CAE NeuroVR

User Guide

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System Specifications

Hardware

Equipment	24 inch (61cm) flat LCD monitor including zoom/focus controls 15 inch (38cm) Touch screen Two (2) Haptic devices Nine (9) detachable surgical instrument handles Stereoscope Dual foot pedal for surgical instrument control Two (2) detachable physical guides: Ventriculostomy head model and Craniotomy plate
Dimensions	Maximum height 94 inches (239 cm) (adjustable work surface at highest setting and stereoscope raised) Minimum height 57 inches (145 cm) (adjustable work surface at lowest setting and stereoscope lowered) Width 28-3/8 inches (72 cm) Depth 48 inches (122 cm)
Weight	195 lb (90 kg)
Electrical	100-120 V, 50-60 Hz, 10 A 200-240 V, 50-60 Hz, 5 A
Storage Temperature	-40 ˚C to +65 ˚C (-40 ˚F to +149 ˚F)
Storage Humidity	20% to 80% without condensation
Operating Temperature	10 ˚C to 32 ˚C (50 ˚F to 90 ˚F)
Operating Humidity	20% to 80% without condensation

Cautions and Warnings

Please read and understand these cautions and warnings before you begin using the simulator.

Operation

- Do not operate your equipment with any covers removed
- Secure the wheel locks before use
- Do not use your equipment in a wet environment. Protect equipment from liquid intrusion
- Before activating the lift mechanism, ensure that no object can interfere with or be crushed by the upward or downward movement of the upper section. Position yourself clear of the unit to avoid possible bodily injury. Pay attention that the stereoscope does not contact any item or hazard overhead, as this may result in damaged equipment.

Ergonomics

- Tip-over hazard: Do not move your equipment without fully lowering the lift mechanism. Failure to do so can result in possible bodily injury and damaged equipment
- Improper or prolonged keyboard use may result in injury
- Repetitive or prolonged instrument manipulation may result in injury
- Viewing a monitor screen for extended periods of time may result in eye strain

Care and Maintenance

- Keep the simulator free of dust and avoid using materials nearby which may result in a spill or spray
- Clean exterior work surfaces with only a damp cloth or mild cleaner if necessary
- Do not dismantle the unit without guidance from NeuroVR Support
- Follow calibration and registration procedures carefully
- When troubleshooting, contact NeuroVR Support if the listed procedures do not improve the problem

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Introduction

Welcome to the CAE NeuroVR Simulator User Guide. This document provides instructions on how to use NeuroVR, a virtual-reality simulator with haptic feedback developed to train and assess technical skills in neurosurgical procedures.

NeuroVR comprises training modules with incrementally increasing difficulty, targeting learners at different levels of experience, and provides immediate objective feedback on performance through the automated metrics that display at the end of each exercise.

The NeuroVR simulator offers a safe, virtual environment for learners to practice neurosurgical techniques and skills. Learners can range from medical students to licensed medical professionals.

The NeuroVR Courseware section provides detailed information on the content of the individual modules, including background information as well as exercise objectives, metrics and techniques.

Simulator Installation

The accompanying **Setup Guide** details the procedure of removing the simulator from its packaging and assembling the main components.
When unpacking the simulator for the first time, use box cutters carefully to protect both the packaging and the product.

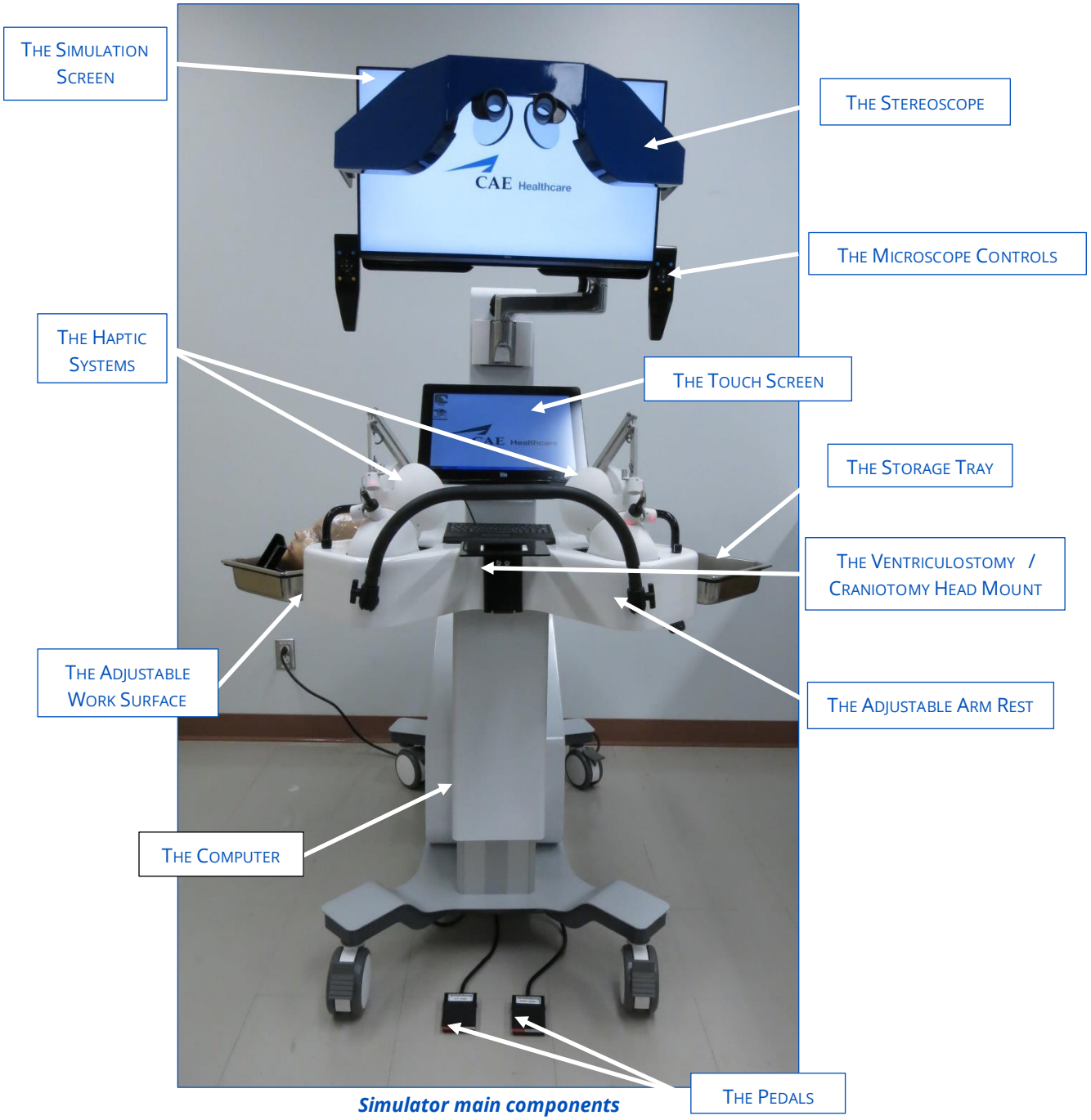
Note: Keep all original shipping materials, including boxes. Warranty and repair items **MUST** be returned and shipped in their original packaging.

The following guidelines should be considered before setting up the NeuroVR simulator:

- Read and understand the Cautions and Warnings at the beginning of this User Guide
- Allow clearance on all sides between the simulator and any other obstacle
- Install the unit in a suitable location with sufficient lighting and ventilation
- Follow and complete the sequence of installation steps carefully
- Minimize the length of power cords between the unit and the wall outlet to avoid tripping hazards
- Verify that the simulator is levelled before powering on
- Do not power on any components until instructed in the text
- Do not install any Windows updates or anti-virus software when connecting to the network

Equipment Overview

The main components of the NeuroVR simulator are shown below, followed by a brief description.



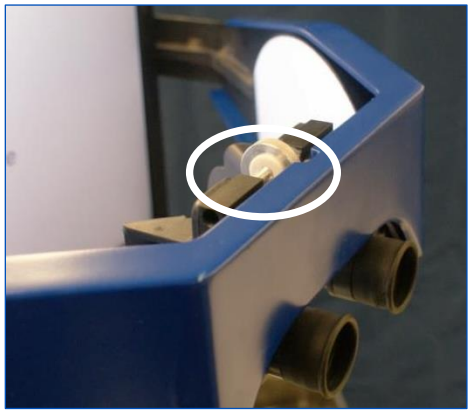
Simulator main components

Stereoscope and Simulation Screen

The simulation screen shows the simulated procedure when running an exercise, with or without the stereoscope. The stereoscope is raised when not in use and lowered for use in exercises requiring the microscope view. When starting an exercise, the onscreen information will specify either the endoscopic (monitor) view or the microscope view.

Stereoscope in raised (Endoscopic) and lowered (Microscope) positions

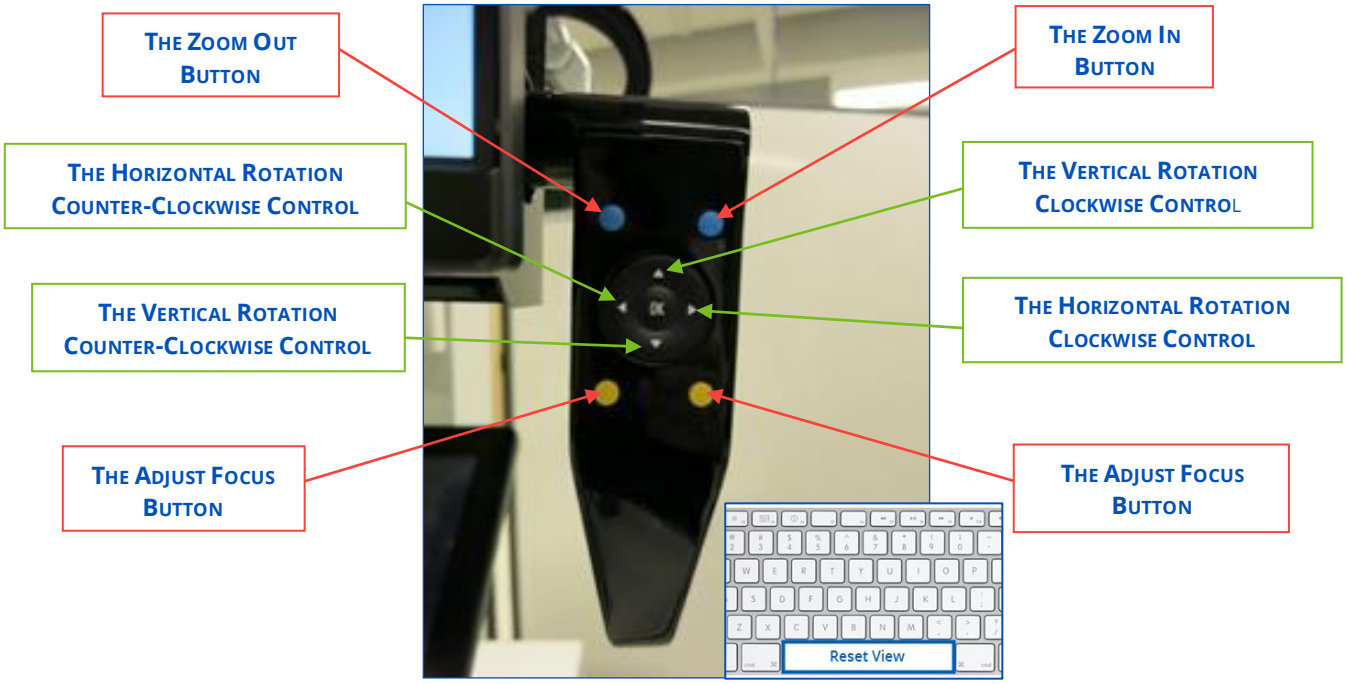
For the endoscopic view, raise the stereoscope completely and use the monitor. When the microscope view is required, lower the stereoscope and adjust the intraocular spacing for your comfort using the knurled nut as indicated.



Operative views with corresponding stereoscope position

Microscope Control Handles

The microscope controls, on either side of the monitor, allow the learner to adjust the virtual microscope for a better view during exercises in the **Instrument Handling**, **Fundamental Skills** and **Microsurgery** modules. The spacebar is used to reset to the default settings.



Adjustment functions on the microscope controls

Touch Screen

The NeuroVR simulator is equipped with a touch screen monitor to display and navigate through the graphical user interface. It displays exercise instructions as well as the results after running a simulation. The touch screen also acts as an observer screen during simulation if none has been set up.

Adjustable Arm Rest

The arm rest supports the user's arms while manipulating the surgical instruments. To adjust the arm rest, unscrew the hand screws to unlock, then move it into the preferred position. The figure below illustrates the range of positions for the arm rest.

Touch Screen and Adjustable arm rest

Keyboard/Mouse

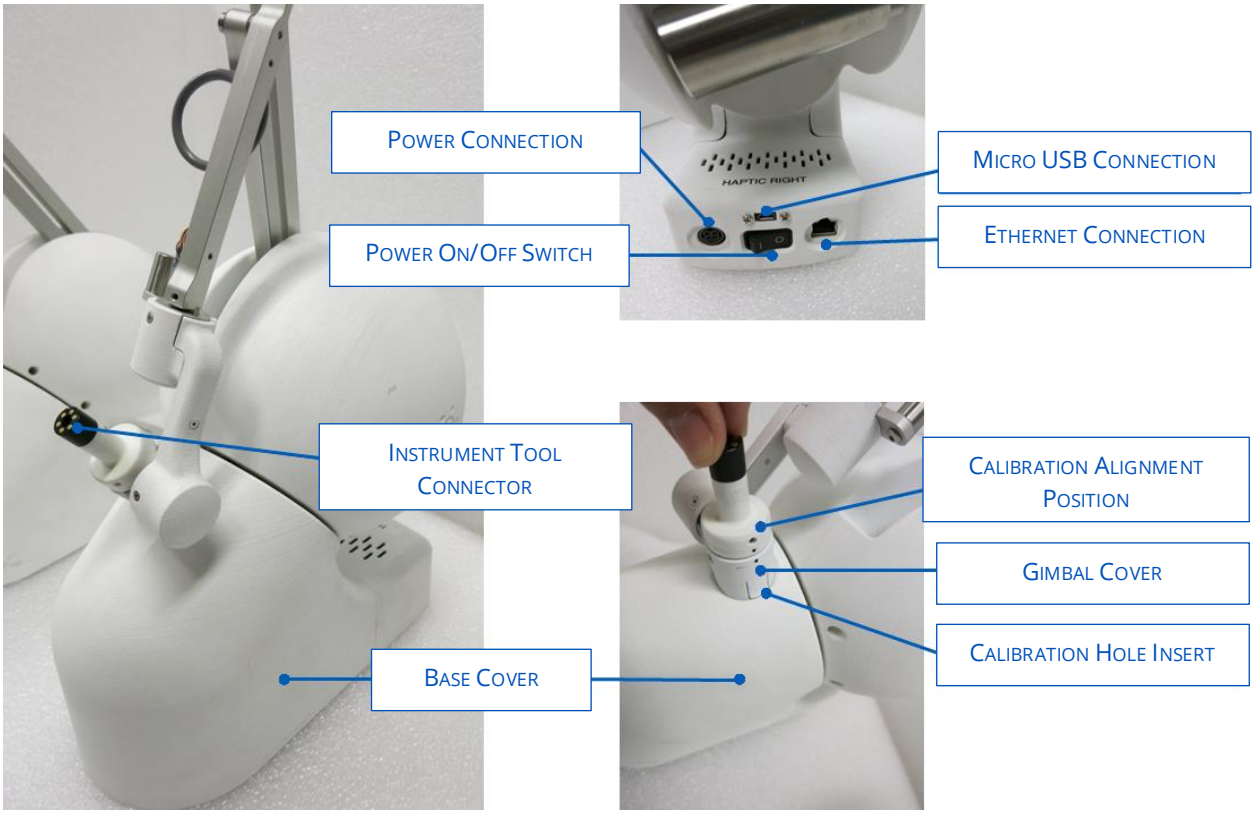
A combination keyboard/mouse is available in addition to the touch screen to navigate the menus and enter alphanumeric information into fields; for example, on the login screen or when saving data.

Keyboard and Mouse

Haptic Systems

Haptic devices enable a truly interactive experience in training exercises by providing tactile feedback to the user in response to tool manipulations.

The haptic devices are integrated into the housing, but are fully removable and can be registered and calibrated as necessary. For details of these procedures please refer to Appendix A.

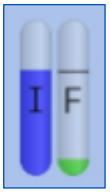


Entact haptic components

Power Knobs

Power knobs are mounted on the table to adjust the instrument intensity level during the procedure. Familiarize yourself with the manipulation of the knob using the opposite hand, i.e., the knob on the left controls the instrument in the right hand, and vice versa.

The intensity setting is visible as the **"I"** gauge in the simulation view.



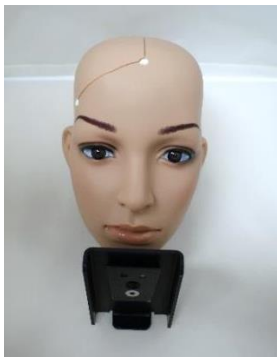
Power knob on workstation; intensity gauge depicted in simulator

Storage Tray for Instrument Tools

Storage Tray for Instrument Tools

Ventriculostomy Head Model

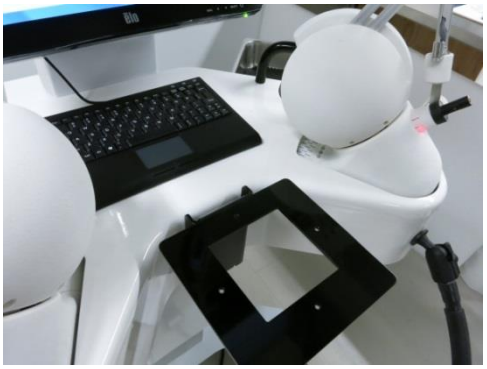
The Ventriculostomy head model has a removable skin flap secured by a thread, with a hypothetical Burr Hole ball joint under the flap for navigation exercises. To install, align the tapering fitting at the base of the head with the corresponding connector on the workstation.



Ventriculostomy head model, connector on work station, and installation

Craniotomy Plate

For craniotomy type exercises where the brain is accessed by removing the bone flap, the Craniotomy plate attachment may be installed to provide guidance for tool positioning. The Craniotomy plate is installed on the same connector as the Ventriculostomy head.



Craniotomy plate; connector on workstation and installation

Pedals

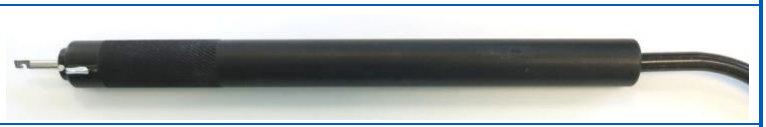
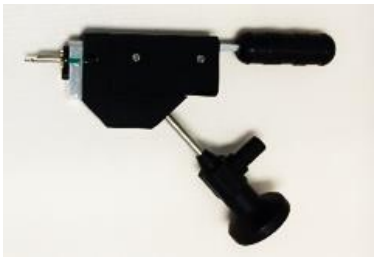
The floor pedals are used to activate some instruments using the foot (ultrasonic aspirator, bipolar forceps, microdrill, microdebrider). They are also used during calibration and registration procedures. The left pedal activates the left-hand instrument, and the right pedal activates the right-hand instrument.

Pedals

External Monitor (Observer Screen) - Optional

The NeuroVR simulator may be enhanced with an auxiliary monitor (not included) for an observer to easily follow the user's performance during an exercise. This viewing option is particularly useful when the stereoscope is lowered.

NeuroVR Surgical Instruments

Tool Name	Image
Bipolar forceps	
Endoscope	
Microdebrider	
Microdrill	
Microscissors	
Neuroendoscope	
Neuronavigation pointer	
Suction	
Ultrasonic aspirator	
Long Tip Cap Entact	
Short Tip Cap Entact	

Setting up the Simulator for Utilization

The following components must be installed prior to powering « ON » the simulator. Follow steps as detailed in Appendix A for haptic devices.

.

- Haptic devices
- Pedals
- Arm rest
- Storage Trays

This section summarizes the steps recommended to ensure all is working normally when first starting up the simulator, and before attempting an exercise:

1. Power on the simulator
2. Adjust the height and position
3. Start the software, click the NeuroVR Icon on the desktop
4. Attach the instruments
5. Test the instruments, power knobs, pedals and microscope controls
6. Calibrate the haptic devices
7. Register Ventriculostomy Head Model
8. Register Burr Hole Site
9. Running a simulation

Note: Contact NeuroVR Support as listed on the back cover with any questions or problems when starting up the simulator for the first time.

Powering on the Simulator

When the simulator is set up and plugged in, activate the two power switches to turn it on:

1. Move the on/off switch at the back of the simulator to the **ON** position

Main simulator power switch

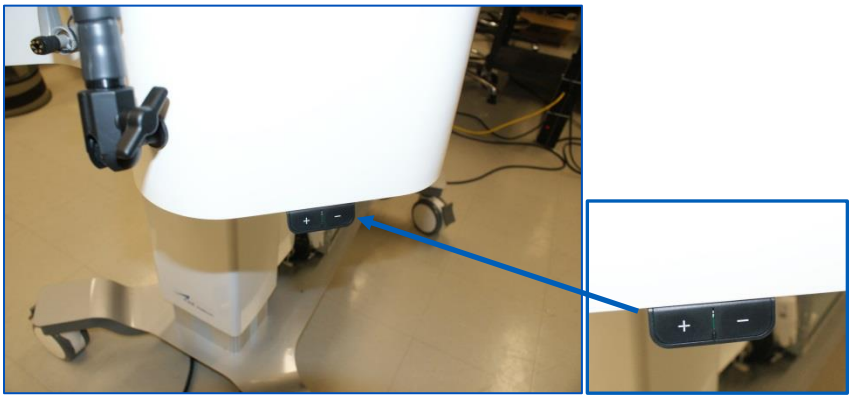
2. Press the round button on the right side panel of the simulator. This button will power the computer.

Simulator computer power button

Adjustments for Height and Position

For your comfort during the exercises, adjust the simulator setup at the start of each session.

The simulator height is adjusted using the up/down controls on the right side. Ensure the work area height maintains the elbows at a right angle (90 degrees) when wrists are resting on the armrest.



Up/down control buttons

If the UP control button does not respond, the lift should be reset by pressing the **DOWN ARROW** until the work surface is at the lowest position. The **UP ARROW** should then function normally.

The vertical position of the monitor/ stereoscope is raised or lowered by grasping the microscope control handles on either side. Position the monitor so that the image is at eye level when looking straight ahead.

Starting the Software

From the desktop screen, launch NeuroVR by double-clicking the **NeuroVR** icon using either the touchscreen or the integrated mouse/keyboard.

NeuroVR icon on desktop

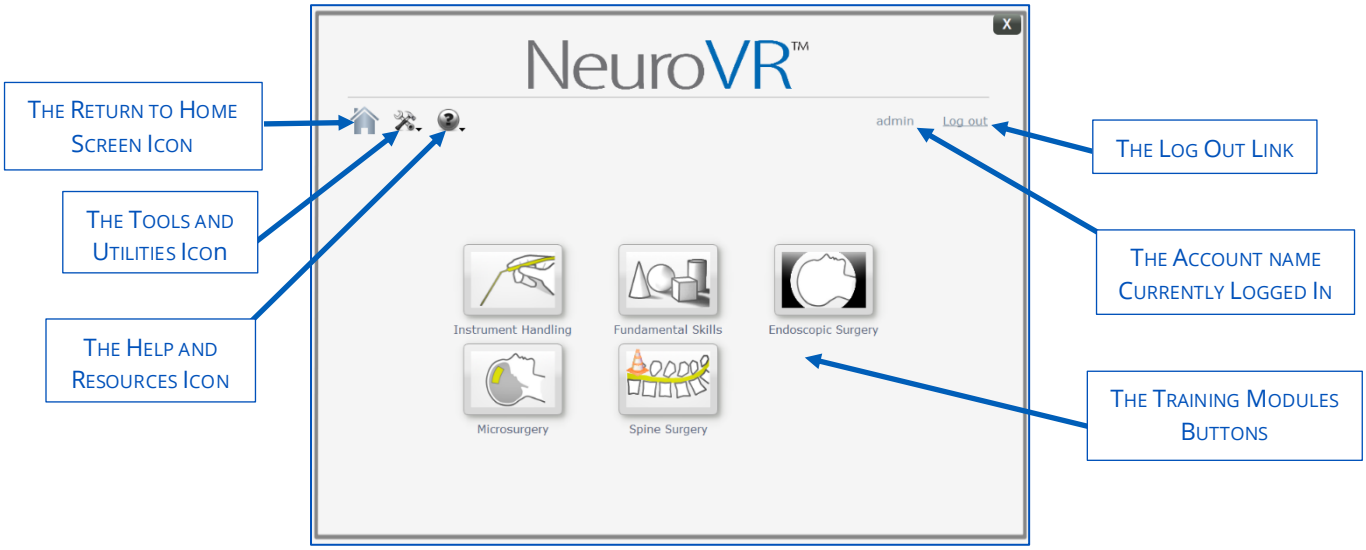
The NeuroVR login screen is displayed.

NeuroVR login screen

Enter your **account name and password** using the screen keyboard or the integrated mouse/keyboard, or select **Enter as guest** on the login screen.

- If you enter as a guest, you will be able to use all exercises normally and view results onscreen, but no performance data will be saved
- An account name and password may be created by your NeuroVR administrator using the Manage Accounts utility
- The system should have a demo account created; password = **demo**

The NeuroVR home screen permits you to select a training module or access tools and resources as indicated in the figure.



NeuroVR home screen

User Access to Procedures

Procedures available to the user depend on the access level. Most users will have Trainee access, which extends to all calibration, registration and testing procedures as well access to all exercises and help resources. Administrators access every utility that the Trainee has in addition to System Configuration, Managing Accounts, Exporting Metrics and Creating User Reports as seen below.

TRAINEE ACCESS

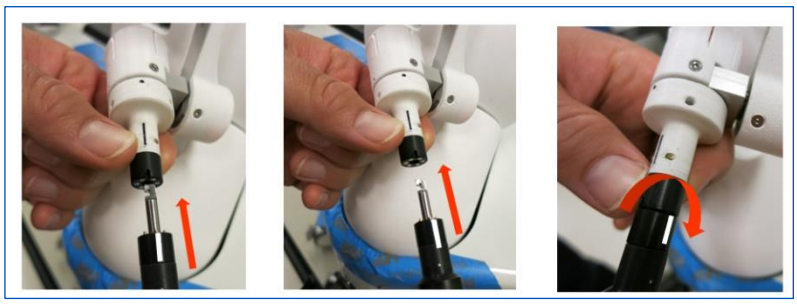
ADMIN ACCESS

ADMINISTRATOR ACCOUNTS HAVE ACCESS TO ALL UTILITIES

Attaching the Instrument(s)

To connect the selected instrument handle:

1. Grasping the tool in one hand and the haptic connector in the other, align the white line on the handle with the corresponding line on the haptic device arm
2. Insert the handle and twist clockwise one-quarter turn. The handle should be fixed in place.



Connecting an instrument handle

The neuroendoscope and the neuronavigation pointer tools are the only instruments which comprise two pieces. The handle part is installed the same way as all others, as depicted in the figures above, while the pointer part fits over the haptic tip, shown on the center image below (denoted by an X).

Connecting the tips for the Neuronavigation Pointer and Neuroendoscope

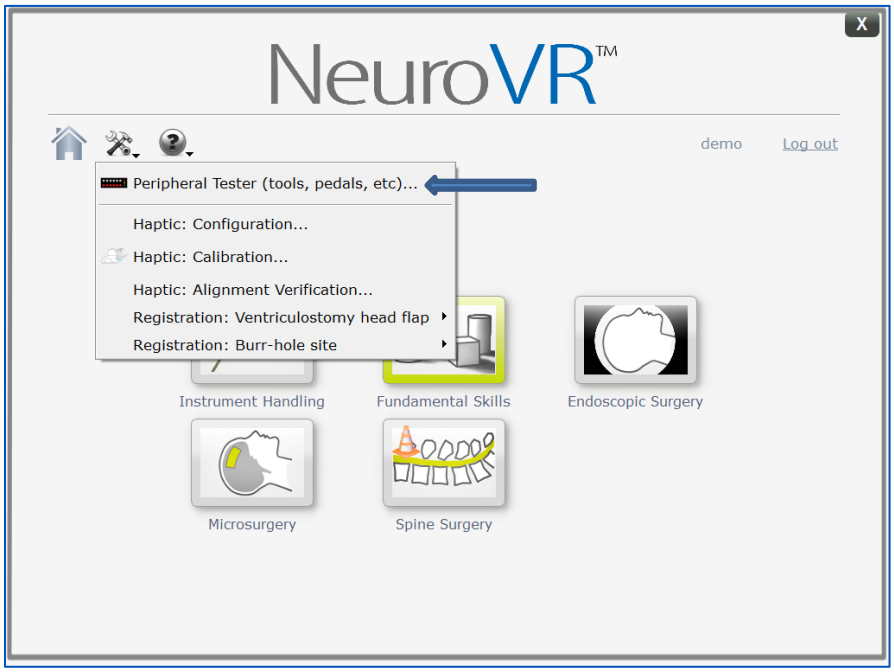
Testing of Instruments, Power Knobs, Pedals and Microscope Controls

The peripheral tester allows any user to verify that instrument handles, pedals and power knobs are functioning as expected. This tool is especially necessary if troubleshooting whether hardware issues are preventing the proper execution of an exercise.

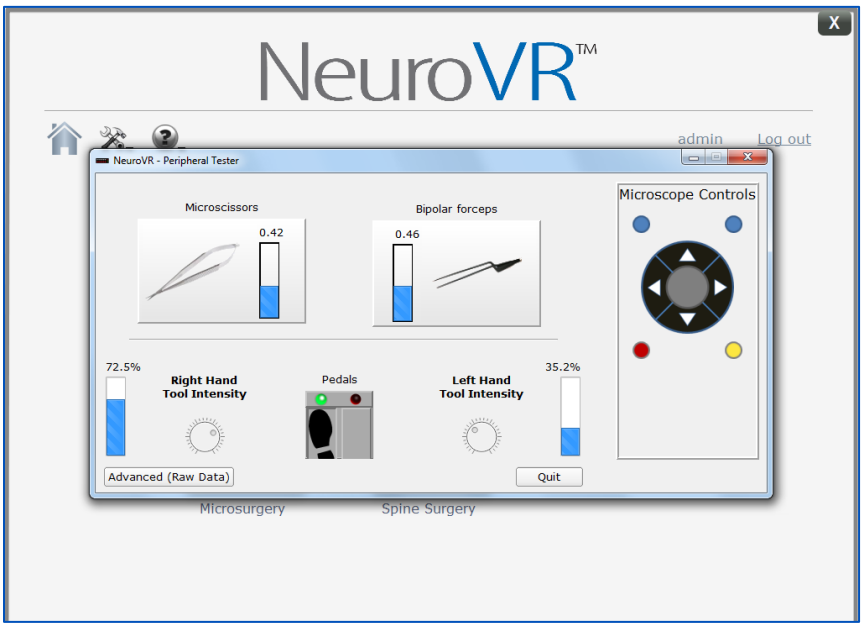
From the Tools and utilities menu, select **Peripheral Tester (tools, pedals, etc.)**.

The tester screen matches the physical layout of the NeuroVR simulator.

- The peripheral tester screen should depict the current situation for tools, pedals, etc.
- Images of the instruments connected to the right- and left-hand haptic devices, as well as the current setting on the instrument signal, appear at the top of the screen
- The power knobs are depicted on the side they are physically located: on the left side for control of the right-hand tool, and vice versa
- Turn each power knob through their full range and confirm that both the knob image and the bar graphic correctly reflect the movement
- The pedal images each have a red light which turns green when the pedal is pressed, as well as a footprint image which appears on the image of the pedal activated. Press each pedal in turn.
- Confirm that the buttons / arrows pressed on the physical microscope controls (right or left side) correspond to the image in the Peripheral tester
- If the display does not reflect the physical set-up, refer to the Troubleshooting section
- If all the preceding steps progress satisfactorily, the system is ready to run a simulation



Selecting Peripheral tester from the Tool and utilities menu



Peripheral tester screen

Calibration of Haptic Devices

Certain components of the NeuroVR simulator require calibration and/or registration so that the simulation images correspond properly to instrument manipulation:

> **Note:** The Craniotomy plate does not require calibration or registration.

Additionally, testing the response of tools, pedals, and power knobs may be required when troubleshooting suboptimal simulator response to commands.

Calibration, registration, and testing procedures are detailed in the following sections.

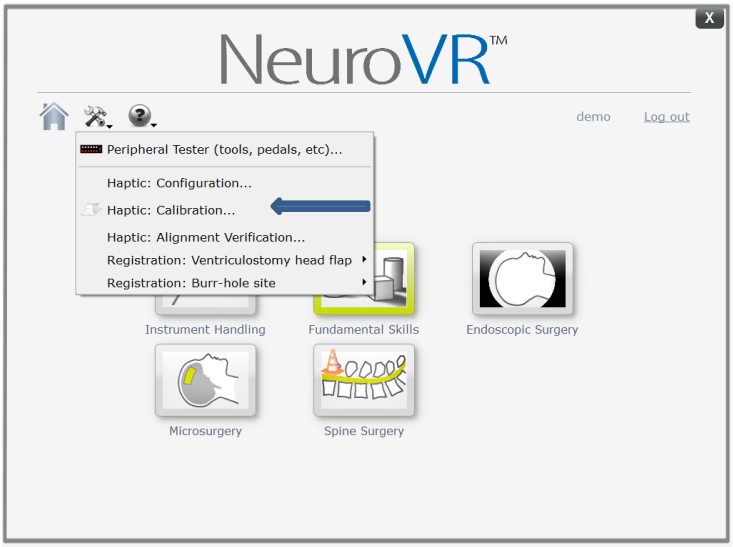
Haptic: Calibration

Calibration of the haptic devices maintains the relationship between its physical position and the virtual position of the instrument.

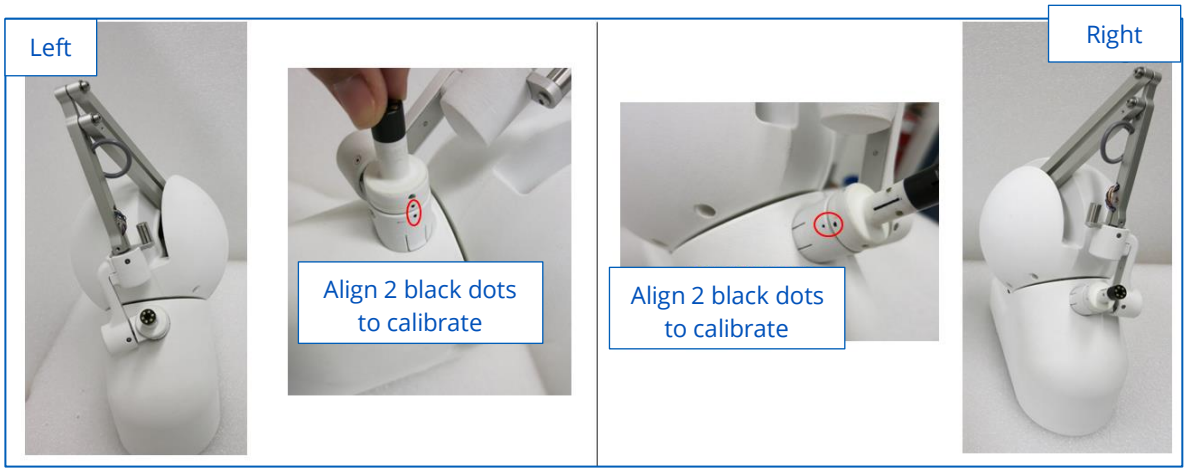
It is necessary to recalibrate the haptic system after it has been powered off, after logging into NeuroVR or as part of troubleshooting if the orientation of the virtual instruments appears to be erroneous.

The haptic devices must be calibrated every time you start NeuroVR. Follow the steps below for a proper calibration.

1. From the Tools and utilities menu, select **Haptic: Calibration...**

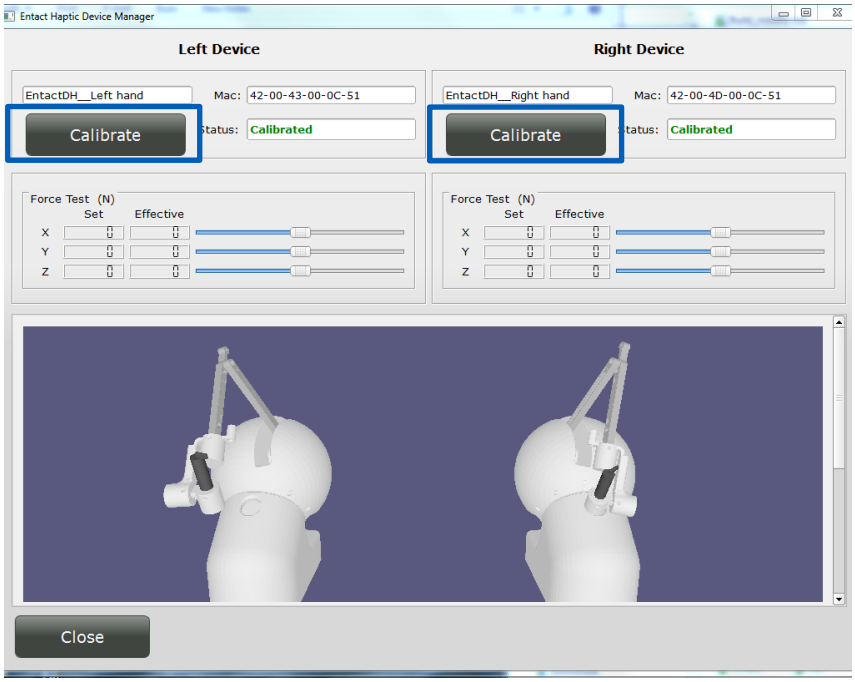


2. Before calibrating the haptics, insert haptic gimbal cover into the calibration hole insert, align the two dots on the left and right haptic devices respectively (circled in red below) to perform a proper calibration of the devices. Do the left & right side separately.



Haptic Physical set up during calibration

3. While aligning the dots, touch the calibrate button on the Touch screen for the right and left side



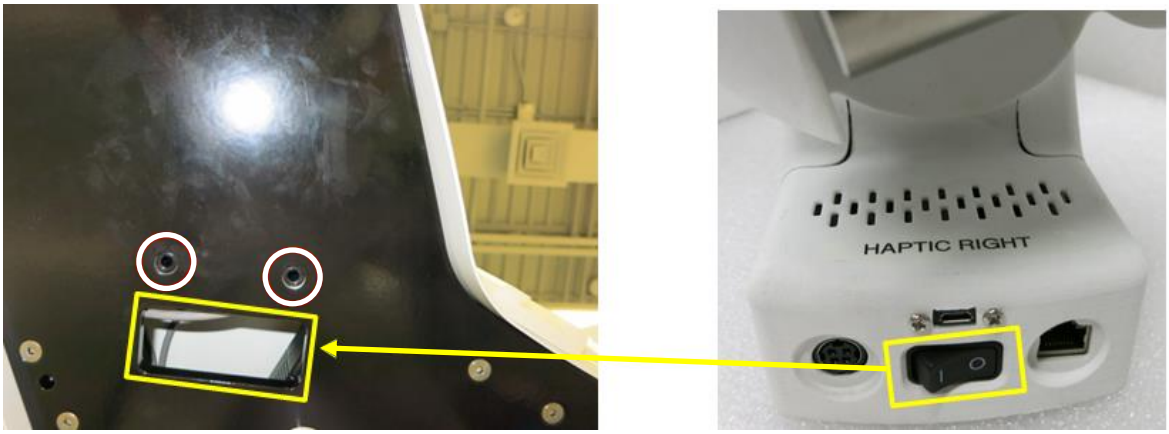
GUI window for Entact haptic calibration

Haptic: Alignment Verification

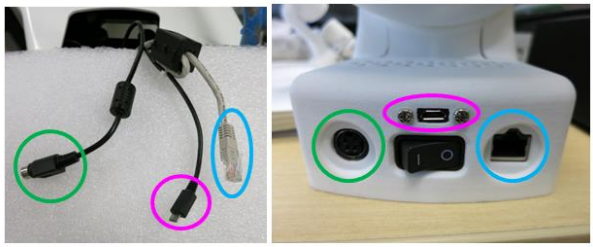
Haptic Alignment Exercise

Proceed to check the alignment of the haptic exercises (Right & Left unit separately). The resulting image on screen shows the approximate alignment of the haptic device.

Note: If the error message "Not Connected or Not Calibrated" appears, check the following;
Turn the haptic devices ON / OFF and try again (on/off accessed by inserting fingers through the rectangular opening underneath platform, denoted by the yellow rectangle below)



Verify the 3 cabled connections of the haptic device (Power, Micro USB (Control/Peripheral Tester, Ethernet)



Refer to the configuration procedure, as detailed in Appendix A: New Haptic Device Configuration, if the haptic device does not want to calibrate.

If a haptic device is replaced or repaired, it must be configured for the NeuroVR simulator. This procedure may also be followed if the simulator no longer recognizes your haptic devices. Refer to Appendix A: New Haptic Device Configuration for the procedure.

