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1   **Usability Assessment of Versius, a New Robot-Assisted**

2   **Surgical Device for use in Minimal Access Surgery**

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4   F. Haig, A.C.B. Medeiros, K. Chitty, M. Slack

5   **SUPPLEMENTARY MATERIALS**

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1   **SUPPLEMENTARY DATA**
2
Supplemental Table 1. Task subgroups undertaken by user group

Subgroup	S	AS	SN	CN
Transport and storage at hospital			✓	✓
System setup	✓	✓	✓	✓
Visualisation and arm draping			✓	✓
Instrument arm draping			✓	✓
Cart draping			✓	✓
Endoscopic camera setup	✓	✓	✓	✓
Cart positioning	✓	✓	✓	✓
Port training and instrument adjust	✓	✓	✓	
Console setup	✓			✓
Menu Navigation	✓	✓	✓	✓
Generic surgical procedure	✓	✓	✓	✓
Instrument change or removal	✓	✓	✓	
Endoscope clean or replace	✓	✓	✓	
Remove all arms		✓	✓	
Convert to open/manual	✓			✓
Close with scope	✓	✓	✓	
Alarms	✓	✓	✓	✓
Teardown and cleaning			✓	✓
Sleep scenario	✓			✓
Knowledge test (e.g. Battery operation and system icon identification)	✓	✓	✓	✓

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1   **Supplemental Table 2.** All tasks undertaken during the simulated use workflow

Category	Task	Critical (Y/N)
Transport and Storage	Take accessory from hospital storage	N
	Collect single-use items from storage	N
	Select appropriate length of drape	Y
	Transport single-use items (and accessories) to OR	N
	Release console brake	N
	Transport console to operating theatre	Y
	Remove brake from Cart	N
	Transport cart to / from operating theatre	Y
System setup	Remove brake from console	N
	Plug in console	Y
	Switch console on	N
	Check if console passes POST	N
	Connect Aux Display to console	N
	Pull out console arms	Y
	Set console height	Y
	Set screen height	Y
	Set screen angle to aid in cart connection and draping	N
	Select 2D or 3D	N
	Move cursor to menu icon	Y
	Select menu or sub-menu	Y
	Assign endoscope angle	Y
	Assign language	N
	Access system status	N

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	Access "About"	N
	Release brake from cart	N
	Engage brake on cart	Y
	User decides on cable length to use	Y
	User finds cable of desired length	Y
	User folds away flip-out console cable retainers	N
	Connect cart to console	N
	Connect cart to cart	Y
	Connect video feed between console and visualisation BSU	N
	Identify there is an alarm on Instrument BSU	N
	Decide what to do (remove arm)	N
	Replace alarmed arm	N
	Power down alarmed unit	N
Draping	Press and hold sleep mode button to wake up Visualisation BSU	N
	Push Visualisation arm to accessible position to facilitate easy draping	Y
	Select appropriate length of drape	Y
	Unpack the Visualisation BSU drape and expose sterile drape to Scrub Nurse	Y
	Place hands into folds as indicated by labels	N
	Place drape on robotic arm	Y
	Fit Visualisation BSU drape cap to mounting bracket	Y
	Unfurl sleeve of drape below elbow (but before shoulder)	Y
	Remove yellow tape	N
	Pull down cart drape to cover cart	Y
	Locate cart drape elastic at top of cart column	Y
	Tether drape in place on arm	Y
	Remove green tape	Y

