
- ☐ Have trocars been removed by direct visualization (when possible)?
- ☐ Is the specimen management and wound closure complete?

d. Checklist 6: Debriefing

- ☐ What are the key concerns for recovery and management of this patient?

- Have any equipment problems been identified that need to be addressed, including robot error messages? If so, who will follow-up?
- What are the opportunities to improve?
- What are the lessons learned?
- Has each member of the team been given the opportunity to provide feedback?
- Was there closed loop communication for any quality improvement/ risk management issues?
- If video was recorded, is it saved and stored?

Testing/Assessment of Team Training and Communication Skills

Test questions

Q1. During the period of time while the patient is positioned and the robot is docked, prior to initiating console-based surgery, name 3 pieces of information which must be conveyed or confirmed with the following OR staff:

A. Nursing
B. Anesthesia
C. Bedside assistant

A1.
A. Nursing
1. Camera/lenses balanced/focused/calibrated?
2. Appropriate equipment available (instruments, disposables, sutures)
3. Expectations discussed, potential problems or departure from standard procedure

B. Anesthesia
1. Length of procedure, potential blood loss, complications discussed
2. Is the patient positioned properly, securely?
3. Are lines and tubes accessible?

C. Assistant
1. Plan of the case discussed
2. Ergonomics adequate (monitors, wires, encroachment from anesthesia equip)
3. Intercom working with adequate 2-way volume.

Q2. During an instrument exchange, what must be conveyed to the scrub tech and bedside assistant?
1. New instrument requested
2. Instrument to be removed
3. Specific instrument arm that will be manipulated: L, R, 4th or 1,2,3

Q3. How should needle removal be ensured?
Bedside assistant announces “needle is out”, scrub tech confirms “I have the needle”
Q4. A piece of equipment is requested which is not available within the operating theater. What is the role of each member of the team to communicate and solve this problem.
Surgeon:

1. Identifies all possible equipment that will be reasonably necessary during the case, communicates this to circulator.
2. If a piece of unanticipated equipment becomes necessary, Surgeon requests it as soon as s/he realizes this, ideally well in advance
3. The equipment request is specific as to name of instrument, size, type, location if known.

Circulating Nurse:

1. Confirms the specifics of requested equipment with surgeon
2. Asks if it is appropriate time to leave the room to obtain the requested instrument.
3. If unable to find equipment, immediately informs surgeon so an alternative plan can be enacted.
4. When circulator returns to the room with requested instrument, immediately announces this fact and reconfirms the specific piece of equipment that has been obtained.

Anesthesia:

1. When circulator leaves, alert to the fact that s/he may be required to fill circulator role temporarily in case of an emergency.

Scrub Tech/Bedside assistant:

1. Once requested equipment is obtained and ready for use, informs surgeon and asks if it should be deployed at this time.

Q5. When the robotic portion of the procedure is completed, what are the responsibilities of each team member?

Surgeon:

1. Ensure procedure completed, drains placed if necessary, and instruments not grasping any tissue.
2. Announces that robotic portion is complete, OK to remove robotic instruments, undock

Scrub tech:

1. Receives instruments, checks for damage, notes if any instruments have expired
2. Ensures that gown/gloves available for surgeon to scrub back in

Bedside assistant:

1. Removes instruments, undocks trocars
2. Robotic arms moved up and away from patient
3. Announces “robot is clear” once complete

Surgeon/Circulator

1. Removes robot from surgical field
2. Undrapes robot

Q6. What should be discussed during the post-procedure evaluation?

1. Were there any mechanical problems during the procedure which need to be conveyed to the manufacturer? Did any instruments expire and need to be replaced
2. Simulations
   - **iii.** Urgent undocking
   - **iv.** Empowerment –anyone can call "stop"
   - **v.** Robot malfunctions
     - **1.** Trouble shooting
     - **2.** Error message interpretation
     - **3.** Vendor support
     - **4.** Disengagement
   - **vi.** Anesthesiologist has concern

Development of the test of cognitive skills in robotic surgery – must be completed before progressing to psychomotor skills training.

A survey of learners and faculty (to improve the curriculum) needs to be completed.

(The following appendix was used in the development of the Curriculum. It includes the suggestions for the formats that can be used for presenting the various parts of the curriculum. These are currently under development)

APPENDIX A Work Table for the Didactic portions of the Curriculum

DIDACTIC CURRICULUM (Working outline)

This material will serve to introduce the trainees to the elements of the robotic surgical system and FRS test components through didactic presentations and to give them an overview about the steps that are necessary to conduct a safe and a successful robotic operation.

The format of the current outline includes a detailed description, suggested presentation formats, and comments for each bullet point of the original didactic component outline.

THIS SECTION COVERS THE BASIC OPERATIONAL ELEMENTS OF A ROBOTIC SURGICAL SYSTEM. IT IS NOT A REPLACEMENT FOR THE MANUFACTURER'S USER'S GUIDE AND OPERATIONS MANUAL.

General Principles

Initials	Topic	Description	Desired Presentation Format (Images/checklists/videos..)	Comments
GB		Many randomized trials have demonstrated the benefits of laparoscopic surgery over traditional open abdominal surgery. But the use of laparoscopic techniques has penetrated only a small percentage of gastrointestinal operations such as gastrectomy as laparoscopic surgery are still considered very difficult to perform. Indeed, many surgeons never overcome the inherent limitations of laparoscopic surgery. Laparoscopic surgery poses many barriers to performing minimally invasive interventions including: 1. Two dimensional imaging – Laparoscopic video laparoscopes project two dimensional images of the operative field onto television monitors. Although laparoscopic surgeons learn to interpret shading, perspective and overlapping to indirectly appreciate depth perception,	Citations and references to studies strengthening the background.	

		this requires great concentration and proves tiring and anxiety provoking. 2. Motion reversal – The laparoscopic trocar used for instrument insertion into the abdomen also acts as a pivot, with the fulcrum causing reversal of the surgeon's hand motions in the motion of the surgical instruments. Moving the handle of the laparoscopic instrument down causes the tip of the instrument to go up; and vice versa. 3. Motion amplification (scaling) - The laparoscopic trocar also acts as a lever arm. As the majority of the laparoscopic instrument is inside the patient and fulcrum, the lever action amplifies surgeon hand motions generating variable and larger excursion arcs of the instrument tips. For example, an inch long displacement of the laparoscopic instrument's handle may cause a three inch displacement of the instruments effector tip. 4. Limited degrees of freedom at the instrument tip – Laparoscopic instruments are limited in instrument tip degrees of freedom to a number the surgeon can safely and comfortably operate. Most current laparoscopic instruments do not feature a wrist at the instrument tip. The surgeon can move the instruments up and down and rotate them. Surgeon dexterity is further limited by location of the trocars which may force the instruments to assume a parallel orientation. The limited types of motion and the parallel alignment of the instruments make complex motions such as instrument tying very difficult. 5. Unstable camera platform – An assistant holds the laparoscopic camera. The camera holding assistant may need to stand for long durations in an uncomfortable position, may become tired and permit the camera to move. The Surgeon lacks direct control of the camera and may need to		