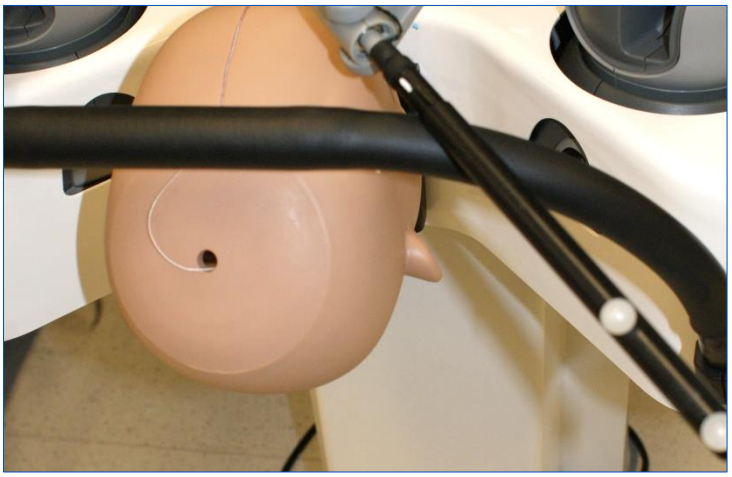
Registration of Ventriculostomy Head Flap

Ventriculostomy Head Flap Registration Using Neuronavigation Pointer

The Ventriculostomy head must be registered to correctly run the exercises which use it. Registration is required only once but may be repeated as needed for troubleshooting.

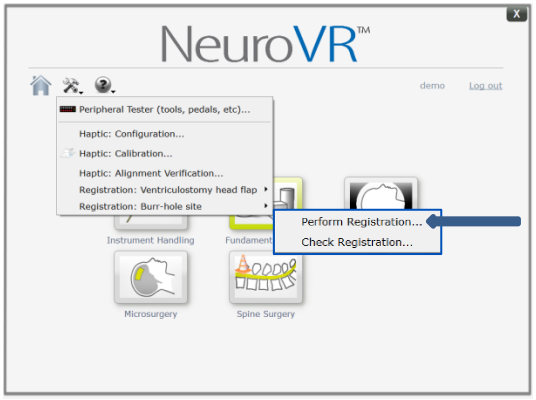
The registration procedures involve using the neuronavigation pointer and the short tip to register the positions on the Ventriculostomy head and verify that the registration is correct, then using the neuroendoscope and long tip to register the manipulation of the instrument in the Burr Hole ball joint.

Ensure that the Ventriculostomy head is installed correctly, that the haptic devices are calibrated (see Calibration of Haptic Devices) and that the Neuronavigation Pointer is connected to the right-hand haptic device.

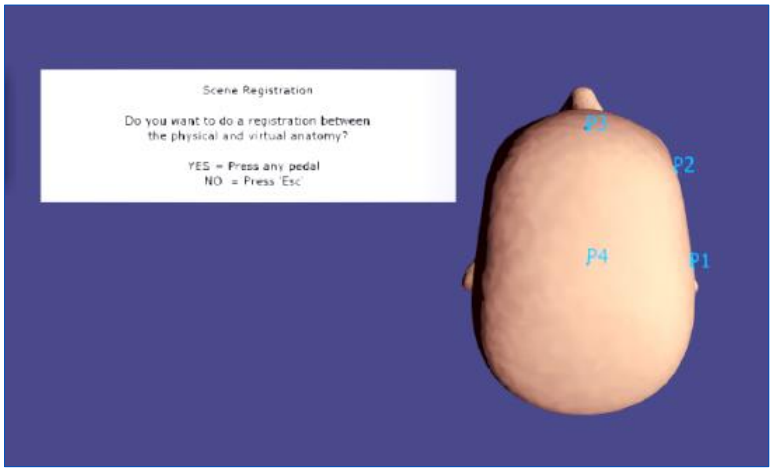


Preparation of simulator for Ventriculostomy head registration

- Start NeuroVR
- Select the **Registration: Ventriculostomy head flap – Perform Registration** module from the Tools and utilities menu

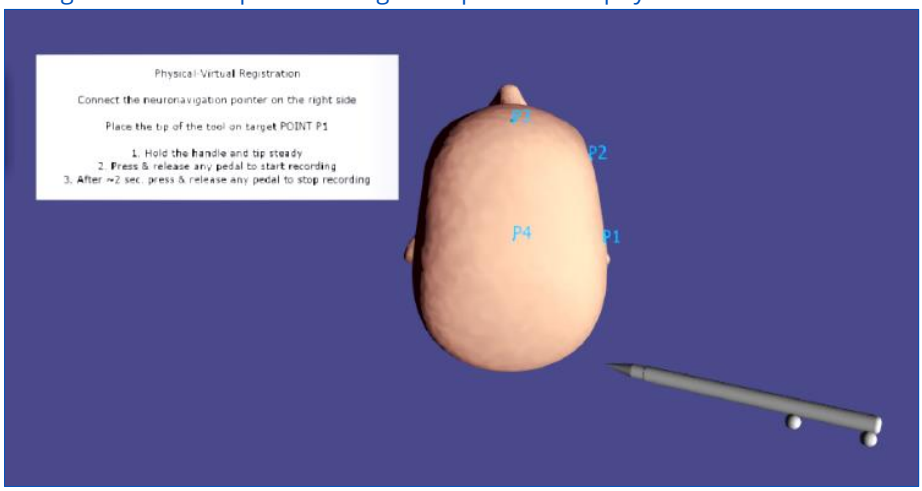


Follow the stepwise instructions on the screen. First, confirm that you wish to perform the registration, by pressing a foot pedal.



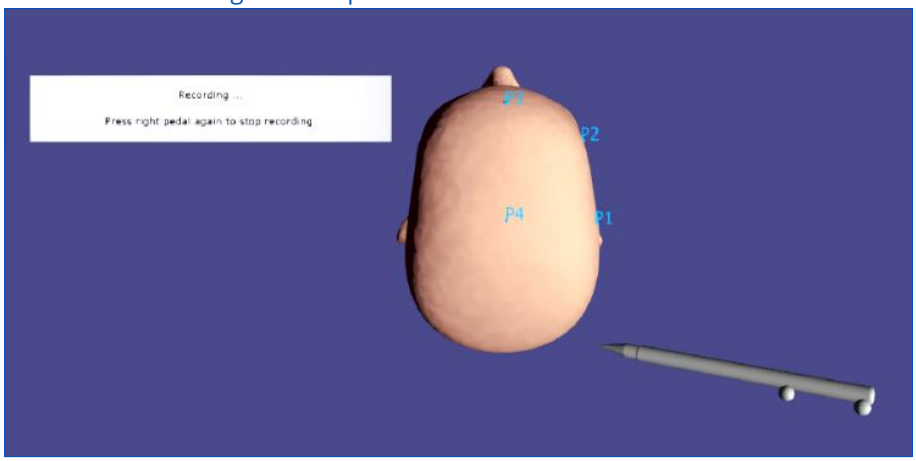
Head flap registration: initial screen

Place the Neuronavigation Pointer tip at the designated point on the physical head.



Head flap registration: instruction screen

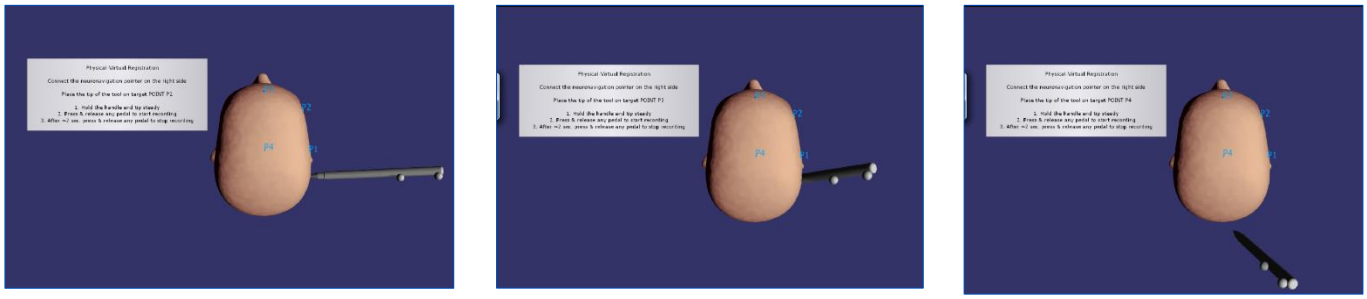
Press the right pedal twice to start and stop the recording. For better registration, try to minimize the time between the start and end recording for each point.



Head flap registration: recording step for P1

Note: An offset between the depicted pointer location and the physical point may be visible on the screen. This is normal but improves after completing the registration procedure.

Point P2 ***Point P3*** ***Point P4***



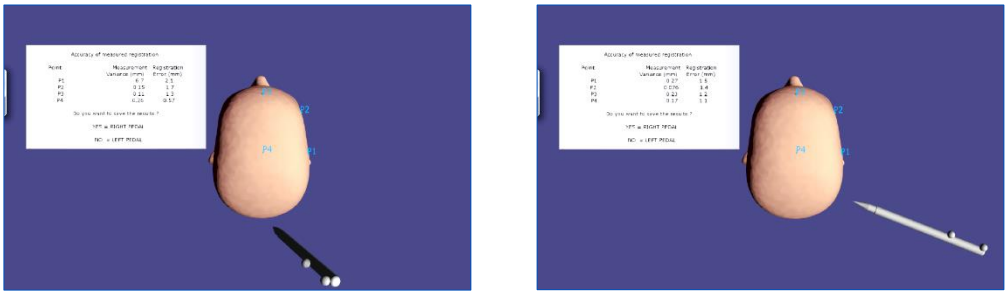
Head flap registration: recording steps for P2, P3, P4

Using the Neuronavigation Pointer during head flap registration

When all four points have been recorded, the calculated registration error is displayed for each, and you will be prompted to either:

- save the results by pressing the right pedal
- discard the results by pressing the left pedal. In this case the user is returned to the main menu and can open the registration menu again.

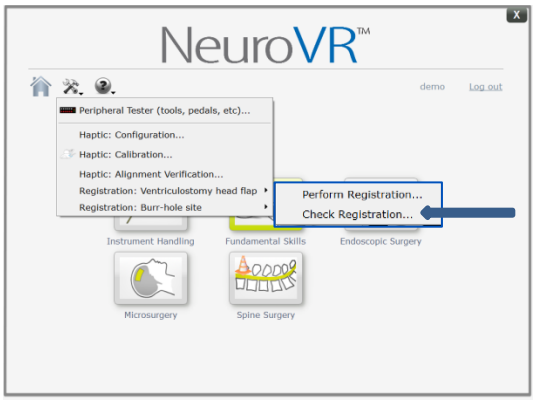
Note: As a rule of thumb, repeat registration for errors greater than 5 mm.



Head flap registration results: left, error greater than 7 mm; right, all less than 7 mm
After saving the results, the user can press the right pedal again to exit.

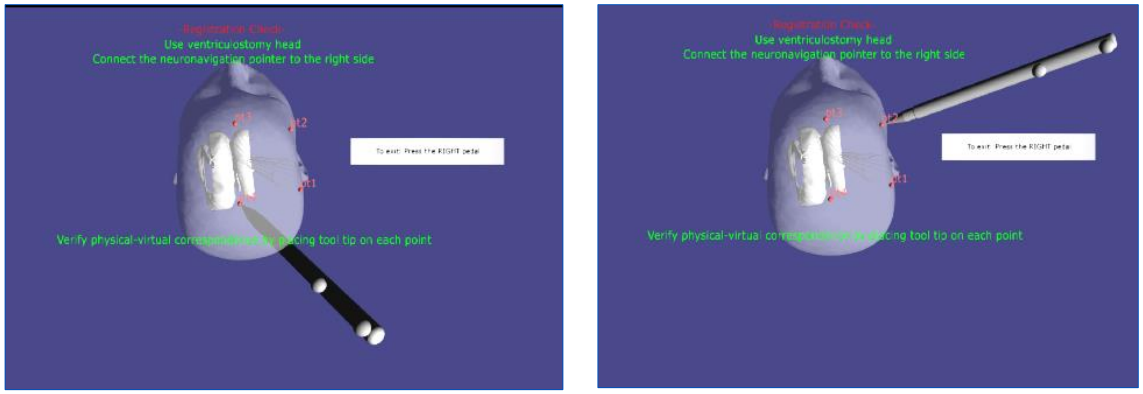
Ventriculostomy Head Flap Verification Using Neuronavigation Pointer

Select the **Registration: Ventriculostomy Head Flap – Check Registration** module from the Tools and utilities menu.



Selection of Ventriculostomy head flap Check Registration function

This selection allows you to verify that the registration is acceptable by moving the instrument tip between the four physical points on the Ventriculostomy head model and tracking its virtual representation onscreen. There should be a match between the physical and virtual representation of the four corners.



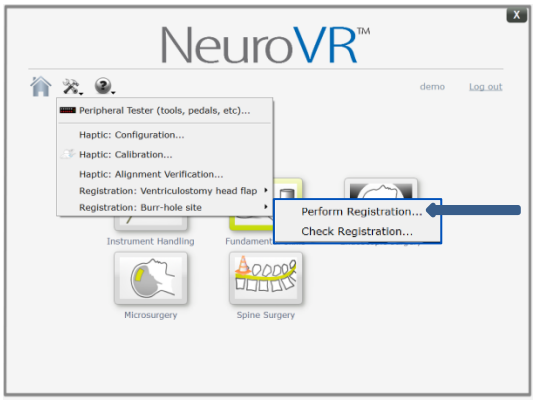
Checking Ventriculostomy head flap registration accuracy at various points

Note: If tool orientation with respect to the head continues to appear incorrectly and the registration errors remain high, it is recommended to redo the haptic system calibration and then redo the head registration.

Registration of Burr Hole Site

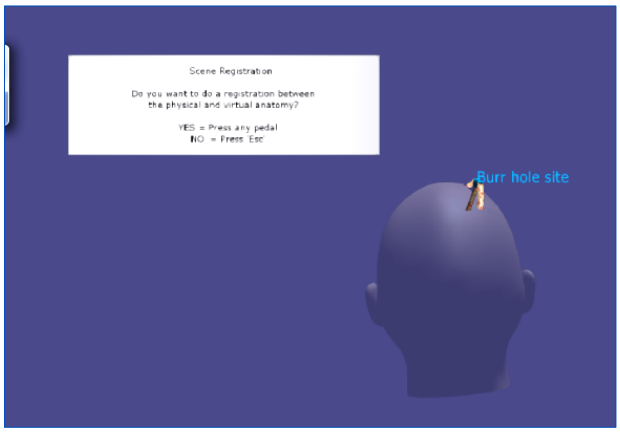
Burr Hole Site Registration Using Neuroendoscope

1. Start NeuroVR
2. Remove the skin flap from the physical Ventriculostomy head to reveal the existing Burr Hole
3. Start the **Registration: Burr Hole Site – Perform Registration** module from the Tools and utilities menu



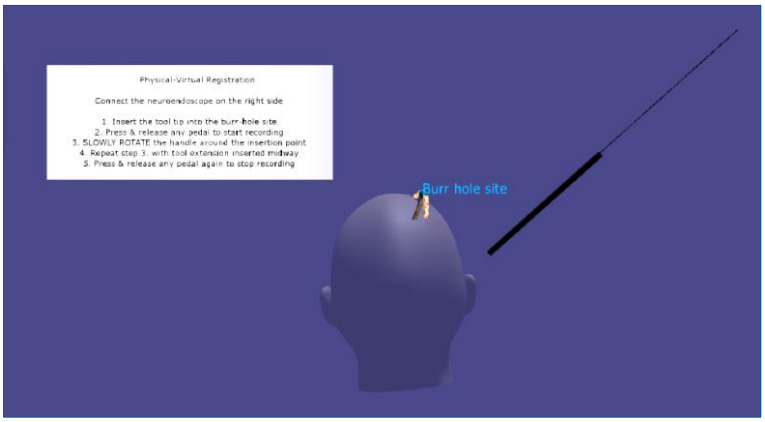
Selection of Burr Hole site registration function

Follow the instructions on the screen:



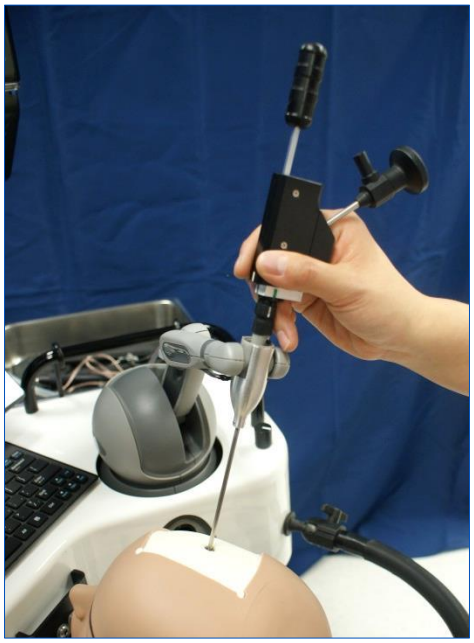
Burr Hole registration start screen

1. Press any pedal to start the registration



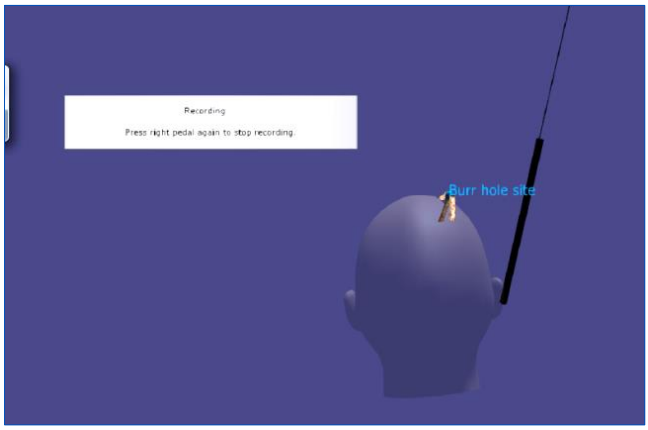
Burr Hole registration instruction screen

2. Connect the Neuroendoscope to the right-hand haptic device
3. Insert the tool tip into the Burr Hole site



Inserting the Neuroendoscope tip into the Burr Hole site

4. Press either pedal and release, to start recording



Recording step for Burr Hole registration

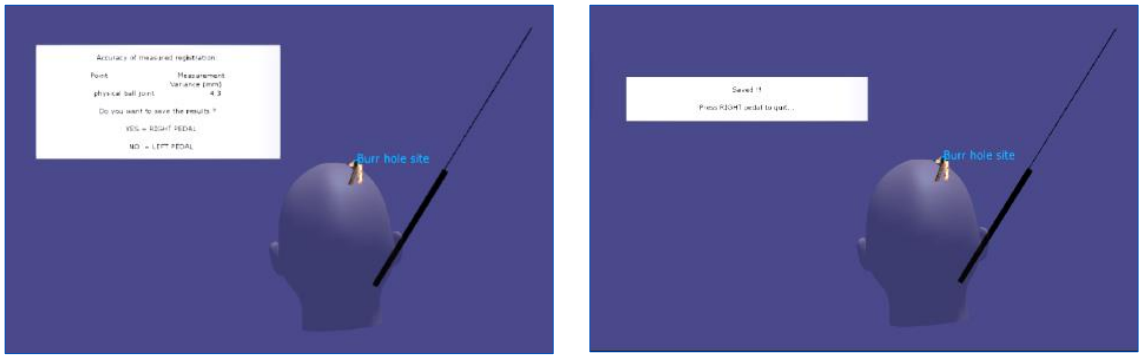
5. Slowly rotate the instrument handle with just the tip inserted

Note: It is important to do the rotation very slowly to minimize the registration error.

Note: An offset between the depicted instrument location and the physical point may be visible on the screen. This is normal and will improve after completing the registration procedure.

6. Then, insert the handle further to its midpoint and repeat the tool rotation
7. Press and release a pedal to stop recording

The screen will display the results of the Burr Hole site registration. When the variance is acceptable (i.e. under 5mm), you may save the results by pressing the right pedal.



Registration results and results saved screen

The following two examples show situations where the registration was not successful and should be repeated.

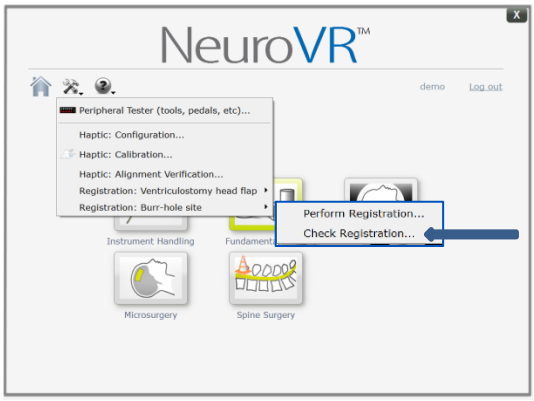
Examples of unsuccessful Burr Hole registration

To repeat the procedure without saving the results, press the left pedal.

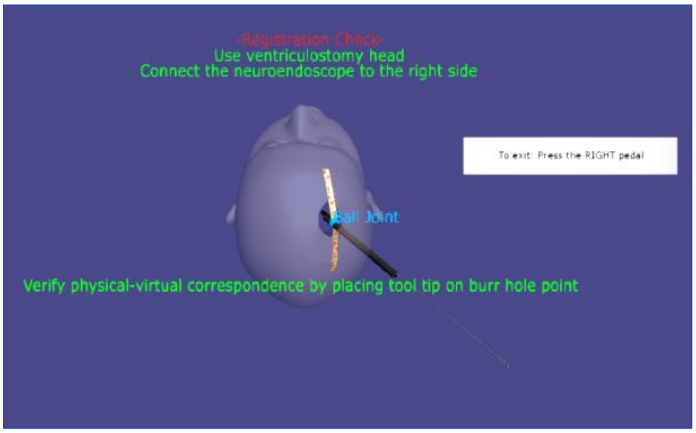
Burr Hole Site Verification Using Neuroendoscope

This selection allows you to verify that the registration is acceptable by inserting the instrument tip into the Burr Hole on the Ventriculostomy head model and tracking its virtual representation onscreen.

Select the **Registration: Burr Hole Site – Check Registration** module from the Tools and utilities menu.



Selection of Burr Hole site to Check Registration function



Burr Hole site verification screen

Place the tool tip at the Burr Hole location on the Ventriculostomy head. If the image of the tool tip onscreen is properly located at the image of the Burr Hole, registration is correct. If the variance between physical and virtual representations is not acceptable, the registration must be repeated.

Press the right pedal to exit. If necessary, return to the Burr Hole registration procedure.

Starting, Running, Stopping a Simulation

Selecting a Simulation

From the home screen, select the module and exercise you wish to practice. NeuroVR offers 5 training modules comprising 37 exercises of various surgical skills and progressive levels of difficulty. This section briefly outlines starting, running and stopping all NeuroVR exercises.

Attach the appropriate instrument handle(s) to use in the preferred position(s) (left or right hand side) for the chosen procedure. The exercise launch screen will indicate "available" instruments, i.e., which tools will be recognized by the simulation as appropriate for the exercise.

The procedure to start and stop the exercise depends on the exercise type. When each exercise is launched, an information window, with instructions, is displayed. Most exercises require the user to press the green **Start** button and the red **Stop** button with the tool tip(s).

Note: If you wish to stop the exercise at any point without saving results, press the **ESC** button on the keyboard.

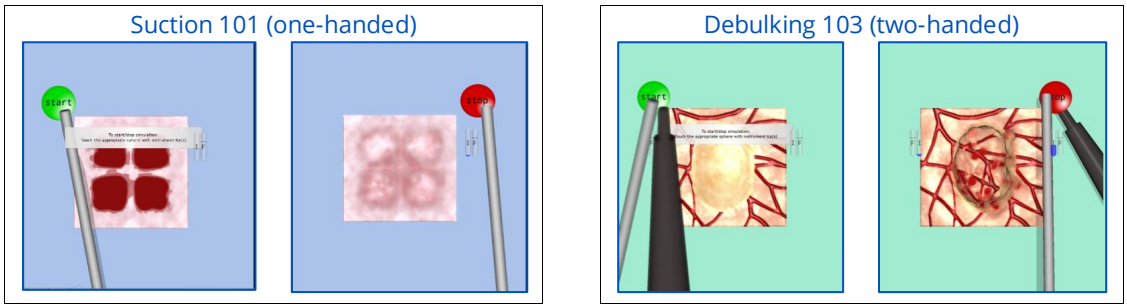
- You will return to a screen where you can restart the exercise, navigate through the NeuroVR menu normally, or exit

Information screen after the ESC button is pressed during an exercise

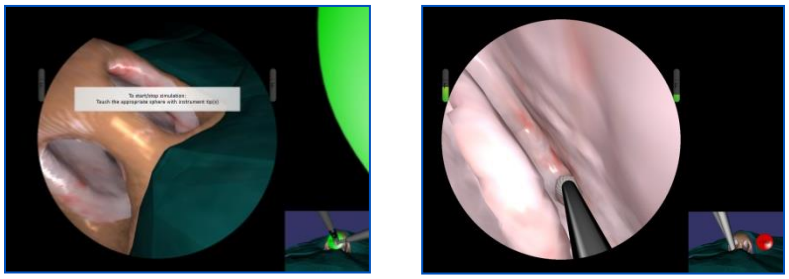
With the required instrument(s) installed, look through the microscope to the screen, navigate the tool tip(s) to the green **Start** button and press until the green button disappears.

Note: For a two-handed exercise, both tools must be used to simultaneously press the start and stop buttons.

When you have completed the exercise, or wish to stop at any time and save the results, use the tool tip(s) to press the red **Stop** button.



Starting and stopping exercises using the green start / red stop buttons



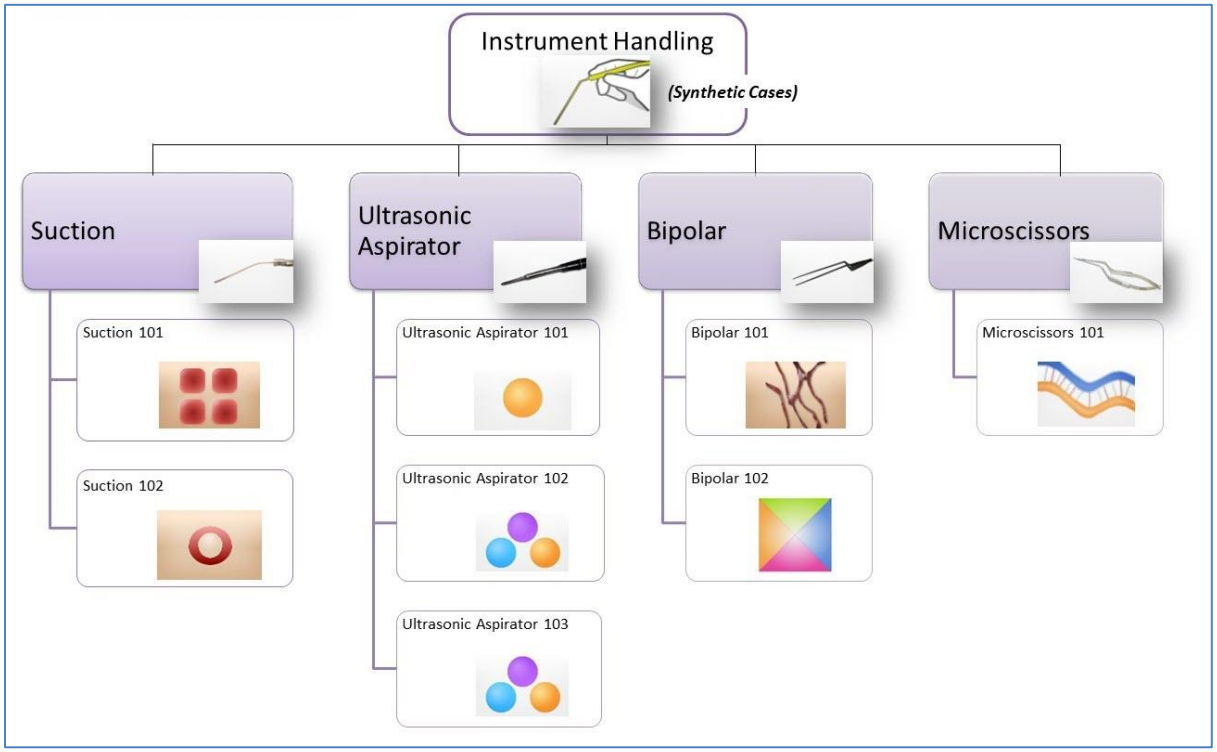
Display of the start and stop buttons in the patient view for endonasal exercises

NeuroVR Training Exercise Library

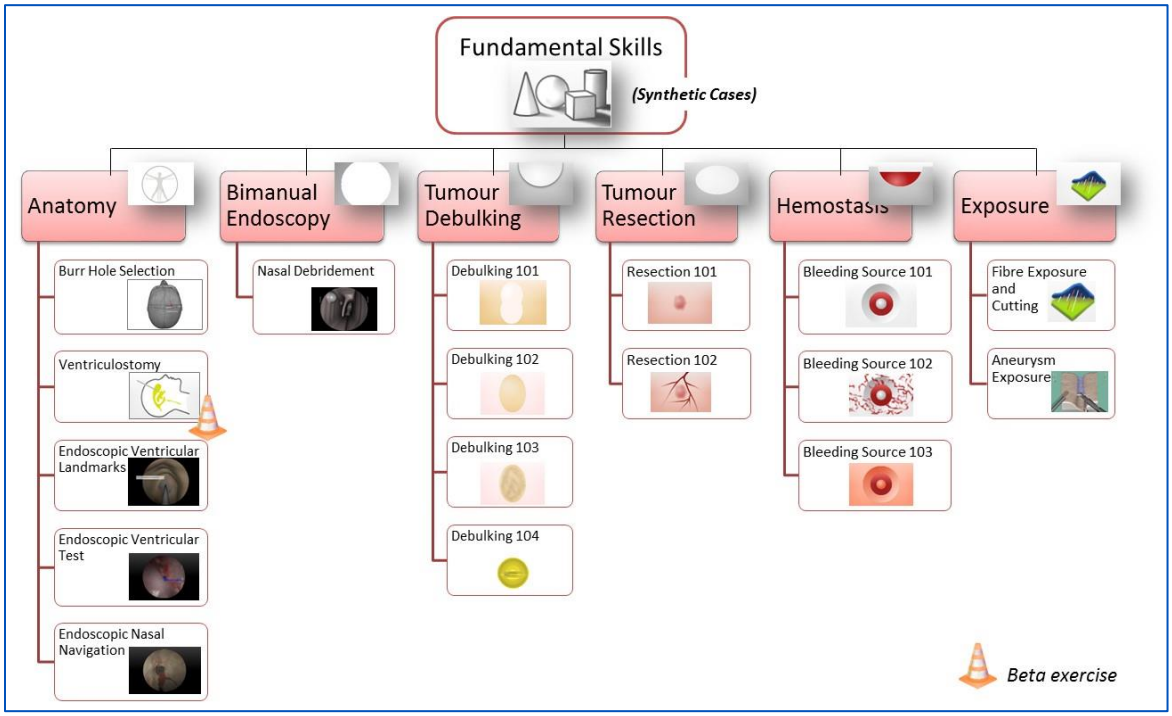
Please see the images below summarizing the available exercises. All icons displayed with a construction cone correspond to exercises that were most recently added.

- Consult Appendix N: NeuroVR Courseware for specific instructions and images regarding an individual exercise

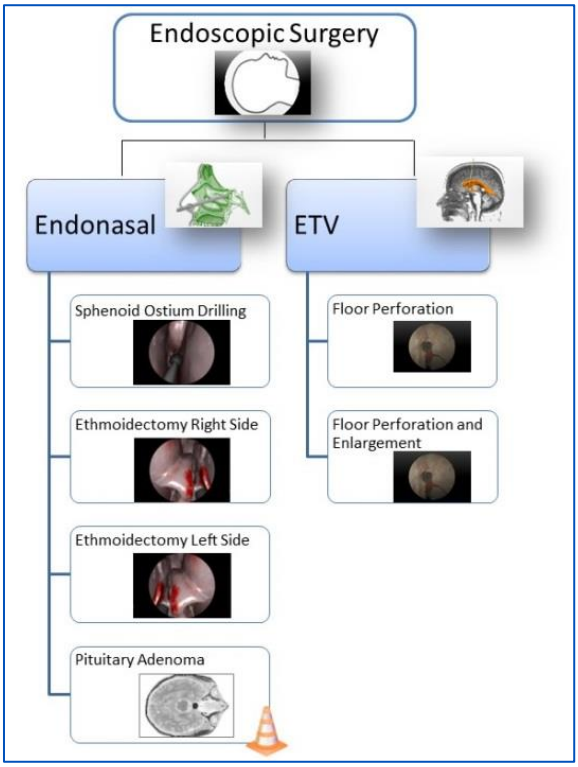
The following diagram shows an outline of all 37 Training Exercises divided into the 5 modules available to all users. Select the module you want to practice on by clicking its icon on the home page.



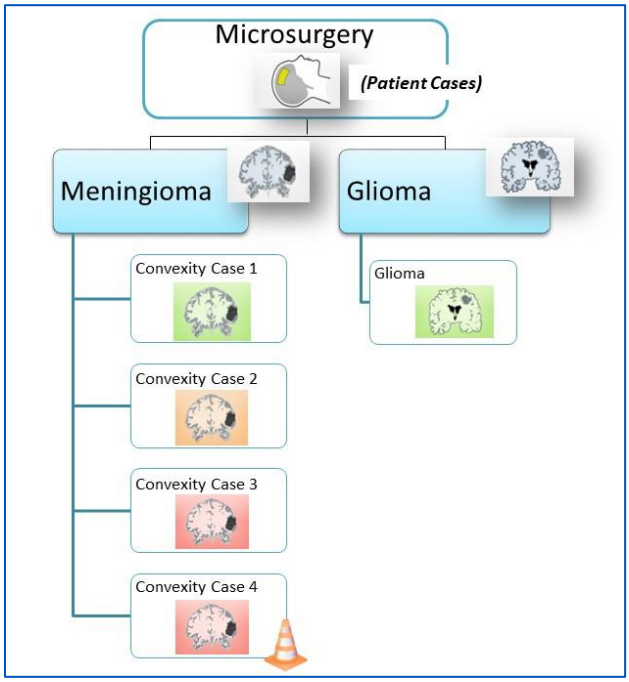
Instrument Handling module exercises



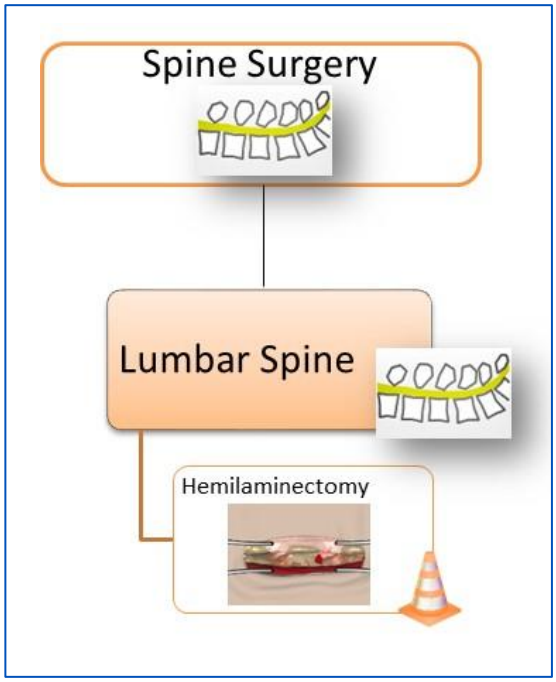
Fundamental Skills module exercises



Endoscopic Surgery module exercises



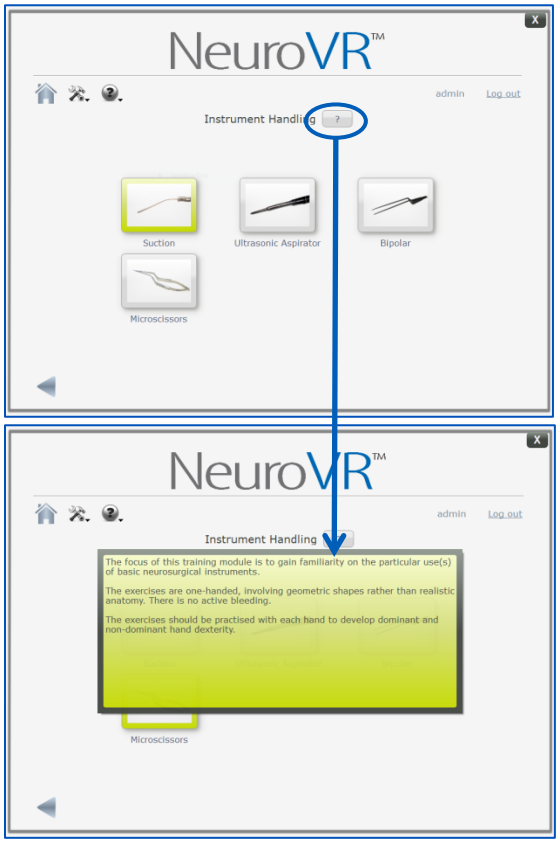
Microsurgery module exercises



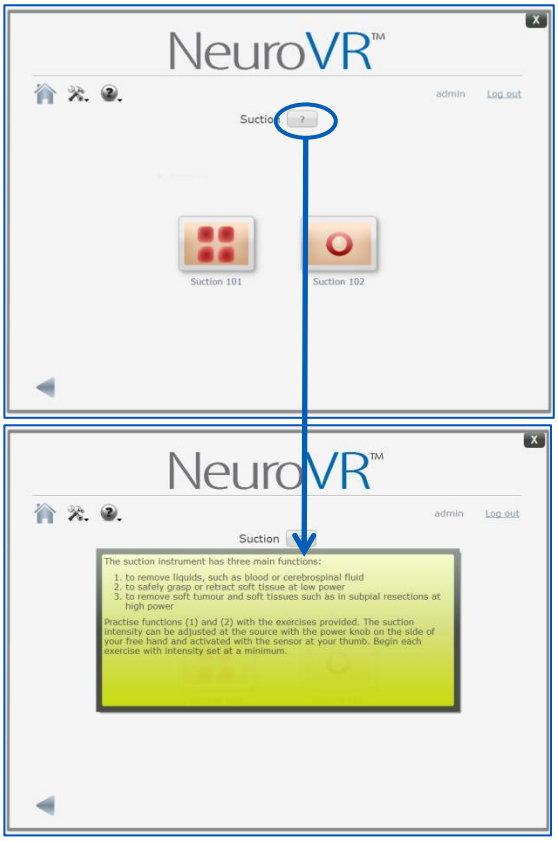
Spine Surgery module exercises

As shown below, when the Instrument Handling module is selected the next screen will provide the available categories of exercises. Clicking the **"?"** button beside the module name (circled in red) provides information on the module exercises and their objectives. Click the information window again to make it disappear.

Select the category of exercises to see one or more exercises available. Clicking the **"?"** button will provide further information about the techniques to be developed through practising these exercises.



Accessing module information



Accessing category information

Select your exercise. The next screen will describe the goal of the exercise along with the available instruments and operative view mode (microscopic or endoscopic).

Exercise launch screen

After reading these instructions, a few options remain:

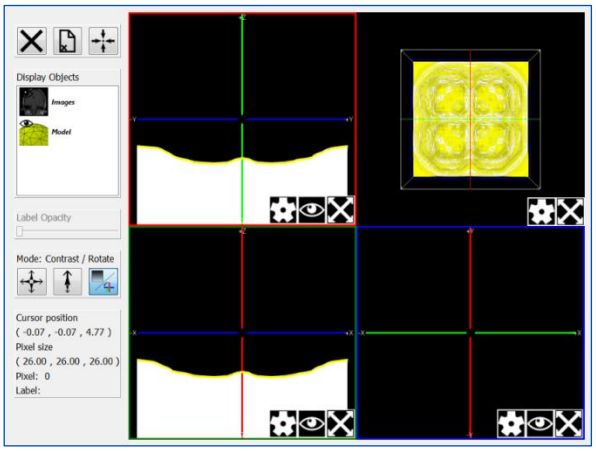
- When you are ready, and have the correct instrument(s) installed, select **Start** to launch the exercise. A progress screen displays the NeuroVR logo, indicating that the exercise is loading.

Progress screen during exercise loading

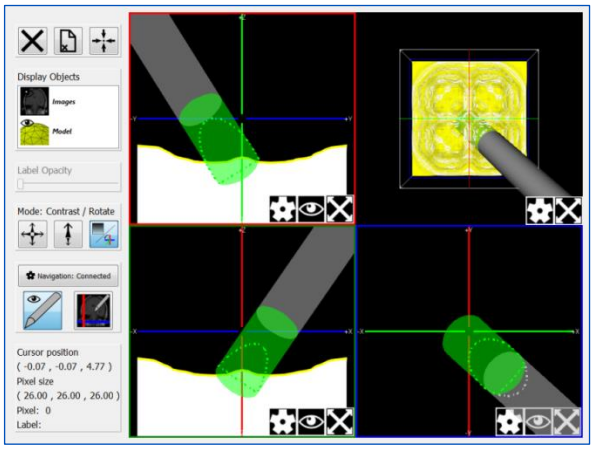
- **View Anatomy** provides a set of grayscale images that represent the target anatomy of the exercise. A multi-planar image viewer is displayed on the touch screen. Click the **X** button to close the image and return to the exercise launch page. See Appendix B: Image Viewer for further details.

  Note: Some training exercises do not offer the **View Anatomy** option.

- The **Enable Neuronavigation** checkbox (activated before pressing **Start**) allows you to practice the exercise with the type of image visible in Image Viewer**.** The dominant tool is seen in the Image Viewer.