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	Press and hold sleep mode button to wake up Instrument BSU	N
	Push the instrument BSU arm to accessible position to facilitate easy draping	N
	Select appropriate length of drape	Y
	Unpack the Instrument BSU arm drape and expose sterile drape to Scrub Nurse	Y
	Place hands into folds as indicated by labels	N
	Place drape on robotic arm	Y
	Fit drape cap to instrument interface	Y
	Engage locking ring on instrument arm drape cap	Y
	Fit drape insert to drape cap	Y
	Remove tape from drape cap insert	Y
	Unfurl instrument arm sleeve down arm	Y
	Remove yellow tape	N
	Pull down cart drape to cover cart	Y
	Locate cart drape elastic at top of cart column	Y
	Tether drape in place on arm	Y
	Remove green tapes	Y
Endoscope draping	Choose telescope based on desired angle	N
	If chosen angle is 30 degrees then put in correct orientation (up or down)	N
	Drape telescope	Y
	Drape camera	Y
	Connect camera to telescope	Y
	Connect video feed between console and visualisation BSU (if not already done during set-up)	N
	Connect camera cable to cart	N
	Connect light cable to camera	N
	White balance camera	Y

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	Insert endoscope (for manual use)	N
BSU positioning	Press elbow button to lock arm before moving to bedside	N
	Release cart brake for cart positioning	Y
	Move cart to desired bedside position	Y
	Activate cart brake for cart positioning	Y
	Set and check relative cart orientation – visualisation ARM	Y
	Adjust cart height for arm setup	Y
	Attach endoscope to arm	Y
	Tether light cable	N
	Press elbow button to lock arm before moving to bedside	N
	Release cart brake for cart positioning	Y
	Move cart to desired bedside position	Y
	Activate cart brake for cart positioning	Y
	Set and check relative cart orientation	Y
	Adjust cart height for arm setup	Y
	Attach instrument	Y
	Identify that instrument life has expired (will happen on 1 arm only)	N
	Connect ES generator to cart	Y
	Tether ES instrument cable down arm	Y
	Plug ES instrument cable to cart	Y

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Port training and instrument adjust	Place endoscope into the port ready for port training	N
	Port train endoscope	Y
	Move (endoscope) to operative area in instrument adjust mode	Y
	Put endoscope in surgical mode	N
	Press wrist button to switch to unlock arm	N
	Insert instrument into port training instrument 2	Y
	Switch arm to Port Training Mode by pressing wrist button	Y
	Use is aware they are in "Port Training" mode	N
	Port Train the VPP by moving the wrist in an arc back and forth	Y
	Port training fails - user required to re-enter port training mode (if it occurs)	Y
	Port training successful - press wrist button to enter instrument adjust	N
	Advance instrument into cavity using arm so that instrument is visible to surgeon	Y
	Press wrist button to switch to Surgical Mode	Y
	Insert instrument into port	Y
	Switch arm to Port Training Mode by pressing wrist button	Y
	Use is aware they are in "Port Training" mode	N
	Port Train the VPP by moving the wrist in an arc back and forth	Y
	Port training fails - user required to re-enter port training mode (if it occurs)	Y
	Port training successful - press wrist button to enter instrument adjust	N
	Advance instrument into cavity using arm so that instrument is visible to surgeon	Y
	Press wrist button to switch to Surgical Mode	Y
	Insert instrument into port	Y
	Switch arm to Port Training Mode by pressing wrist button	Y
	Use is aware they are in "Port Training" mode	N
	Port Train the VPP by moving the wrist in an arc back and forth	Y
	Port training fails - user required to re-enter port training mode (if it occurs)	Y

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	Port training successful - press wrist button to enter instrument adjust	N
	Advance instrument into cavity using arm so that instrument is visible to surgeon	Y
	Press wrist button to switch to Surgical Mode	Y
Console set-up and menu navigation	Pull out console arms (if not already done)	Y
	Set the console height (if not already done and/or if the surgeon wants to adjust)	Y
	Set screen height (if not already done and/or if the surgeon wants to adjust)	Y
	Select 2D or 3D	N
	Surgeon puts on 3D glasses	N
	Move cursor to menu icon	Y
	Select menu or sub-menu item	Y
	Assign language	N
	Check hand scaling and change if necessary	Y
	Select claim surgery	N
	Scan QR code with mobile or tablet	N
	Assign endoscope angle	Y
	Assign connected arm to hand	Y
	Disengage instrument	N
	Turn video recorder on and off	Y
	Exit menu	N
	Access system status	N
	Access 'About'	N