		frequently let go of one of the laparoscopic instruments to manually adjust the camera position. 6. Poor ergonomics – The laparoscopic towers holding the monitor and electronics equipment, may require the surgeon to stand in poor ergonomic position. Robotic Surgical Systems overcome these inherent limitations of laparoscopic surgery and facilitate the performance of minimally invasive surgery in ergonomics more comparable to traditional open surgery. This facilitation has encouraged more surgeons to offer minimally invasive procedures to their patients. Robotic surgical system advantages include: 1. 3-dimensional imaging – the imaging telescope contains two separate video cameras on its tip. These generate a true three dimensional video image by providing a separate two dimensional image to each eye, much like field binoculars. Viewing the operative field in three dimensions increases precision, reduces fatigue, and generates less anxiety during the operation. 2. Eliminate motion reversal – Robotic systems translate the motions of the surgeon's hands to the motion of the surgical instruments reversing the fulcrum effect present in conventional laparoscopic surgery. Moving the surgeon's hand up will move the surgical instrument up. This natural motion translation greatly simplifies the performance of complex tasks with the surgical instruments; 3. Permit favorable and configurable motion scaling – The surgeon can select specific levels of motion scaling appropriate for a procedure or task. For example, the surgeon might select a one to one translation of his hand motions to motion of the instrument or a 3 to 1 ratio or a 10 to 1 ratio for separate coarse and fine tasks of a		

		procedure; 4. Additional degrees of freedom in motion of the surgical instruments- Robotic instruments may include a wrist with additional roll/pitch/yaw ability at the instrument tip. The Surgeon can still move the surgical instruments up and down as well as rotate them. In addition, the wrist permits dexterous movement of the effectors separately from the long axis of the instruments. This added freedom of motion overcomes parallax issues and facilitates complex motions such as dissection, suturing and instrument tying; 5. Stable camera platform controlled by the surgeon – An assistant is no longer needed. The surgeon conveniently moves the camera telescope to the position offering the best visualization of the operative field by themselves. The camera maintains its position while the Surgeon manipulates the other surgical instruments to perform the operation. The field of view remains stable without tremor, rotation or migration. 6. Improved ergonomics – The surgeon may be able to sit during the operation at a surgeon's console. The visualization system may reconfigure to provide an ergonomic sitting position. In addition, padded configurable hand rest permit the fore arm, wrists and fingers to move with reduced fatigue for controlling the motions of the instruments. 7. Eliminate tremor – the mechanical and computing interfaces may be able to filter out tremors in the surgeon's hands making very delicate motions of the robotic instruments possible; In addition to overcoming the limitations of laparoscopic surgery, robotic surgical systems offer additional advanced safety mechanisms including: 1. Redundancy - Multiple sensing mechanisms and high precision		

		actuators suitable for surgical use. 2. Fault tolerance - The system recognizes errors and alerts the surgeon, allowing the operator to correct the error; and 3. Graceful degradation - Error in one robotic arm does not shut down the whole system; it merely degrades system performance to the remaining arms.		

System Components

Initials	Topic	Description	Desired Presentation Format (Images/checklists/videos)	Comments
RK	Components of robotic surgical systems and their individual functions.	Definition: A typical robotic surgical system consists of the following elements: - The Surgeon's Console - The Remote manipulator arms - The visualization support system - Accessories and their controls and cables and connectors One or more surgeon(s) consoles control the surgical instruments at the operative field by using master manipulators while viewing a monitor presenting the operating environment. The surgeon console also integrates controls to configure the whole system and the ability to communicate with the rest of the operating team, . Foot pedals and hand switches are available for system mode changes such as camera control or instrument operation. A set of patient-side manipulators designed to pivot about the entry ports hold a variety of removable dexterous or flexible surgical	• Images of all robotic elements – patient cart, vision cart/core, master console (multiple images – viewer, hand controls, input consoles/touch screen, grippers/masters, foot controls). • Two videos showing master grasping/activating instruments, foot controls. • A step-by-step identification guide for the images with annotations. • Example of set up joints The left and right pods house the user interface controls and are located on either side of the surgeon control armrest. The left pod houses the ergonomic control levers. The right pod houses the power button and emergency stop button. The touchpad that is located in the middle of the armrest controls the system audio and video, and saves	N/A

		instruments. These manipulators may be attached to passive articulating arms allowing their optimal positioning over the patient's body. A wide range of instruments for cutting, suturing, application of energy, and other needs can be attached and replaced during the procedure as required for the surgery. The input to the surgeon's monitor is generated by a stereo-endoscopic vision system that includes the camera, electronics, and a separate monitor for the operating team and assistants. Additional console(s) may enable training, assistance, collaborative, or remote surgery.	unique user preferences. The foot switch panel allows activation of energy and other patient cart controls such as instrument clutching, camera control, and arm swapping.	
TL	Monitor interface (including alerts/errors).	Operating data and alerts are presented and superimposed on the visual field of the operating surgeon and secondary displays improving information awareness and making error detection easier. Important events may also generate an audible alarm. For example, icons appear that report expired instruments, non-recognition of the instrument by the robot suggesting either adapter-arm connection issues or instrument-adapter connection issues, or which foot switch is being activated. Picture in picture capabilities also exist to allow the surgeon to simultaneously view additional surgery specific information	Pictures of each icon highlighted and alerts.	
DS	Secondary consoles	Secondary consoles allow for training, assistance, remote surgery, and surgeon collaboration. These console(s) allow control of the instruments and performance the procedure if	Images of secondary console Images/ animation of exchange between primary and secondary console and guidance with annotations	

		delegated by the primary surgeon. A system mode change permits the control of surgical instruments to be transferred between consoles. On screen annotations allow specific visual instructions such as indicating the planes of dissection or identification of target anatomy.		
RK	Master-slave relationship	Current robotic systems are not autonomous and unable to perform any function without the input of the operator; they merely translate surgeon commands into actions. In the normal operating mode, the surgical instruments reproduce the surgeon's hand motions at a configurable scale. For example, the system could be configured to operate at a "fine" scale where 5mm of master motions produce 1mm of slave motion. The instruments maintain the same hand orientation regardless of motion scaling. The camera is operated separately and differently from the remaining instruments. A mode switch disconnects the instruments (they will not move until you return to normal operation) and connects the camera to the both masters permitting change in camera position, orientation, and zoom. For example, moving both hands in/out will move the camera out/in, respectively (zoom). The system will not operate if the masters and slaves relationship is disrupted by overpowering the controls.	• Images of hand /instrument poses • Images of pedals • Images of icons and signs • Images of warnings/errors • Images of instrument attachment/removal A step-by-step identification guide with annotations.	Your hands are constrained by the master manipulators as if holding the two edges of the viewing screen. You can roll/pitch/yaw/zoom by moving this "haptic" bar intuitively. must remain matched in orientation. If the masters are overpowered or slaves are obstructed, the system will display an indication indicating you must