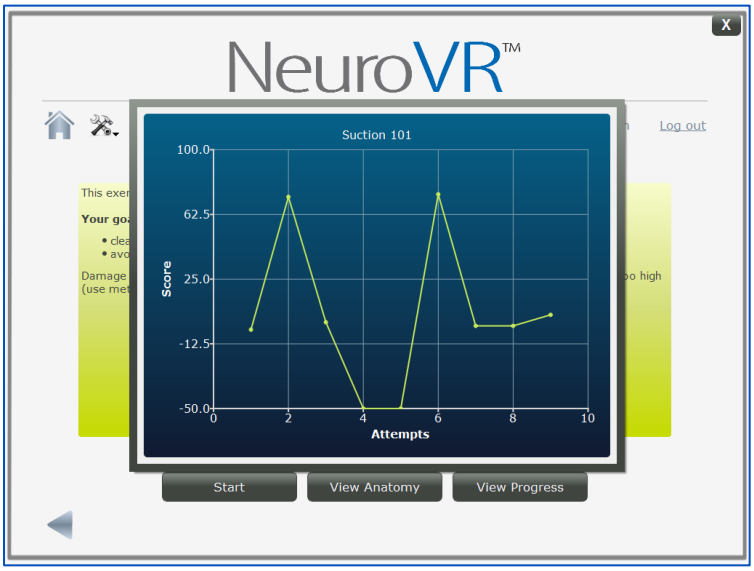


Example Image Viewer screen



Exercise practiced with Neuronavigation enabled

- If you are logged in with an account name and you have practiced the exercise before, you may also click **View Progress** to see a graph of performance data from previous attempts. Click the graph window again to make it disappear.



Progress graph

Viewing Results from a Simulation

When you end a simulation normally (not pressing ESC to abort the procedure), the Results screen automatically displays the final simulation image, score history, specific metrics and the overall score.

Results screen displayed when an exercise ends normally (example: Debulking 104)

Additional data on each metric may be accessed by pressing the plot icon under **Details**. For more information regarding the Results screen, please refer to the NeuroVR Courseware.

When finished with the Results screen, the user may select:

- **Try Again** – press this button to attempt the exercise again immediately
- **Back arrow** – return to the exercise information screen to navigate elsewhere or log out

NeuroVR Administrator Utilities

Calibration of Microscissors and Bipolar Forceps

These instruments are calibrated prior to shipping, and additional calibration should not be required. However, a replaced or repaired instrument should be calibrated with the simulator.

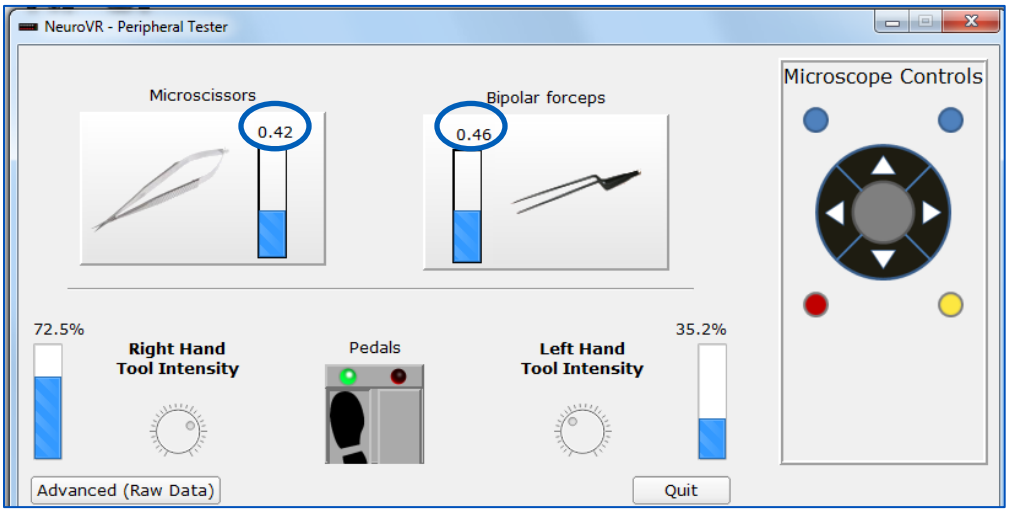
Calibration sets the correct relationship between the signal sent from the instrument handle and its representation onscreen. This calibration should only be required once. Improper response is apparent when the virtual tool tips do not mimic the physical manipulation of the instrument.

The procedures to calibrate the Microscissors and the Bipolar forceps are the same:

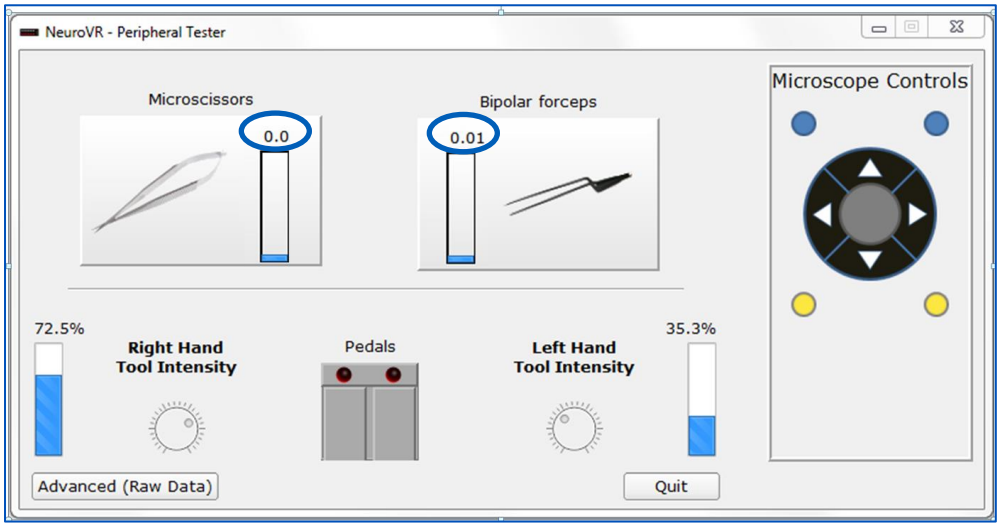
1. Connect the instrument handle to the right-hand haptic device. It is not necessary to remove any instrument connected to the left-hand device.
2. Start NeuroVR and log in as a NeuroVR administrator
3. Select the **Peripheral Tester** from the Tools and Utilities menu

Selection of Peripheral Tester function

4. The image of the right-hand instrument should represent the correct instrument
5. Close and release the instrument handle three (3) times, then write down the lowest and highest values viewed in the instrument signal box (circled in blue)
   - The setting of the power knob for the instrument has no effect on the calibration



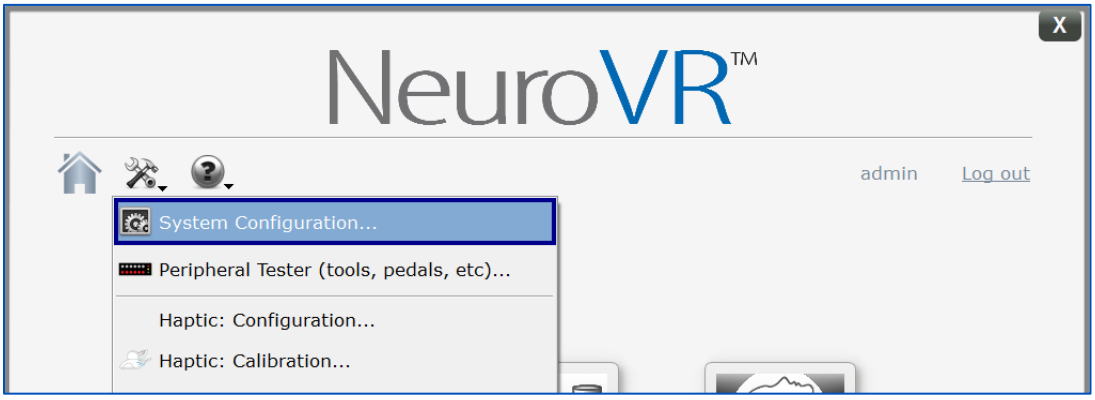
Peripheral tester screen for Microscissors and Bipolar forceps: fully open



Peripheral tester screen for Microscissors and Bipolar forceps: fully closed

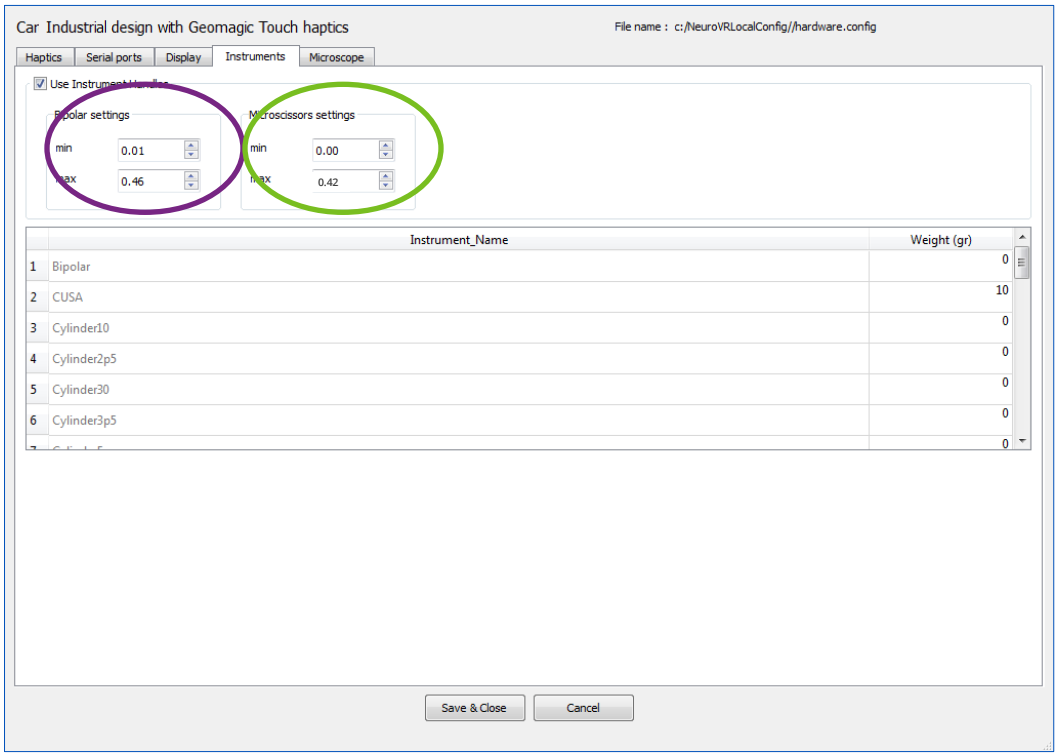
6. Select **Quit** to close the application

7. Open the System configuration application from the Tools and utilities menu



Selection of System Configuration function

8. Select the Instruments tab



Instruments tab highlighting data entry fields for Bipolar forceps (purple) and Microscissors (green)

9. Fill in the boxes with the maximum and minimum values recorded in step 6. In the image, Bipolar values are circled in purple and Microscissors values are circled in green.
   - For the example figures depicted here:
     Bipolar forceps: maximum 0.46 minimum = 0.01
     Microscissors: maximum 0.42 minimum = 0.00

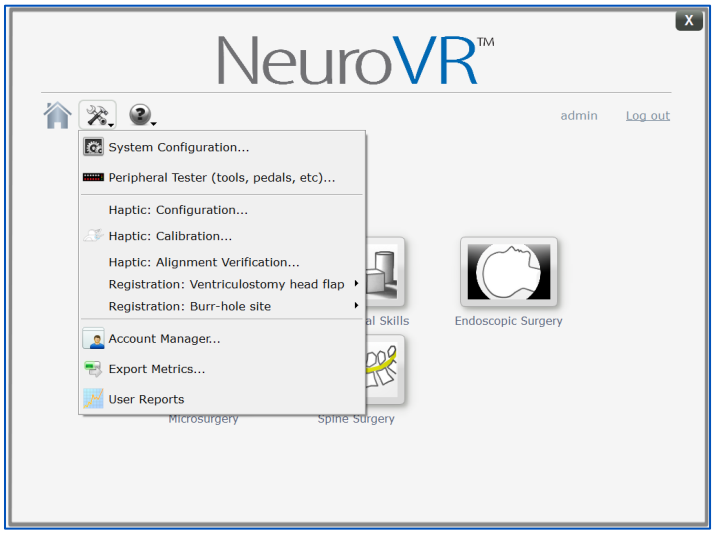
10. Select **Save & Close**

Managing Accounts

Only a NeuroVR administrator can create, modify or delete NeuroVR user accounts.

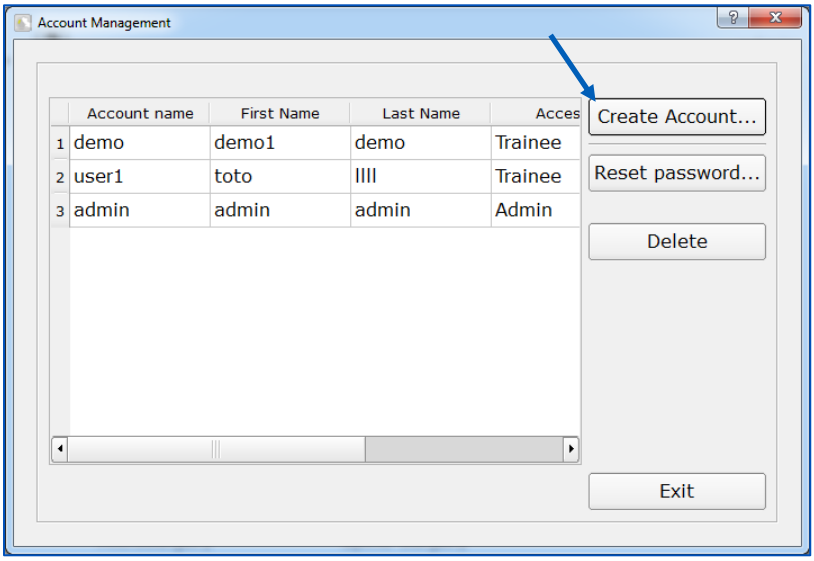
Create New Account

Log into NeuroVR using your administrator account. Select **Account Manager** from the Tools and Utilities menu.



Selection of Account Manager function

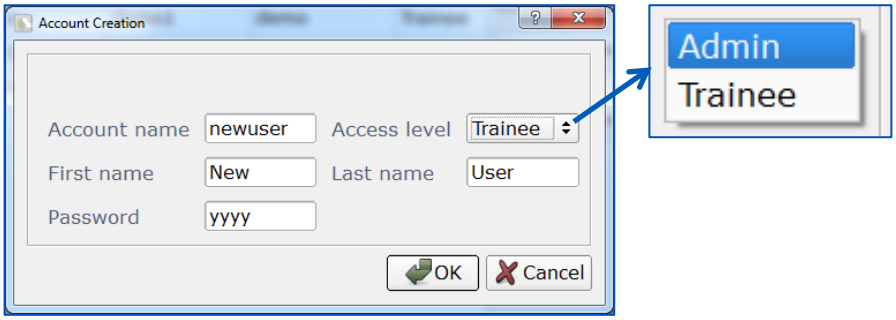
The list of NeuroVR user accounts is displayed in the account management window. Create a new account by clicking **Create Account**.



Account Management screen

Complete the fields in the Account Creation window and press **B**.

- The access level should be set as **Trainee** for most users. The Administrator access level allows you to access configuration functions, manage accounts and export data.

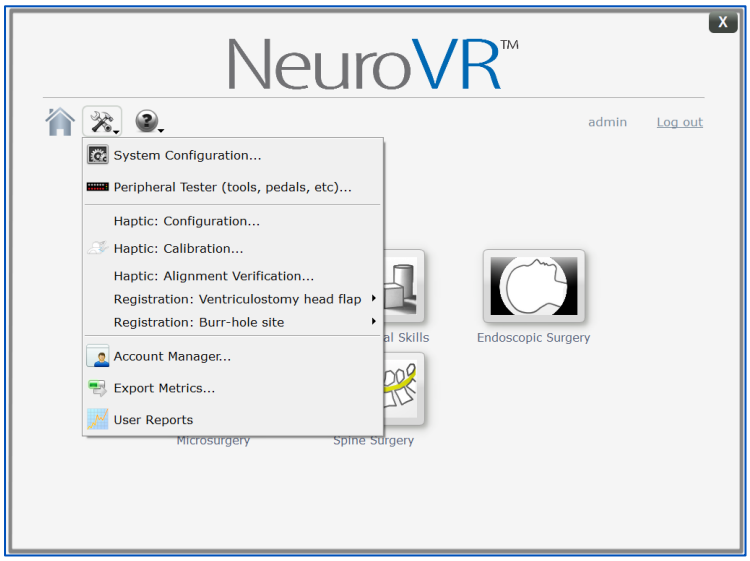


Account Creation window and the selection of access level

Exporting Metrics

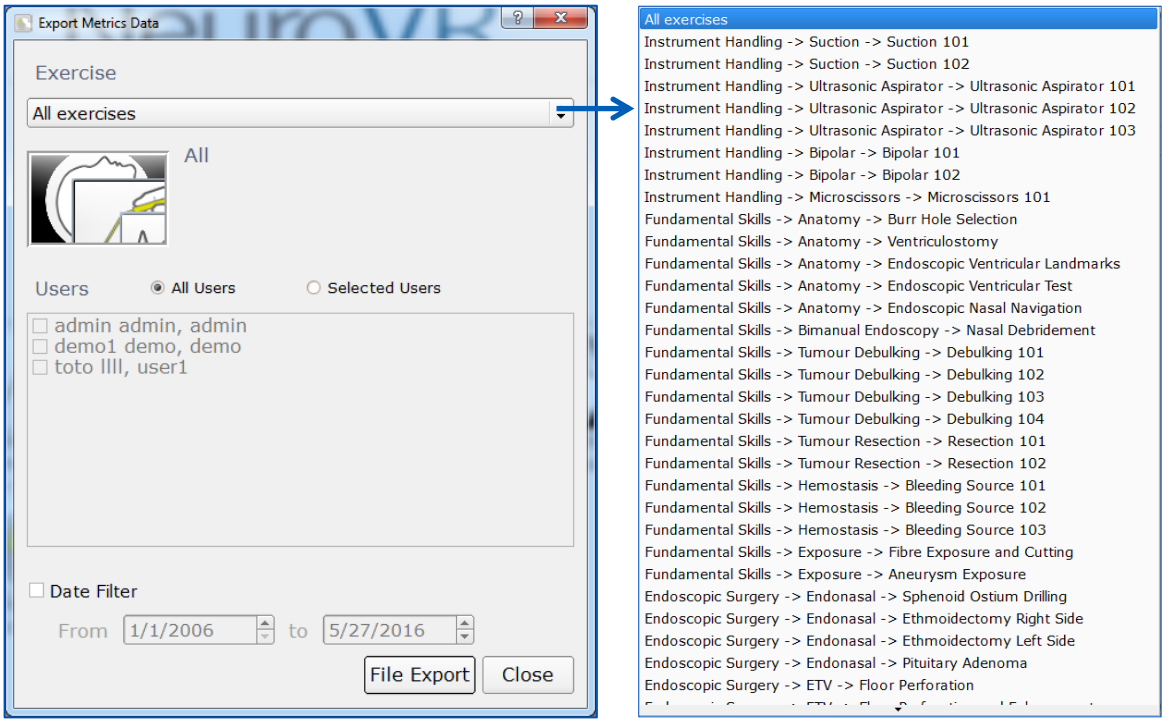
A NeuroVR administrator can export users' accumulated data for further post-processing.

- Start NeuroVR and log in as a NeuroVR administrator
- Start the **Export Metrics** module from the Tools and utilities menu



Selection of Export Metrics function

A new window will pop up displaying a list of exercise(s) and user(s) for whom you want the data to be exported. Use the dropdown menu to select either **All Exercises** or a specific one(s).

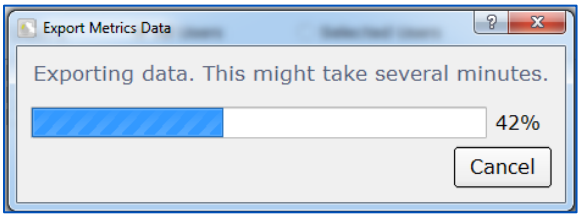


Selection of exercises in the Export Metrics Data window

- Select either **All Users** to export all data, or **Selected Users** and then check the box(es) corresponding to the user(s) for whom you wish to export data

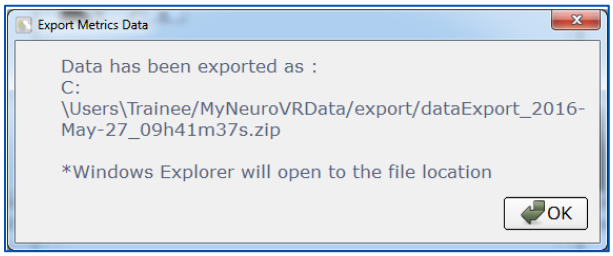
To export data accumulated only during a specific time, check **Date Filter** at the bottom of the window and specify the time range.

- Click **File Export**. The export process starts automatically.

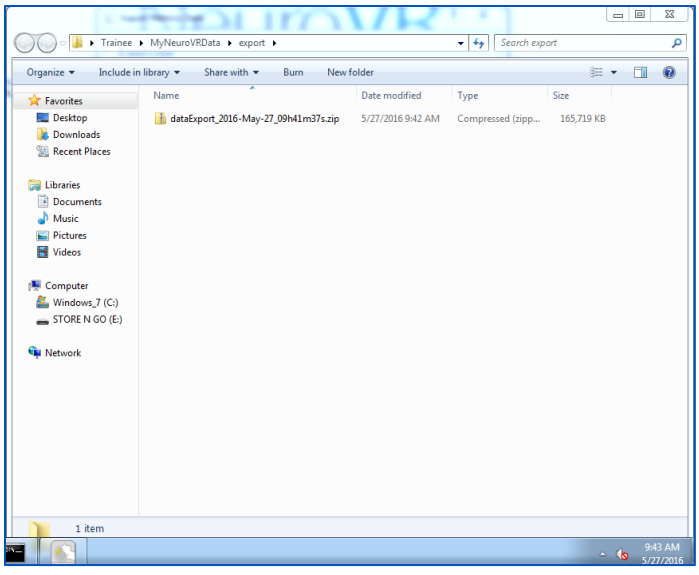


Progress bar during export process

Once completed, you will be prompted with the location of the zip archive file containing the specified data, and a Windows Explorer window will open to the file location (typically: C:\Users\Trainee\MyNeuroVRData\export#dataExport_****.zip).



Confirmation screen following data export



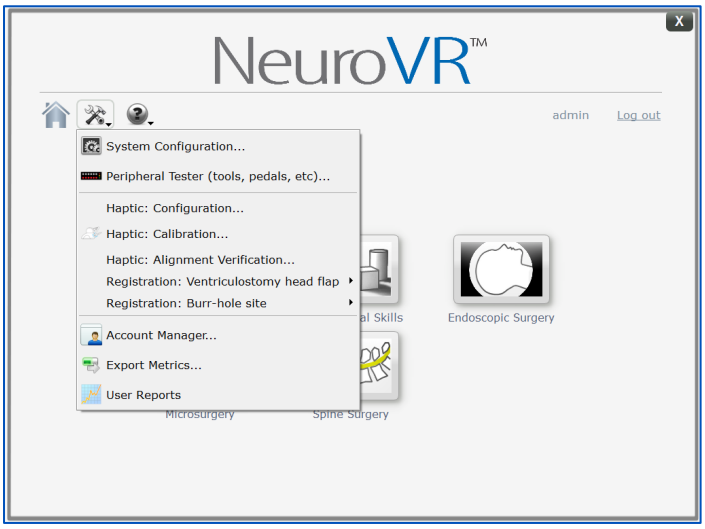
Pop-up Windows Explorer window allowing access to exported data

Unzipping the archive file will give you access to a summary of the simulation results and the raw user data accumulated.

Creating User Reports

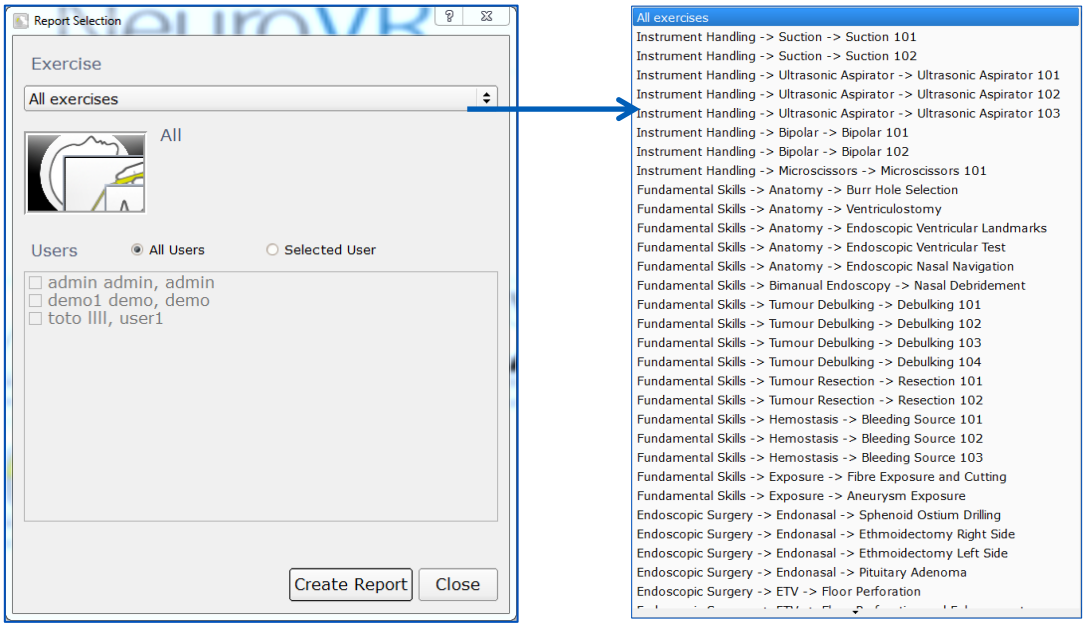
NeuroVR administrators can create a report summary of all users having a NeuroVR account.
To create a report:

- Start NeuroVR and log in as a NeuroVR administrator
- Select **User Reports** from the Tools and utilities menu



Selection of User Reports function

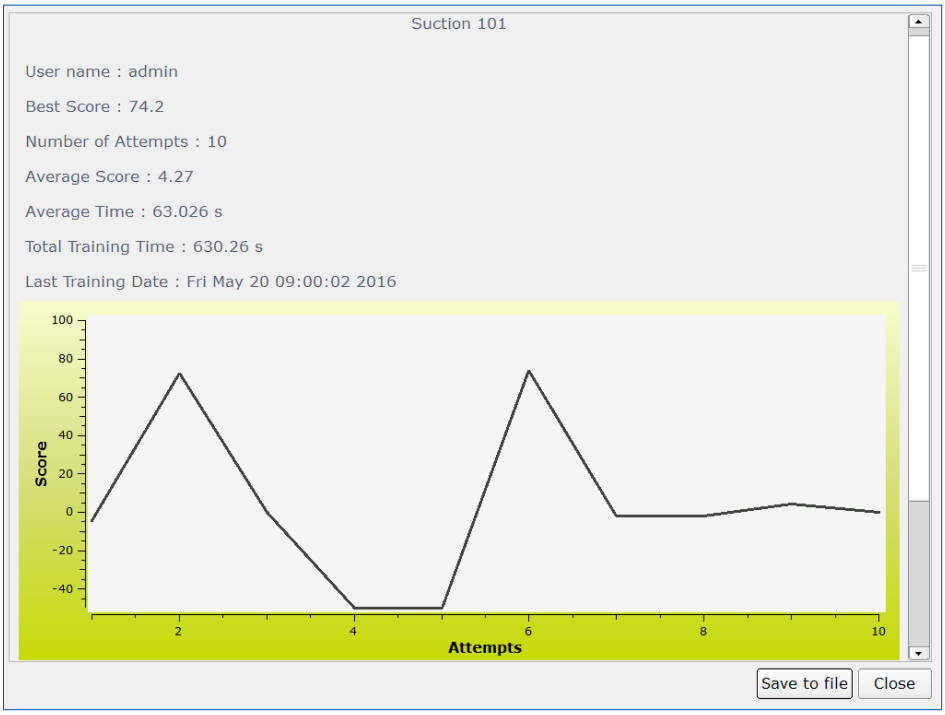
A new window opens displaying a list of exercises and users for whom you want the data to be exported. Use the dropdown menu to select either **All Exercises** or a specific one.



A Selection of exercises in the Report Selection window

Select either **All Users** to export all data, or **Selected Users** and then check the box(es) corresponding to the user(s) for whom you wish to export data.

Click **Create Report**. A report, showing the accumulated data according to the selection loads automatically.



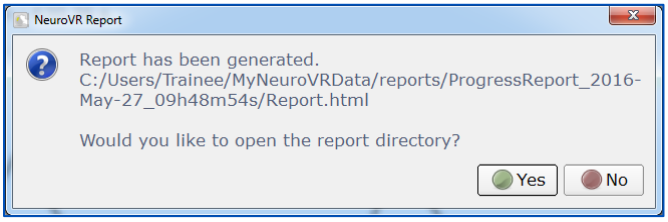
User report generated onscreen (Example: Suction 101)

A summary is displayed for each exercise and each user selected, including:

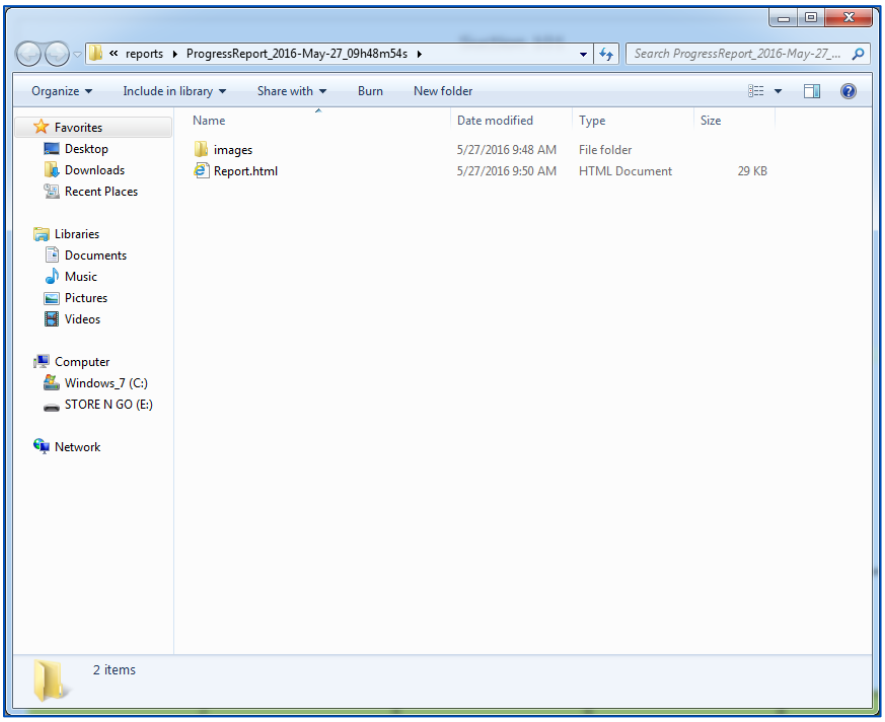
- The exercise
- The user
- The best score obtained
- The number of attempts
- The average score
- The average time taken to do the exercise
- The total training time for this selected exercise
- The last training date
- A performance graph, tracking the score over successive attempts

Click **Close** to close the report and go back to the selection window.
Click **Save to file** to save the created report.

A popup window provides the file location
(typically: *C:\Users\Trainee\MyNeuroVRData\reports\ProgressReport_date_time\username_Report.html*)
and a prompt to open the directory in a Windows Explorer window.

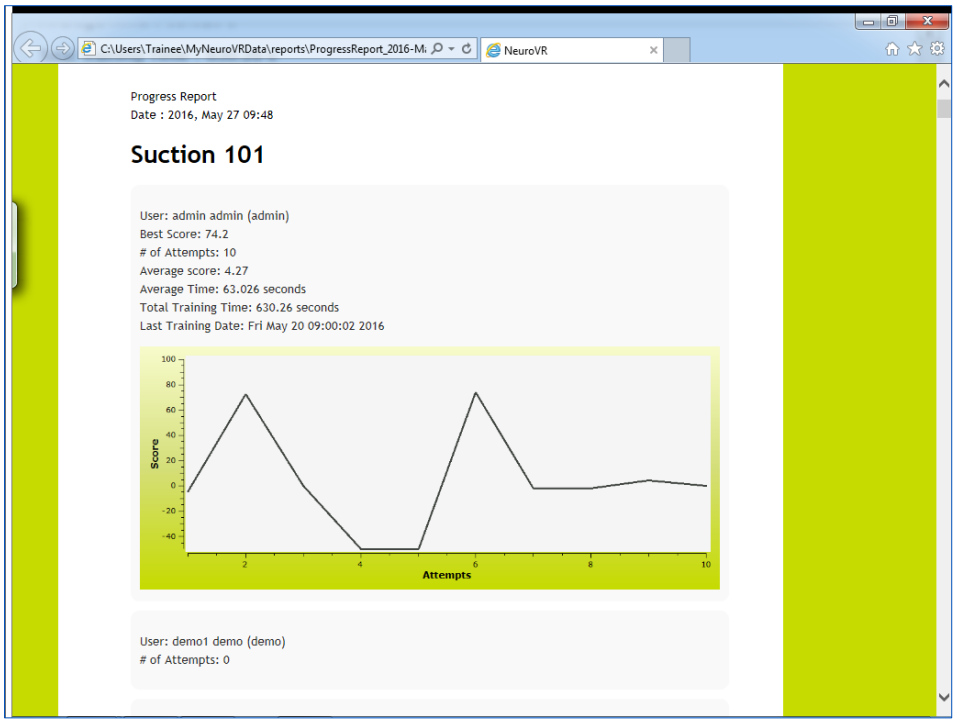


Confirmation screen for user report creation



Pop-up Windows Explorer window allowing access to user report

Double-click the .html file to view the created report with Internet Explorer. You may also copy it to a USB key to consult the report later.



User report .html file

Click **Close** to close the user report window. Click **Close** again to close the report selection window and go back to NeuroVR, or to select another user/exercise to create a report.

System Diagnostics

If the simulator is not performing as expected, simple corrective steps may resolve the issue. Some common problems and corrective steps are listed below. For any problems not listed, or if the suggested actions do not resolve the issue, contact NeuroVR Support.

Confirm Which NeuroVR Version is Installed on Your System.

1. Start NeuroVR and select **About** from the Tools and utilities menu
2. A window will pop up with information on your NeuroVR version and contact email address
3. Click **OK** to close the window.

You Have Connected Your Instrument Handle, but the Instrument Does Not Appear Onscreen.

1. Verify that the instrument is properly connected to the haptic device
2. Use the peripheral tester, as described in Testing instruments, pedals and power knobs, to assess whether the system recognizes the instrument correctly
3. If the instrument still does not appear, follow the next procedure

The Connected Instrument Handle Does Not Appear Correctly Onscreen.

1. Follow the Calibration of haptic devices procedure. In the calibration screen, move the haptic device arm and check that the movement is captured.
2. If the haptic device does not respond appropriately, repeat the New haptic system setup procedure and check the instrument's response
3. If the instrument is still not depicted or responding correctly, contact NeuroVR Support

The Intensity Level Does Not Respond When You Adjust using the Power Knob.

1. Contact NeuroVR Support for resolution of the problem

Bipolar Forceps or Microscissors no Longer Open or Close.

1. Calibrate the instrument(s) according to Microscissors and Bipolar Calibration

Suction no Longer Aspirates.

1. Verify correct connections as explained in Testing Instruments, Pedals and Power Knobs

Keyboard, Speaker, and/or Touchscreen do not Respond.

1. Ensure that all components are correctly connected to the USB ports

Endonasal procedures require you to insert the endoscope and other instrument(s) using the external view of the nostrils, then navigating internally. The patient view is visible in the bottom right corner at all times as illustrated below. The ENTER key switches the main screen display between patient and endoscopic views as required.

Appendix A: New Haptic Device

If a haptic device is replaced or repaired, it must be configured for the NeuroVR simulator. This procedure may also be followed if the simulator no longer recognizes your haptic devices.

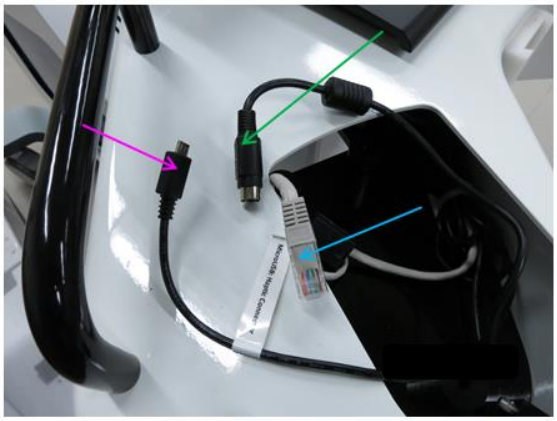
Entact Haptic Device Installation

Carefully unpack the Entact Haptic Devices from the box and identify the left and right haptic device.

Haptic devices in box

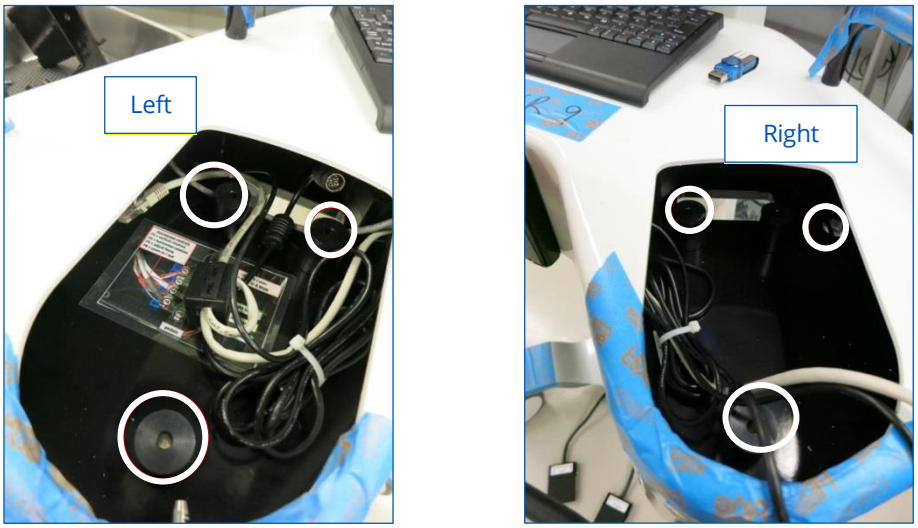
Prior to inserting the haptics entirely into the slots, make the 3 connections with the cables available

- Power
- Micro USB (Control/Peripheral Tester)
- Ethernet



Haptic device connections

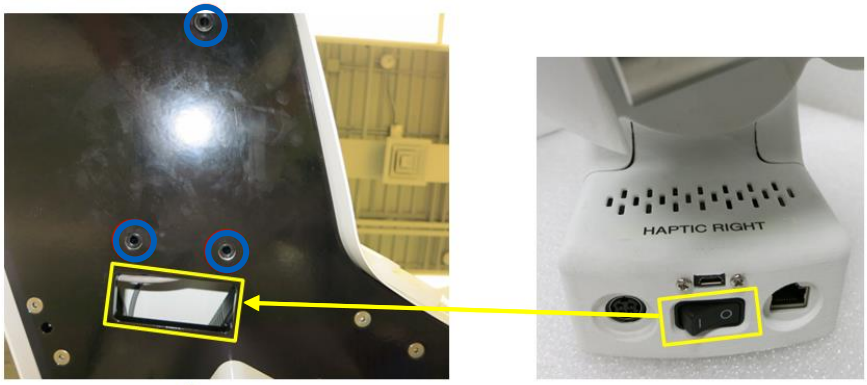
Once the connections have been made with the 3 cables, place the Right haptic device completely into the right slot opening and likewise for the left side. Position and align the haptics on the 3 cylindrical columns highlighted in white.



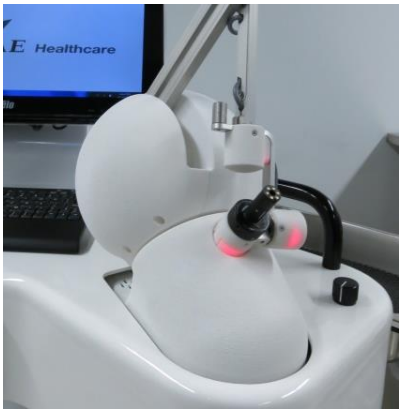
Haptic device cylindrical resting columns

Once the haptic devices have been connected and are placed into their respective openings, use the screws (3) provided to fasten the haptics securely to the table platform. Make sure to verify that the haptics do not move.

To access the on/off switch of the haptic device, you must go through the yellow rectangular opening under the table. The haptic devices can remain in the ON position at all times. If the system does not recognize the haptic device, try clicking the on/off a few times.