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Surgical procedure – Surgeon	Place endoscope into the port ready for port training	N
	Port train endoscope	Y
	Put endoscope in surgical mode	N
	Undock the hand controllers	N
	Stow the dock features into the arm rest	N
	Visualise the surgical field	Y
	Orientate the instrument	Y
	Move instruments to the operative field	Y
	Engage instrument	Y
	Surgeon disengages instruments	Y
	Actuate jaw control	Y
	Actuate articulated instrument (instrument pitch, roll, yaw)	Y
	Select ES mode	Y
	Actuate electrosurgery	Y
	Rest hands letting go of hand controllers)	Y
	Rest hands (grasping the hand controllers)	Y
	Selecting of alternative instrument/arm	Y
	Dock the hand controllers	N
	Communications between members of surgical team	Y
	Miscellaneous errors arising during general surgical procedure	Y
	Clear instrument jaws of anatomy (instrument change scenario)	Y
	Straighten/close instrument jaws manually (instrument change scenario)	Y
	Straighten/close instrument jaws using thumb stick (instrument change scenario)	Y
	Surgeon request Instrument Change	Y
	Hand not detected if this happens - User identifies there is an issue and corrects	Y
	Surgeon requests instrument change (instrument adjust scenario)	Y

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	Surgeon clears instrument jaws of anatomy (instrument adjust scenario)	Y
	Surgeon straightens/closes instrument jaws manually (instrument adjust scenario)	Y
	Surgeon straightens/closes instrument jaws using thumb stick (instrument adjust scenario)	Y
	Surgeon requests endoscope is cleaned	N
	Surgeon requests endoscope is changed	N
	Surgeon disengages instruments	Y
	Actuate Stop	Y
	Recognise Stop	N
	Identify there is an alarm (arm high priority alarm scenario)	Y
	Identify there is an alarm (system medium alarm console flashing yellow leading to locking of arms scenario)	Y
	Pause alert audio (only if surgical team choose this action)	N
	Unpause alert audio (via console)	N
	Unpause alert audio (via menu)	N
Instrument change	Press the wrist button to put the arm in instrument change mode	Y
	Recognise that arm has entered instrument change mode	N
	Use one hand to retract instrument by sliding along the virtual Z rail. Use other hand to hold the port.	Y
	Remove ES cable form instrument (if applicable) (instrument change mode)	N
	Remove the instrument by squeezing together instrument latches on the instrument using one hand (instrument change scenario)	Y
	Pass instrument to scrub nurse or place on the robotic instrument tray (instrument change scenario)	Y
	Pick up new instrument from scrub tray in front or to the side (instrument change scenario)	Y
	Attach new instrument	Y
	Attach ES cable (if applicable, in instrument change or instrument adjust scenario)	Y
	Slide new instrument along the virtual Z rail until it is in view of endoscope	Y
	Press the wrist button to return arm from instrument change mode to surgical mode	Y
	User moves to Instrument Adjust by pressing elbow button	Y
	Uses one hand to retract instrument by sliding back through port. Use other hand to hold the port.	Y