				relax your hands to allow masters to match the surgical instrumen t orientatio n. This will also occur when a new instrumen t is inserted, except when the system remember s the previous instrumen t pose.
TL	Instruments (end effectors) and accessories	Unlike laparoscopic instruments, robotic instruments allow for wristed motion at the instrument tip. A wide range of instruments exist and are being continuously updated. Please see manufacturer's product catalog for a complete list of instruments for your system.	Product catalog(s)	
TL	Energy sources	There are a variety of thermal/energy sources including monopolar shears/paddles/hooks, bipolar graspers, PK Gyrus, ultrasonic shears are available for robotic systems and each have their respective activation process.	Video of wrong thermal energy foot pedal selection. The two right-sided blue foot pedals on the floor plate govern the monopolar (right) and bipolar (left). Before depressing theses pedals, hover your foot over the desired pedal to ensure that the correct pedal will be depressed. There is an	
TL	Simulation components (surgical rehearsal).	The design, mechanism, and visualization of the robotic system can all be simulated. This affords the opportunity of less expensive training platforms and self-directed practice and surgical	Video of dry lab modules: suturing, block transfer, ring tower, rocking peg board. Pics of each simulator. Pics of some modules from	

		rehearsal. Simulation training can be performed with reality-based (RB) and virtual reality-based (VR) curricula. Dry lab (RB) training is critical for robot set-up, docking, patient positioning, understanding differences in suture material/size, and recognizing grasp effects of instruments on tissue phantoms. VR platforms exist to accelerate learning curves for instrument manipulation, clutching, camera movements, thermal cautery devices, knot-tying, warm-up, and some procedure-specific rehearsal. Evidence now exists that novices and experienced robotic surgeons derive a technical skills performance boost after simulation warm-up prior to actual surgical performance; thus, imbedding such a protocol before robotic surgery may be beneficial.	each VR simulator. Currently there are three primary VR platforms: MIMIC dV-Trainer (desktop simulator), Intuitive backpack simulator, and the RoSS (Robotic Surgery Simulator).	

System Functions

Initials	**Topic**	**Description**	**Desired Presentation Format (Images/checklists/videos..)**	**Comments**
RK	Adjusting the robotic console settings.	The surgeon's console(s) provide a wide range of configurable options. Options may include: Console ergonomics, camera type, motion scaling, and haptic feedback, digital zoom, control of any secondary consoles, control of energy and other devices, and communications control. A secure sign-on procedure may be available to automatically recall your configurable settings. This may be done via a menu in the console touch screen, at the secondary display, or may require operation of controls on the console.	• Images of the console user interface for storage/recall of console configuration (including sign-on if available). A step-by-step identification guide with annotations.	

RK	Ergonomics (for surgeon at console). Hyperlink definition to wikipedia	Prior to operating the instruments, it is essential to establish an operating workspace that permits free hand movement, comfortable body posture, and optimal visualization. Secondary hand and/ or feet controls may permit reconfiguration of the surgeon's workspace to avoid collisions with console hardware, or with each other. It is important that these controls are easily accessible and in positions where they are not accidentally activated. An essential component to maintaining appropriate ergonomics is recognizing fatigue symptoms such as eye fatigue, or body part discomfort and taking immediate steps to alleviate it.	• Images of the controls. A step-by-step identification guide with annotations. (Identify the ergonomic configuration for you.) TEST of understanding of ergonomics	A foot switch initiates camera control, and other switches/ pedals may operate cautery, irrigation, suction and similar related accessorie s
DS	Operating master controllers	The master controllers allow control of the instruments and the endoscope. Surgeons obtain control of the instruments by grasping these controllers (i.e. using their thumb and index finger) only if their vision is engaged in the operating field (i.e. by having their forehead inside the view panel). An inherent property of robotic systems is that when a handling error occurs an alarm or message can be displayed and control of the system may be temporarily suspended until the error is resolved. For example, the system will not operate if the masters and slaves relationship is disrupted by overpowering the controls. Applying too much pressure on the controllers will generate an error and temporary locking of the instrument. If this happens releasing the pressure and trying	Intuitive site has excellent presentations on this; something similar would work well; video animations likely best option showing how to move the controls and the effect of their movement on instrument motion Specific examples: It is also important to understand that if the forehead sensor is activated and the surgeon takes his fingers off the controllers after he/she has activated the instruments, the instruments could move uncontrollably potentially leading to an injury. This should be avoided. Moving the controllers in moves the camera away from the target anatomy while moving them out has	

		to move them gently again will fix usually the problem. To operate the camera, instrument control must be paused while the field of view is being adjusted. For example camera control is activated through a switching mechanism (i.e. a foot pedal, hand switch, or voice command). Camera focus is also adjustable.	the opposite effect. The camera focus can be adjusted if the camera foot switch is compressed and one of the controllers is rotated in the absence of in or out motion.	
DS	indexing /clutching	Due to the motion scaling capability of the robotic system and changes in the field of view, operator hand controls may need to be periodically repositioned to the optimal operating position. Clutching is used when the master controllers reach their limits of movement (collide with the console walls or with each other) or the surgeon operating position becomes uncomfortable. During this adjustment the master controls move independently from the instruments while maintaining instrument orientation	Intuitive site has excellent presentations on this; something similar would work well; video animations likely best option demonstrating each function By compressing the clutch the master controls can be brought back into an excellent ergonomic position and the procedure can be continued.	
DS	Visualization capabilities	In addition to providing a stable camera platform and navigation robotic systems may integrate advanced capabilities for visualization. This includes imaging beyond visual spectrum (i.e. near infrared), non-visual imaging (i.e. Ultrasound), and integration of preoperative imaging. For example, the 3D high-definition endoscopes are available in 12 mm and 8.5 mm diameters, 0, and 30 degree up and down. Each endoscope allows for a wide-angle 60-degree field of view and up to five levels of digital zoom. Visualization systems typically have to be white balanced and calibrated for stereo visualization	Intuitive site has excellent presentations on this; something similar would work well; video animations likely best option showing camera movement and sharpness control To move the camera, the camera foot switch has to be compressed; the master controls then direct camera position when moved together and allow the surgeon to change the viewing field. Moving the controllers in moves the camera away from the target anatomy (zoom out) while moving them out has the opposite effect (zoom in). Image sharpness can be adjusted if the camera foot switch is compressed and	