Haptic device screw locations and on/off switch opening



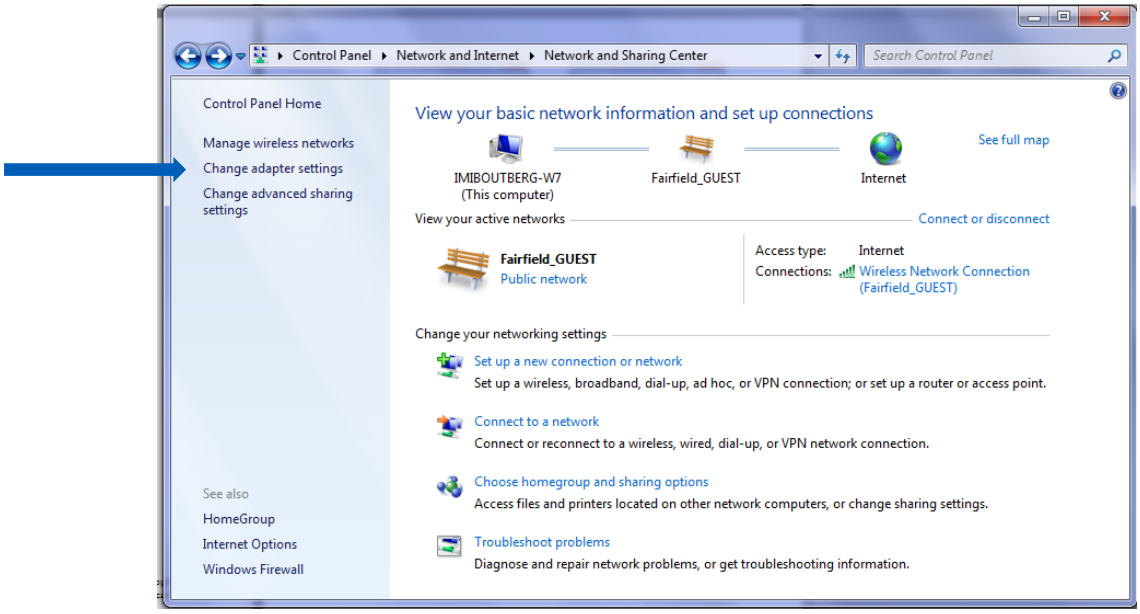
Final position of Right Haptic Device

Entact Haptic Device Configuration

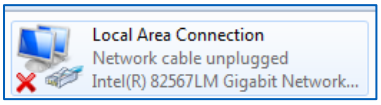
The following steps are usually not required. Your system will be delivered already configured with the correct parameters. In case you would need to re-configure the network parameters, read the following steps. Before starting the Entact configuration, make sure that the Rosewill Network Adapter is installed. If the network card is defective or no longer operational one of the following StarTech drivers must be used and installed on the computer:

- Driver: Rosewill Network Adapter
- Driver: StarTech USB2.0 Ethernet Adapter
- Driver: StarTech USB3.0 Ethernet Adapter

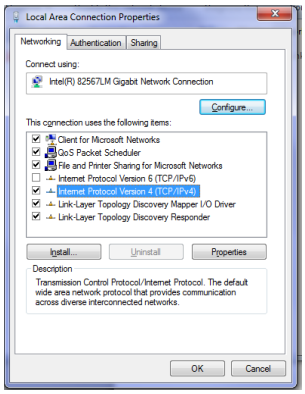
To configure the Entact Haptics, (configure one device at a time), go to:
Control Panel\Network and Internet\Network and Sharing center\Change Adapter settings



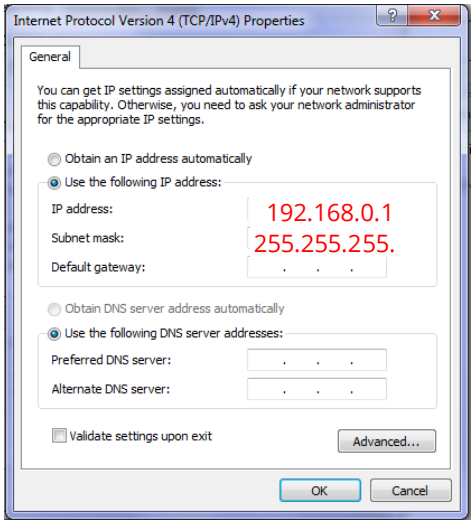
Click **Local Area Connection** (where Entact device is connected to)



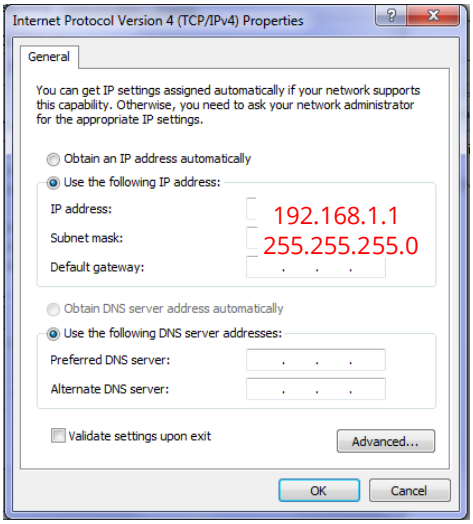
Right click to access the **Network Properties**. The following window opens:



- Click **Internet Protocol Version 4**
- Click **Properties**. The following window opens
- Click **Use the following IP address**
- Enter the IP addresses shown for the network cards of the Left & Right Haptics



Left Entact network card properties



Right Entact network card properties

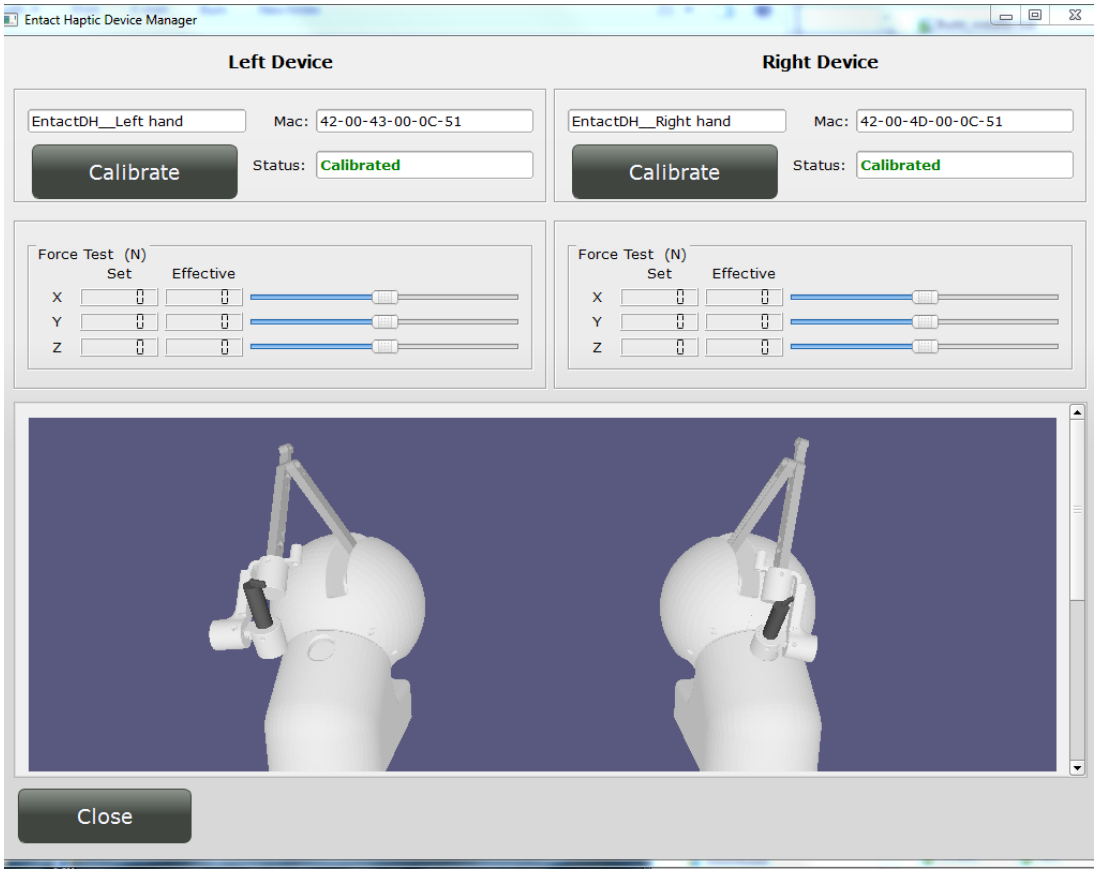
Left		Right
192.168.0.1 255.255.255.0	← Network Card IP address → Subnet mask	192.168. 1.1 255.255.255.0
192.168.0.148	← Device IP address → *(already set by haptic manufacturer)*	192.168.1.148

If haptic devices are not recognized by NeuroVR, open a DOS command prompt (click on Windows icon and type cmd) and take note of the results;

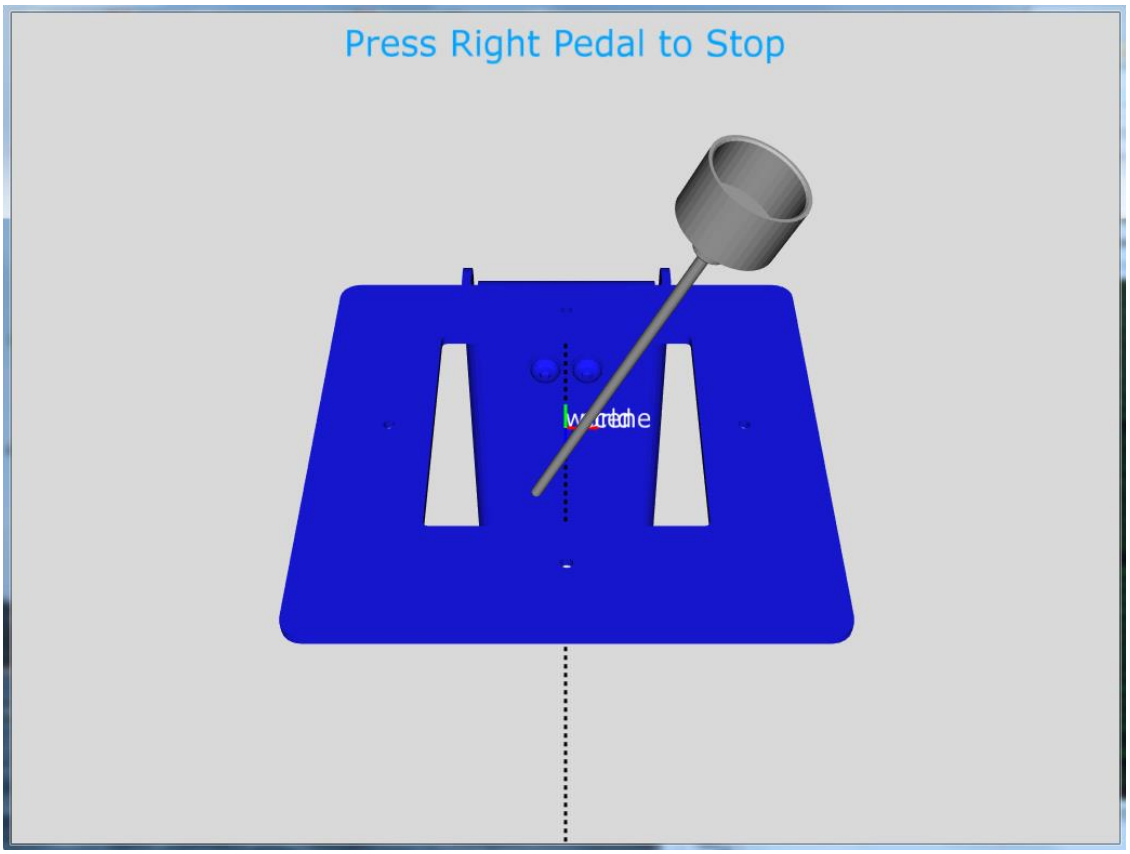
- ping 192.168. 0 . 1 (left network card port)
- ping 192.168. 1 . 1 (right network card port)
- ping 192.168.0.148 (left device)
- ping 192.168.1.148 (right device)

Entact Haptic Device Calibration

The haptic devices must be calibrated every time you start NeuroVR. Follow the steps below for a proper calibration.



Align the 2 black dots on the left and right haptic devices respectively (circled in red above) to perform a proper calibration of the devices. calibrate the left & right side separately. While aligning the dots, touch the calibrate button on the Touch screen.



Proceed to check the alignment of the haptic exercises (Right & Left unit separately)

Appendix B: Image Viewer

The image viewer is used to display the target anatomy before beginning an exercise. The relevant areas of the interface are shown below.

Display Control Buttons

From left to right these buttons are:

- Quit the viewer program and return to the NeuroVR interface
- Clear all objects from the display
- Re-center all objects within the display

Displayed Objects

The entries in this table include all objects that can be displayed. There are three types:

- **Images:** If the case was derived from medical images (MRI, CT, etc.) these will be the original images. Otherwise they will be simple grayscale images that represent the synthetic anatomy.
- **Models:** These are three-dimensional objects that represent structures in the simulation. Typically, they will be the visual surface as seen in the simulation.
- **Labels:** These are color images that represent, if available, areas within the anatomy that have been identified for special consideration. For example, they may be no-go zones, or ideal target regions to be used within the simulation.

The objects may be added or removed from the display by pressing on them, or dragging them to the viewer on the right side of the interface.

Overlay Opacity

When an image and a set of labels are displayed at the same time, the labels are displayed above the image. Use this slider to adjust the opacity of the labels.

Manipulation Mode

Select the behavior when dragging within the viewer on the right side. The choices are, from left to right:

- **Pan:** Move the objects that are displayed within the view
- **Zoom:** Increase / decrease the size of the objects
- **Contrast / Rotate:** In the two-dimensional image views, adjust the window and level of the images. In the three-dimensional view, rotate about the center.

Cursor Position

Gives the position of the coloured cross-hair cursor in space. If any image or label is underneath the crosshair, it will also be reported.

Viewer

Either a multi-planar or three-dimensional view of the data may be selected. The two-dimensional multi-planar view gives slices through the image volume in three planes. The images are registered so that the orientation of the planes corresponds to the positioning of the patient, namely:

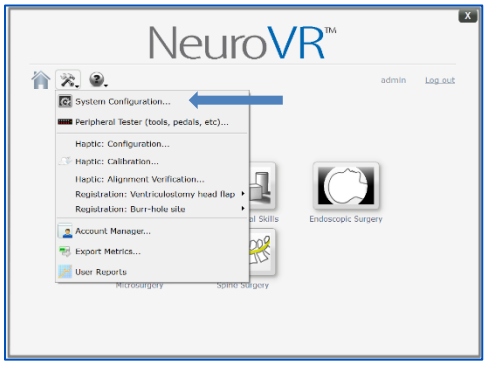
- **Blue:** A slice that is parallel to the flat surface of the simulator cart
- **Red:** A slice in the direction from the user's right to left when looking through the simulator microscope
- **Green:** A slice in the direction from the user’s back to front when looking through the simulator microscope

Any displayed models are shown in the two-dimensional views as a yellow cross section at the position of the displayed image. In the three-dimensional views, the position of the two-dimensional image planes and any three-dimensional models are displayed.

Appendix C: System Configuration Settings

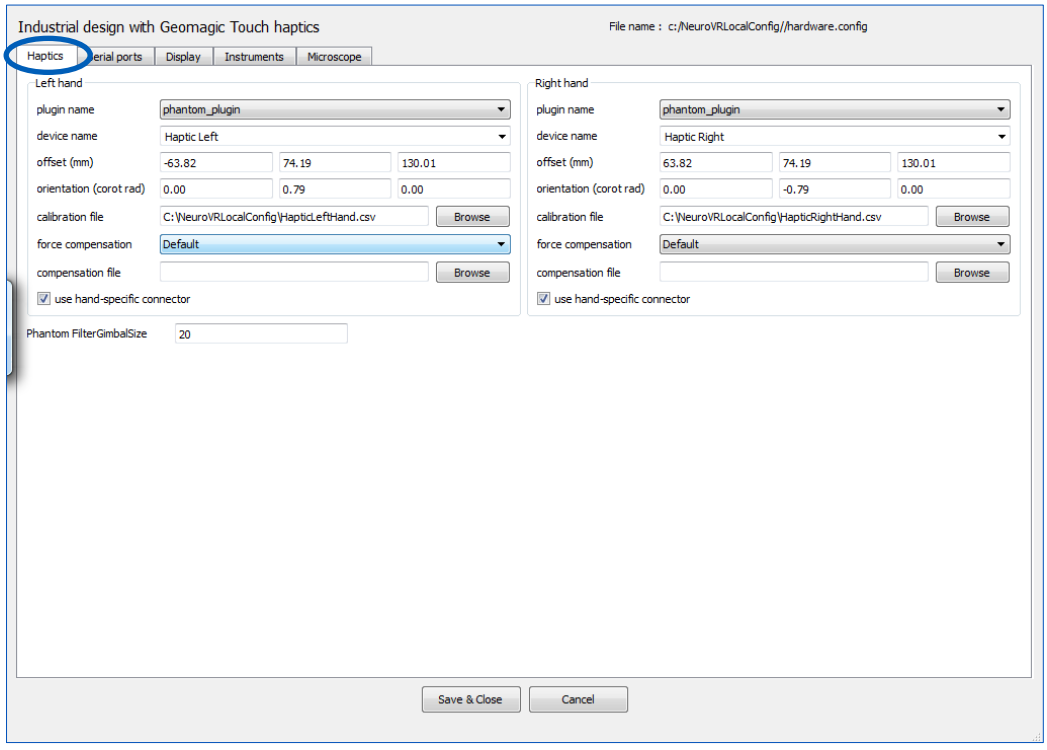
Only a NeuroVR administrator may open the System Configuration screen to confirm the simulator settings are correct, such as already demonstrated for the calibration of the Bipolar forceps and Microscissors using the Instruments tab. These settings should remain as originally configured except with the guidance of NeuroVR Support.

Select **System Configuration** from the Tool and utilities menu.

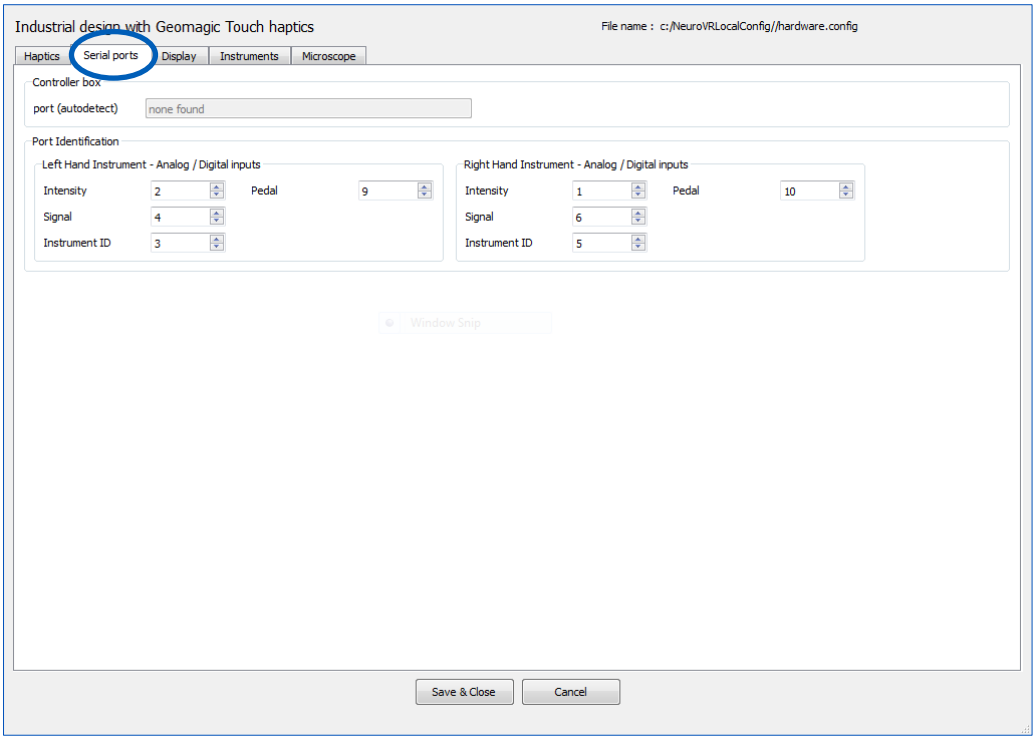


Selection of System Configuration function

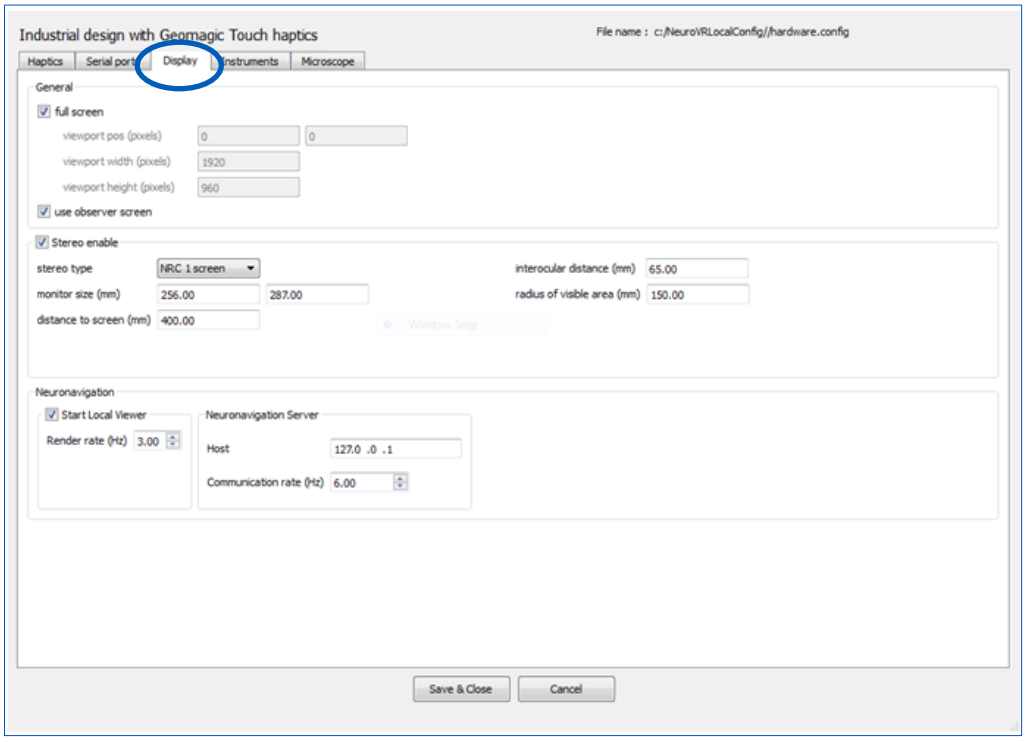
The configuration screens include tabs for Haptics, Serial ports, Display, Instruments, and Microscope.



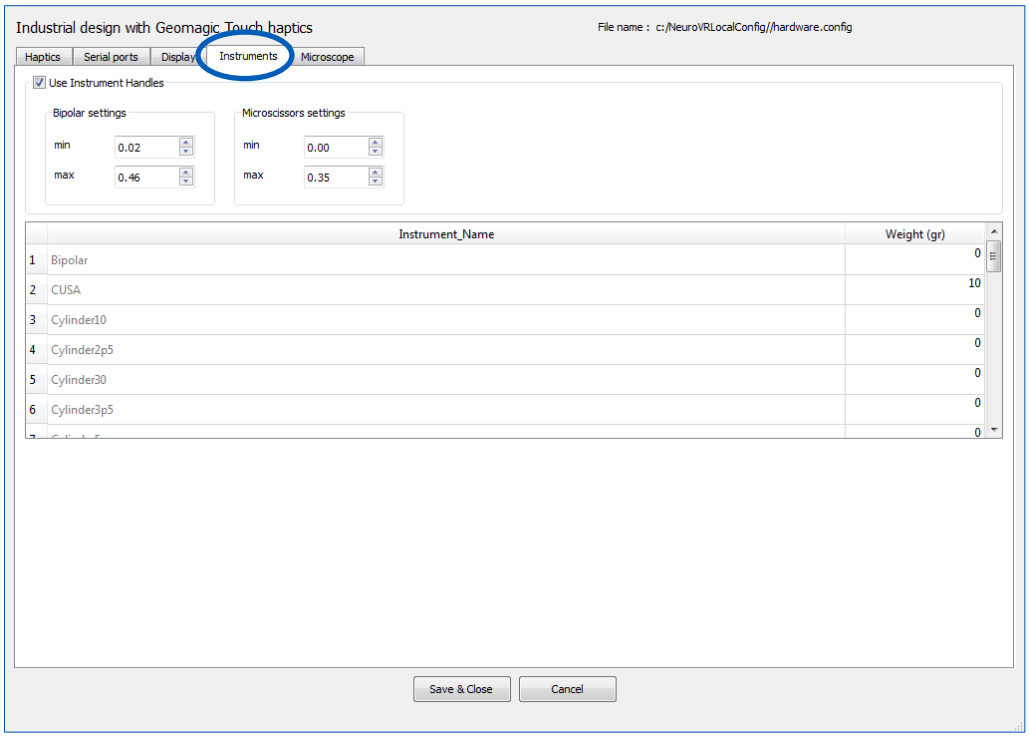
Haptics screen settings in System configuration



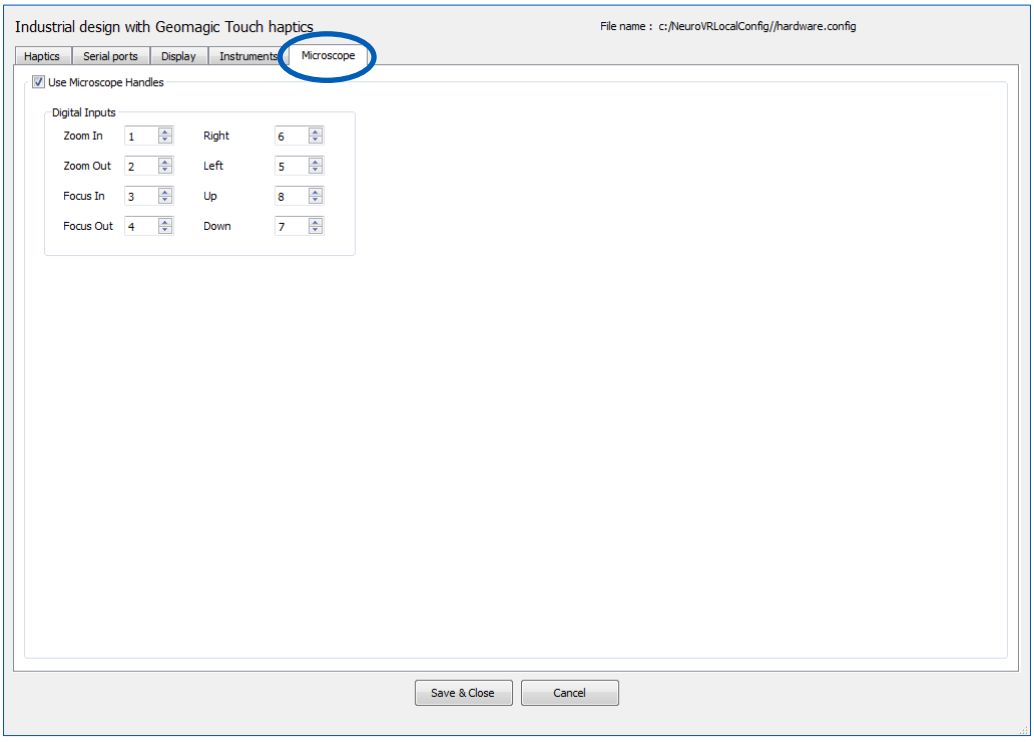
Serial ports screen settings in System configuration



Display screen settings in System configuration



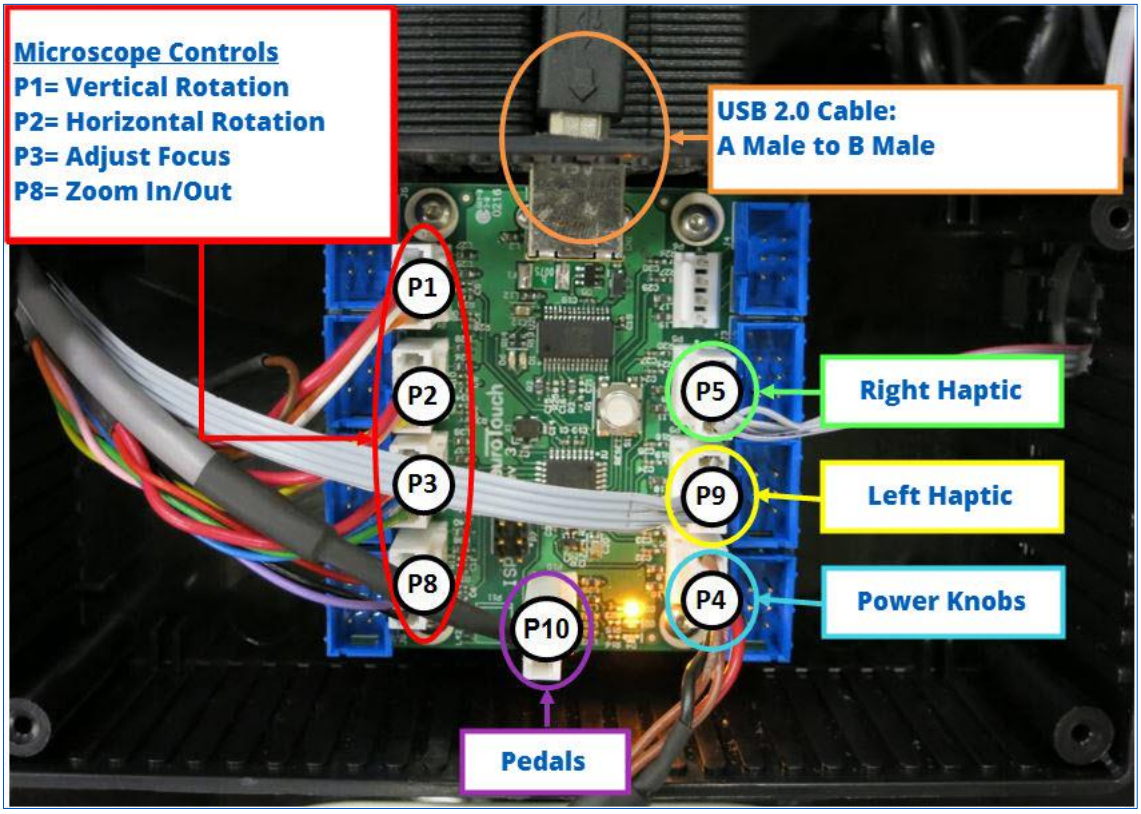
Instruments screen settings in System configuration



Microscope screen settings in System configuration

Appendix D: Accessing the Control Box

The “control box” is the assembly of physical connections which enable the communications between different components of the simulator and allow it to function correctly. Under the guidance of NeuroVR Support, these connections may be accessed and verified. The main components of the Control Box can be tested by accessing the Peripheral Tester in the NeuroVR Graphical User Interface menu options.



Main components of the control box

The following procedure to access the control box and connect a new cable serves as a reference, to be used while consulting with NeuroVR Support.

Remove adjustable arm rest and storage trays and raise simualtor to the highest possible position.

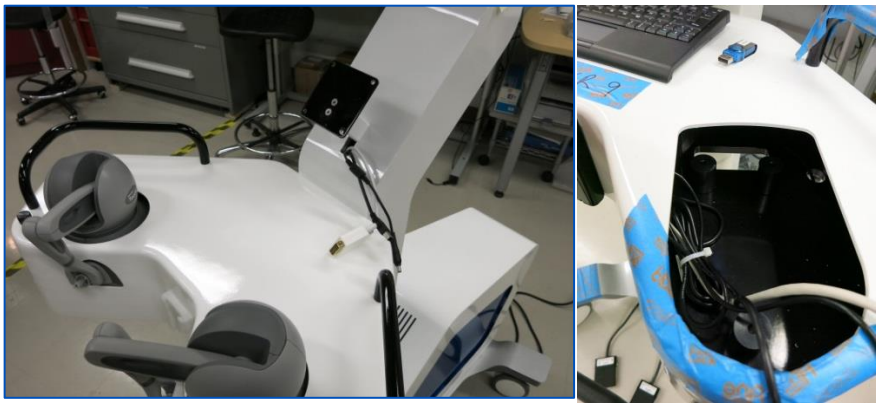
Raise simulator to the maximum highest position.

Remove the touchscreen, by disconnecting the cables behind the touchscreen and unscrew the 4 screws.

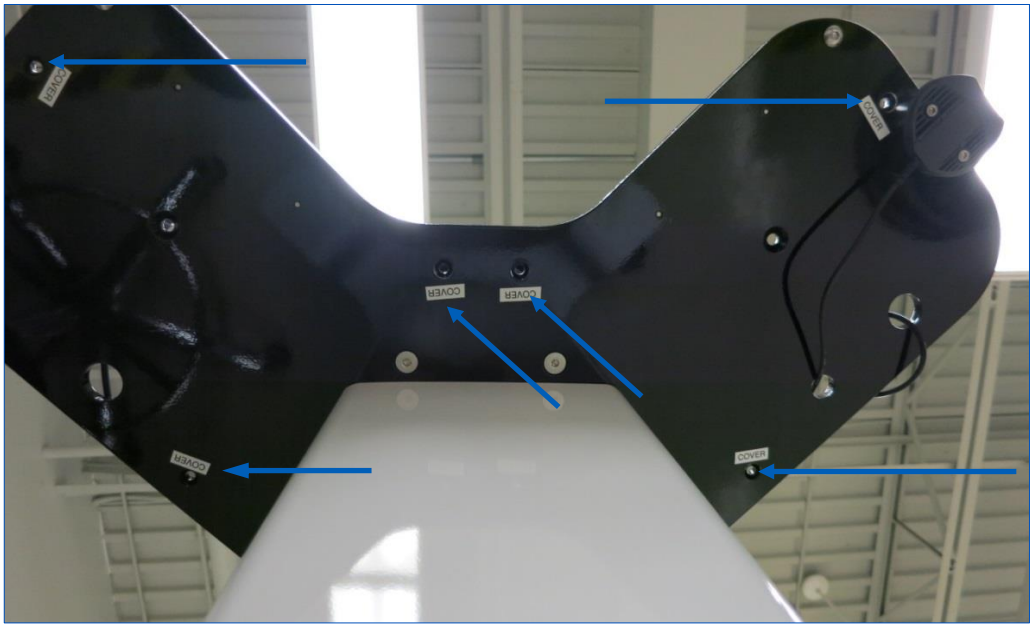
Note: Be sure to hold the touchscreen while unscrewing; failure to do so may result in dropping the touchscreen.

Disconnect the cables and remove the 4 screws in back of the touchscreen.

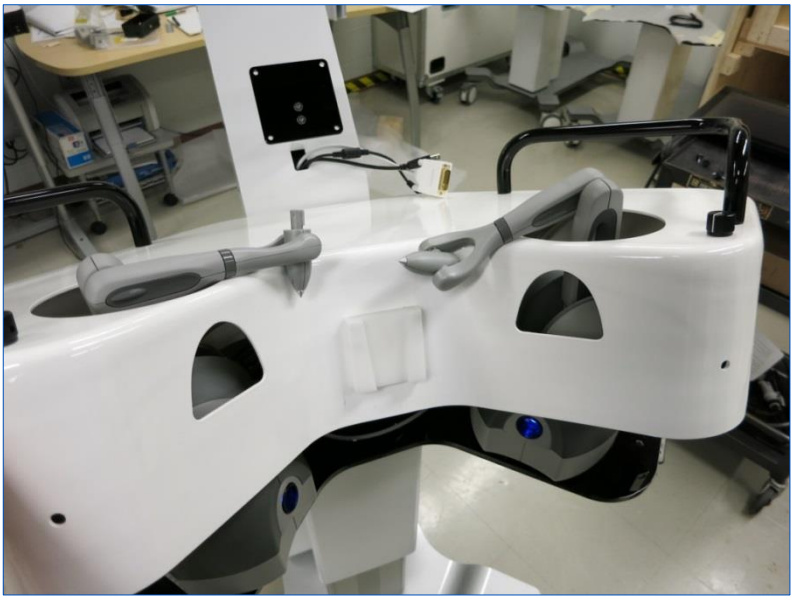
Remove the touchscreen from the simulator and place it on a safe, clean surface. If your system is equipped with the Entact Haptic System, remove the 3 screws of the haptic system and remove haptics from the system.



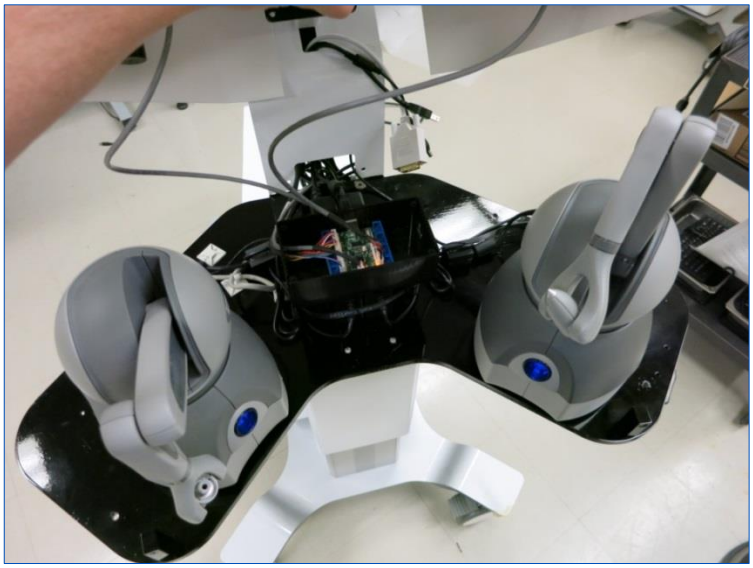
Place yourself under the simulator to remove the screws on the black plate. There are six (6) screws which secure the white table cover. You will need a **5/32" Allen key** to remove the screws.



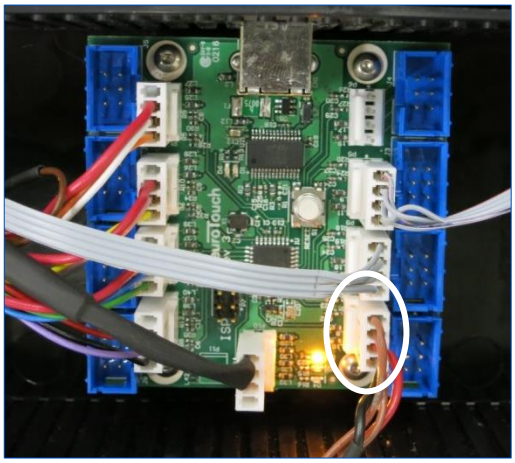
If your system is equipped with the Geomagic haptics, be careful to not damage the haptic device arms when lifting the white cover.



Raise the white cover slowly as the potentiometer cable is still connected.

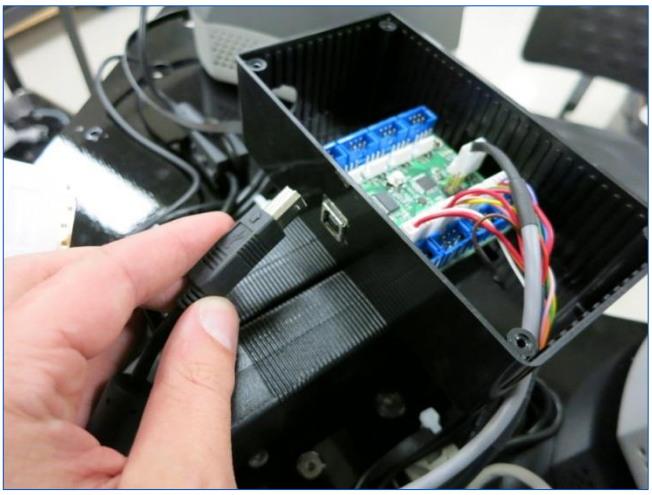


Disconnect the Power Knob connector at the bottom-right connection of the control box.

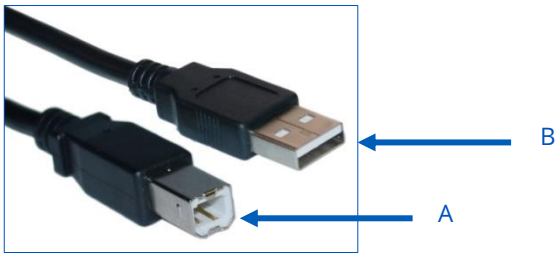


Remove white table cover and put it on a safe, clean surface.

Disconnect the USB cable at the back of the control box.



If a faulty cable is assumed, connect a new USB A – USB B cable from the control box to the back of the computer.



Appendix E: Computer Access

To access the computer, remove the computer cover by locating the 4 Push-Button Quick-Release Pins located under the NeuroVR base and releasing them from the base cover.