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	Remove ES cable from instrument (if applicable)	N
	Remove the instrument by squeezing together instrument latches on the instrument using one hand	Y
	Pass instrument to scrub nurse or place on the robotic instrument tray (instrument adjust scenario)	Y
	Pick up new instrument from scrub tray (in instrument adjust scenario)	Y
	Attach new instrument	Y
	User attaches ES cable (if applicable)	Y
	User reinserts instrument into port and advances to surgical site in instrument adjust mode under visualisation	Y
	Press the wrist button to return arm from instrument adjust mode to surgical mode	Y
Surgical procedure – bedside team	Communication between members of the surgical team	Y
	Move elbow (for access)	Y
	Miscellaneous errors arising during general surgical procedure - where applicable	Y
	Maintain sterility	Y
	Surgeon requests endoscope is cleaned	N
	Press the V-Wrist button to put the arm in instrument change mode	Y
	Enter instrument change mode	N
	Use one hand to retract endoscope by sliding along the virtual Z rail. Use the other hand to hold the port.	Y
	User wipes the endoscope with gauze	Y
	Press the wrist button to return the arm to surgical mode	Y
	Enter surgical mode (clean scope scenario)	Y
	Surgeon requests endoscope is changed	N
	Change of endoscope (assume endoscopic camera has been retracted from patient in instrument change mode)	Y
	Slide new endoscope back along the virtual Z rail until you have visualisation of the operative area	Y
	User unplugs cable from cart	Y
	Operate arm while disconnected from console and battery low such that arm becomes locked	N
	Recognise Stop	N
	Press resume button	N

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	Identify there is an alarm (arm high priority alarm scenario)	Y
	User rushes to arm to support weight	Y
	User removes instruments from alarmed arm (small movement to expose pickups)	Y
	User manually opens and clears instrument jaws (if applicable)	Y
	Withdraw instrument from patient under visualisation	Y
	Unplug cart to free arm operation (to remove alarming arm and replace with new cart)	Y
	Pause BSU alarm audio	N
	Unpause BSU alarm audio	N
	Identify there is an alarm (system medium alarm console flashing yellow)	Y
	User removes instruments from arms	Y
	User manually opens instrument jaws (if applicable)	Y
	Withdraw instrument from patient under visualisation using alternative endoscope	Y
	Use one hand and retract endoscope. Use other hand to hold the port	Y
	Remove the endoscope by squeezing together endoscope latches on endoscope using one hand	Y
	Untether light cable from drape	N
	Release brake from Visualisation BSU and move away from bed	Y
	Reposition Visualisation BSU cart about bed to a more convenient position	N
	Activate Visualisation BSU brake	Y
	Long press elbow to move to unlocked	N
	Reposition robotic arms away from patient	N
	Press elbow button to lock arms	N
	Release brake on instrument carts	Y
	Pull cart away from bedside	Y
	Apply brake to cart	Y

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Convert to open/manual	Announce covert to manual procedure		N
	Hand controllers disengaged		N
	Dock the hand controllers		N
	Access system status (check instrument life)		N
	Access 'About' (tech support)		N
	Exit Menu		N
	Select "end of surgery"		N
	Turning video recorder off		Y
	Surgeon leaves console		N
Post-surgery	Use endoscope manually to visualise during close		N
	Check instrument inventory on HUD		N
	Select 'End of Surgery' (If not already occurred)		N
	Turning video recorder on and off		Y
	Dispose of out of life instruments		N
	Disconnect light cable		N
	Untether light cable from drape		N
	Place light cable on tray for sterilization		Y
	Disconnect camera from cart		N
	Untether camera cable from drape		N
	Wipe clean camera using universal wipes		Y
	Safely store clean camera for next procedure		Y
	Place endoscope in tray / basket for sterilisation		Y
	Disconnect ES cables from cart		N
	Untether ES cables from drape		N
	Place ES cables in tray for sterilisation		Y
	Wipe instrument shaft, attachment head and instrument tip using single-use lint free cloth, to remove excess soiling		Y

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	Use syringe to flush instrument primary flush port with 50ml pH neutral enzymatic detergent (or cold water)	Y
	Submerge flushed instruments in detergent or water or foam in sealable container	Y
	Send instruments to reprocessing areas as soon as possible after preparing them	Y
	Undrape bedside unit	Y
	Wipes surface of arms top down	Y
	User wipes surface of cart	Y
	Lower cart to minimum height for transport and storage	N
	Disconnect auxiliary screen cable from console	N
	Clean auxiliary screen cable	Y
	Store auxiliary screen cable	N
	Disconnect cart power cable	N
	Clean cart power cable	Y
	Store cart power cable	N
	Switch off console power switch	N
	Disconnect console power cable from wall	N
	Disconnect console power cable from console	Y
	Clean console power cable	Y
	Clean 3D glasses	N
	Store 3D glasses for next procedure	N
	Clean console	N
	Push console arms in for transport and storage	N
	User checks for clearance around arm before folding arm	Y
	User presses and holds sleep button to fold arm	Y
	Move console into storage area	N
	Move cart to/from operating theatre	Y