		(stereopsis or 3D view) prior to the procedure using the appropriate calibration equipment (i.e. calibration block).	one of the controllers is rotated in the absence of in or out motion. The camera can also be moved at the bedside by clutching the camera arm	
DS	Motion scaling	The robotic system scales hand motion. This permits translation of large hand motions by the surgeon into small motions by the instrument. For example, a 3:1 scale factor translates 3 cm of movement at the master controllers to 1 cm of movement at the instrument tip.	Images of motion scaling controls It will be harder but is doable to have an animation demonstrating the effect of different scaling levels on instrument movements Other scale factors available are 2:1 and 5:1 for ultrafine tasks such as cardiac or vascular surgery.	
TL	Collision avoidance	Because of the fulcrum nature of laparoscopic surgery instruments may collide both inside and outside the patient body and operator hand controls may collide with each other or the console. Collisions can be reduced by optimal trocar placement and robotic arm positioning at the beginning of the procedure. If a collision is encountered adjustments may need to be made at the bedside by repositioning of the arm manipulators; similarly clutching of the master controllers will mitigate surgeon hand collisions	Once the arms are all docked, attention must be taken to separate the elbows of the working arms from the camera arm to avoid arm collisions	
TL	Arm switching	Current Robotic systems may contain more than two arms; given that the surgeon can only control two of them at the same time a mechanism exists to exchange control between arms. For example, to swap arm control between the active and inactive arms, the console surgeon must activate the swapping switch. When such swapping occurs the master controllers must first assume the orientation of the new instrument before any motion is permitted. This ability also permits the use of inactive arms	Pic for arm swap pedal	

		for retraction, stable camera platform, or other assistance.		
RK	System operations	System operations begin with setting up the robot. The different components of the system have to be connected to ensure functionality. This is followed by customization and configuration of the operating interfaces (initialization and preferences) In order to maintain sterility disposable sterile barriers are required to cover the parts of the system that are within the operating field. Typically the console that controls the instruments is outside the sterile field; thus, the surgeon does not have immediate access to the bedside Both the surgeon and the bedside assistant have the ability to disable all robotic system motion using stop buttons in the event of an emergency. In the event of an unrecoverable error (e.g. power failure, system malfunction) the surgeon should not panic and follow manufacturer's specific instructions on recovering from the error, or removing the robot from the patient	• Images of the operating room with system components configured for preoperative phase. A step-by-step identification guide with annotations	

Preoperative Phase Didactic Instruction

Goals

Take the necessary steps to conduct a safe, successful robotic operation in a time effective manner.

Minimize the possibility of errors that may arise at subsequent steps of the operation.

Steps:

Initials	Topic	Description	Desired Presentation Format (Images/checklists/videos..)	Comments
RK	Identifying	The system may have been	• Images of the connected	

	structure of robot console and arms	connected by the operating team and its elements located in appropriate parts of the operating room. This includes: - The Surgeon's Console - The Remote manipulator arms - The visualization support system - Accessories and their controls and cables and connectors The surgeon should identify the components of the system (console, remote manipulator arms, visualization system, accessory control devices and control towers). It is also important to ensure that connections are correct, robotic, and accessory controls are accessible, and that the operating room is configured for safe operation. A walk-around is recommended prior to the procedure to ensure all components are connected and cables are not likely to be disconnected by accident.	system in an OR. A step-by-step identification guide with annotations. A template checklist for this step.	
RK	Setting up robotic system	Setting up the system involves configuring components so that they will have the workspace required for the operation. Operational requirements are dependent on the particular case, surgeon discipline and preferences. The set up specifically requires: a. Calibration – of the camera, patient side manipulators and the master manipulators, b. Configuration of patient	• Images of calibration steps A step-by-step identification guide with annotations. A template checklist for this step. Manufacturer's checklist for the device	

		arms according to the requirements of the procedure, c. Selection of remaining user preferences Upon configuration the appropriate checklist must be completed.		
RK	Turning on robot and calibration	Surgeons have to ensure that all components of the robotic system they are using are powered on. A power-on self-check is typically performed automatically but its successful completion may have to be verified by the team. A verification of the calibration process should be included in the checklist prior to positioning the robot arms. The power-on sequences should be completed with no accessories installed on the patient side manipulators. A calibration failure may render the robot inoperative for surgery and will require maintenance to repair and recertify the robot for human surgery. To prevent conversion during human surgery, it is advisable to schedule system maintenance instead of attempting power-off/recalibration steps. A robotic surgical system will recognize and interactively guide the user for some errors, but not all possible errors. Failed calibration and disconnected cables are detected and an audio alarm and message is displayed. However, if accessories	• Images of power and emergency buttons • Examples of successful and failed calibration. A step-by-step identification guide with annotations. A power switch is located on the surgeon's console. If not turned-on, turn on the robot.	

		remain installed on a training robot then calibration step may be "successfully" avoided. This must be manually monitored and indicated/assessed. After system configuration the appropriate checklist item must be completed.		
RK	Positioning of components (console, cart/arms, etc)	The components of the robotic system must be positioned in a way that prevents collisions with other equipment or the patient. For example, in a cart based manipulator extended arms may interfere with or break floor or ceiling mounted equipment. Care must be taken to orient the arms in the recommended stowing position prior to moving the cart base. Practice and familiarization is needed to safely operate the cart around patients. Positioning of the cart depends upon the surgical procedure and surgical preference. The visualization system must be positioned where the assistants/operating team can safely view, and interact with it. The console should be positioned safely outside the sterile field such that the surgeon is able to view the operative field without having to step away from the console. Upon configuration the appropriate checklist item must be completed.	• Images of patient cart and its wheels and controls. • Examples of successful and failed positioning. • With appropriate safety mechanisms, the cart controls can be activated. Cart controls are located in the cart handle. • Motorized carts will move on their own power if no accessories are attached. The system permits both forward and backward locomotion and manual steering. Please consult the procedure protocol for cart location.	
RK	Checklist of	The robot console	• Images of console elements	

	the settings on the robot console (check & respond)	configuration includes ergonomic positioning of (but not limited to): ▪ Ergonomic height of 3D viewer, ▪ Viewing configuration such that the surgeon sees a focused 3D view ▪ Location/configuration of seating ▪ Location/reconfiguration of foot controls where appropriate ▪ Location/reconfiguration of accessory controls, ▪ Location/reconfiguration of hand controls ▪ Location/reconfiguration (speaker and microphone volumes) of communication systems ▪ Motion scaling configuration for master-slave teleoperation ▪ Camera configuration/selection. Upon completion of moving and configuring the system components, an appropriate checklist item should be completed.	A step-by-step identification guide with annotations.	
DS	Draping of robot	Draping of the robotic arms should occur before the start of the case. Attention should be given to avoid contamination of the draped arms while they are not being used. Drapes and sterile protections should not interfere with arm motions. Upon draping completion the system sterility should be verified (i.e. No holes in drapes)	Video of appropriate draping (mainly geared towards nursing personnel?)	
DS	Patient transfer into operating room	No modifications are needed for the transfer of patients to the operating room; usual process is adequate	NN	
DS	Table	Table positioning and draping	Video example of positioning	