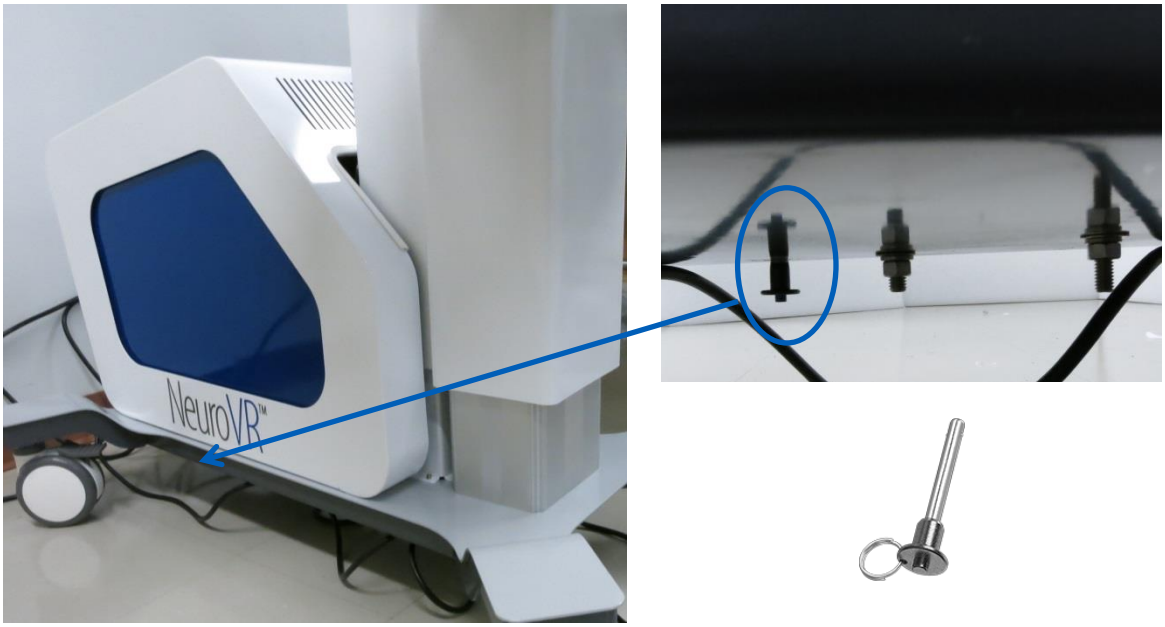


Figure 1 : Releasing Computer cover

Remove the computer cover with care as to protect the paint on the column.

IMPORTANT: Make sure to ground your body by touching a metal surface before touching any electronic component.

All connections of video output are connected to the top video card as shown below:

Elo Touch screen	Column Cable (Observer / Auxiliary Monitor)	Stereoscope Monitor
DVI cable	DisplayPort to DVI Video Adapter DVI Cable	HDMI Cable
Port 3 *Tripp Lite: P561-006*	Port 2 *StarTech: DP2DVI2* *DataPro: 1143-06C*	Port 1 *Molex: 0887689820*

Figure 2 : Typical computer back panel

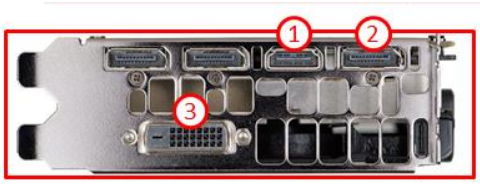


Figure 3 : View of top graphics card rear IO

Replace the computer cover and align the clip on the nut on the thumbscrew attached to the base. Turn the thumbscrews clockwise to secure the cover.

Appendix F: Configure Display Settings

The NeuroVR simulator is enhanced with a touch screen monitor to display and navigate through the graphical user interface. It prevents unnecessary stereoscope manipulation and acts as an observer screen during simulation if none has been setup.

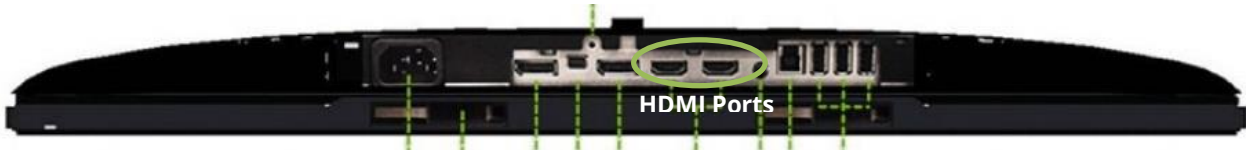
If you are having difficulties connecting your touch screen or it is not functioning properly, read the following points to ensure a proper set-up:

- Locate the four cables coming with the touch screen (Power, Video (DVI), Touch cable (USB) and USB cable from keyboard)
- Locate the appropriate input under the screen and connect the four cables
- Secure the connections

- The power cable goes into the simulator power outlet bar. The DVI video cable as well as the USB cable for the touchscreen goes directly into the back of computer panel.
- Locate the appropriate video output on the computer back panel. The system is equipped with more than one graphics card however, all video connections are made on the top graphic card.
- The top graphic card may differ on some systems. Identify your system using the preceding picture.
- The DVI cable from the Touch Screen goes into Port No. 3 (shown above)

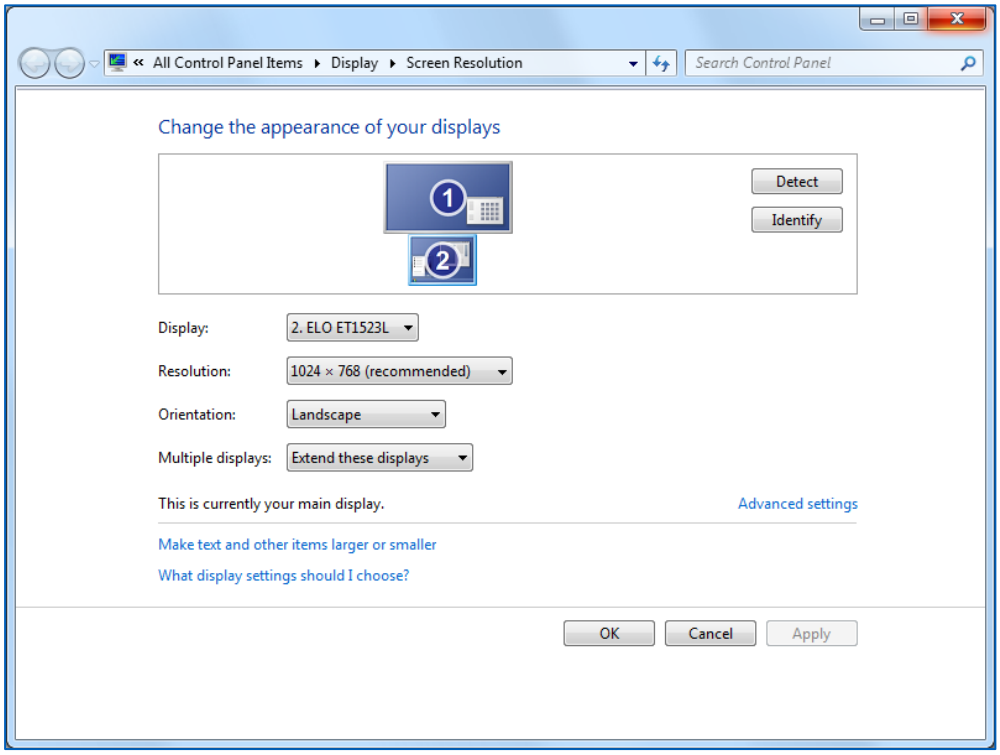
Screen Resolution & Display Settings:

To configure the simulator for a touch screen and set proper Display Settings (make sure this setting is applied for both HDMI ports on the stereoscope monitor, if you have 2 HDMI ports):

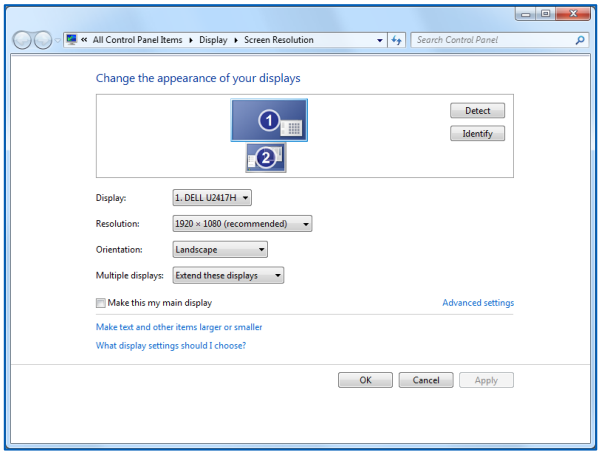


Display settings must be set for both HDMI ports

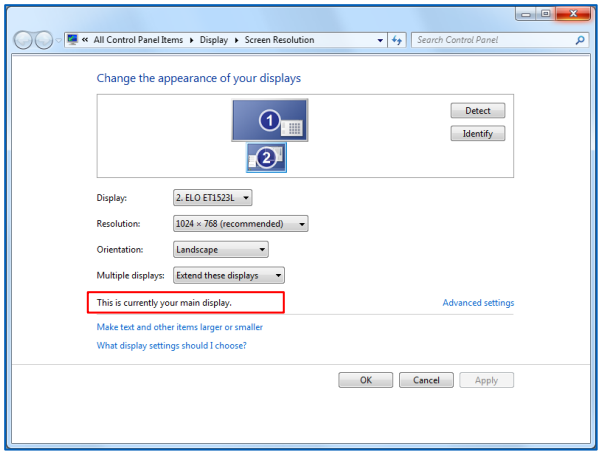
- Log in as the Windows administrator: select the ***LocalAdmin*** user and type in the password
- Right-click on the simulator desktop and select **Screen Resolution**
- Click **Identify** to identify the actual displays
- Click on the image of the touch screen display **(2)** and under **Multiple displays**, select **Extend these displays**
- The layout should be the following:



- Make sure that the main display is set to the touch monitor (ELO ET1523L)
- Click **Apply**
- Select the recommended resolution for your touch monitor: 1024 x 768
- Click **OK**



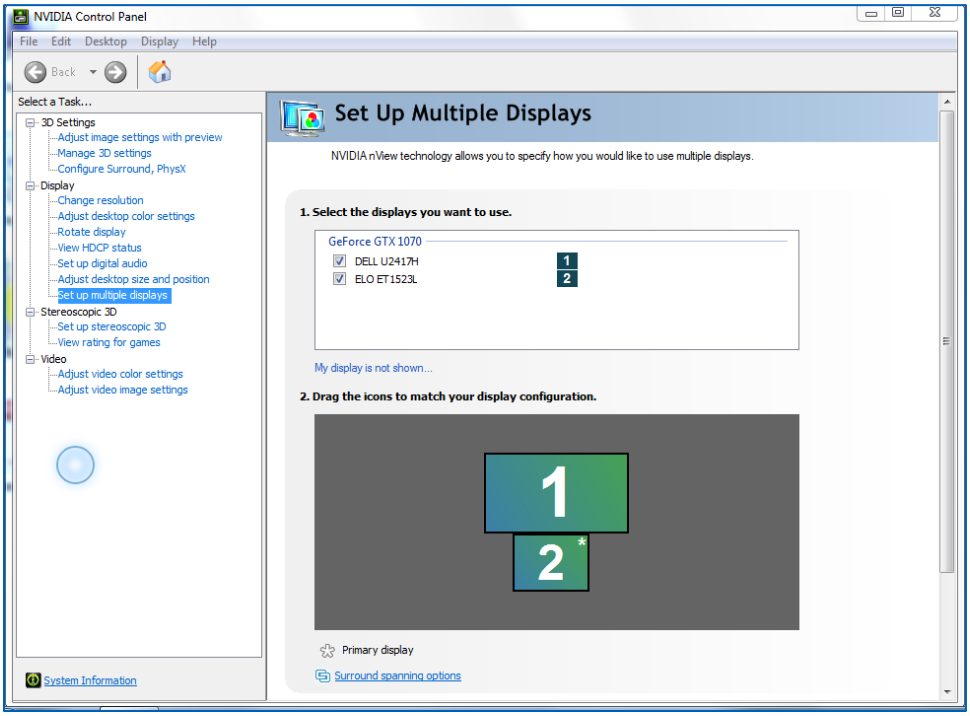
Correct settings for the Stereoscope monitor



Correct settings for the Touch screen monitor

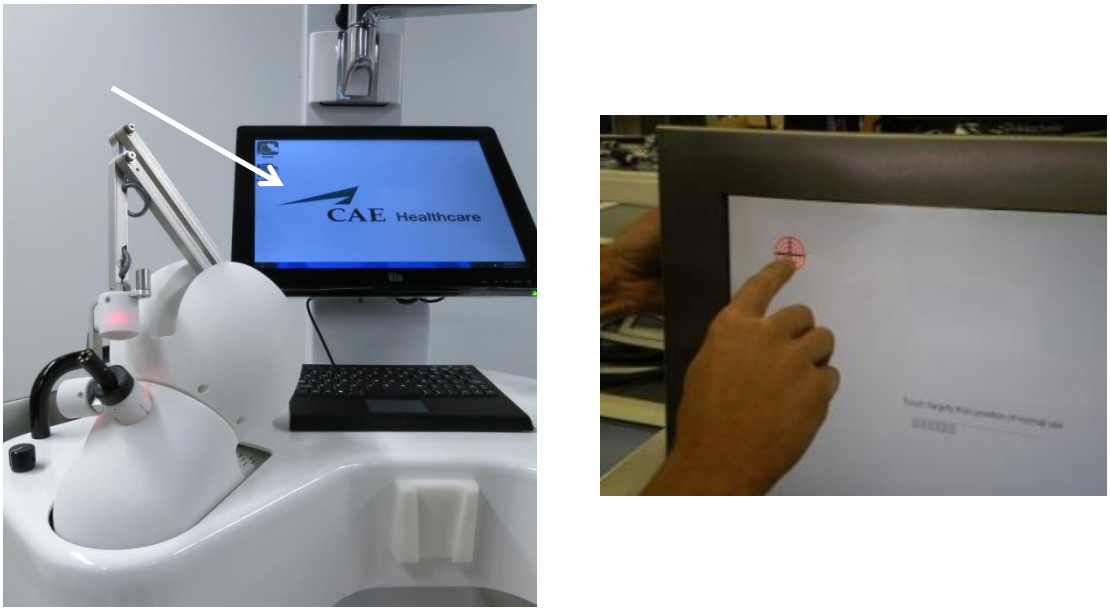
NVIDIA Control Panel:

- Right-click the simulator desktop and select **NVIDIA Control Panel**
- On the left side menu, select **Set up multiple displays,** under Display
- The layout should be as follows:



- Unselect the primary display (Dell Monitor) and click **Apply**
- The primary screen will go black and you will be asked to accept the changes. Click **Yes**.
- Re-select the primary display (Dell Monitor) and click **Apply**
- The primary screen will flash and display your chosen background and you will be asked to accept the changes. Click **Yes**.
- Close the **NVIDIA Control Panel**

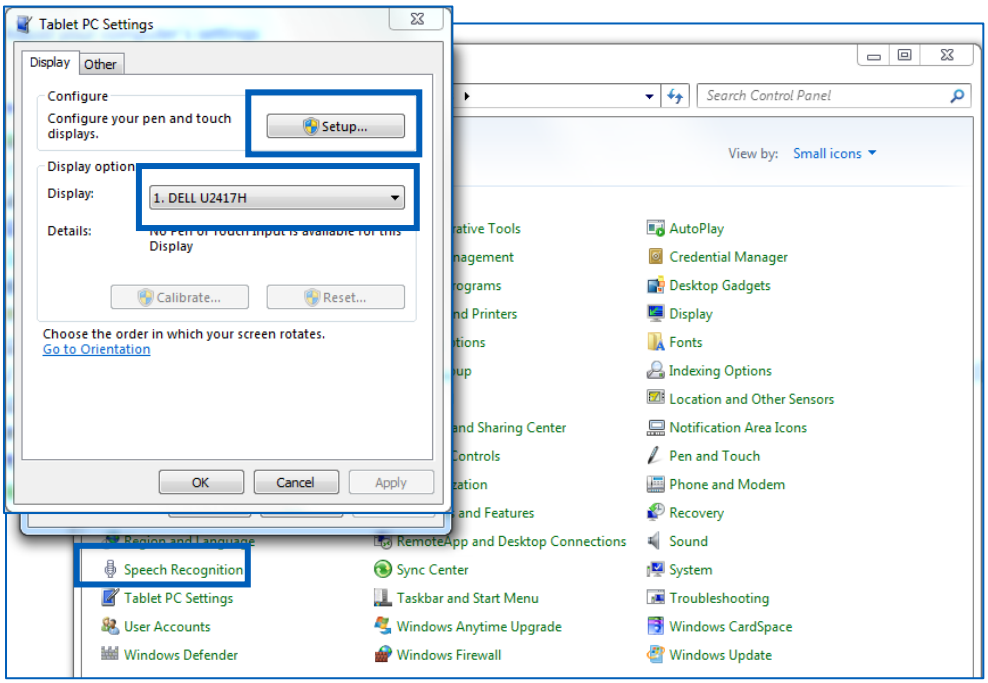
Appendix G: Initialize / Calibrate Touch Screen



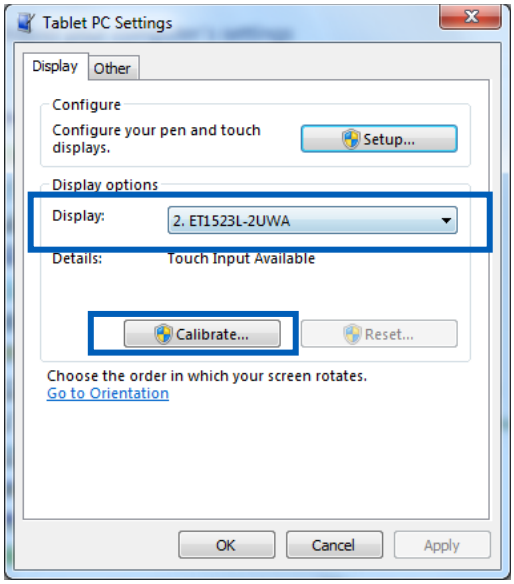
Initializing or Re-Calibrating Touch Screen

- Log in as Windows administrator: select the **LocalAdmin** user and type the password
- Open the **Control Panel** (Start Menu / Control Panel)
- Select **Tablet PC Settings**

The following window appears:



- Under the Display tab / Configure section, click **Setup** to select the screen that has the touch input capability
- Follow the onscreen instructions
- Go back to the **Tablet PC Settings** window / Display options section, and select the touch screen monitor under Display: ET1523L
- Click **Calibrate** and follow the instructions to calibrate the touch screen
- If the touch screen monitor has already been calibrated, click **Reset** and re-do the calibration by clicking **Calibrate**.

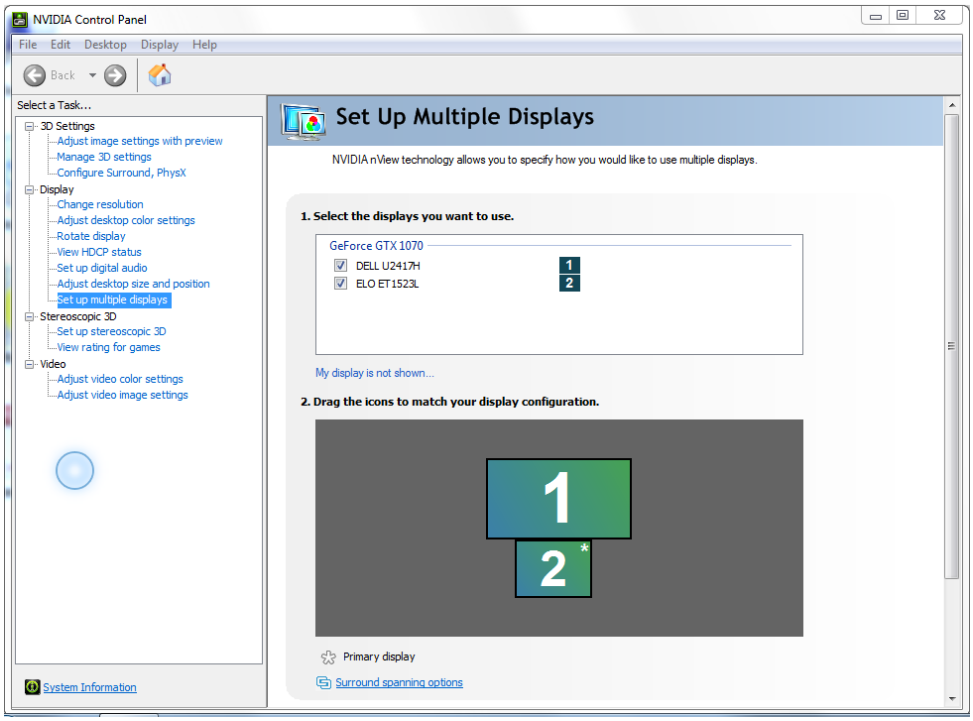


- Click **OK** to close the window

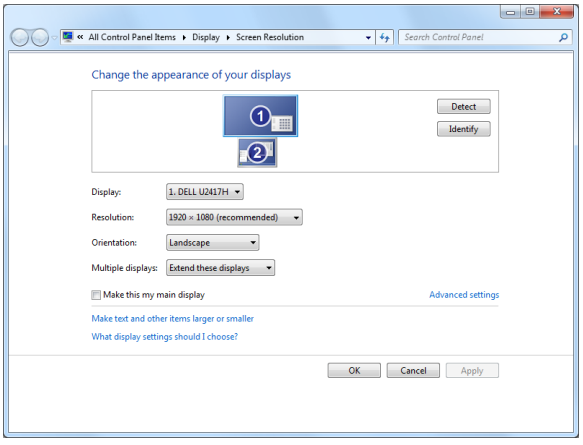
Appendix H: Observer / Auxiliary Screen Installation

The NeuroVR simulator may be enhanced with an auxiliary monitor for an observer to easily follow the user's performance during an exercise.

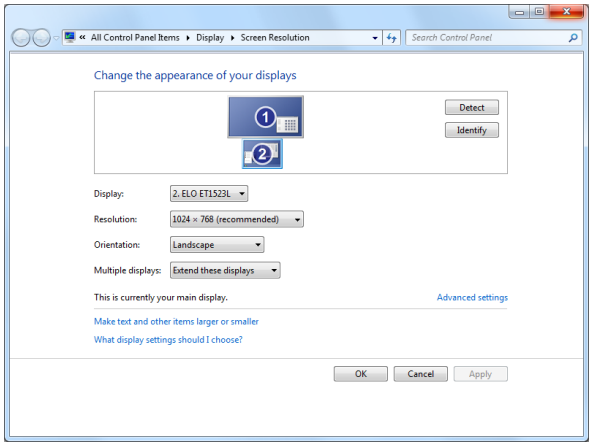
Set-up with no Observer screen (regular setup)



NVIDIA Control Panel Properties (no observer screen)



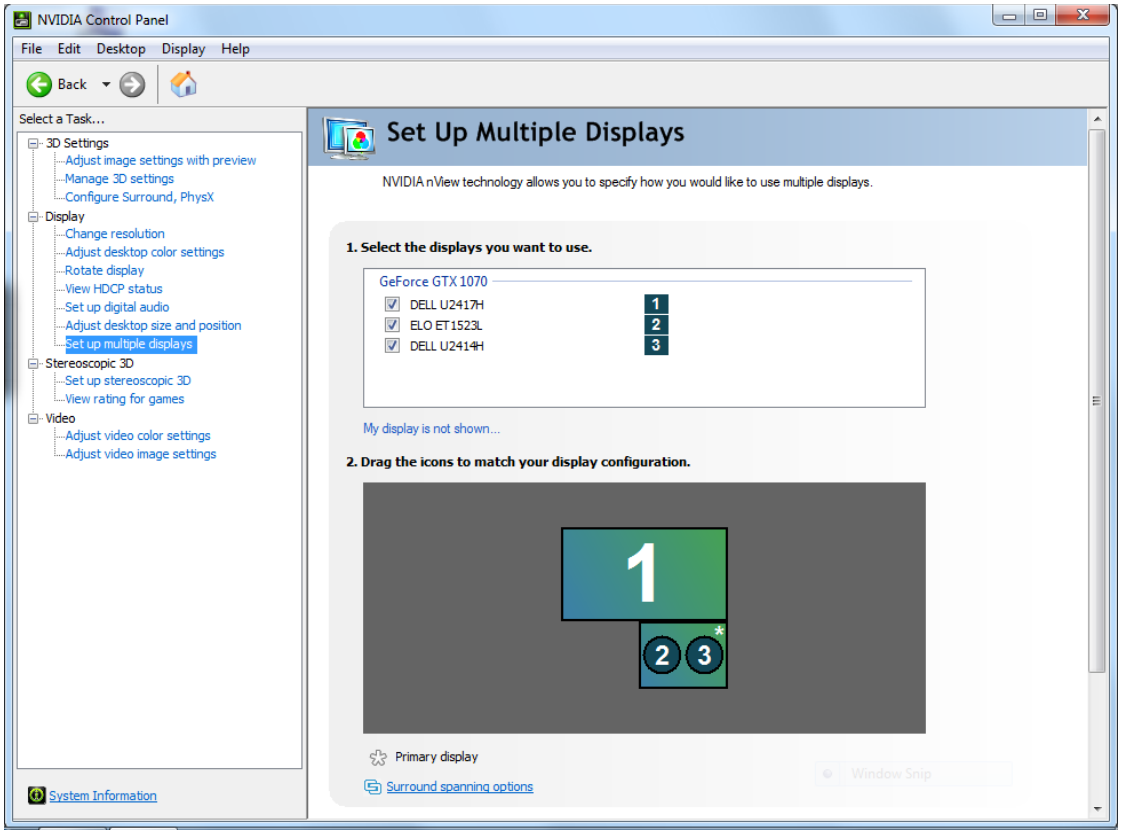
Screen Resolution Properties (Stereoscope Monitor)



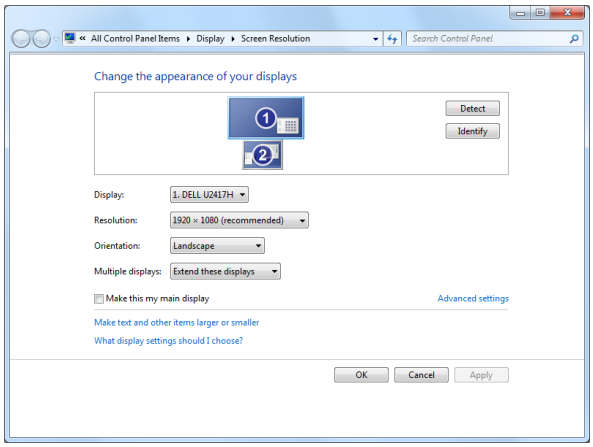
Screen Resolution Properties (Touchscreen Monitor)

Set-up with Observer screen

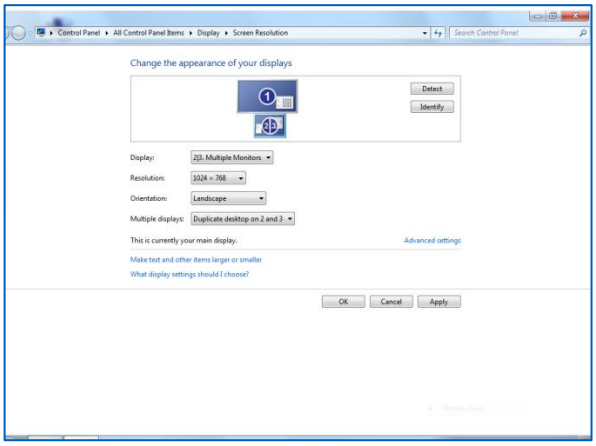
Locate the DVI output on the simulator side panel and connect a DVI cable from side panel to an observer screen.



NVIDIA Control Panel Properties (with observer screen)
3rd screen acting as the observer screen



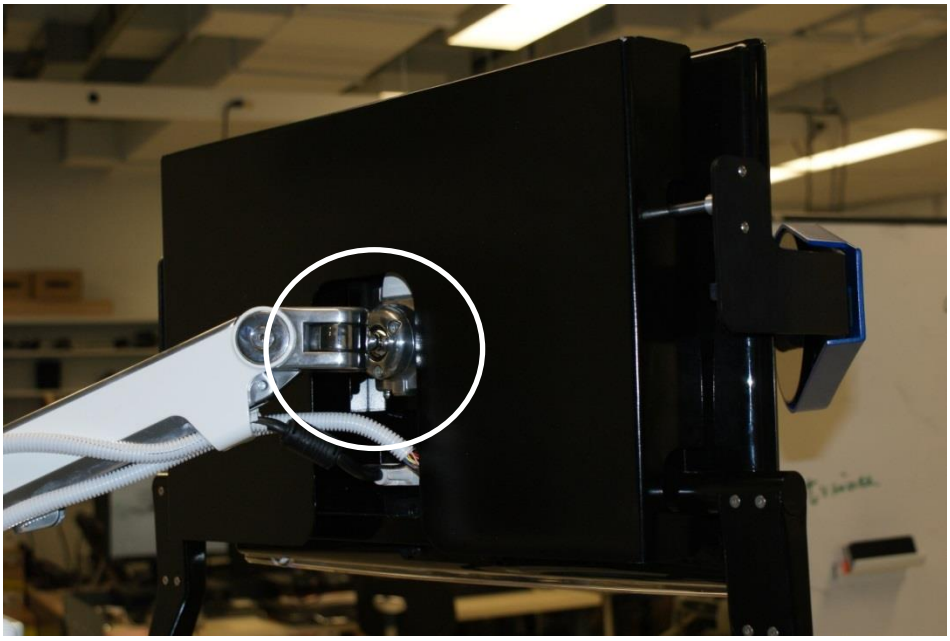
Screen Resolution Properties (Stereoscope Monitor)



Screen Resolution Properties (Touchscreen & Observer Monitors)

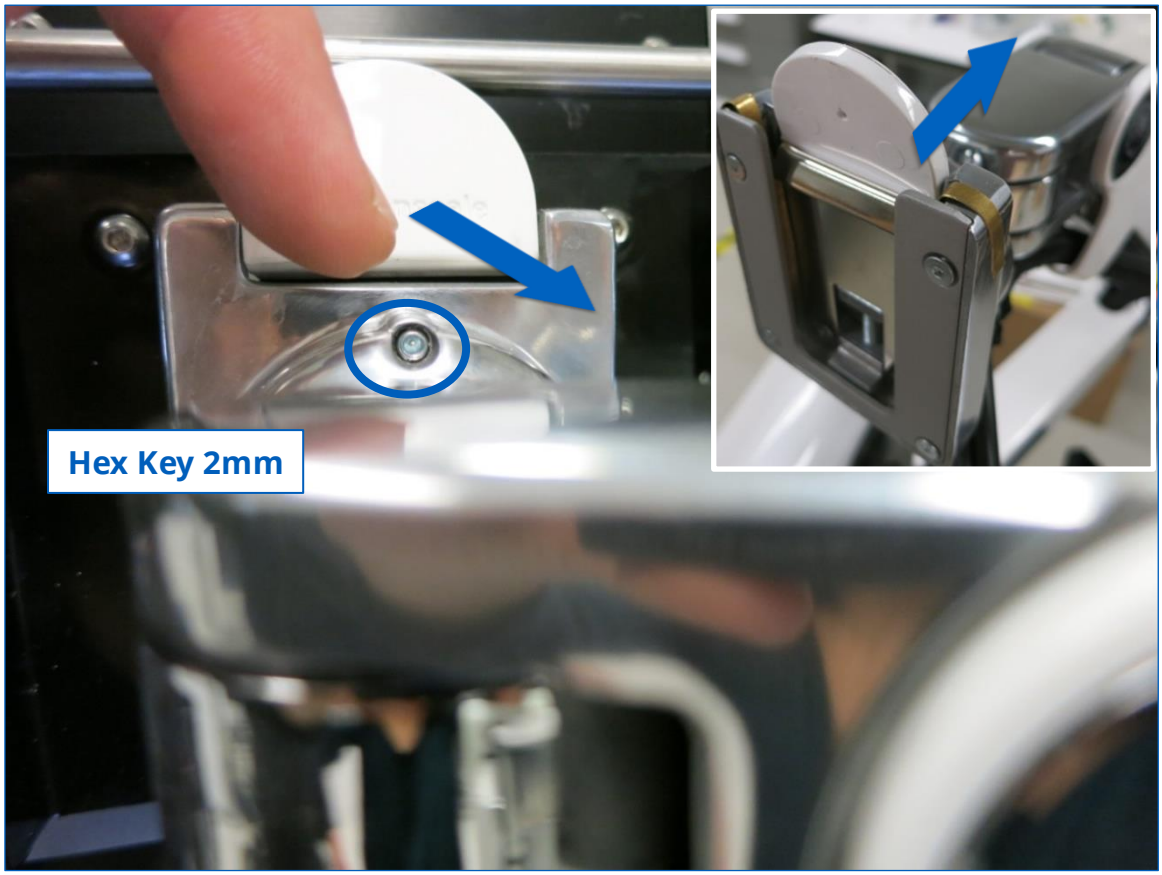
Appendix I: Stereoscope Insertion & Positioning

Stereoscope Insertion into Flexible Arm Clip



- Check the screw (i.e in highlighted circle)
- Screw must be visible and not screwed in too deep

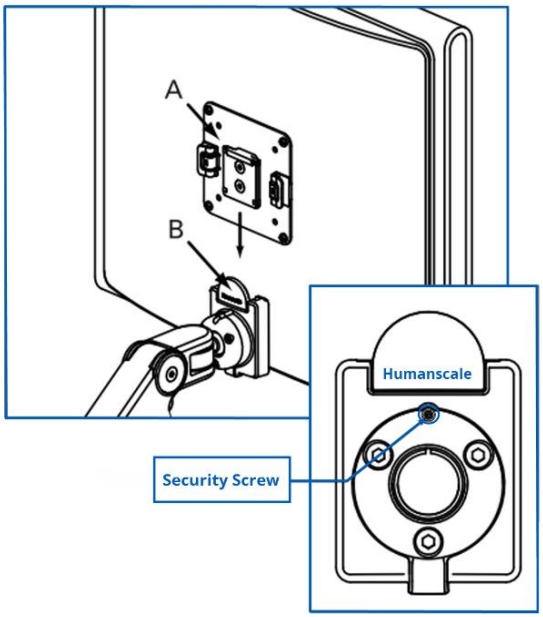
- The screw must be visible to allow the stereoscope installation / removal while pulling outward on the white clip



1. Slide VESA Bracket (A) into Ball Joint until it clicks

2. To remove, depress Quick-Release Tab (B) and slide monitor up and away from Arm

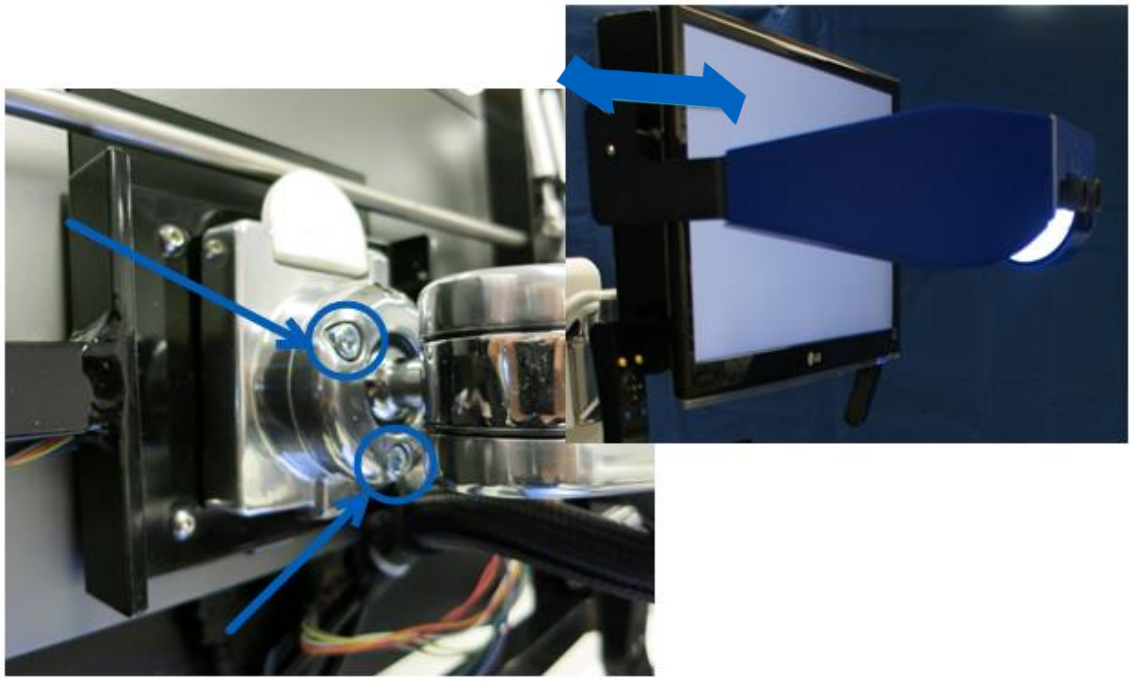
3. If security is requires, tighten the Security Screw using Hex Key A



Stereoscope Positioning

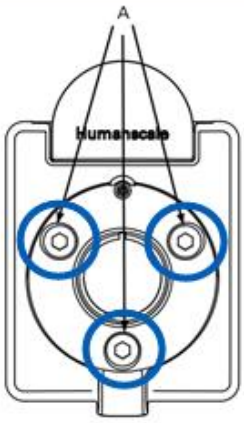
Check the positioning and friction of stereoscope (monitor should be in the upright position):

- If the monitor is leaning too forward, check the screws on back plate, loosen them, re-position to the ideal position and tighten screws (3)
- Use key 4mm



FRICTION ADJUSTMENT

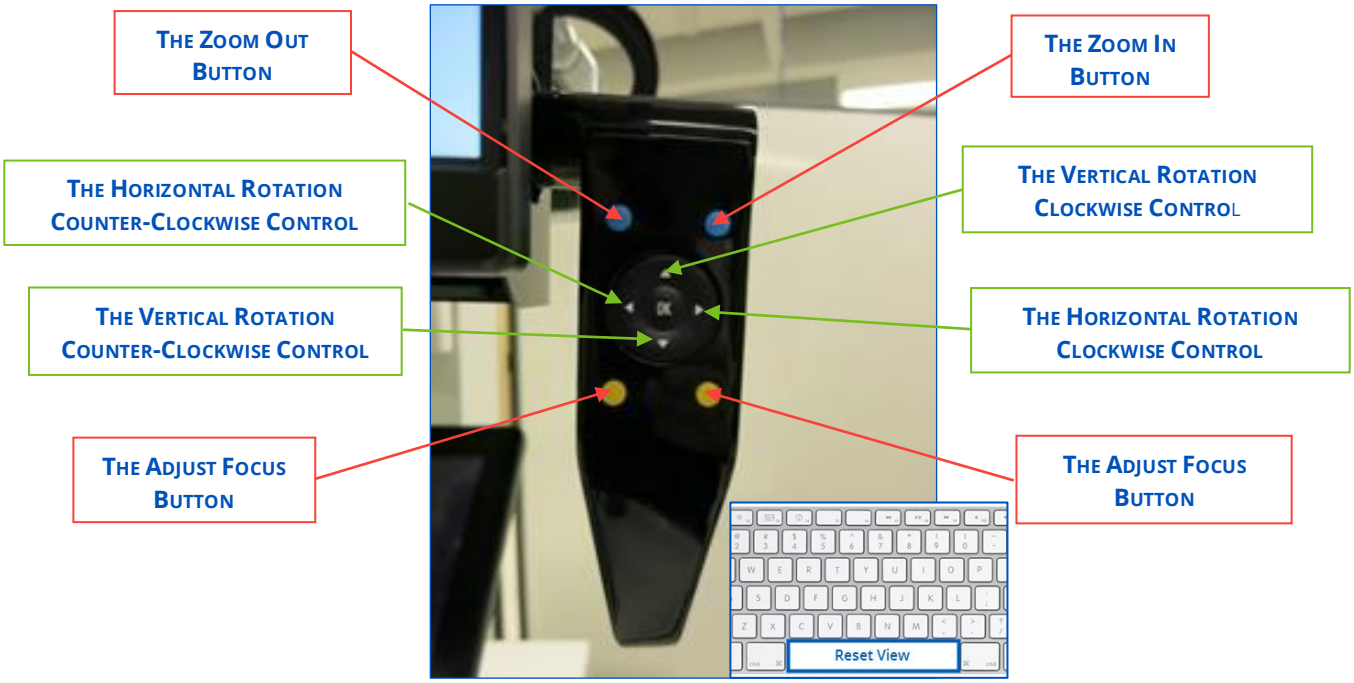
If your monitor is particularly heavy, or after prolonged use, the Ball Joint Swivel/Tilt Mechanism may require increased friction. This can be achieved by tightening the 3 Ball Joint Friction Screws (A) using Hex Key B.



Appendix J: Microscope Handle & Controls

Faulty Microscope Control Handle Buttons

The microscope controls, on either side of the monitor, allow the leaner to adjust the virtual microscope for a better view during the Instrument Handling, Fundamental Skills and Microsurgery modules.

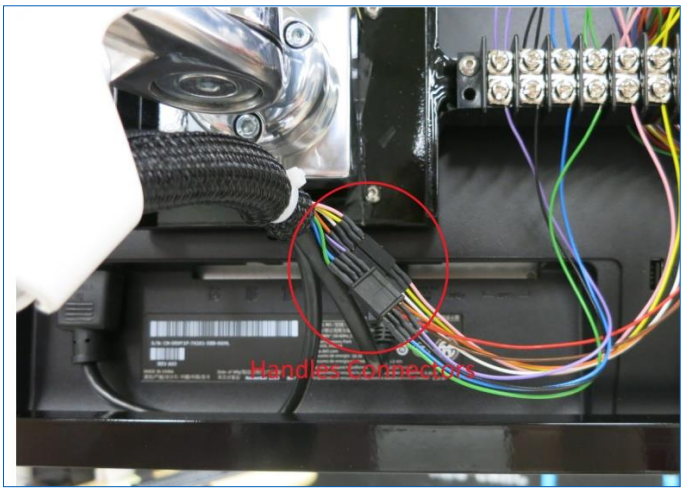


Adjustment functions on the microscope controls

Note: The spacebar is used to reset to the default settings.