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Drills – Surgeon	Select the correct input source	N
	Unplug Versius Trainer and power cycle console	N
	Surgeon or Nurse selects 2D or 3D using monitor controls	N
	Attach instrument	Y
	Press wrist button to unlock arm	N
	Insert instrument into port	Y
	Switch arm to Port Training Mode by locating and pressing wrist button	Y
	Port train the VPP by moving the wrist in an arc back and forth	Y
	Port training successful - user presses wrist button to enter Instrument Adjust Mode	N
	Press wrist button to switch to Surgical Mode	Y
	Press the V-Wrist button to put the arm in Instrument Change Mode	Y
	Use one hand to retract endoscope/ instrument by sliding along the virtual Z rail. Use other hand to hold the port.	Y
	Remove the instrument by squeezing together instrument latches on the instrument using one hand.	Y
	Pass instrument to Scrub Nurse or place on the robotic instrument tray	Y
	Pick up new instrument from scrub tray in front or to the side	Y
	Attach new instrument	Y
	Slide new instrument along the virtual Z rail until it is in view of endoscope	Y
	Slide new endoscope back along the virtual Z rail until you have visualisation of the operative area	Y
	Press the wrist button to return arm from instrument change mode to surgical mode	Y
	User moves to instrument adjust by pressing elbow button	Y
	Use one hand to retract instrument by sliding back through port. Use other hand to hold the port.	Y
	Remove the instrument by squeezing together instrument latches on the instrument using one hand.	Y
	Pass instrument to Scrub Nurse or place on the robotic instrument tray	Y
	Pick up new instrument from scrub tray.	Y
	Attach new instrument	Y
	User reinserts instrument into port and advances to surgical site in Instrument Adjust Mode under visualisation	Y

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	Press the V-Wrist button to return the arm to Surgical Mode	Y
	User checks for clearance around arm before folding arm	Y
	User presses and holds sleep button to fold arm	Y
	User aborts sleep operation because of obstruction or change of plan	N
Drills – Assistant Surgeon	Move cursor to Menu icon	Y
	Selecting Menu or sub-item	Y
	Assign language	N
	Assign endoscope angle	Y
	Exit Menu	N
Drills – Circulating/Scrub Nurse	Remove brake from console	N
	Transport console to operating theatre	Y
	Move console up/down ramp	Y
	Move console into storage area	N
	Remove brake from cart	N
	Transport cart to/from operating theatre	Y
	Move cart up/down ramp	Y
	Select the correct input source	N
	Unplug Versius Trainer and power cycle console	N
	Surgeon or Nurse selects 2D or 3D using monitor controls	N
	Move cursor to menu icon	Y
	Select Menu or sub-item	Y
	Assign language	N
	Assign endoscope angle	Y
	Exit Menu	N

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Knowledge test	Where in the instructions can you find the precautions you should observe when preparing the instruments for reprocessing?	Y
	Where in the instructions can you find the equipment you need to prepare the instruments?	Y
	Which parts of the instrument do you need to wipe? Can you identify on which page of the reprocessing instructions you would find this information?	Y
	What should you use to flush the instrument? Can you identify on which page of the reprocessing instructions you would find this information?	Y
	Can you find in the instructions how much liquid you need to use?	Y
	Can you talk through step 3 of reprocessing a Versius instrument?	Y
	Once you've finished preparing the instruments, when should you send for reprocessing? Can you identify on which page of the reprocessing instructions you would find this information?	Y