	positioning and patient draping	should follow standard processes and is specific to the operation performed. For example, upper abdominal procedures reverse Trendelenburg position and for pelvic procedures Trendelenburg position provide good exposure. The OR table should not be adjusted while the robotic arms are engaged in the patient. It is, therefore, important to obtain the table position that provides the best exposure prior to docking of the robot. Sterile patient drapes should cover all exposed surfaces and should not interfere with the positioning of the robotic arms	and draping for different procedures	
DS	Positioning of anesthesia, assistants and nurses	The surgeon should review the position of all robotic components in relation to ancillary equipment and OR personnel with the anesthesia team in order to ensure patient safety. Positioning should take into consideration potential problems that may occur during surgery. For example for cart-based systems clear the pathway that the robotic arms will take during docking.	Image of positioning for different procedures Example: If access to the mouth is needed (ie for an endoscopy) the positioning of the robotic arms should allow for this to occur For example the alignment of the cart to the target anatomy da Vinci(+sweet spot)	
DS	Time out	Prior to the start of every robotic procedure a time out of the surgical team should be performed to verify the identity of the patient and the correct procedure	Checklist	
DS	Anesthesia administration	The surgeon should communicate with the anesthesia team at the beginning and during the case to ensure adequate paralysis of the patient throughout the	Maybe a video of such communication during a live case	

		procedure to avoid patient injury by the robotic arms. In addition, to prevents delays in the extubation of the patient the surgeon should notify the anesthesia team in a timely manner about the anticipated procedure completion		

Preoperative Phase Errors

Initials	Title	Description	Desired Presentation Format (Images/checklists/videos..)	Comments
RK	Turning on robot and calibration: no power, data or other cables, failure to Calibrate	• Failure to calibrate the system • Failure to appropriately connect the system components to ensure functionality • Failure to recognize and address system error notifications •	*N/A.*	
RK	Checklist of the settings on the robot console (check & respond): doesn't perform list	• Failure to set or verify the appropriate console settings • Failure to use the checklist		
RK	Ignoring or failing to recognize error messages	• Failure to recognize and address system error notifications		
RK	Incorrect positioning of anesthesia, assistants and nurses	• Incorrect positioning of patient bed, OR staff, and equipment that leads to preventable collisions • Incorrect positioning of patient bed, OR staff, and equipment that prevents access to needed parts of the		

		patient		
DS	Time out: Time out check not performed	• Timeout not performed	NN	
DS	Draping of robot: contaminating sterile drapes or improper drape position interferes with instruments or camera	• Draping not performed • Drapes contaminated. • Drapes Damaged • Improper or incomplete draping	Examples of how the robotic drapes can be contaminated during or after draping. Examples of wrong placement of drapes that interferes with the case flow (i.e. docking and instrument exchanges etc). Video of how wrong draping can lead to problems docking the ports and placing/ exchanging the instruments	
DS	Patient positioning and draping: inadequate prepping, inadequate securing of patient position after docking (patient could move/slide during the procedure)	• Improper patient positioning – poor exposure or patient movement during the procedure. • Patient is not secured to the bed adequately by belts, tape, then during initial bed rotation or Trendelenberg positioning, • Patient slides or fall off the bed leading to injury. • Intended maximal positions of the bed are not tested after securing the patient, but prior to draping (injury may ensue due to patient shifting during the case and/or excessive pressure on certain body parts.) • Moving the OR table after the robot is docked (could potentially be prevented if the OR table is locked or its power cut (unplug)	Video showing the predraping/ docking table position testing ideally with demonstration of patient sliding. Also video that shows different positions corresponding to different exposures	

		so that it cannot be moved inadvertently during surgery) • Operative field and patient condition not verified after table motion • Inadequate prepping (may lead to contaminations of the operating field especially if draping has to be manipulated during the procedure. This can be prevented with wide prepping)		

Intraoperative Phase Didactic Instruction

Goals:

1. Demonstrate the completion of tasks to a benchmark of proficiency without critical error.
2. Understand the use and purpose of these individual tasks to future procedures.
3. Improve psychomotor, spatial, perceptual, cognitive, communication, leadership, and management skills to the benchmark level of proficiency.
4. Learn and become proficient in alert recognition, identification of source and correction of errors.

Steps:

Initials	Title	Description	Desired Presentation Format (Images/checklists/videos..)	Comments
TL	Trocar placement	Trocar insertion technique is dependent on surgeon preference. Trocar positioning is specific to the procedure and robotic system. For abdominal cavity procedures, typical access is initiated at the umbilicus. Many procedures use the umbilicus for the 12mm or 8.5mm camera port and 2-3 additional working 8mm or 5mm robotic ports. Identification and/or marking of anatomic landmarks helps guide the user for appropriate targeting to the desired operative field. There are varying strategies for positioning including triangulation, diamond, and HIDES positioning. (THE FOLLOWING SEGMENT HAS BEEN ADDED UNEDITED FROM THE RESPECTIVE ERROR SECTION)	Pics for trocar insertion, possible video of port placement, examples of triangulation, diamond, HIDES, thoracic insertion.	

		Several errors can occur during trocar placement. Most important is to avoid injuries during trocar insertion. Therefore the type of access technique and the familiarity of the surgeon with this technique are critical. In general all access techniques (open and closed) can be performed safely if appropriately used. For open cut-down techniques usually the umbilicus is used. For closed techniques an off midline entry location is preferred as it prevents potential injury to the big vessels that can be fatal. The surgeon should be familiar with different entry techniques to be able to switch from one to the other when difficulty is encountered; this approach will likely decrease injury risk. A general rule is that initial entry should be away from previous scars to prevent injuring any adherent bowel underneath. (for abdominal access). It is also of paramount importance that surgeons look for injuries after trocar placement to verify their absence. Surgeons should also have an appropriate plan for where they will place their trocars to be able to accomplish their procedure safely. While trocar placement is procedure specific		

		common errors such as placing the trocars too close to each other (<10cm apart) is likely to lead to collisions of the robotic arms during the procedure and compromise its feasibility and safety. In addition, appropriate trocar placement in relation to the target anatomy is important. Generally a distance of 10-20 cm between the trocar and target anatomy is considered appropriate. Short or too long distances can be problematic. Robotic trocars need to be inserted up until the thick black line can be visualized at the level of the peritoneum. If this is not the case injuries to the port site can occur. Surgeons need to check for appropriate position of the trocars prior to docking (especially if part of the case till then was done laparoscopically) EXAMPLES: Because insufflation distorts anatomic landmarks in the abdomen marking of working port insertion sites should occur after insufflation is complete. Initial access to the chest is dependent on the craniocaudad position of the target anatomy and the camera port is placed between the ribs. For		