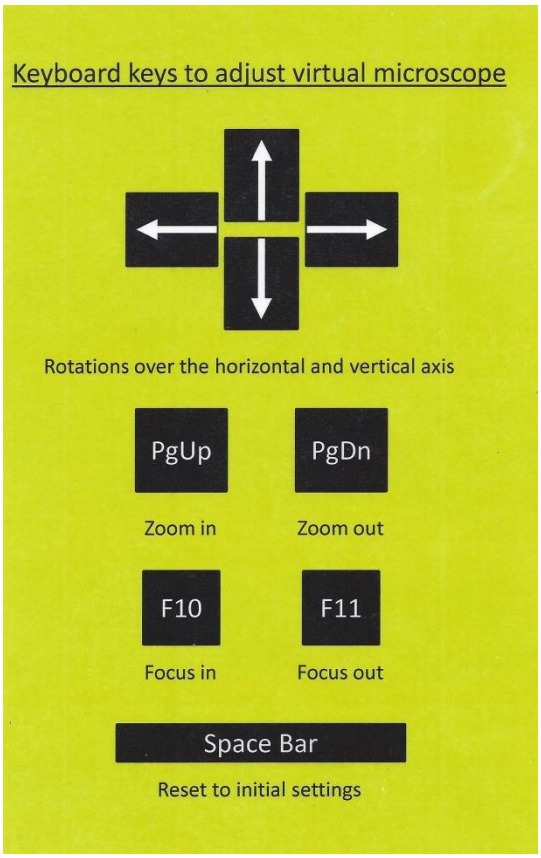
If the microscope handle buttons are not working properly, contact the customer service department in your area to help you diagnose the problem. However, for a temporary fix to the problem follow the instructions below:

1. Disconnect the colored cables behind the main monitor (i.e. Stereoscope monitor) as seen below:



Microscope Handle connections in back of main monitor

2. Use the keyboard function keys (below) to replace the same functionality as the microscope handle buttons.



Keyboard map keys to replace microscope handle buttons

Appendix K: Reinitialize Column

If your NeuroVR unit is experiencing technical difficulties with the moving column, you may need to re-initialize / restart the Movetec column by following the instructions given below. The Movetec column can be found in the back panel of the simulator. If only one motor is used, it should connect to the port next to the RJ45 port. The outer port won't work, unless a 2017 model is installed. The motors manufactured after 2017, will work on either port.

Movetec Control Box for Column

MOVETEC Solutions ApS
Lollandsvej 1
DK – 5500 Middelfart
Tel.: (+45) 64 89 28 05
E-mail: info@movetec.dk
Web: www.movetec.dk

MOVETEC
Tailor-made Lifting Column, Actuator and Servo Solutions

Operating Instructions Control Units Type TC11, TC15, TC16

Installation (only for authorized personnel)

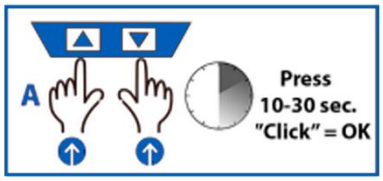
- Plug in the drives into the 8-pin molex sockets.
- Connect the handset with the RJ-45 socket in the control box.
- Plug in the main power supply. Please make sure that the operating voltage of the system conforms with the local power supply.

Starting up

Always reset the lifting system to zero before using for the first time: Hold down the up-button and the down-button at the same time for 10-30 seconds. The actuators will be moving up and down. If the actuators are not down at the bottom, the actuators will move down. Keep holding the buttons until beeps are heard. The number of beeps depends on the number of actuators/lifting columns (figure A).

Note: Before starting up, make sure that all drives/lifters are plugged in completely and correct and that there cannot be a collision while moving down.

Operating: Use the "Up" or "Down"-buttons to move the drives.



Operating Instructions Control Units Type MCB-COMPACT

Installation (only for authorized personnel)

- Plug in the drives into the 8-pin molex sockets.
- Connect the handset with the 7-pin socket in the control box.
- Plug in the main power supply. Please make sure that the operating voltage of the system conforms with the local power supply.

Starting up

Always reset the lifting system to zero before using for the first time: Make sure the actuators are down at the bottom – hold down-button for 10-30 seconds (figure A). Release down-button (figure B). Hold the down-button in again for 10 seconds until a click is heard (figure C).

Note: Before starting up, make sure that all drives/lifters are plugged in completely and correct and that there cannot be a collision while moving down.

Operating: Use the "Up" or "Down"-buttons to move the drives.

Appendix L: Simulator Dimensions for Shipping and Storage

Simulator Dimensions for Shipping and Storage

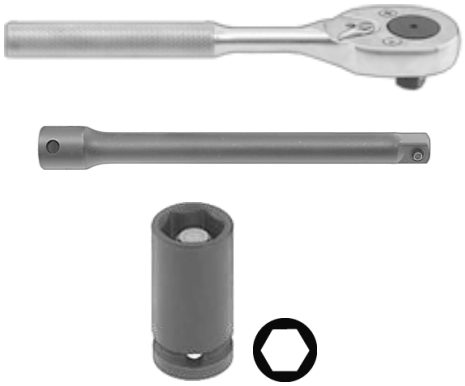
Shipping Container (exterior dimensions)	
Height	69 inches (175 cm)
Width	33 inches (84 cm)
Depth	62.5 inches (158 cm)

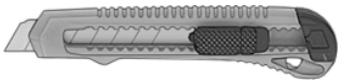
Simulator Alone (no stereoscope)	
Height	54.25 inches (138 cm)
Width	29 inches (74 cm)
Depth	48 inches (122 cm)

Stereoscope Box	
Height	11 inches (28 cm)
Width	30.5 inches (77 cm)
Depth	30.75 inches (78 cm)

Appendix M: Unpacking and Setup

Tools Required to Unpack / Pack NeuroVR in the Wooden Crate:

1		NeuroVR Crate
2		Drill (Cordless or Electric)
3		**Using Drill** Bit Adapter, Power, 1/4" Hex Male, 3/8" Square Male, 2" Length 3/8" Square Drive Thin-Wall Power Socket 6 Point Deep, 1/2" Size, 2" Overall Length
		**No Drill – Manual** 3/8" Square Drive Reversible Ratchet Wrench High Torque, 7" Overall Length 3/8" Square Drive Impact Socket, 6" Extension 3/8" Square Drive Thin-Wall Power Socket 6 Point Deep, 1/2" Size, 2" Overall Length
4		**Using Drill** Phillips Bit for No.8 screw size
		No Drill – Manual Ultra-Grip Screwdriver Number 2 Phillips, 8-3/4" Overall Length

5		#8 x 2" Flat Head Phillips/Square Drive Sharp Point Lubricated Finish Furniture Screw #8 x 3" Flat Head Phillips/Square Drive Sharp Point Lubricated Finish Furniture Screw
6		Tape Gun
7		Utility Knife
8		Stretch Wrap with Handle
9		Set of Imperial / Metric Allen Key Sets (optional) (required to disassemble simulator components for troubleshooting)

Images obtained on the www.mcmaster.com/# and www.fastenal.com/home website

This guide will help you unpack and setup the NeuroVR simulator...

Front Panel

Using tools 4 and 2 (optional), unscrew all identified screws on the front panel from bottom to top and place the panel aside. If front panel contains latches, undo the 6 latches.

Front panel

Wooden Stereoscope Box

- Remove all boxes on top of the stereoscope box. These boxes contain all the instruments, accessories and documentation included with the NeuroVR simulator.

Boxes to remove

- Using tools 4 and 2 (optional), remove all 4 identified screws on the side of the crate to release the stereoscope box

Stereoscope's side screws

- Slide the box out and place it on the ground. TOP facing up
- Using tools 4 and 2 (optional), remove all 4 identified screws on top of the box

Top of the stereoscope box

- Remove the plywood cover

Inside the stereoscope box

- Remove the black rear panel by pulling lightly on it as you do, the Velcro will come loose
- Put the box aside until the installation of the stereoscope

Back Plate

Using Tools 4 and 2 (optional), remove the 4 identified screws on the vertical back plate and put the back plate away.

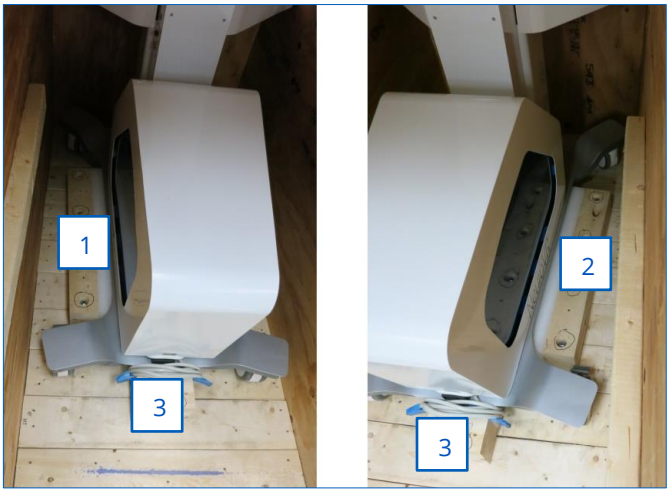
Back plate

Unloading Ramp

- Slide the ramp out from the top of the box
- Position as shown below:

Unloading ramp

- Using tools 3 and 2 (optional), with a ½ inch hex socket (or 13mm) and a ratchet, remove all bolts (10 bolts) from blocks 1, 2 and 3 as shown below



Anchor block

- Remove the blocks with care
- Unlock the brakes on the simulator wheels
- Pull the simulator out of the wooden crate and lift the simulator lightly by pulling on the black handles covered by blue tape to make sure it passes the ramp easily

IMPORTANT: Pull on the handles near their anchor points, not in the middle.

Lifting handles

Setting up NeuroVR Simulator

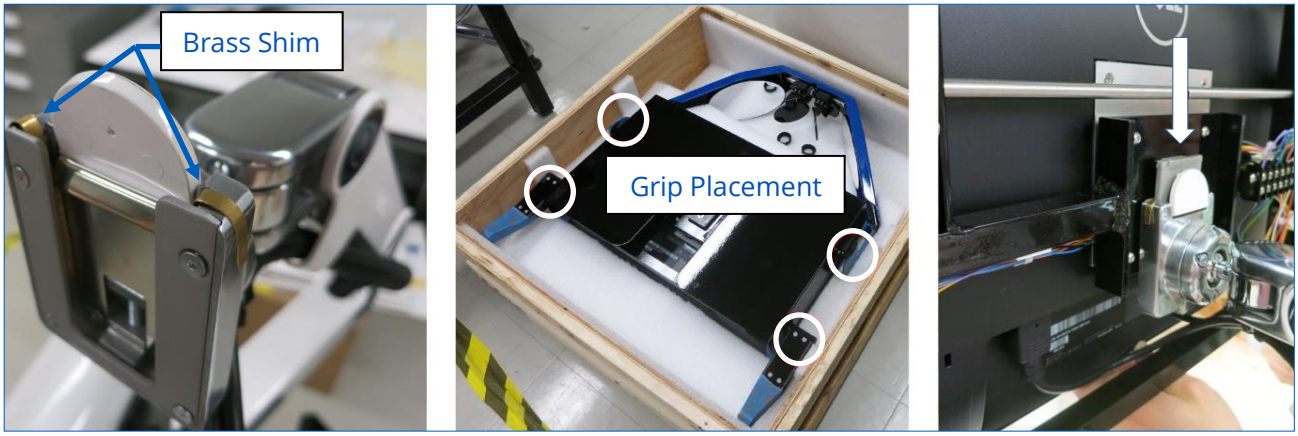
- Remove the transparent film around the stereoscope arm

Note: Keep constant pressure downward on the arm, as it is spring-loaded and will raise up.

Stereoscope arm

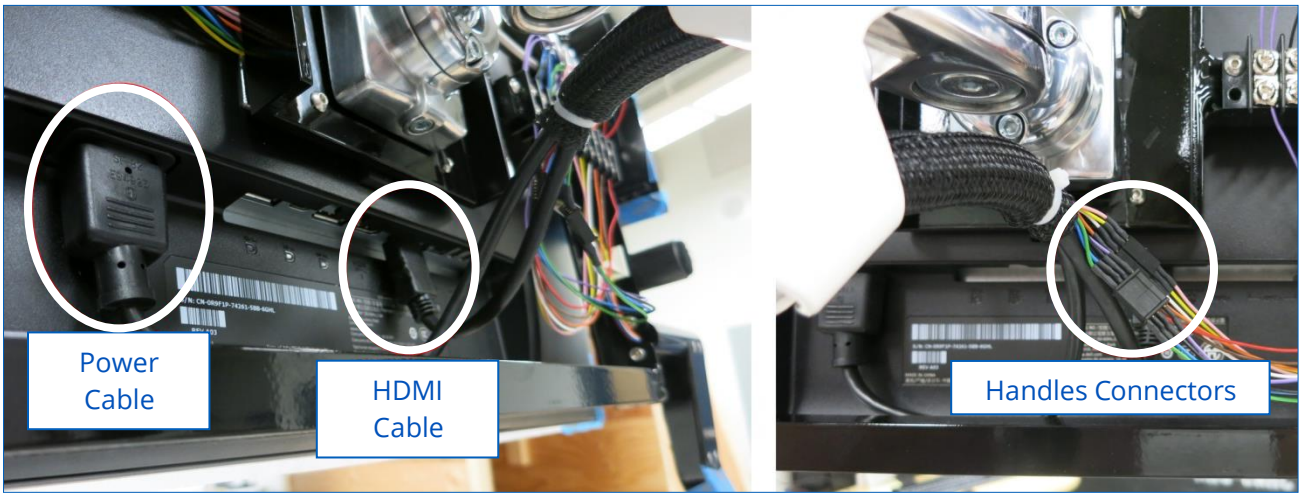
This next step should be done by two persons. Ensure that the brass shims are in the correct position then clip the stereoscope into the arm.

Note: Grip the stereoscope as shown below.



Stereoscope installation

Plug in all cable and connectors as shown below.



Stereoscope connections

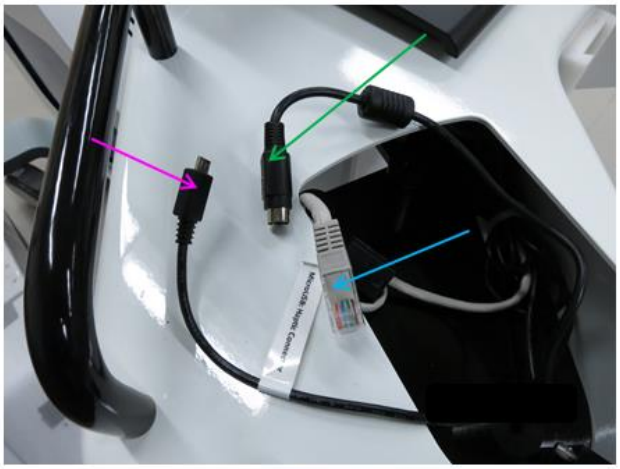
Entact Haptic Device Installation

Carefully unpack the Entact Haptic Devices from the box and identify the left and right haptic device.

Haptic devices in box

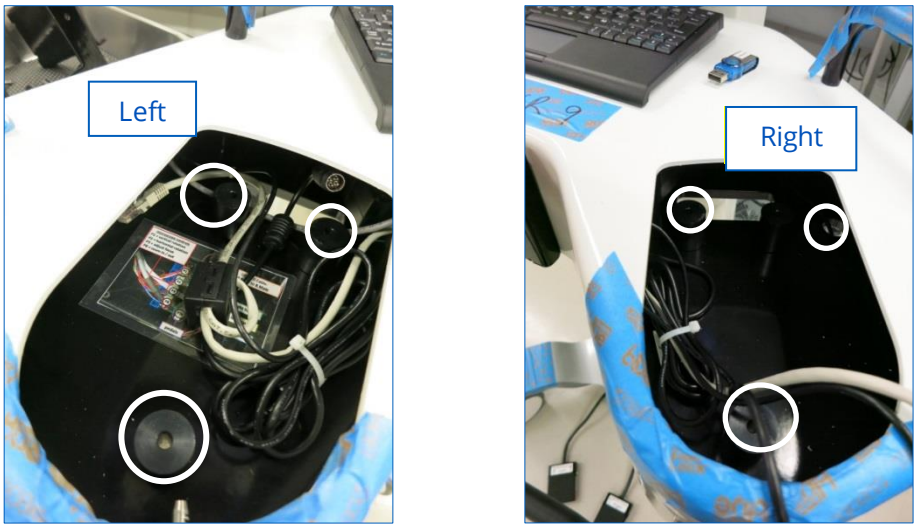
Prior to inserting the haptics entirely into the slots, make the 3 connections with the cables available.

- Power
- Micro USB (Control/Peripheral Tester)
- Ethernet



Haptic device connections

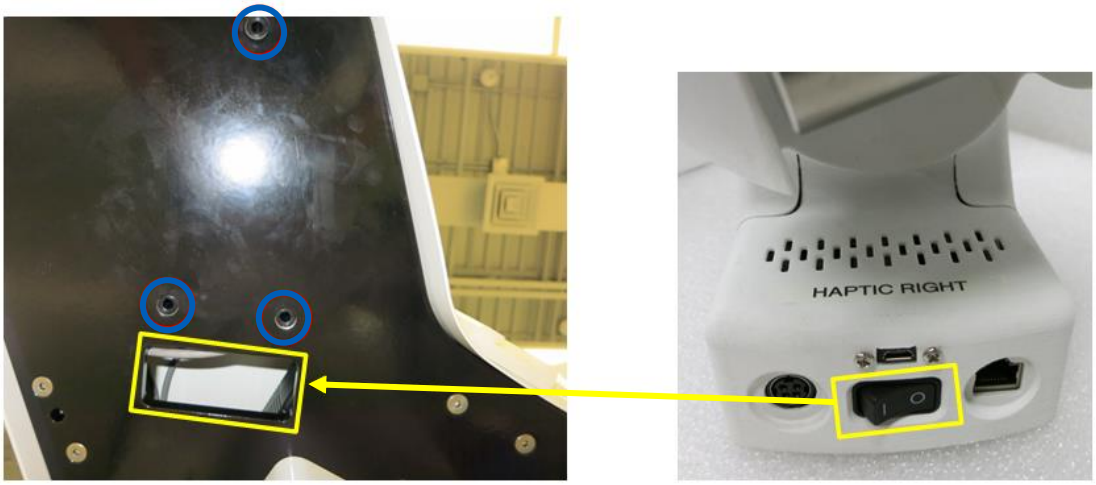
Once the connections have been made, place the right haptic device completely into the right slot opening. Repeat this for the left side. Position and align the haptics on the 3 cylindrical columns highlighted in white.



Haptic device cylindrical resting columns

Once the haptic devices have been connected and are placed into their respective openings, use the screws (3) provided to fasten the haptics securely to the table platform. Make sure to verify that the haptics do not move.

To access the on/off switch of the haptic device, user must go through yellow rectangular opening under the table. The haptic devices can remain on the ON position at all times. If system does not recognize the haptic device, try clicking the on/off a few times.



Haptic device screw locations and on/off switch opening

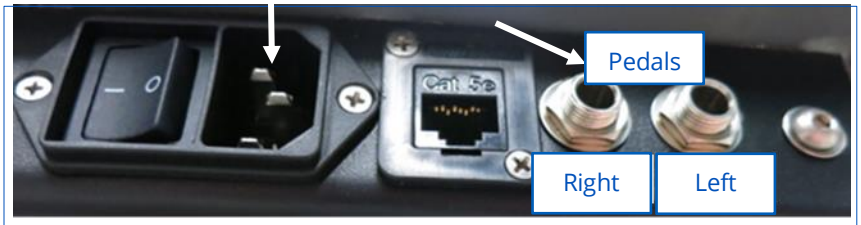
Final position of Right Haptic Device

The following components must be installed prior to powering « ON » the simulator. Follow steps as detailed in Appendix A.

- Haptic devices
- Pedals (Connect the pedals to the jacks located at the back of the simulator)
- Arm rest
- Storage Trays

Turning the Simulator ON

Connect the country specific power cord into IEC 320 C14 Power Inlet Socket on the NeuroVR, and the opposite end into the wall (Figure 18).



Simulator Power extension cord & foot pedal jacks

Once all the power cables are connected, power on the system using the power switch at the back of the NeuroVR simulator On and then pressing the round power button on the side of the column (Figures 17-18).

"On switch" at the back of simulator (left) and on side column (right)

Appendix N: NeuroVR Courseware

Disclaimer:

The NeuroVR Courseware has been designed to complement technical skills training in NeuroVR by providing didactic context to the simulation exercises. It is not intended for use as a guideline in neurosurgical practice. The information in this manual is a work in progress and is based on a collaborative effort between the National Research Council of Canada (NRC) and the NRC's surgical simulation program advisory network. The learning modules were continually reviewed to ensure that the information is accurate and pertinent to current neurosurgical practice. However, as this is a work in progress, no party involved in the preparation of this work warrants that the information contained herein is accurate or complete and they are not responsible for any errors or omissions or for the results obtained from the use of such information. The Courseware and the NeuroVR simulator are strictly intended for research and/or educational purposes. Trainees in accredited neurosurgical programs should always practice according to the clinical, supervisory, and all other policies of their residency training program, program director, faculty, home institution and regional licensing authority.

Copyright:

The contributors to this work are NRC surgical simulation researchers in collaboration with the program's advisory committee network.

NeuroVR (https://caehealthcare.com/surgical-simulation/neurovr) was developed by a team of over 50 experts at the National Research Council of Canada (NRC), in collaboration with teaching hospitals across Canada. Today, NeuroVR developments take place within a growing consortium of hospitals from around the world. NeuroVR is a virtual-reality (VR) simulator with haptic feedback developed to train and assess technical skills in cranial micro neurosurgery. The simulator features the surgical workspace of an open neurosurgical procedure by replicating the stereoscopic view and ergonomics of an operating room (OR) microscope. The platform can also accommodate the 2D indirect view associated with an endoscopic procedure. NeuroVR houses two haptic devices to permit tactile interaction of virtual soft tissue with a surgical instrument in each hand. The developed software allows physics-based simulation of tissue properties and behaviour, the interaction of surgical instruments with soft and bony tissue and bleeding dynamics. These components are integrated to provide realistic surgical simulation that can be seen and felt.

Suggested Reading on NeuroVR:

1. Gélinas-Phaneuf N, Del Maestro R, Surgical Expertise in Neurosurgery: Integrating Theory into Practice, Neurosurgery 73(4):S30-S38, 2013.
2. Rosseau G, Bailes J, Del Maestro R, Cabral A, Choudhury N, Comas O, Debergue P, De Luca G, Hovdebo J, Jiang D, Laroche D, Neubauer A, Pazos V, Thibault F, DiRaddo R. The Development of a Virtual Simulator for Training of Neurosurgeons to Perform and to Perfect Endoscopic Endonasal Transsphenoidal Surgery. Neurosurgery 73(4):S85–S93, 2013.
3. Jiang D, Hovdebo J, Cabral A, Mora V, Delorme S. Endoscopic third Ventriculostomy on a microneurosurgery simulator, Simulation 89(12):1442-1449, 2013.
4. Gélinas-Phaneuf N, Choudhury N, Al-Habib AR, Cabral A, Nadeau E, Mora V, Pazos V, Debergue P, Diraddo R, Del Maestro RF. Assessing performance in brain tumor resection using a novel virtual reality simulator. Int J Comput Assist Radiol Surg 9(1):1-9, 2014
5. Neubauer A, Wolfsberger S. Virtual endoscopy in neurosurgery: A review. Neurosurgery, 72(1):A97-A106, 2013.
6. Choudhury N, Gélinas-Phaneuf N, Delorme S, Del Maestro RF. Fundamentals of Neurosurgery: virtual reality tasks for training and evaluation of technical skills. World Neurosurgery 80(5):e9-e19, 2013.
7. Boisvert J, Poirier G, Borgeat L, Godin G. Real-time Blood Circulation Model for Surgical Training. IEEE Transactions on Biomedical Engineering, 60(4): 1013-1022, 2013.
8. Clarke DB, D'Arcy RCN, Delorme S, Laroche D, Godin G, Hajra SG, Brooks R, DiRaddo R. Virtual Reality Simulator: Demonstrated Use in Neurosurgical Oncology. SAGE Journals Surgical Innovation 20(2): 190-197, 2013.
9. Neubauer A, Brooks R, Brouwer I, Debergue P, Laroche D. Haptic collision handling for simulation of transnasal surgery. Computer Animation and Virtual Worlds, 24(2): 127-141, 2013.
10. Delorme S, Laroche D, DiRaddo R, Del Maestro RM. NeuroVR: A Physics-Based Virtual Simulator for Cranial Microneurosurgery Training. Neurosurgery 71(1 Suppl Operative):ons32-42, 2012.
11. Borgeat L, Massicotte P, Poirier G, Godin G. Layered surface fluid simulation for surgical training. Med Image Comput Assist Interv 14:323-330, 2011.
12. Delorme S, Cabral A, Ayres F, Jiang D. Modeling the thermal effect of the bipolar electrocautery for neurosurgery simulation. Stud Health Technol Inform 163:166-172, 2011.
13. Jiang D, Choudhury N, Mora V, Delorme S. Characterization of Suction and CUSA Interaction with Brain Tissue. Lecture Notes in Computer Science 5958:11-19, 2010.
14. Mora V, Jiang D, Brooks R, Delorme S. A computer model of soft tissue interaction with a surgical aspirator. Med Image Comput Comput Assist Interv. 12(pt 1):51-58, 2009.

NeuroVR™
admin
Log out
Instrument Handling
Fundamental Skills
Endoscopic Surgery
Microsurgery
Spine Surgery

Acknowledgements

Representatives from the following hospitals have contributed to the courseware:

Hospital	Location
Victoria General Hospital	Victoria, BC
Vancouver General Hospital	Vancouver, BC
Alberta Children's Hospital	Calgary, AB
Foothills Medical Centre	Calgary, AB
University of Alberta Hospital	Edmonton, AB
Royal University Hospital	Saskatoon, SK
Health Sciences Centre	Winnipeg, MB
London Health Science Centre	London, ON
St. Joseph's Healthcare	Hamilton, ON
Toronto Hospital for Sick Children	Toronto, ON
Toronto Western Hospital	Toronto, ON
Kingston General Hospital	Kingston, ON
Ottawa Hospital	Ottawa, ON
Centre Hospitalier Universitaire Sainte-Justine	Montreal, QC
Montreal General Hospital	Montreal, QC
Royal Victoria Hospital	Montreal, QC
Montreal Neurological Institute and Hospital	Montreal, QC
Hôpital Maisonneuve-Rosemont	Montreal, QC
Centre Hospitalier Universitaire de Sherbrooke	Sherbrooke, QC
Centre Hospitalier Universitaire de Québec	Quebec City, QC
Saint John Regional Hospital	Saint John, NB
Queen Elizabeth II Hospital	Halifax, NS
Medical University Vienna	Vienna, Austria
NorthShore University Health System	Chicago, IL

Pedagogical Content in a Nutshell

The objective for training with the simulator is to facilitate the acquisition of fundamental psychomotor skills in neurosurgery. A conceptual framework for the simulation content in NeuroVR was defined with the input of collaborating surgeons. The simulator comprises a set of training exercises targeting residents at different levels of experience (junior to senior PGY). The modules were designed with incrementally increasing difficulty to favour optimal learning. The content is organized to first allow the user to become familiar with a given surgical instrument, proceed to advanced levels to practice technique and finally, perform procedures. Modules progress from simpler one-handed exercises through greater technical challenges using both hands, culminating in procedures based on actual patient anatomy:

- Instrument Handling (Figure 1 and Table 1)
- Fundamental Skills (Figure 2 and Table 2)
- Endoscopic Surgery (Figure 3 and Table 3)
- Microsurgery (Figure 4 and Table 4)
- Spine Surgery (Figure 5 and Table 5)

At the end of all exercises, the trainee is provided with objective feedback on performance through automated metrics (Table 6). Some are immediate, appearing onscreen during the simulation, while others are obtained through post-processing.

Metrics are tailored for each exercise: Figure 6 illustrates an example score screen obtained after execution of the Ultrasonic Aspirator 101 (Instrument Handling) exercise, while Figure 7 demonstrates the detail of performance analysis available by scrolling through additional screens. Figures 8 and 9 depict score screens for the Debulking 101 (Fundamental Skills) and Sphenoid Ostium Drilling (Endoscopic Surgery) exercises, respectively, to indicate typical performance feedback for different procedures.

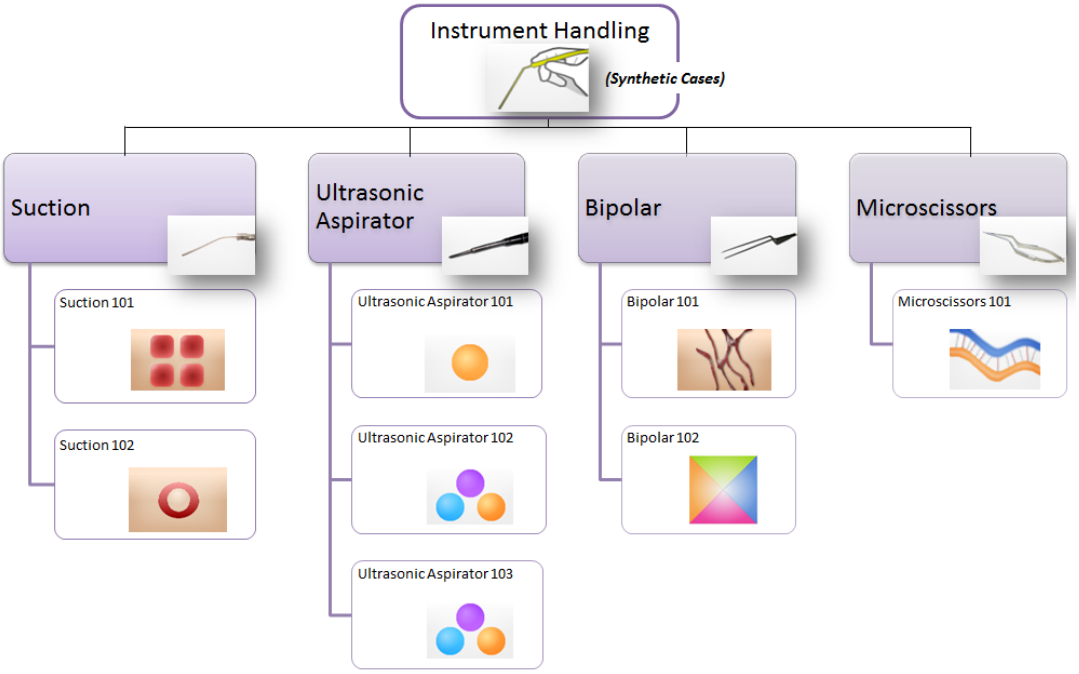


Figure 1: Instrument Handling module (one-handed exercises)

Category Name	Exercise	Goal
Suction	Suction 101	Aspirate blood on surface of tissue
	Suction 102	As above + retraction of tissue
Ultrasonic Aspirator	Ultrasonic Aspirator 101	Remove stiff inclusion
	Ultrasonic Aspirator 102	As above + inclusions of varying stiffness
	Ultrasonic Aspirator 103	As above + damage created when applying too much stress to white material
Bipolar	Bipolar 101	Cauterise surface vessels
	Bipolar 102	Grasp and flip tissue flaps
Microscissors	Microscissors 101	Cut fibres connecting tissues

Table 1: Instrument Handling exercises (click the category name for details)

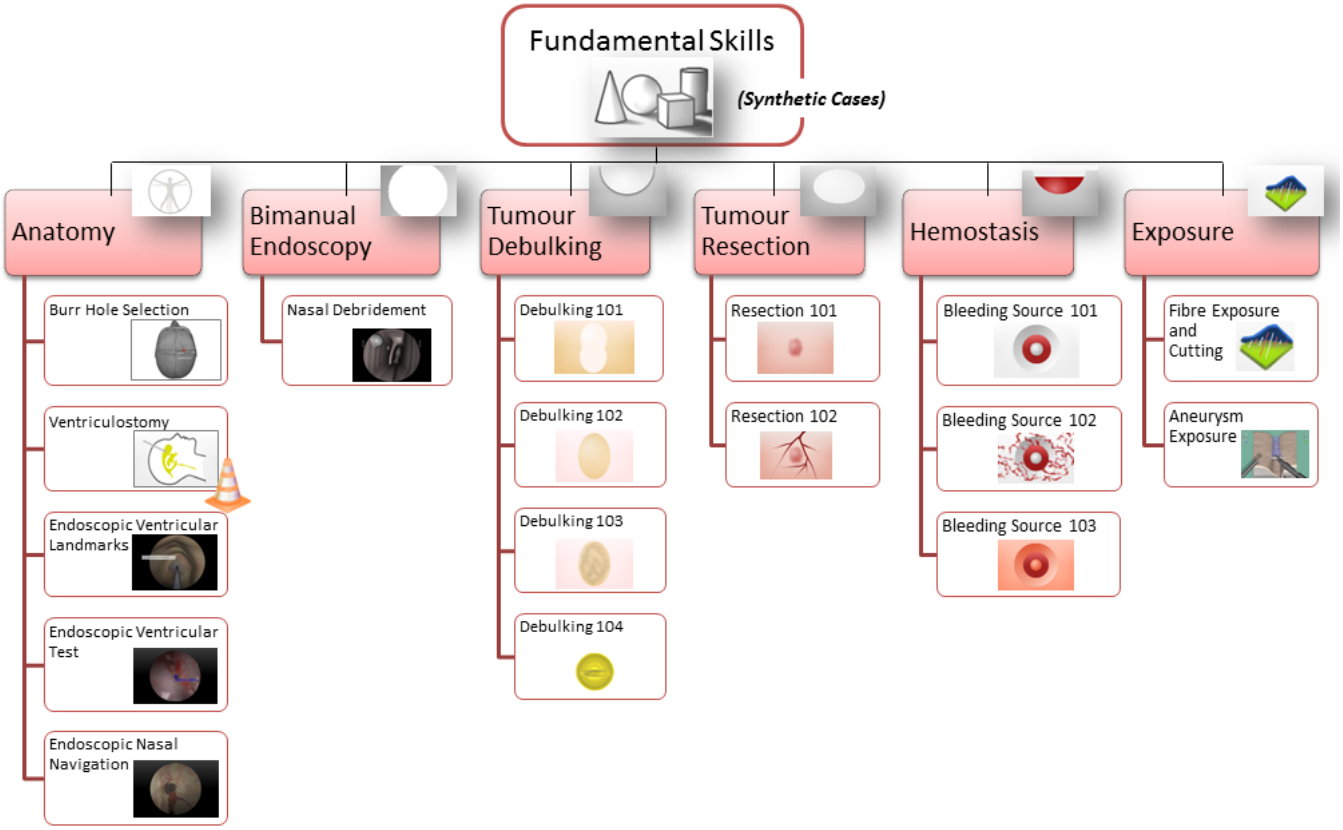


Figure 2: Fundamental Skills module (anatomy lessons and two-handed exercises; cone icon indicates beta exercise in version 16.03)

Category Name	Exercise	Goal
Anatomy	Burr Hole Selection	Place and aim drain on head model to target Foramen of Monro
	Ventriculostomy	Insert ventricular drain in proper orientation so as perforate right ventricle
	Endoscopic Ventricular Landmarks	Scoreless exercise to learn landmarks
	Endoscopic Ventricular Test	Navigate to specified landmark
	Endoscopic Nasal Navigation	Locate sphenoid ostia
Bimanual Endoscopy	Nasal Debridement	Debride all of the polyps
Tumour Debulking	Debulking 101	Debulk Meningioma-like inclusion
	Debulking 102	As above + inclusion difficult to access
	Debulking 103	As above + non-uniform tumour stiffness
	Debulking 104	Debulk tumour inside a capsule
Tumour Resection	Resection 101	Resect glioma-like inclusion
	Resection 102	As above + with bleeding
Hemostasis	Bleeding Source 101	Locate and seal bleeding source
	Bleeding Source 102	Discern and seal bleeding source
	Bleeding Source 103	Locate and seal multiple bleeding sources
Exposure	Fibre Exposure and Cutting	Separate tissue connected by fibres
	Aneurysm Exposure	Dissect membrane and remove fibres to expose aneurysm while managing bleeding

Table 2: Fundamental Skills exercises (click the category name for details)

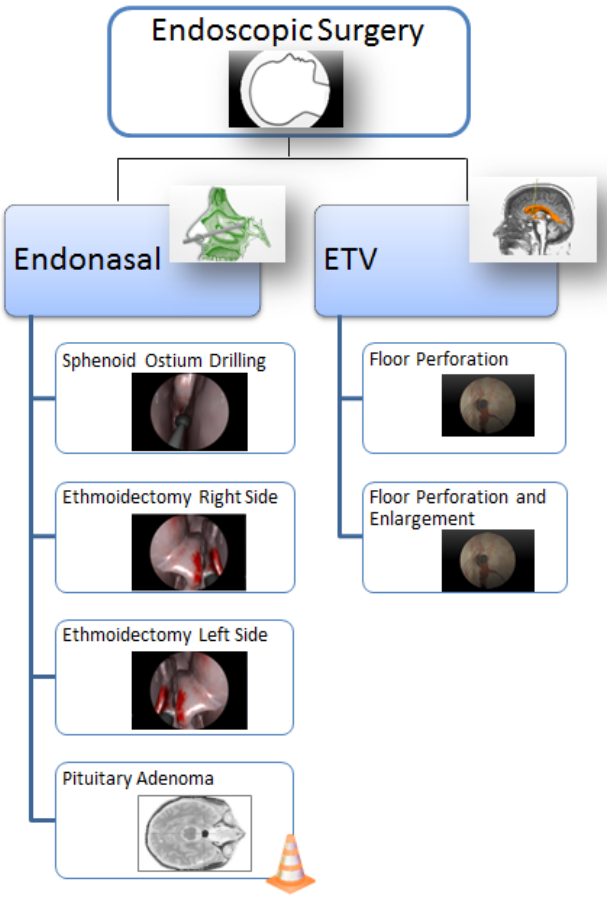


Figure 3: Endoscopic Surgery module (cone icon indicates beta exercise in version 16.03)

Category Name	Exercise	Goal
Endonasal	Sphenoid Ostium Drilling	Enlarge sphenoid ostium to gain access to sphenoid sinus
	Ethmoidectomy (left or right side)	Perform Ethmoidectomy followed by wide Sphenoidotomy
	Pituitary Adenoma	Perform Sphenoidotomy followed by pituitary adenoma resection
ETV	Floor Perforation	Select perforation site on ventricular floor
	Floor Perforation and Enlargement	Perforate and enlarge opening in ventricular floor

Table 3: Endoscopic Surgery exercises (click the category name for details)

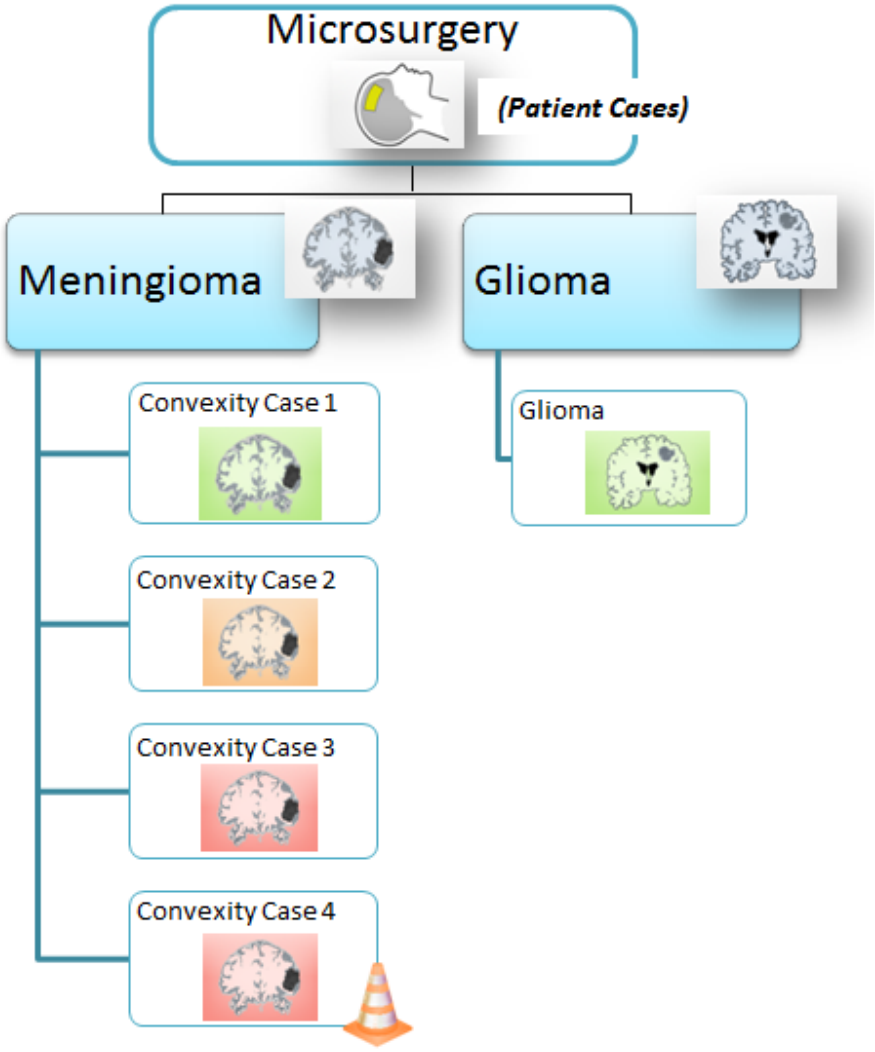


Figure 4: Microsurgery module (cone icon indicates beta exercise in version 16.03)

Category Name	Exercise	Goal
Meningioma	Convexity Case 1	Debulk a frontal convexity Meningioma
	Convexity Case 2	As above + highly vascular tumour
	Convexity Case 3	As above + nonuniform tumour stiffness
	Convexity Case 4	As above + tumour capsule
Glioma	Glioma (GBM Case 1)	Resect a subcortical glioma with oedema

Table 4: Microsurgery procedural exercises (click the category name for details)

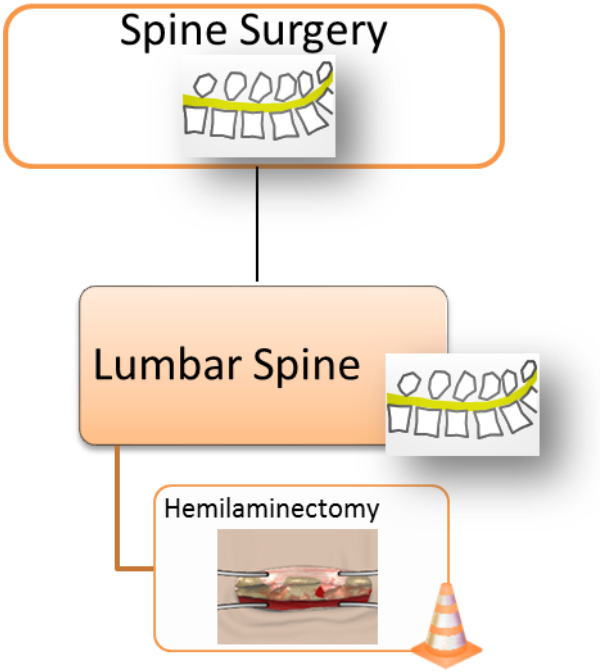


Figure 5: Spine Surgery module (cone icon indicates beta exercise in version 16.03)

Category Name	Exercise	Goal
Lumbar Spine	Hemilaminectomy	Remove lamina on L3 vertebra while managing bleeding

Table 5: Spine surgery exercises (click the category name for details)

Metric	Unit
Outcome	
Percentage of target tissue (e.g., tumour, polyp) removed	%
Volume of vertebra removed	cc
Hemostasis achieved?	yes/no
Located target anatomical landmark?	yes/no
Perforated ideal site on ventricular floor?	yes/no
Number of tissue flaps inverted	(number)
Target fibres successfully cut	(number)
Distance between user tool position and target (ideal) point	mm
Surface of tissue well-cauterised	mm^2
Efficiency	
Time to complete the task	s
Error	
Volume of healthy brain removed or damaged	cc
Percentage or volume of other tissue removed	% or cc
Excessive force applied to tissue (duration)	s
Volume of blood remaining in operative field	cc
Total blood loss	cc
Endoscopic navigation error resulting in potential damage to tissue or critical structure	yes/no
Surface of tissue substantially over-cauterised	mm^2
Arteries/ veins severed	(number)
Similarity of perforation shape to ideal	--

Table 6: NeuroVR metrics for feedback on performance.