1   BSU: bedside unit; ES: electrosurgery; N: no; OR: operating room; VPP: virtual pivot point; Y: yes.

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1   **Supplemental Table 3.** Root cause analyses of use errors encountered during critical task completion

Task	Description	Root Cause
Move console up/down ramp	T1SN could not control the movement of the console	One of the console wheels became locked
	T4SN unable to move the console up/down the ramp	A console wheel became stuck
Engage brake on cart (while moving to OT or another area)	T15SN did not apply brake to two carts when moving them to their desired location prior to draping	T15SN stated they felt rushed and wanted to complete the task in a timely manner
Engage locking ring on instrument arm drape cap	On two carts, T12SN left the red marks exposed on the drape cap after engaging the locking ring	T12SN did not pay attention to the red marks
Fit drape insert to drape cap	T4SN did not fit the drape cap insert on the purple arm	T4SN stated that they thought she had fitted the drape cap insert onto the drape cap
	T5SN failed to establish connection between drape cap insert and drape cap. T5SN broke sterility when rearranging position of the insert	No root cause established as instance recognised after the event
Pull down cart drape to cover cart either from inside or using cuff	T8CN did not completely pull down one side of the drape on the purple arm	T8CN stated that they were unaware of it and did not notice at any point during the session
Locate cart drape elastic at top of cart column	T6SN did not drape elasticated drape collar correctly	T6SN stated that it is hard to position the elasticated collar at the top of the column
	T1SN left a small gap between the arm and cart drape, exposing the casework below the drape	T1SN was observed to be carefully checking around the interface between the top of the cart column and the cart drape elastic for some time
	T11SN – Elastic was not positioned under the metal ring on the cart halo on the visualisation arm	The camera light cord interfered with the positioning of the elastic
	T16SN did not place elastic collar fully under the groove for every BSU	The metal ring on the cart does not fully retain the elastic
Port training endoscope	T14AS used very small circles of the arm to get the virtual pivot point	T14AS could not recall exactly how it was mentioned in training regarding the arc/circles
Activate cart brake for cart positioning	T1S tried to port train a number of times until they realised the BSU was not braked	T1S pushed the brake button but not long enough and did not look at the HUD for confirmation
	T4AS trapped the video feed cable under braked skirt	T4AS was unaware that the cable was caught
Set and check relative cart position	T6S had difficulty moving instruments in desired direction because the BSU was orientated in the wrong direction	T6S thought that the directional arrow light was not very clearly visible

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Task	Description	Root Cause
Attach new instrument (either during first port-training or in instrument change or instrument adjust)	T6S did not properly attach the instrument to the purple arm	When the instrument was attached to the arm, T6S thought that it was correctly attached
	T9AS failed to clip instrument fully down on one side	T9AS found the clips too small to hold
	T2AS attached a fenestrated grasper to the purple arm with the arm unlocked at the bedside	T2AS was aware that the arms were unlocked when attaching the instruments. T2AS stated they were distracted and knew that the arms should be locked
Insert instrument into port	T9AS transitioned into unlocked mode, then inserted the instrument into the cavity, crossing through the field of endoscope vision but proceeding beyond it	T9AS missed part of the training, including practice on inserting instruments
Switch arm to port training mode by locating and pressing wrist button	T5AS left an arm in unlocked mode with an instrument attached inside the port	T5AS knew not to leave an arm in unlocked mode with an instrument attached inside the patient. This was an unintentional error
	T14AS left the needle holder resting at the tip of a port in unlocked mode	T14AS attention was diverted whilst resolving other issues
Port train the virtual pivot point by moving the wrist in an arc back and forth	T8AS held port whilst conducting port training on two attempts	T8AS mentioned too many steps and different actions to remember
	T14S – port training failed first time as they held wrist and quickly let go	T14S stated that they failed to remember what they practiced in training
Advance instrument into cavity using arm so that instrument is visible to surgeon	T13S advanced scissors into cavity and hit surgical mode with tip out of view	T13S cited inexperience as the cause of the error
Set the screen height	T2S did not adjust the height of the console screen	T2S was focused on adjusting herself to the system and the use of the instruments
Assign endoscope angle	T4S did not check or assign endoscope angle during console setup	T4S knew how to perform the task as they did check/assign endoscope angle during the procedure but failed to remember during console setup
	T9S did not change the endoscope angle setting in the HUD menu when the angle changed from the 30° down to 0°	T9S attention was diverted as this task coincided with another
Moves instrument to the operative field	T6S tried to move the instrument on the blue arm but had limited range of motion on the arm	T6S believed the team did not adequately anticipate the range of motion required for the port placement and stated there were problems with insufflation
	T16S – sometimes the surgeon would move the instrument into vision, as opposed to moving the camera towards the instrument	T16S stated that he knew at all times where the instruments were due to extensive experience
Engage instrument	T12S engaged several instruments while not under vision	T12S stated he had trouble getting back to view and when he looked over at the visualisation arm, he noticed one of angles was very acute