		transoral, transorbital, subcutaneous trocar insertion, please review anatomy-specific curricula.		
TL	Position of patient and robot cart - orientation of all arms	The orientation of the surgical cart (robot) to the patient is dictated by the target compartment. 1) Pelvis – at the feet, between the legs, or side-docked. 2) Flanks – along side of patient. 3) Upper abdomen – position cart over the shoulder. 4) Chest – alongside chest. The working arms are typically positioned on either side of the camera arm.	Pics for pelvis, flank, upper abdomen, and chest surgery. Show pic of most common arm position and side docking.	
TL	Docking of robot cart and arms correctly (Collision avoidance)	The robotic arms can be docked in varying sequences to ensure minimizing likelihood of arm collisions. 1) Docking from right or left arm first and going in sequence across the camera port than one or two other opposite working ports. 2) Camera port first. 3) Camera port last. Once the arms are all docked, attention must be taken to separate the elbows of the working arms from the camera arm to avoid arm collisions once docked. To avoid bruising on the skin, each port should be manipulated (burped) to slightly evert the skin as opposed to depressing the skin into the patient. This also increases the distance of the trocars to the target anatomy which is especially	Video of separating elbows of arms. Video of burping camera.	

		important for the camera port in small spaces.		
TL	Instrument insertion	Whether using 8mm or 5mm instruments, instrument end effectors should be straightened before insertion to avoid puncture of trocar seals. First engage the tip of the instrument into the diaphragm of the trocar seal, and then seat the housing of the instrument against the sterile adapter above the sterile adapter tracks. The instrument is then slid down into the sterile adapter tracks until the four spindles engage the instrument. If the insertion is the first one of the case, the clutch button will need to be depressed to slide the instrument in and position the arm. If the insertion is a tool change, the clutch button does not need to be depressed to insert the new tool to the existing position (guided tool change). The instrument tip will be 2-3mm proximal to the tip position of the previous instrument tip as a result of this software safety mechanism.	Video of tool insertion.	

Surgeon Transition to Console:

RK	Establish ergonomics: Put head in surgeon's console, hands on the master controls. (Input devices handles)-configure viewer & hand/foot controls in a comfortable position.	Prior to operating the robot, surgeon ergonomic positioning should be established for the duration of the procedure (please refer also to the ergonomics section in the introduction). Appropriate ergonomic are important to minimize surgeon fatigue during the procedure which may jeopardize patient safety and/ or to avoid chronic musculoskeletal injuries. Ergonomic settings can usually be established manually or recalled from stored system memory. For example, in existing systems surgeons have the ability to place the viewer, level of hand rest, and foot controls in a comfortable position and configure the 3D stereo vision.	Images/video of uncomfortable seating positions, and conflicting hand controls with annotations.	
RK	Locate the task supplies and instruments	Task supplies are usually located within the surgical workspace such that a trainee is able to navigate to the supplies themselves by reconfiguring instruments and camera.	Images of locations of supplies and instruments.	
RK	Set up visual field: navigate to the operative field for the specific task	To set up the visual field, the surgeon has to activate the visualization system and obtain the appropriate field of view for the respective procedure. The focus and level of zoom can be adjusted as needed. To increase safety, the surgeon should strive to maintain the widest field of view possible for the task performed, and to keep the operating instruments in the center of the field. Frequent readjustments of the view field may be necessary during a procedure.	Images/video of good/poor visual field setup with annotations.	

DS	Activate the instruments.	To activate the robotic instruments the surgeon has to engage the robotic console. For example, placing their head within the console visual monitor rest. Next the surgeon has to place their fingers inside the controllers and gently move them to obtain control of the instruments. Applying too much pressure on the controllers will generate an error and temporary locking of the instrument. If this happens releasing the pressure and trying to move them gently again will fix usually the problem. In the current robotic system, if the forehead sensor is activated and the surgeon takes their fingers off the controllers after he/she activating the instruments, the instruments could move uncontrollably potentially leading to an injury. This should be avoided	Video of doing this	
DS	Perform the task according to instructions	INSERT INSTRUCTIONS FOR THE SPECIFIC TASKS	VIDEO of task performance	
DS	Perform pre-test of all tasks	A pre- test for each task is necessary to obtain baseline performance of learner to be able to assess impact of training on future performance	MAYBE ADD DETAILS OF HOW TO DO THIS	
TL	Performance of tasks* (task specific instructions need to be developed).	*AFTER PSYCHOMOTOR GROUP SPECIFIC TASK OUTLINES* Dry lab docking exercises should be performed to accelerate performance times and become fluent with tool changes.	Pics/videos of each standard task. Didactic slides describing each task.	
TL	Review performance of task(s) and obtain feedback and correct	Surgical instructors will establish performance benchmarks and go over each skill with the learner. A video demonstration will be viewed	Standard protocol for OSATS/GEARS of surgical performance. Crowd-sourced	

	errors	with a brief didactic portion describing the task. Learner performance can be viewed real-time or video-taped for later instructor grading. Debriefing of learner should ensue, ideally directly after the performance sessions. Errors will be highlighted for the learner through self-video appraisal, one-on-one instructor appraisal, or crowd-sourced appraisal.	protocol.	
TL	Repeat task(s) until benchmark proficiency has been achieved to at least 2 consecutive trials have achieved benchmark criteria score.	Repeat task performance until provided proficiency measures have been met. Typically, at least two consecutive trials must meet proficiency thresholds before a task is considered to have been completed with adequate proficiency.	Develop standard 'worksheet' for instructor to capture learner performance and possibly do real-time error tracking (MSCORE, etc.)	???should group establish draped docking time benchmarks, create standard docking platforms?? Should we use average human tool change times to grade learners??
TL	Prevention of injury to patient during surgery	When positioning the robot to the patient, docking the instrument manipulators, and installing/exchanging instruments, specific procedures (see manufacturer protocol) must be followed to enhance safety and prevent patient injury. Ensure that all the arms are free of collision with the patient. It may be difficult to visually appreciate whether the arms are pressing on the anatomy under the drapes; for example the legs (for pelvic surgery), the head or chest (for over the shoulder positioning – upper abdominal surgery), or patient arms on arm boards/at side (for flank surgery). The bedside assistant may need to verify appropriate positioning of the robot by sweeping the open space with their hands by enabling manual motion of the instrument manipulators	Video of check for avoiding arm collisions with draped patient. Video of following instrument into patient with camera. This is not necessary for subsequent tool changes if the clutch has not been depressed because of the built in guided tool change software functionality. – guided tool change is patented, will not exist in other systems – RK.	

		(clutching) and moving them to the steepest and shallowest positions. During surgery, each inserted instrument must be visually monitored (manually by the assistant for first insertion or by the surgeon for exchanges) with the camera to its operating position. While some systems may provide assistive modes for instrument exchanges, these are only aids and do not excuse visual monitoring of instrument insertion.		