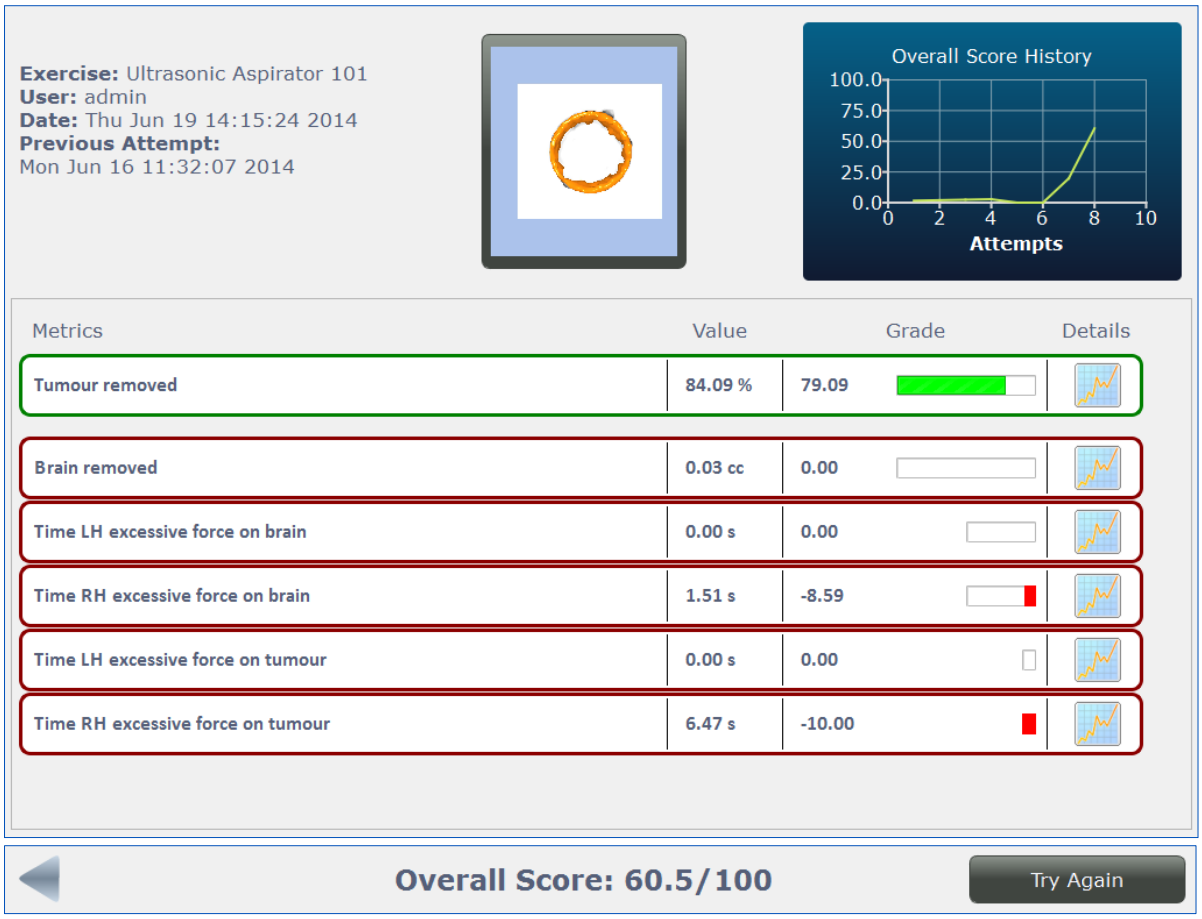


Figure 6: Tailored metrics and score for the Ultrasonic Aspirator 101 exercise. The exercise goal (outcome) appears at the top, outlined in green. Potential errors are listed below the goal and outlined in red. Grades for every metric value achieved are shown as both a number and a bar graph, where the length of bar indicates the maximum magnitude attainable. The overall score (out of 100) is the sum of all metric grades.

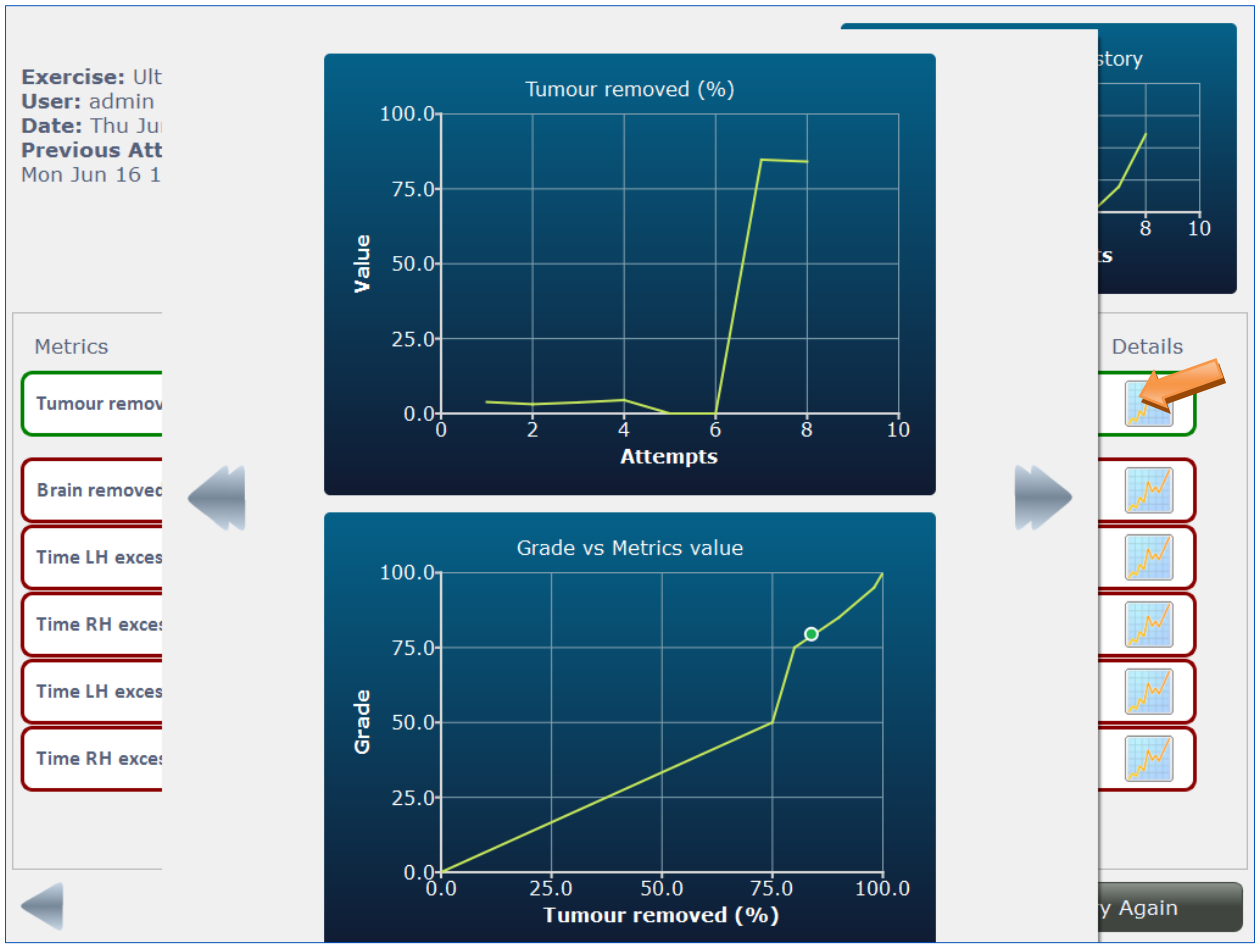
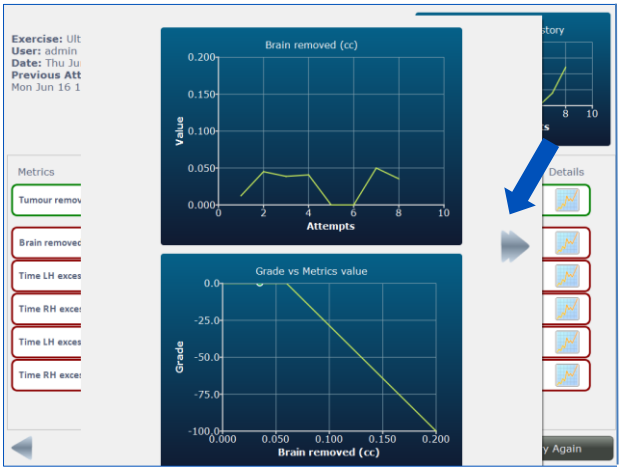
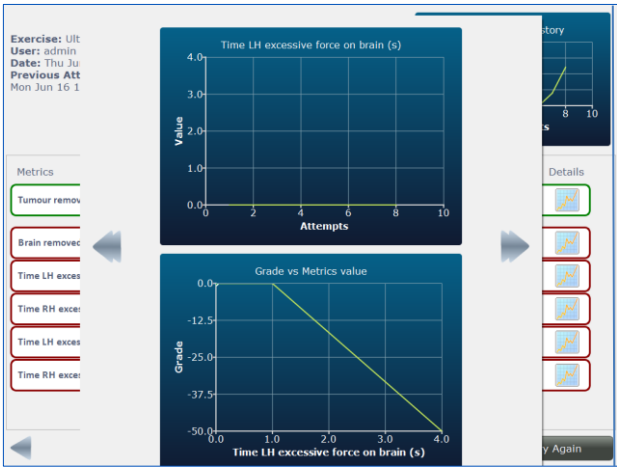
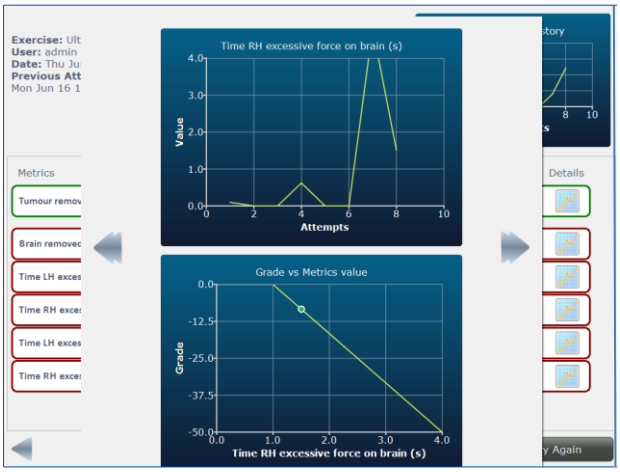
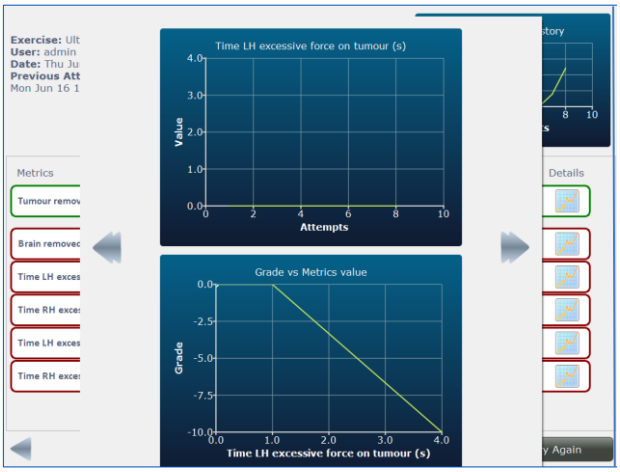


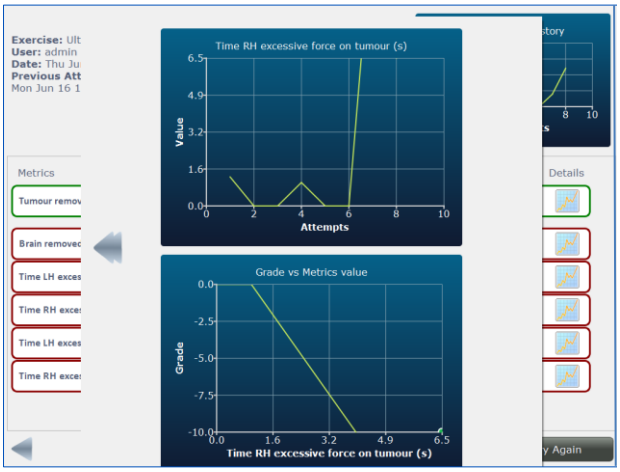
Figure 7: Performance feedback displayed by clicking the "Details" chart icon (indicated by orange arrow). The upper image plots the exercise goal grade through all attempts by this user. The lower image positions the obtained raw metric value versus the actual grade, according to the relationship defined for each exercise and summarized in the Performance Metric tables in this Courseware.



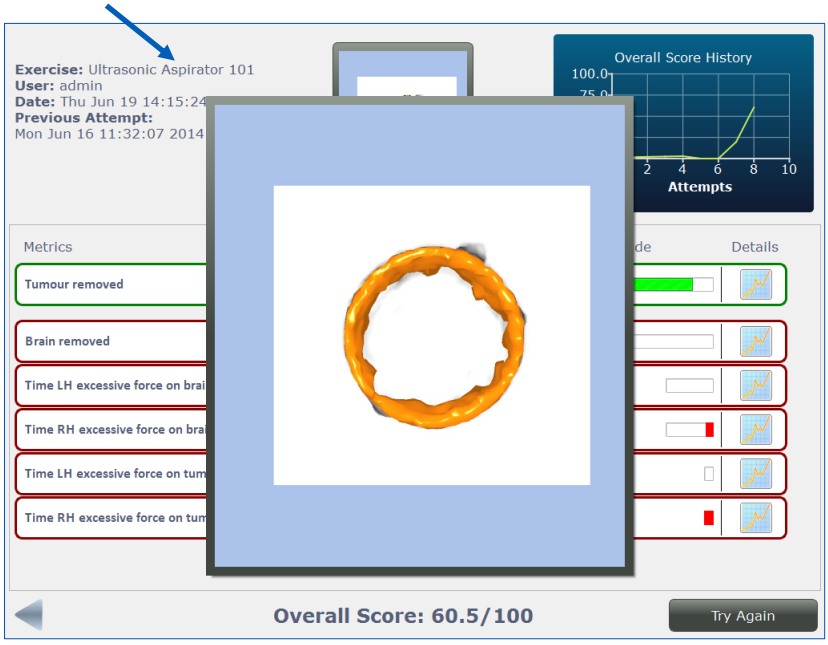








Clicking the left and right arrows (indicated by purple arrow) scrolls through plots of each metric defined for the exercise.



Clicking the scenario final image (green arrow) provides a close-up view.

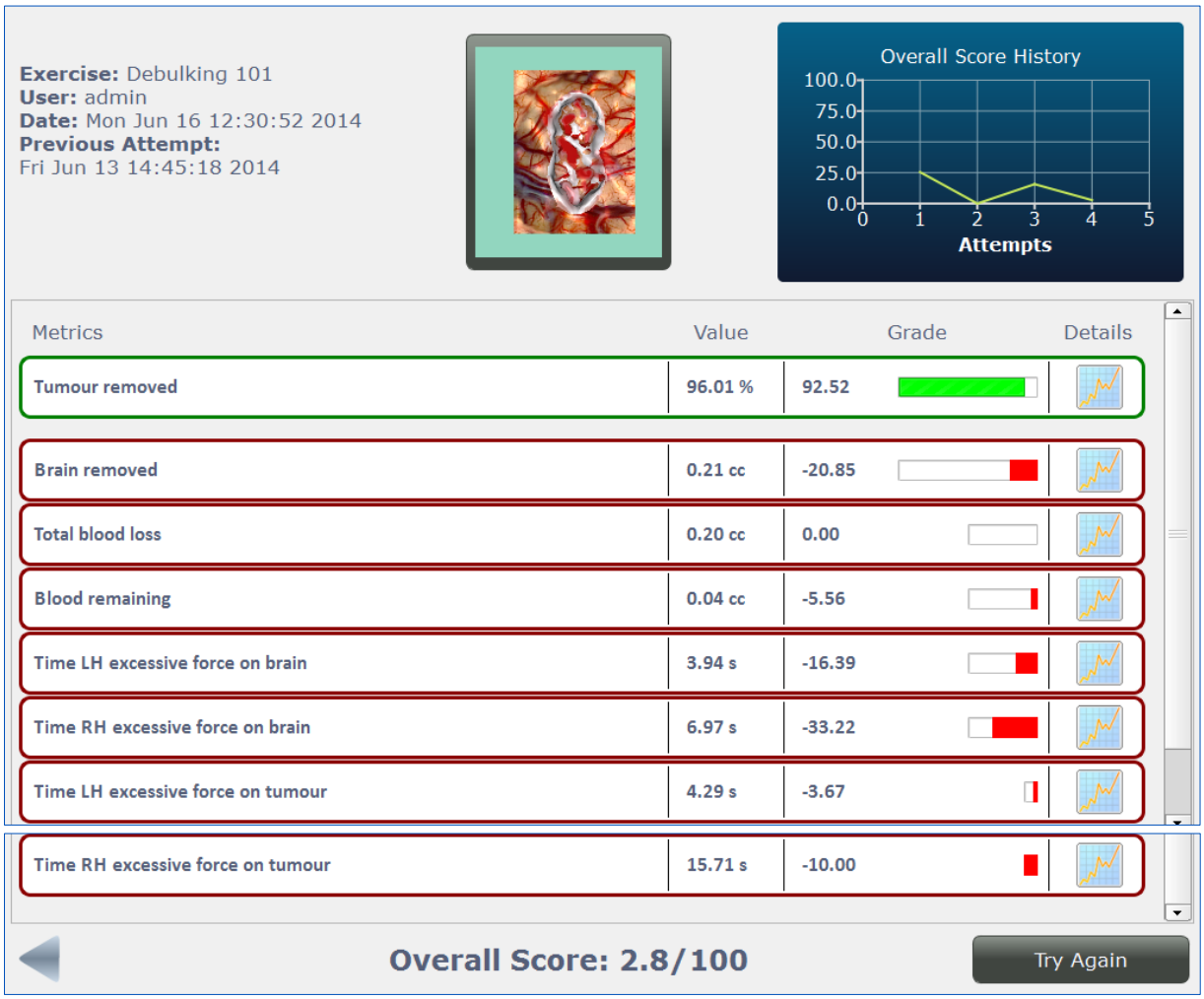


Figure 8: Example score screen for Debulking 101 exercise in the Fundamental Skills module.

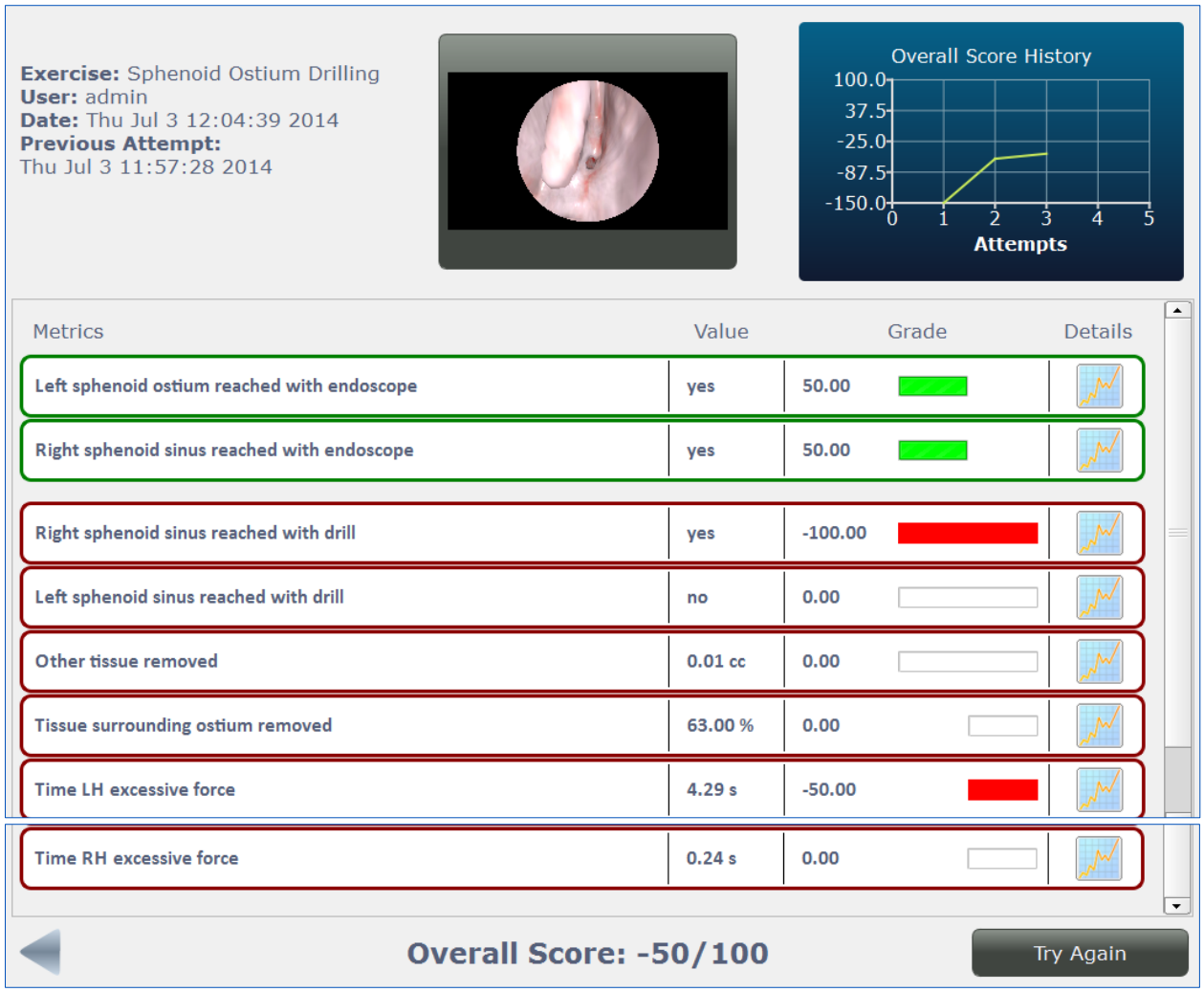
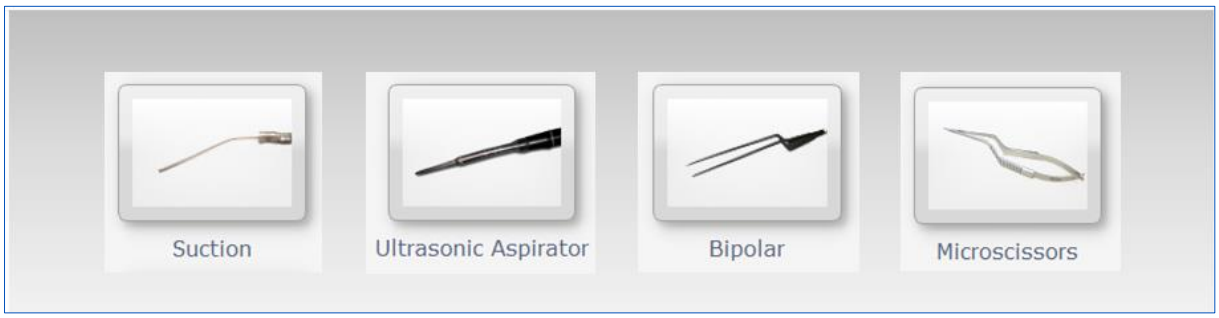


Figure 9: Example score screen for Sphenoid Ostium Drilling exercise in the Endoscopic Surgery module.

Instrument Handling Module

Each exercise in the instrument handling module practices manoeuvring the most commonly- used surgical instruments in neurosurgery. The training scenarios are one-handed, involving geometric shapes rather than realistic anatomy, and without any bleeding such that the trainee can focus solely on learning the proper use of the instrument.



Suction – an Introduction

The basic suction tool is the most widely used single-shaft neurosurgery tool, often in the non-dominant hand of the surgeon. The suction tool is commonly held as a pencil, between the thumb and the index finger, at any point along the shaft. The hand or forearm is rested close to the surgical opening or on arm rests (depending on which is more comfortable) for stability and dexterity.

The suction tool comes in a variety of sizes and is regulated at the surgeon's thumb for variable pressure settings (keyhole) or pressure switching ON/OFF. The aspiration power can be further adjusted at its source (i.e., suction pump).

The suction tool has three main functions:

1. To remove liquids, such as blood or cerebrospinal fluid
2. At low power, to safely grasp or retract soft tissue
3. At higher power, to remove soft tissues as in subpial resections or soft tumour removal

Suggested Reading:

1. Rhoton AL, Operative Techniques and Instrumentation for Neurosurgery, Cranial anatomy and surgical approaches. Lippincott Williams & Wilkins, 2007.
2. Yasargil M. Instrumentation and Equipment, Microneurosurgery of CNS tumours IVB. Stuttgart, George Thieme Verlag, 1996.

Suction 101-102 Exercises

Objective

To become familiar with the basic suction tool.

Intended User

PGY-1 neurosurgery resident.

Training Goal

The suggested practice time for this exercise is until the trainee can completely remove the blood without error, demonstrated consecutively three times (once per day over three separate days). This must be shown with each hand.

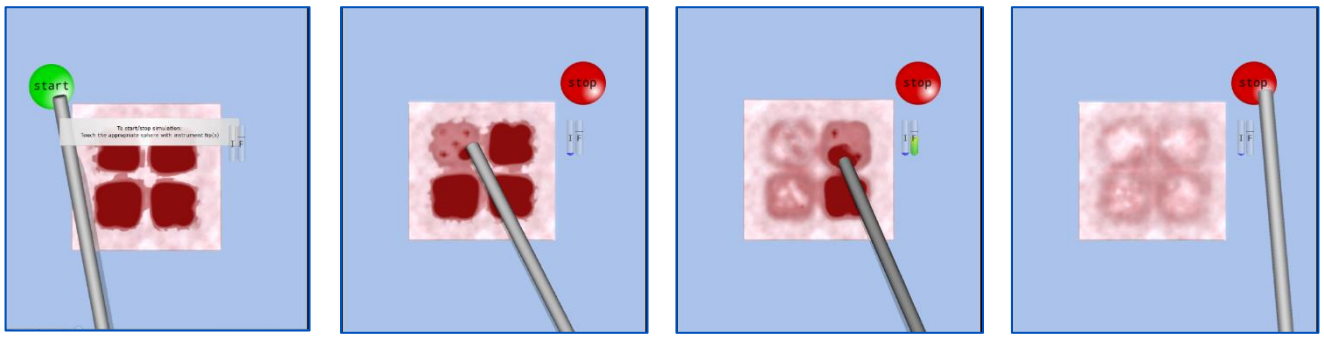
	Performance Metrics
Outcome	▪ Volume of blood remaining
Efficiency	▪ N/A
Error	▪ Use of excessive force (duration) ▪ Removal of healthy brain

Description

The exercises currently available in the simulator practice the first two of the three main functions described in the previous section:

1. The removal of liquids, such as blood or cerebrospinal fluid
2. At low power, to safely grasp or retract soft tissue
3. At higher power, to remove soft tissue such as in subpial resections or soft tumour removal

"Suction 101" consists of an abstract surface of tissue with four crevices, each filled with a pool of blood. The user is instructed to use suction to clear away the blood from the operating view while being careful to not apply excessive pressure on the underlying tissue. An "F" (force) gauge is shown in overlay during performance of the task to provide live feedback on the acceptable amount of force that can be applied. When too much force is applied, the gauge moves into the red (danger) zone. The aspiration is activated by the "ON/OFF" sensor at the thumb and its intensity, indicated onscreen as the "I" gauge, can be adjusted with a power knob. The blood is cleared at a faster rate as the aspiration pressure is increased. However, care must be taken not to accidently remove any of the underlying "healthy" tissue when the aspiration power is at the maximum. It is up to the trainee to determine the setting that permits efficient clearing of blood while minimising the risk of damage. Feedback on performance includes time to complete the task and errors, such as any healthy tissue removed, remaining blood and time spent in the excessive force zone.

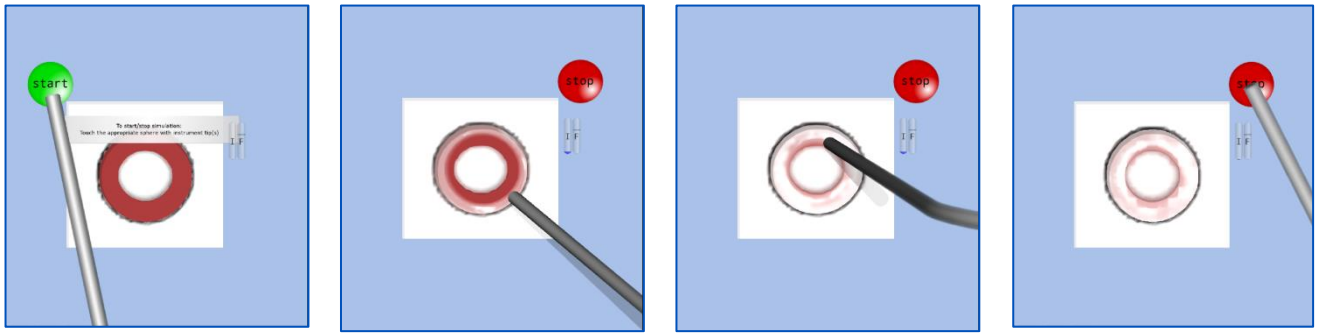


Suggested technique for the exercise:
Start with a relatively high aspiration power at the beginning. As the level of blood diminishes and the surface of tissue is approached, lower the aspiration power either at the source by adjusting the knob or at the fingertips by removing the thumb from the keyhole.

Performance – Suction 101

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Volume of blood remaining in operative field	cc	0 0.01 ≥0.04	100 100 0	100%
Volume of healthy brain removed	cc	0 0.005 ≥0.01	0 0 100	-100%
Excessive force applied to tissue (duration)	s	0 0.5 1 ≥3	0 0 5 100	-50%

"Suction 102" practices using the suction tool as in the previous exercise but with the added difficulty of requiring gentle retraction of soft tissue to complete the task.



Suggested technique for the exercise:
Begin with a low- to mid-range aspiration power setting to avoid damage to the sphere at the centre of your operating field. When the blood level is diminished, gently retract the sphere to clear the remainder of the blood. To do this, remove your thumb from the suction switch so that you are at minimum aspiration pressure for safe retraction. Proceed to retract the tissue with the suction tool shaft while simultaneously aspirating the remainder of the blood.

Performance – Suction 102

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Volume of blood remaining in operative field	cc	0 0.02 ≥0.07	100 100 0	100%
Volume of healthy brain removed	cc	0 0.005 ≥0.01	0 0 100	-100%
Excessive force applied to tissue (duration)	s	0 0.6 ≥3	0 0 100	-50%

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Ultrasonic Aspirator – an Introduction

Ultrasonic aspirators, such as the Cavitron Ultrasonic Surgical Aspirator (CUSA), are used to remove tissue too stiff for a suction tool. Briefly, the ultrasonic aspirator differs in its ability to generate high-frequency vibrations to selectively liquefy soft tissues in the vicinity of its tip prior to aspiration. This permits the ultrasonic aspirator to be less traumatic to tissue. The ultrasonic aspirator is activated using a foot pedal, and a console is used to control its parameters: aspiration, irrigation, amplitude and tissue selectivity. Unlike the suction tool, the ultrasonic aspirator is not used for tissue grasping. It is solely used for the removal of soft tissues with simultaneous liquid aspiration.

Suggested Reading:

1. Rhoton AL. Operative Techniques and Instrumentation for Neurosurgery, Cranial anatomy and surgical approaches. Lippincott Williams & Wilkins, 2007.
2. Epstein F. The Cavitron ultrasonic aspirator in tumour surgery, Clinical neurosurgery, pp. 497–505. Wolters Kluwer Health, 1983.

Ultrasonic Aspirator 101-103 Exercises

Objective

To become familiar with the ultrasonic aspirator.

Intended User

PGY-1 neurosurgery resident.

Training Goal

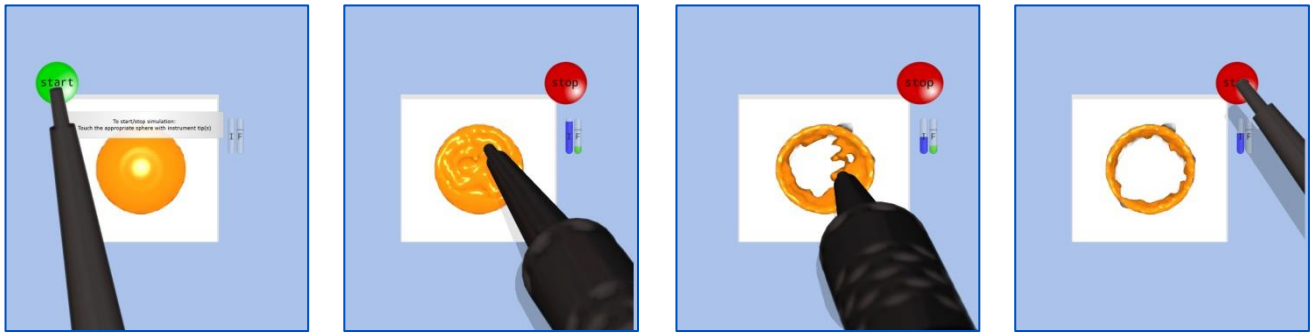
The suggested practice time for this exercise is until the trainee can completely remove the inclusions without any damage to the brain, demonstrated consecutively three times (once per day over three separate days). This must be shown with each hand.

Performance Metrics

Outcome	▪ % of tumour resection
Efficiency	▪ N/A
Error	▪ Use of excessive force (duration) ▪ Removal of healthy brain

Description

"Ultrasonic Aspirator 101" was designed to practice using the ultrasonic aspirator to remove simple spherical "tumours" embedded in a block of healthy "brain". The sphere is randomly assigned a different stiffness at the start of the simulation. It is up to the trainee to correctly adjust the ultrasonic aspirator amplitude for a particular tumour. If the power is set too low, the aspirator will not be able to remove any of the tumour, and setting it too high risks damage to adjacent healthy tissue. The ultrasonic aspirator setting is adjusted with the power knob and corresponds to the intensity "I" gauge visible during simulation. Aspiration is held constant at a low level for fluid removal and cannot be adjusted. The instrument is activated via a foot pedal. Feedback on performance includes the percentage of tumour resected. Errors include volume of healthy brain removed and time spent in the excessive force zone.



Suggested technique for the exercise:
Start with a relatively high aspiration power in the centre until the margins are reached. At this point, decrease the power to avoid injury to surrounding healthy tissue.

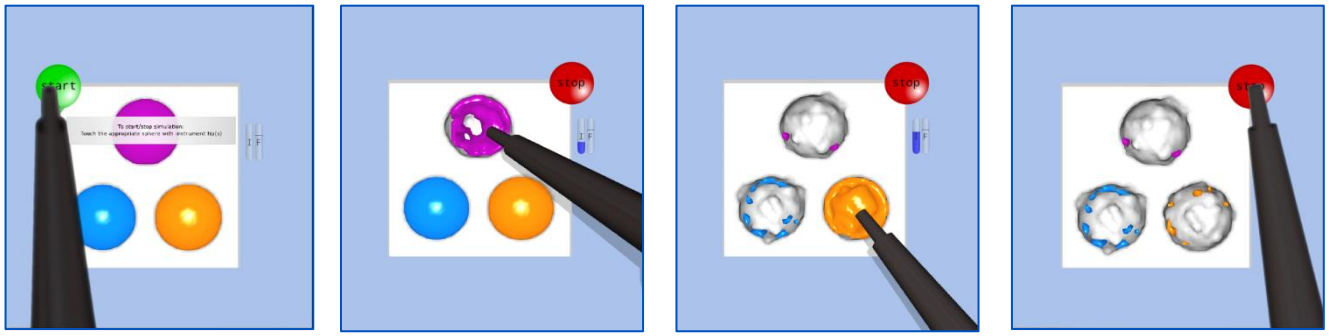
Performance – Ultrasonic Aspirator 101

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 75 80 90 98 100	0 50 75 85 95 100	100%
Volume of healthy brain removed	cc	0 0.06 ≥0.2	0 0 100	-100%
Excessive force applied to brain (duration)	s	0 1 ≥4	0 0 100	-50%
Excessive force applied to tumour (duration)	s	0 1 ≥4	0 0 100	-10%

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Description

"Ultrasonic Aspirator 102" practices using the ultrasonic aspirator as in the previous exercise but with the added difficulty of removing inclusions of varying stiffness.



Suggested technique for the exercise:
The stiffness of each inclusion is randomly set and can be discerned by probing with an inactivated ultrasonic aspirator. Generally, a stiffer material is more difficult to remove and dictates the instrument power required.

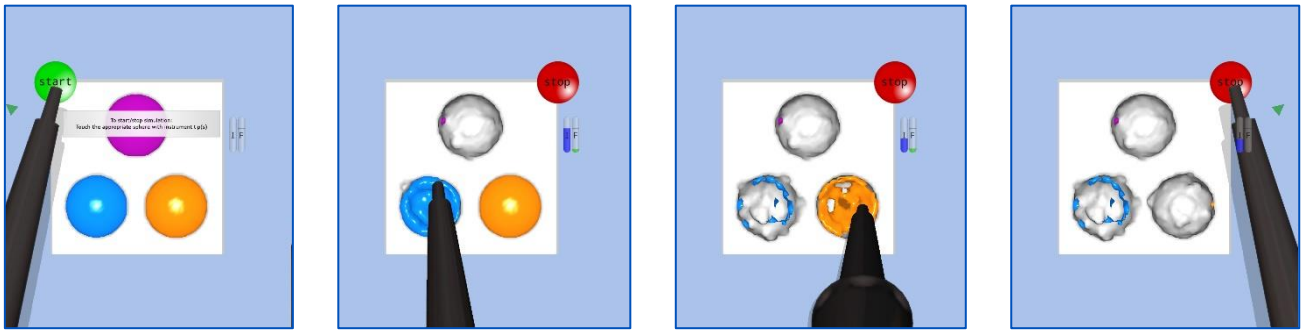
Performance – Ultrasonic Aspirator 102

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 75 80 90 98 100	0 50 75 85 95 100	100%
Volume of healthy brain removed	cc	0 0.06 ≥0.2	0 0 100	-100%
Excessive force applied to brain (duration)	s	0 1 ≥4	0 0 100	-50%
Excessive force applied to tumour (duration)	s	0 1 ≥5	0 0 100	-10%

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Description

"Ultrasonic Aspirator 103" practices using the ultrasonic aspirator as in the previous exercise but with the added penalty of damage to the white material when applying too much stress.