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Task	Description	Root Cause
Actuate electrosurgery	T10S engages electrosurgery twice while trying to disengage the instrument	T10S stated that he got confused and engaged the wrong button
	T11S unintentionally activated electrosurgery	T11S thought that she was hitting the clutch button while trying to maneuver closer
	T14S was using the cut mode on monopolar curved scissors and touched the tip of the instrument with the bipolar Maryland grasper	T14S may not have been aware that instrument tips were too close together
Miscellaneous errors arising during general surgical procedure	T4S used engaged instruments (holding tissue) when the HUD was not working	T4S stated that if he had visualisation and the instruments were working, he would continue
	T4AS and T4SN allowed instruments to be left in the cavity when insufflation was unexpectedly lost	Insufflation was accidently turned off by the research center staff
	T6S continued to work using engaged instruments when HUD icons disappeared from the screen	T6S felt that he still had control of the instruments and decided to continue working
	T6AS aware of continuing surgery without HUD icons	T6AS was happy to continue if the surgeon was happy
	T7SN performed an instrument change in instrument adjust mode despite having no icons available	The system has two forms of feedback (visual and audio). The audio feedback was functional
Maintain sterility	T1AS touched their back on the visualisation arm drape. User was not aware they did this	T1AS acknowledged that space is limited between units when changing instruments
	Drape cap insert had come off when removing an instrument off the arm	T7AS did not realise that it was part of the arm, and therefore did not realise that it was unsterile
	T9AS touched a draped arm as the BSUs were being brought to the bedside	Caused by small room used compared to the size of the operating room T9AS would expect
	T9SN pressed against the patient's undraped, raised right knee in order to reach the cyan arm	Participant thought it was fine to do so as it was not a real procedure
	T9SN switched positions from between the patient's legs (and touching patient's right foot with non-working hand) to working with arms in sterile field	The participant thought it was fine to do so as it was not a real procedure
	T9SN made brief contact between the hanging, non-sterile portion of the draped cable and the sterile portion of the other draped camera	T9SN stated they did not notice this, and that if they had noticed, would have re-draped the camera
	T9SN reached down and briefly lifted the non-sterile, hanging portion of the draped camera cable	T9SN did not remember the occurrence, but acknowledged they should have re-gloved
	T11S tried to go to system status but hand detect would not work as they were wearing gloves.	T11S confirmed that T11CN stated that they would scrub in but that this did not happen