Intra-operative Phase Errors

Initials	Title	Description	Desired Presentation Format (Images/checklists/videos..)	Comments
DS	Trocars placement: trocar entrance injury, incorrect position, spacing and location, incorrect insertion depth, port-site injury	• Ports placed in areas of previous scars • Not checking for injuries after placement • Tip of the trocar not visualized during insertion	Video demonstrations of safe use of open cutdown, Verress needle, and Optiview techniques. Ideally video showing injuries occurring Video of arm collisions at the bedside due to inappropriate trocar placement Video or picture showing injury to port site when port not inserted appropriately Images of correct and incorrect port positions (outside view and inside)	
TL	Docking: failure to lock robot arm to trocar, moving the bed after docking (so bed does not move)	• Inadequate/incorrect positioning of the arm prevents secure seating of the trocar within the clasping/attaching mechanism. Trocar not securely attached/locked. • Trocar motion due to incorrect positioning of the fulcrum point. • Bed rotation/patient repositioning after	Steps that can be taken to streamline arm attachment to the trocar include: clutching the arm and angling the arm in the same angle of incidence to the patient as the trocars lies, guiding the arm with one hand while depressing the set-up joint button and using the opposite hand to support the trocar. If there is significant resistance to depressing the trocar clasping wings, the	

		docking. • Port damage/patient injury during docking.	trocar is probably not seated appropriately. Release the trocar and reposition the angle of the arm.	
TL	Instrument insertion: instrument not completely through trocar, not maintaining view of instrument during the insertion, collision of instrument with tissue upon insertion (automatic insertion mode).	• Instrument insertion not followed visually • Wrist not visible past the trocar (instrument not ready for surgical control) – This is done by the assistant, not the console surgeon (RK). • Overpowering the master controls prevents master/slave alignment and instrument activation.	If the console telemanipulators cannot receive control of the instrument after insertion, check to make sure that the instrument tip is completely out of the trocar. Clutch the affected arm and slide the instrument in further to clear the trocar edge.	
TL	Final review of set up: does not perform final review of robot arms, instrument/trocar position before going to console, change position of arm or trocar without removing instrument.	• Review not performed. • Patient positioning not verified		

Surgeon Transition to Console

RK	Removal of instrument while still grasping tissue	• Attempting to remove the instruments when they are still attached on tissue or crossing inside the patient • Clutching the robotic arm during instrument exchange without monitoring the new instrument tip during reinsertion	Images of careful, careless tissue handling along with annotations of error levels.
RK	Failure to ask for instrument change, failure designate instrument to specific Arm and other communication errors	• Surgeon does not specify and communicate to the team which instrument arm has to be exchanged • Surgeon or bedside assistants do not communicate clearly requests (for instrument exchange, suture	*N/A*

		insertion, energy activation etc) • Poor guidance / communication with of the bedside surgical assistant	
DS	Collision of instruments outside of field of view during insertion	• Instruments inserted without direct visualization - Inserting instruments without direct visualization and guidance is dangerous and is an error. Collisions of the instruments with tissue can occur that may lead to preventable injuries. To avoid this risk it is advisable to zoom the camera out during instrument exchanges to widen the view field or try to visualize the trocar tips as the instruments are introduced if possible. This can be achieved by the bedside assistant clutching the camera arm and moving it in the direction of the trocar having a new instrument inserted or by the surgeon clutching the camera/manipulators in direction of the trocar. • Instruments inserted rapidly - Communication should occur between the bedside assistant and the surgeon to mark the beginning and end of a tool change. It is an error for the bedside assistant to clutch the working arm unless manual bedside arm movement is required or the instrument insertion is the first one of the case. In the current robotic platform, a guided tool change is a safety measure that allows the bedside assistant to perform a tool exchange without clutching the arm. Passage of the instrument travels to within 2mm proximal of the original tool tip position.	This may be better served by an animation that shows an instrument collision outside the field of view when not approached appropriately A video or animation of the impact of clutching during instrument exchange may also be useful;
TL	Assistant safety from robotic injury – monitoring assistant (eg: injury from assistant holding suction, etc)	• Accidental assistant contact or injury • Lack of (or insufficient) communication between the console surgeon and the assistant • Console surgeon request for	Establish a safe working space for the bedside assistant when placing assistant ports. Make sure that the console speaker is on so that the

		assistant to place body parts in robot workspace when arms are in motion	assistant can hear intentions of the console surgeon and make sure room noise is minimized so that the console surgeon can hear the bedside assistant. The bedside assistant should avoid/minimize placing hands/arms in between two moving arms to prevent pinching or crushing. Especially for shorter bedside assistants, care must be taken to avoid positioning head near robot arms.
TL	Visualization/camera: inadequate or loss of pneumoperitoneum or vision.	• Loss of pneumoperitoneum (e.g. air seal leak from trocar diaphragms, an open trocar valve, inadvertent disconnection of the insufflation tubing to the trocar valve), • inadvertent dislodgement of the trocar out of the patient • CO2 availability (empty tank) not recognized • Delay in or (lack of) recognition of degradation in visualization	To trouble shoot the loss of pneumoperitoneum, check all aspects of the insufflation circuit. loss of visualization can also occur from a broken light bulb

Post-operative Phase Didactic Instruction

Goals

1. Ensure all instruments/supplies are removed and there is no intra-operative injuries.
2. Safely undock robot and transfer patient.

Steps

Initials	Title	Description	Desired Presentation Format (Images/checklists/videos)	Comments
RK	Checklist: no retained foreign body, undetected injury outside operative field -- specific for	At the end of each procedure the surgeon should ensure that all foreign bodies and specimens have been removed from the patient and no undetected injuries have occurred. To accomplish this it	Examples of foreign bodies left (rings, sutures, needles …) as appropriate in image and annotations.	

	robot	is important to re-inspect the operating field and all areas outside the operating field where an injury to tissues could have occurred (ie. Near trocar insertion sites). A checklist that verifies that foreign bodies introduced in the operative field or specimens have been removed and a check for injuries has been performed can be very valuable. Failure to complete this step may lead to adverse patient outcomes and constitutes a serious error.		
RK	Safe removal of all instruments, supplies, trocars	All instruments, supplies, and trocars used in a procedure should be removed carefully. In addition, they should be inspected to verify that no damage occurred during the procedure that could have resulted in foreign body retention in the patient. Dropping of instruments or equipment during removal can lead to patient/staff injury or damage the system. It may also lead to costly repairs. (i.e. dropping and breaking the camera)	Examples of unsafe removal (minor damage to major damage) with annotations.	
DS	Closing the incisions (port site).	Evidence-based standard port closure practice is recommended based on port size and location. (See Example COCHRANE review REFERENCES if available.) Generally fascial incisions related to ports> 10mm should be approximated with suture. For smaller fascial closure it is up to the surgeon to determine the closure requirements.	*Videos of port site closure techniques*	
DS	Undocking robot and moving away from patient	Prior to undocking all instruments have to be removed from the patient and prior to instrument removal all instruments need to be disengaged from any tissue	*Video of undocking procedure*	