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Task	Description	Root Cause
Surgeon clears instrument jaws of anatomy	T13S did not release bowel from the grasper jaws after requesting an instrument change	T13S confirmed that it was a mistake not to open the grasper
Surgeon request instrument change	T9S gave a confusing instrument change request to the bedside team	The moderator was briefed to ask the surgeon (at a point when he was grasping tissue) to request an instrument change in instrument adjust mode
Use one hand to retract instrument by sliding along the virtual Z rail. Use other hand to hold the port	T13AS removed the grasper on the blue arm the grasper was grasping the bowel tissue	T13AS stated they were agitated by the environment
Slide new instrument along the virtual Z rail until it is in view of endoscope	T14AS was unable to slide needle holder along z-rail back into cavity	Observer unable to determine why the user was unable to re-insert the instrument
Press the wrist button to return arm from instrument change mode to surgical mode	T14AS did not complete this task (specific to instrument change, did demonstrate with endoscope)	Suspected system error meant instrument was unable to return along z-rail
Surgeon straightens/closes instrument jaws using thumbstick	T13S straightened grasper but did not close instrument jaws	T13S stated he forgot due to inexperience
User moves to Instrument Adjust by pressing elbow button	T1AS entered unlocked mode intentionally with an instrument inside of the patient	T1AS acknowledged that a user should not have the instrument unlocked within the patient
	T11SN entered unlocked mode intentionally with an instrument inside of the patient, tested the range of motion then withdrew the instrument	T11SN was responding to a direct request from the surgeon
Use one hand to retract instrument by sliding back through port. Use other hand to hold the port (instrument adjust scenario)	T2AS did not look at the auxiliary screen when retracting an instrument	T2AS did not think vision was required as the instrument was not grasping tissue
	T6AS hit tissue when removing instrument	T6AS stated that losing insufflation caused them to hit the tissue
	T9AS withdrew Maryland grasper from the patient without releasing tissue	T9AS missed part of the training, including practice on inserting/removing instruments
Attach new instrument (in instrument adjust mode)	T1S did not fully attach instrument	As a surgeon, T1S would not be doing this. Therefore, did not pay enough attention

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Task	Description	Root Cause
Apply brake to cart (remove all arms scenario)	T2SN, T4AS, T4CN, T4SN, T5SN and T14SN failed to brake BSU(s)	T2SN, T4AS, T4CN and T14SN inattention led to the incompletion of this task
		T4SN and T5SN stated that as SNs they would not normally complete this task
Activate visualisation BSU brake (close with scope scenario)	T4AS and T5CN failed to activate the BSU brake	T4AS pressed the brake button but not for long enough
		T5CN stated they were distracted by something else they deemed to be a higher priority
Withdraw instrument from patient under visualisation using alternative endoscope	T2AS did not look at the auxiliary screen when manually retracting an instrument after alarm	T2AS used their clinical judgement and did not look at the screen because she knew the instrument was not grasping tissue
Place electrosurgical cables in tray for sterilisation	T15 sent two sets of cables to the incorrect location	T15SN stated that the team felt rushed during the clean-up and nervous with observers watching
Wipe instrument shaft, head and tip to remove excess soiling	T7SN wiped the instrument shaft and tip but did not wipe the instrument head	T7SN stated that this was normal practice and acceptable in her hospital
User wipes surface of cart	T10SN and T12SN did not apply cart brake and so the unexposed part of the cart was not cleaned	T10SN and T12SN inattention resulted in not all of the cart being wiped
	T16CN did not wipe the skirt of the cart	T16CN was aware that this needed to be done, but forgot
Q: How long do you need to wipe the cables for	T6CN thought because the cables were not near the patient, disinfecting for 2 minutes not needed	T6CN and T11CN stated that this would not normally be their job
	T11CN did not answer the question but said it would be done by someone else	
Switch off console power switch	T12CN did not switch the console off before unplugging its power cable	T12CN forgot the console was still on when unplugging the power cable
Clean console power cable	T12CN did not clean the power cable	T12CN forgot to clean the cable
User checks for clearance around arm before folding arm (sleep scenario)	T17S did not create adequate space around the arm prior to attempting to put it to sleep.	T17S stated that a lack of thought arising from the unfamiliarity with the task caused the problem

BSU: Bedside unit.

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1   **Supplemental Figure 1.** System Workflow