		contact. The camera should also first be removed. To undock the arms the arm-trocar locking mechanism needs to be released first and then the arms be disconnected from the trocars. Next the arms are elevated away from the trocars and positioned in a way to freely clear the patient upon rolling the robot away from the patient. CHECKLIST PER TEAM TRAINING EFFORT		
DS	Reposition patient for incision closure and transfer	After the robotic cart has been removed from the patient the OR table is usually brought back to its neutral position for incision closure and patient transfer to the stretcher.	*Not needed*	
TL	Transfer from bed to gurney	Upon expiration of anesthesia, patients may move erratically without balance. Assistants should monitor the patient on the OR table until the gurney is beside the bed. Usual safe transfer practices must be followed. Safe transfer may involve a roller board or slide board placed underneath the patient to utilize low friction transfer to the gurney.	Pic of rolling patient. Reference to safe transfer section of textbook.	
TL	Transport to recovery room	Usual safe practices for transport must be followed. A member of the primary surgical team should accompany the patient to recovery to facilitate adequate handoff of the patient to the recovery nursing staff. Any drains should be double checked for security because of the recent moves from the OR table and the awakening patient.	Pic of twisted/malpositioned Foley urethral catheter. Reference to safe transport section of the textbook.	

Post-operative Phase Errors

Initials	Title	Description	Desired Presentation Format (Images/checklists/videos...)	Comments
RK	Not performing the checklist	• not performing the checklist • retained foreign body or specimen • unrecognized patient injury	Examples of incomplete ignored checklists.	
RK	Crossing of instruments prevents removal	• Attempting to remove instruments when they are still attached on tissue or crossing inside the patient • Undocking the ports before the instruments are removed • Advancing the instruments towards the patient during removal (instead of just pulling them out; this could happen especially if the arm is clutched during removal) • Clutching the robotic arm before instruments are removed	Examples of open or non-neutral position instrument preventing removal from cannula, crossing of instruments causing collisions	
RK	Dropping of camera lens or other instruments	• Dropping instruments or other equipment during removal	Images of damaged camera/endoscopes.	
DS	Discarding camera mount while removing drapes	• Camera mount discarded: when removing the drapes from the robot the camera mount should not be discarded as it is reusable.	Image of what it is so people can recognize it	
DS	Move table before robot undocked, injury to	• Bed position moved while the robot is engaged with the patient - Repositioning	Images or videos of errors (patient movement prior to undocking, robot patient	

	patient arm/body part, damage to robot by crashing into obstructions in the OR, not disconnecting and damaging cables/cords	should occur only after the robotic arms have been removed from the OR table and the patient. It is an error to move the robot away from the patient without ensuring that the arms are clear of the patient or the OR table. • Robot path not cleared - ensure that the path the robot will be backed out in the OR is not clear or IV poles, fixed or moveable equipment. • Cables not organized - gather any connecting robotic cables off of the floor in the immediate path of the backing-up robot to avoid damage to the cables.	and robot other equipment collisions during undocking and movement away, running over cables with the robotic cart, etc)	
DS	Visual removal of trocars - unrecognized bleeding at trocar site	• Trocars not visualized - observe the removal of the trocars under direct vision from within the abdomen or from outside the patient as missed bleeding could result in morbidity.	Video of abd. wall bleeding after trocar comes out	
TL	Unrecognized bleeding, failure to approximate fascia when appropriate	• Unrecognized abnormal condition (e.g. bleeding) • Poor illumination not recognized. • Port site closure of fascia without appropriate visualization (unless closure device used)	In the event of pooling blood, halt surgery and inspect the pool for active bleeding. Make sure suction is available to clear the field. Inspection of the port sites as the patient wakes up or coughs. Provide evidence of incomplete fascial closure with a distinct bulge under the closure. If illumination within the abdominal or chest cavity decreases without any change in the light	

			settings, one should look for active bleeding as pooling blood absorbs light.	
TL	Damage bed, or table or gurney when repositioning OR table	• Safe repositioning protocol not followed • Collisions between or damage to OR equipment, bed, table or gurney. • Table rails or table not lowered • Patient injury during repositioning	Pic of trapping gurney with lowered OR table Sketches or images of the gurney approaching the OR table for patient transfer, the gurney trapped under the OR table rails as the OR table is lowered.	
TL	Transfer from bed to gurney, transport to recovery room	• Safe transfer protocol not followed • Patient condition not verified • Staff not identified/directed to accompany patient to recovery room	Image of patient transport to recovery room.	

At the end of the didactic presentations, the candidates will be asked to complete a survey to assess curriculum.

FRS task specific text

Initials	**Topic**	**Description**	**Desired Presentation Format (Images/checklists/videos...)**	**Comments**
RK	Locate the task supplies and instruments	Task supplies are usually located within the surgical workspace such that a trainee is able to navigate to the supplies themselves by reconfiguring instruments and camera.	Images of locations of supplies and instruments.	
DS	Perform the task according to instructions	INSERT INSTRUCTIONS FOR THE SPECIFIC TASKS	VIDEO of task performance	
DS	Perform pre-test of all tasks	A pre- test for each task is necessary to obtain baseline performance of learner to be able to assess impact of training on future performance	MAYBE ADD DETAILS OF HOW TO DO THIS	
TL	Performance of	*AFTER PSYCHOMOTOR GROUP*	Pics/videos of each	

	tasks* (task specific instructions need to be developed).	*SPECIFIC TASK OUTLINES* Dry lab docking exercises should be performed to accelerate performance times and become fluent with tool changes.	standard task. Didactic slides describing each task.	
TL	Review performance of task(s) and obtain feedback and correct errors	Surgical instructors will establish performance benchmarks and go over each skill with the learner. A video demonstration will be viewed with a brief didactic portion describing the task. Learner performance can be viewed real-time or video-taped for later instructor grading. Debriefing of learner should ensue, ideally directly after the performance sessions. Errors will be highlighted for the learner through self-video appraisal, one-on-one instructor appraisal, or crowd-sourced appraisal.	Standard protocol for OSATS/GEARS of surgical performance. Crowd-sourced protocol.	
TL	Repeat task(s) until benchmark proficiency has been achieved to at least 2 consecutive trials have achieved benchmark criteria score.	Repeat task performance until provided proficiency measures have been met. Typically, at least two consecutive trials must meet proficiency thresholds before a task is considered to have been completed with adequate proficiency.	Develop standard 'worksheet' for instructor to capture learner performance and possibly do real-time error tracking (MSCORE, etc.) ??? Should group establish draped docking time benchmarks, create standard docking platforms?? Should we use average human tool change times to grade learners??	