Suggested technique for the exercise:
Not only does each tumour exhibit its own stiffness; that of the healthy brain must be accounted for as well. Stay aware of the force you are exerting and be ready to adjust the instrument intensity to avoid causing damage.

Performance – Ultrasonic Aspirator 103

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 75 80 90 98 100	0 50 75 85 95 100	100%
Volume of healthy brain removed	cc	0 0.06 ≥0.2	0 0 100	-100%
Volume of healthy brain damaged	cc	0 0.04 0.2	0 15 100	-100%
Excessive force applied to brain (duration)	s	0 1 ≥4	0 0 100	-50%
Excessive force applied to tumour (duration)	s	0 1 ≥5	0 0 100	-10%

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Bipolar Forceps – an Introduction

The Bipolar forceps are the most commonly used double-shafted tool in neurosurgery, in the dominant hand of the surgeon. Double-shafted tools are held in a specific area, else the instrument will feel awkward and unbalanced. The middle finger and thumb squeeze and release the shaft of the tool to close and open its tips. The Bipolar forceps functions:

1. To coagulate vessels and bleeding sites on soft tissues
2. As a grasper
3. To bluntly dissect tissues
4. To sharply cut tissues at high power
5. As a retractor

Low, medium and high settings, controlled on a console, are respectively used to coagulate blood vessels, coagulate tumours and cut soft tissues.

Suggested Reading:

1. Rhoton AL. Operative Techniques and Instrumentation for Neurosurgery, in: Rhoton's Cranial anatomy and surgical approaches. Lippincott Williams & Wilkins, 2007.
2. Yasargil M, Instrumentation and Equipment, in: Microneurosurgery of CNS tumours IVB. Stuttgart, George Thieme Verlag, 1996.

Bipolar 101 Exercise

Objective

To become familiar with bipolar cauterisation.

Intended User

PGY-1 neurosurgery resident.

Training Goal

The suggested practice for this exercise is until the trainee can perform good cauterisation with each hand, without error, consecutively three times (once a day over three separate days).

	Performance Metrics
Outcome	▪ Quality of cauterisation
Efficiency	▪ N/A
Error	▪ Use of excessive force (duration)

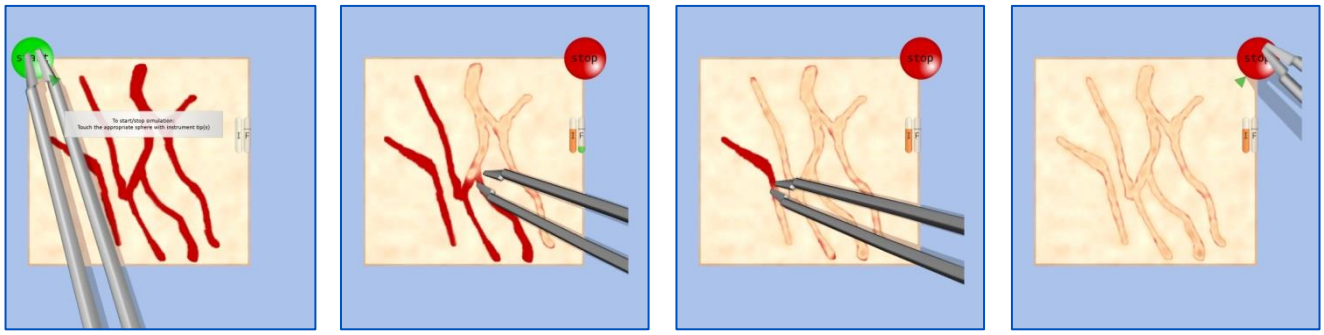
Description

"Bipolar 101" practices the first of the five functions of the bipolar forceps:

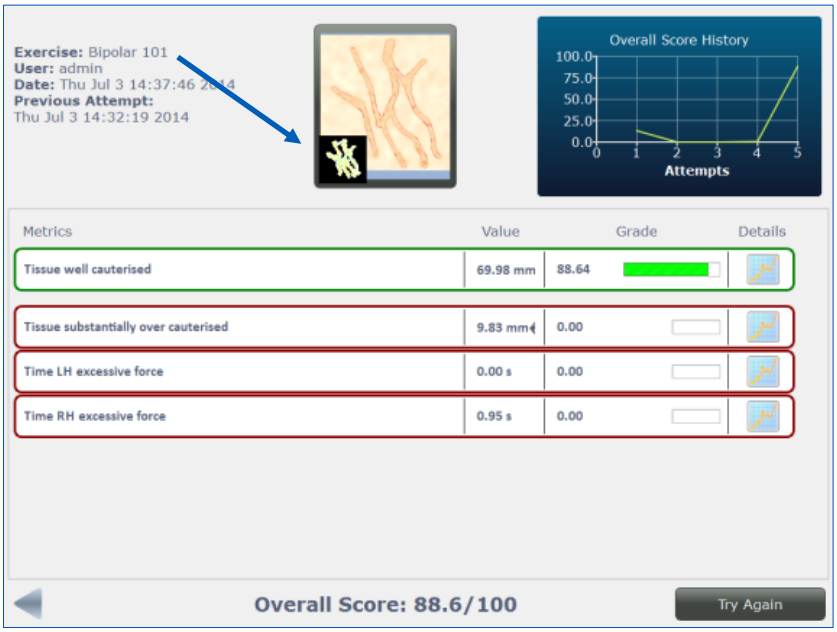
1. To coagulate vessels and bleeding sites on soft tissues
2. As a grasper
3. To bluntly dissect tissues
4. To sharply cut tissues at high power
5. As a retractor

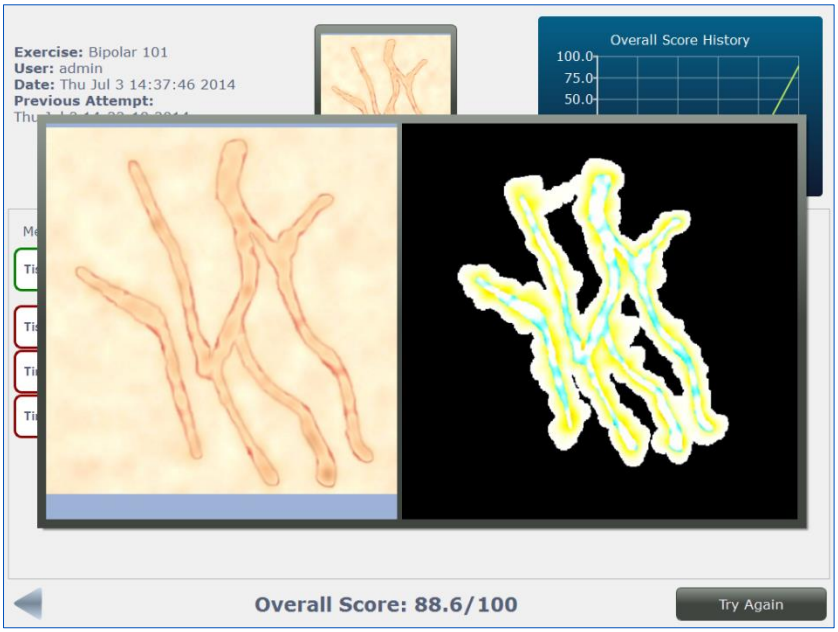
A representation of blood vessels on the surface of tissue is used to practice using the bipolar for cauterisation. The scenario was designed for novice users, with no active bleeding present. To coagulate effectively, the forceps must be gently applied over the target rather than pushing forcefully on the blood vessel. Cauterisation is activated using a foot pedal and will only function if the forceps tips are at a proper distance apart with each tip in contact with tissue. The vessels do not bleed; they simply disappear with cauterisation.

Tissue in contact with active bipolar tips is subject to proximal heating and changes in colour from a whitish to a burnt hue. The colour change depends on the power, distance between the bipolar tips and duration of cauterisation. Performance metrics include the surface area of tissue considered to have adequate quality of cauterisation. Errors include burning tissue with excessive cauterisation and applying too much force on the tissue.



The score screen provides the final scenario image and an additional post-processing image indicating the quality of cauterisation throughout the operating field. Click the small image in the corner (blue arrow in the example score screen figure) to enlarge the images. The extent of cauterisation is represented by colour ranging from blue, signifying tissue is under-cauterised, through white and yellow to red, which means it is substantially over-cauterised.





Suggested technique for the exercise:
Avoid pushing forcefully on the tissue while coagulating. Do not pinch the forceps completely closed because electricity cannot pass between the tips of the bipolar and thus cannot cauterise. Instead, open and close the forceps in a pulsatile manner over the site until the vessel has disappeared. Finally, rather than coagulating for an extended period over the same spot, choose to coagulate over a short segment. This will prevent tissue from sticking to the bipolar tips and burning.

Performance – Bipolar Forceps 101

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Surface of tissue well-cauterised	mm^2	0 75 100	0 95 100	100%
Surface of tissue substantially over-cauterised	mm^2	0 15 50 100	0 0 50 100	-50%
Excessive force applied to tissue (duration)	s	0 1 ≥10	0 0 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Bipolar 102 Exercise

Objective

To become familiar with grasping tissue using the bipolar forceps.

Intended User

PGY-1 neurosurgery resident.

Training Goal

The suggested practice for this exercise is until the trainee can flip the tissue flaps with each hand, without error, consecutively three times (once a day over three separate days).

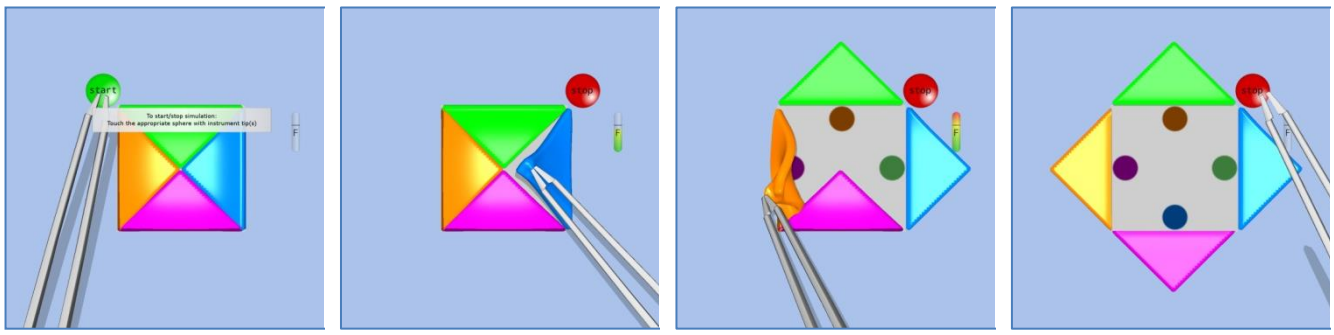
	Performance Metrics
Outcome	▪ Number of tissue flaps inverted
Efficiency	▪ Time to complete the task
Error	▪ Use of excessive force (duration)

Description

"Bipolar 102" practices the second of the five functions of the bipolar forceps:

1. To coagulate vessels and bleeding sites on soft tissues
2. As a grasper
3. To bluntly dissect tissues
4. To sharply cut tissues at high power
5. As a retractor

A simple geometric scheme of four coloured "tissue" flaps, each covering a spot, are used to practice the grasping technique.
The trainee must manipulate the Bipolar forceps to gently pull the corner of the tissue flap and expose the underlying spot, at a different approach angle for each flap, all the while retaining their grasp on the tissue. The key performance metric is to successfully flip all four flaps. Errors include taking more than 30 seconds to achieve this goal and excessive force applied to the tissue.



Suggested technique for the exercise:
Avoid pushing forcefully on the tissue while grasping. Adjust your hand positioning as you approach each flap corner with the bipolar so that a simple grasp-and-pull motion will overturn the flap and minimize its propensity to flip back to its original position. Use the momentum of the overturning tissue to complete the flip without undue force.

Performance – Bipolar Forceps 102

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Number of tissue flaps inverted	-	0 4	0 100	100
Time to complete the task	s	0 30 ≥120	0 0 100	-100%
Excessive force applied to tissue (duration)	s	0 0.5 1 ≥3	0 0 5 100	-50%

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Microscissors – an Introduction

Microscissors are small scissors with extremely sharp tips, used frequently in microsurgery for the cutting of fine anatomical structures including sutures, fibres or membranes connecting tissue. Microscissors are commonly used in combination with a grasping tool, such as the bipolar forceps, in order to expose and cut fibres.

Unlike other medical scissors, Microscissors do not have right or left hoops, thus may be used by both right- and left-handed surgeons. This versatility makes Microscissors an indispensable part of any operating room. The length and shape of the instrument varies depending on the specific procedure: short, straight Microscissors may be preferred when cutting close to the brain surface, whereas bayonet-shaped instruments are employed closer to the brainstem, base of the skull or during transsphenoidal surgery, and long, angled scissors are ideal for dural opening in pituitary surgery.

While regular scissors cut, micro scissors shear, which allows a surgeon to accurately cleave a specific section of tissue without damaging other surfaces? Microscissors have a greater shearing angle than most scissors, which prevents tissue crushing.

References:

Jabbour PM, ed., Neurovascular Surgical Techniques, JP Medical Ltd, 2013.
http://www.wisegeek.net/what-are-micro-scissors.htm

Microscissors 101 Exercise

Objective

To become familiar with the cutting of fibres using Microscissors.

Intended User

PGY-1 neurosurgery resident.

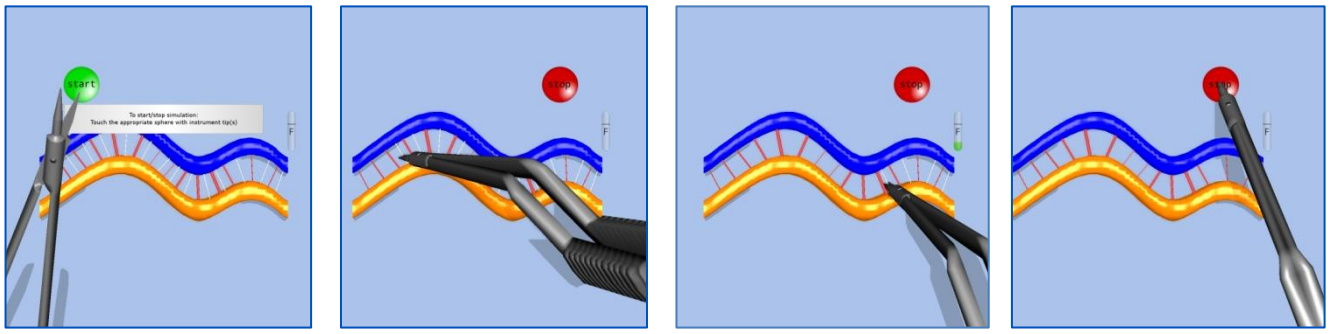
Training Goal

The suggested practice for this exercise is until the trainee can consistently cut fibres with each hand, without error, consecutively three times (once a day over three separate days).

	Performance Metrics
Outcome	▪ Connecting fibres successfully cut
Efficiency	▪ Time to complete the task
Error	▪ Use of excessive force (duration) ▪ Arteries severed

Description

"Microscissors 101" practices cutting fibres between two simple structures representing tissue. The two curved structures, blue and orange, are connected by an alternating pattern of red and white lines. The red "fibres" are blood vessels to be left intact while cutting through all 14 of the general white "fibres". Penalties are assessed for severing a blood vessel, taking too much time and applying excessive force to the surrounding tissue.



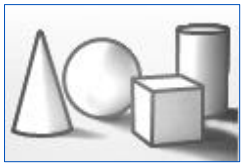
Suggested technique for the exercise:
Avoid undue force by setting the intensity knob as low as possible and experimenting with the approach angle to minimize contact with either the blue or orange tissue. Gently insert the Microscissors tips between the red and white fibres to correctly position the blades for cutting without damaging the arteries.

Performance – Microscissors 101

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Number of white fibres cut (maximum 14)	-	0 14	0 100	100%
Time to complete the task	s	0 30 ≥120	0 0 100	-100%
Excessive force applied to tissue (duration)	s	0 0.5 1 ≥3	0 0 5 100	-50%
Number of arteries (red fibres) cut	-	0 14	0 100	-100%

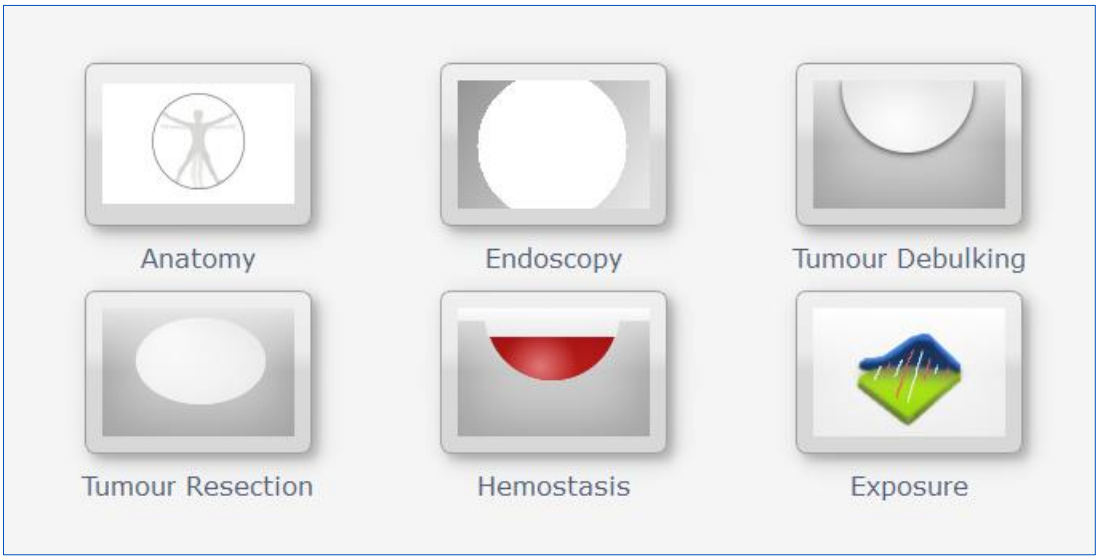
****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Fundamental Skills Module



The Fundamentals of Neurosurgery (FNS) were developed within the NeuroVR project to teach basic and advanced neurosurgical technical skills. The FNS were designed according to the technical skill requirements for graduating residents in neurosurgical oncology (Royal College of Physicians and Surgeons of Canada, Congress of Neurological Surgeons as well as the neurosurgery training programs at McGill University and Yale School of Medicine), summarized in the Appendices (Table 1A). Cognitive task analyses were performed for procedures involving the most commonly occurring brain tumours (glioma, Meningioma and pituitary adenoma) to identify tasks representative of required skills, including aspects of operating either under the microscope or with an endoscope. Examples are provided in the Appendix (Figure 1A-2A).

The FNS tasks were elaborated into complete training modules by integrating learning objectives, instructions, levels of difficulty and performance metrics.



Anatomy – an Introduction to Surface Landmarks and Endoscopic Navigation

For correct performance of any intervention, a thorough understanding of the anatomy involved is essential. The exercises contained in this training module focus on the surface landmarks to perform a freehand Ventriculostomy, as well as learning the nasal and ventricular anatomy encountered during endoscopic procedures.

Surface Landmarks for Ventriculostomy

A Ventriculostomy is commonly performed to relieve buildup or blockage of cerebrospinal fluid (CSF) in the skull, causing hydrocephalus, or to measure intracranial pressure. This is a frequently performed procedure and one of the first that a neurosurgical resident will encounter. It requires the insertion of a small tube (ventricular catheter) into the cortex to drain CSF externally. The drain is flexible and is equipped with a rigid stylet used to guide the drain in a straight line along the chosen path. A frontal Ventriculostomy is most often performed, where a Burr Hole (5 mm) is made 1-2 cm anterior to the coronal suture and approximately 2-3 cm lateral to midline (at mid-pupillary line). Generally, the non-dominant hemisphere of the patient is used. By default, use the right side. The Burr Hole must be drilled at the angle of the planned trajectory of the catheter, else it will hinder the final desired placement. Careful selection of the area ensures that functional areas of the cortex are avoided.

The dura is then opened and the pia is coagulated where the drain is to be inserted. The drain must be inserted perpendicular to the surface and advanced into the brain by approximately 6 cm from the skull's outer table, at which point the ventricular lining is pierced and a resulting "pop" sensation is felt. The target is to place the tip of the drain within the frontal horn, anterior to the foramen of Monro. If the anatomic landmarks are used correctly, this goal will be achieved and CSF will flow out of the drain when the stylet is removed.
The level of difficulty of any Ventriculostomy is related to the size of the ventricles, the presence of a mid-line shift and other anatomical variations. In cases of Hydrocephalus, the ventricles are dilated, making access easier than when tumour blockage causes the ventricles to shrink, almost to slits. Common preventable complications are breaching the medial and lateral limits: the width of a non-dilated frontal horn is only about 1.3 cm. This can result in insertion into the brain only or damage to critical structures such as the insula. The corpus callosum may also be crossed, resulting in insertion into the contralateral ventricle or advancing the catheter too deep and into the brainstem. Finally, crossing a sulcus could encounter a blood vessel, resulting in haemorrhage.

Suggested Reading:

1. Dunn IF, Fierichs K, Day A, Kim DH, Ventriculostomy, in: Schmidek and Sweet's Operative Neurosurgical Techniques: indications, methods and results, 5th edition, WB Saunders, 2006.
2. Epstein ML. Surgical Management of Hydrocephalus, in Schmidek HH, Sweet WH (eds): Operative Neurosurgical Techniques: indications, methods, and results. Philadelphia, W.B Saunders Company, 1988, pp 141-150.
3. Aitken AR. Neuroanatomical and cranial geometry of the frontal horn of the lateral ventricle. J Clin Neurosci 2:329-332, 1995.

Landmarks for Endoscopic Third Ventriculostomy

An alternative treatment for Hydrocephalus is endoscopic third Ventriculostomy (ETV), which creates a new internal pathway for the fluid to escape within the brain cavities (ventricles) without the need for an external drain.

In ETV, a Burr Hole is placed in the same position as for a frontal Ventriculostomy. The peel-away sheath used in the procedure is inserted with the same trajectory as that for the catheter insertion to lead to the foramen of Monro. The Neuroendoscope is inserted and advanced along the ventricular system until the foramen of Monro is seen. Anatomical landmarks are used to identify the foramen borders and to orient the scope. Careful navigation with the scope is required to avoid touching the choroid plexus, to prevent bleeding, as well as the foramen borders, in particular the fornix, because this can lead to short-term memory loss in the patient. When the third ventricle is reached, a perforation site is selected using the anatomical landmarks of the ventricular floor. The first step is to locate the clivus through palpation and then to select the optimal zone directly underneath it and above the mammillary bodies. Once again, numerous critical structures must be identified to correctly select the perforation site and also to avoid contact and potential damage, such as the basilar artery.

Suggested Reading:

Farin et al. Endoscopic third Ventriculostomy. J Clinical Neuroscience 13:763-330, 2006.

Neurosurgical Nasal Anatomy

Accessing the sphenoid ostium is typically the first major step in the endoscopic transnasal approach to resecting a pituitary adenoma. Generally, the task involves holding an endoscope in one hand and a retracting instrument, such as a dissector, in the other. The patient is supine; the head positioned such that the forehead and chin are aligned horizontally. The surgeon is typically positioned perpendicular at the top of the patient's head. The nasal passages have been decongested with epinephrine, allowing access to navigate along the patient's nasal cavities. The endoscope is held in the non-dominant hand and inserted into the nostril. Then, the instrument in the dominant hand is inserted. Because there is no visual cue for insertion, the endoscope shaft is used as a guide to advance the tool tip until it is visualized with the endoscope. Proper bimanual coordination keeps the tool tip in view at all times. Using anatomical landmarks, such as the turbinate, choana and spheno-ethmoid recess, the ostium of the sphenoid sinus is located and visualized.

The level of difficulty for this task is related to the anatomy of the patient: for example, a septal deviation or small nasal passages making the landmarks harder to locate and navigation more difficult. Complications that can occur are bleeding resulting from tools rubbing on the nasal mucosa or perforating the septum, and damage caused by applying force to structures that should normally not be touched, such as the ethmoid sinuses.

Suggested Reading:

1. Cappabianca P, Esposito F, Cavallo LM, Esposito in: Clinical Pearls in Endoscopic Pituitary Surgery: A Neurosurgeon's Perspective. In: Endoscopic Pituitary Surgery: Endocrine, Neuro-Ophthalmologic, and Surgical Management, Thieme, 2012.
2. Cappabianca P, Cavallo LM, Esposito F, de Divitiis E. Endoscopic endonasal transsphenoidal surgery: procedure, endoscopic equipment and instrumentation. Childs Nerv Syst 20:796-801, 2004.
3. Jho HD. Endoscopic transsphenoidal surgery. J Neurooncol 54:187-195, 2001.
4. Bakker NH, Fokkens WJ, Grimbergen CA. Investigation of training needs for functional endoscopic sinus surgery (FESS). Rhinology 43:104-108, 2005.
5. Snyderman C, Kassam A, Carrau R, Mintz A, Gardner P, Prevedello DM. Acquisition of surgical skills for endonasal skull base surgery: a training program. Laryngoscope 117:699-705, 2007.

Burr Hole Selection Exercise

Objectives

1. To identify surface landmarks on head
2. To use landmarks to maintain orientation.
3. To localize ventricular structures.

Intended User

PGY-1 to PGY-2 neurosurgery resident

Training Goal

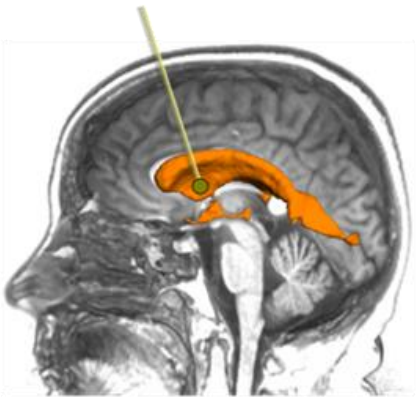
To select the proper location of the Burr Hole on the skull, then choose the insertion angle such that when the catheter is advanced, its tip is in the right ventricle, close to the foramen of Monro. This is to be demonstrated consecutively three times (once per day over three separate days).

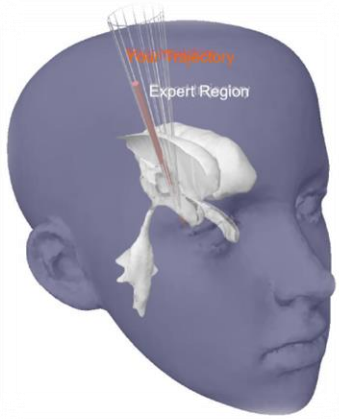
	Performance Metrics
Outcome	▪ Catheter trajectory falls into region that an expert would use (yes/no)
Efficiency	▪ N/A
Error	▪ N/A

Description

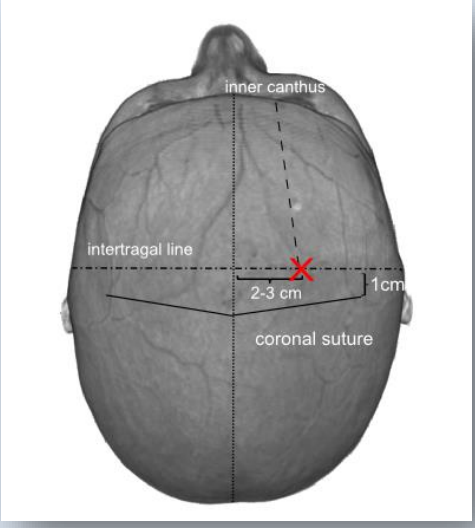
"Burr Hole Selection" serves as an introduction to learning the surface landmarks pertinent to performing a freehand Ventriculostomy. The exercise permits practice in selecting the site of the Burr Hole in order to position a ventricular catheter. To test knowledge of the landmarks, the user is asked to select the location of the Burr Hole. The challenge of this exercise is to properly position the catheter by using the anatomical landmarks of the eyes, nose and ears of the mannequin head. The goal is to choose the correct insertion point and angle such that, when the catheter is advanced, its tip is in the right ventricle, placed anterior to the foramen of Monro.

The interactive simulation is equipped with a mannequin head and a virtual ventricle model. Haptic systems are used to track the selected entry site on the mannequin head and map it to the virtual model. Ending the simulation gives qualitative feedback of performance by comparing the trainee's path versus that of an expert trajectory.





Suggested technique for the exercise:
The mannequin head is aligned as would be in the operating room (supine, at 30 degrees). Typically, the position of the Burr Hole is located by first palpating the skull to discern the coronal suture. However, the coronal suture is not palpable on the provided mannequin. Instead, locate a point 2-3 cm lateral to the midline on the intertragal line (connecting the tragus at each ear). This point corresponds to a proper location for the Burr Hole and catheter entry point. Next, use the inner canthus as an aim to determine how the catheter should be angled.



Performance – Burr Hole Selection

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Selected Burr Hole position relative to ideal position	mm	0 5 7 10 >15	100 100 75 20 0	25%
Catheter tip position relative to target (foramen of Monro)	mm	0 3 16** ≥26	100 100 60 0	75%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

** In a retrospective study of 98 freehand Ventriculostomies, it was defined that a successful outcome of this procedure is obtained when the catheter tip is 1.6 cm from the foramen of Monro (Aitken 1995).

Ventriculostomy Exercise

Objectives

1. To handle the Neuroendoscope with indirect view onscreen
2. To select a proper instrument orientation based on recognition of landmarks
3. To navigate along a suitable path between the Burr Hole and the ventricle

Intended User

PGY-1 to PGY-2 neurosurgery resident

Training Goal

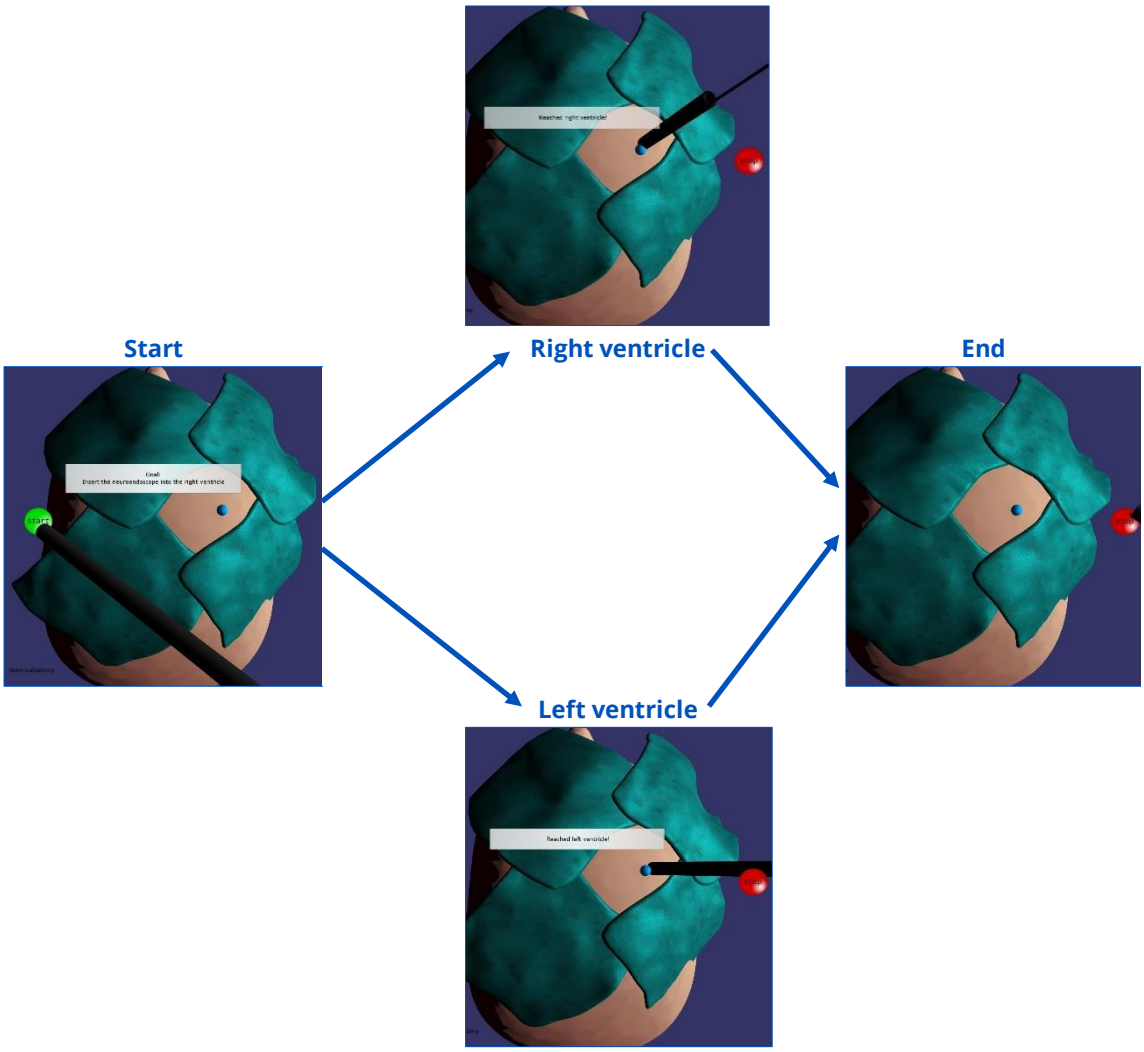
To perforate the right ventricle by carefully moving the drain in the proper orientation while minimizing the path between the Burr Hole and the ventricle. This is to be demonstrated consecutively three times (once per day over three separate days).

	Performance Metrics
Outcome	▪ Ventricle localization (yes/no)
Efficiency	▪ N/A
Error	▪ Excessive brain damage during navigation (volume)

Description

"Ventriculostomy" takes up where the previous exercise left off, thus the Burr Hole location is already selected. The head flap on the mannequin head is removed so that the drilled hole is visible. The challenge is for the user to call upon learned physical cues to correctly orient the Neuroendoscope and reach the right ventricle in a straight path, as divergence from a direct trajectory could result in unnecessary damage to the brain. The exercise is accomplished using solely the external operative view, meaning the user must rely on their memory and judgment of position and angle of orientation.

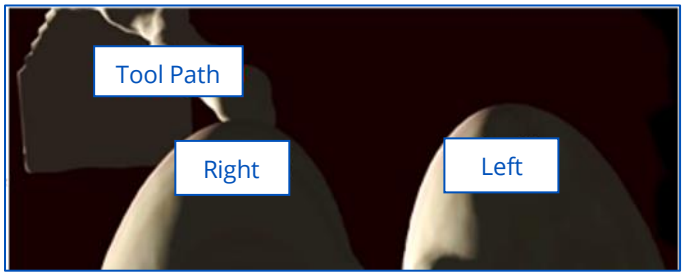
While the Ventriculostomy can be achieved by perforating the left ventricle instead, it is a longer distance for tool navigation and increases the risk of damage to healthy brain tissue. In this exercise, navigating to either ventricle results in full points for the outcome.

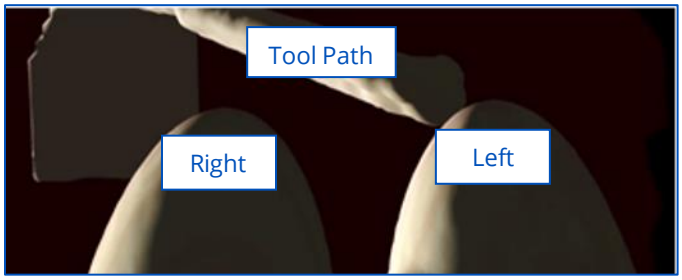


Suggested technique for the exercise:

- Ensure that the Burr Hole location is properly registered prior to the exercise.
- Begin with the Neuroendoscope outside of the head model and the probe retracted.
- Insert the instrument into the existing Burr Hole at a right angle to the skull surface. Use the anatomical landmarks to angle the Neuroendoscope correctly.
- Advance the Neuroendoscope no more than 6 cm, corresponding to the length required to perforate the ventricle.
- If you navigated correctly, the message onscreen will confirm that you reached the ventricle.
- Slight adjustments may succeed; however, repeated attempts to correct will likely result in too much healthy brain being damaged by tool navigation.

After each attempt, the score screen includes a three-dimensional image of the ventricles and the tool path as controlled by the user during the exercise. The following example figures illustrate a relatively smooth approach to the desired ventricle based on external visual cues.





As reflected in the threshold values in the Performance table, the metric for brain damage does allow for a certain amount of tissue to be displaced by normal tool navigation. Excessive damage, resulting in penalties, can reflect too many insertion attempts or navigating too far from the foramen of Monro.

Performance – Ventriculostomy

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Right or left ventricle reached (yes/no)	--	no yes	0 100	100%
Volume of brain damaged	cc	0 0.87-1.2 ≥ 2	100 0 100	-100%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Endoscopic Ventricular Landmarks

Objectives

1. To handle the Neuroendoscope with indirect view onscreen
2. To learn the anatomy of the ventricular system and recognize anatomical landmarks

Intended User

PGY-3 neurosurgery resident or any person desiring to practice endoscopic skills.

Training Goal

Use the Neuroendoscope to navigate into the ventricular system and probe structures to obtain their names.

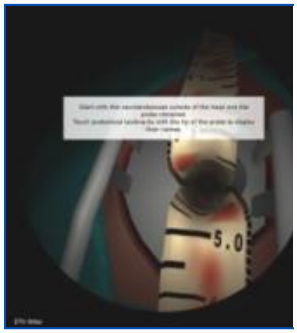
Performance Metrics

none

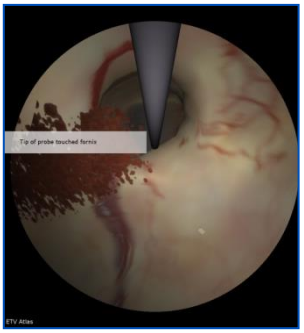
Description

"Endoscopic Ventricular Landmarks" is intended for early users as a fundamental learning exercise to practice navigating the ventricular passages with a Neuroendoscope in one hand, in preparation for conducting the Endoscopic Ventricular Navigation exercise. The scenario involves dilated ventricles with a transparent ventricular floor. The peel-away tube and Burr Hole are already in place.

Once the Neuroendoscope is inserted, landmark labels appear on the screen to indicate which anatomical structure has been contacted by the probe.

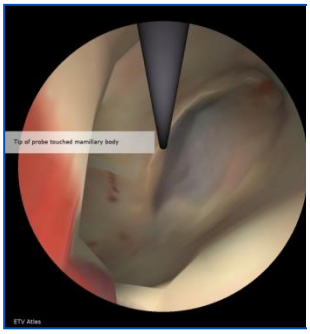


Start



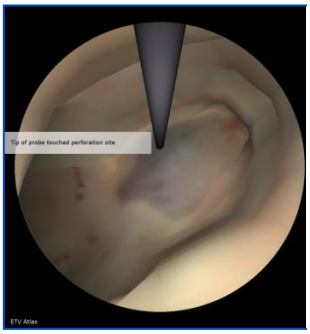
Fornix

Lateral ventricle

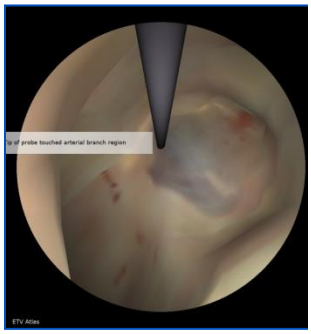


Mammillary body

Basilar region

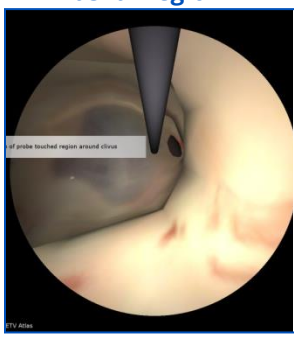


Perforation site

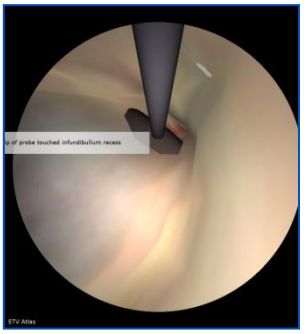


Arterial branch region

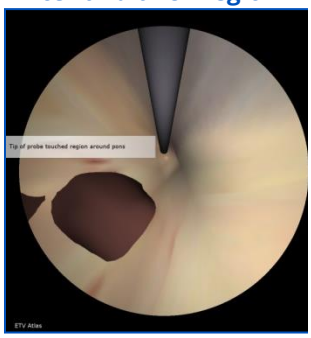
Wall of third ventricle



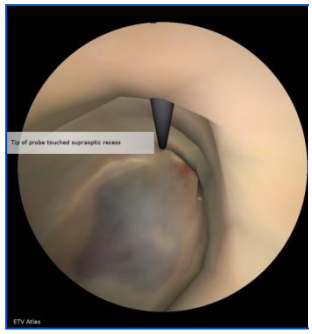
Clivus



Infundibulum recess



Pons



Supraoptic recess

Suggested technique for the exercise:

- Insert the Neuroendoscope into the Burr Hole and rotate the scope handle to correctly orient the view
- Navigate the scope through the peel-away tube and then advance the probe
- Experiment with probe location and scope orientation to display the many landmark labels

Endoscopic Ventricular Test

Objectives

1. To handle the Neuroendoscope with indirect view onscreen
2. To identify the specified anatomical landmark and touch it with the probe
3. To avoid touching other structures

Intended User

PGY-3 neurosurgery resident or any person desiring to practice endoscopic skills.

Training Goal

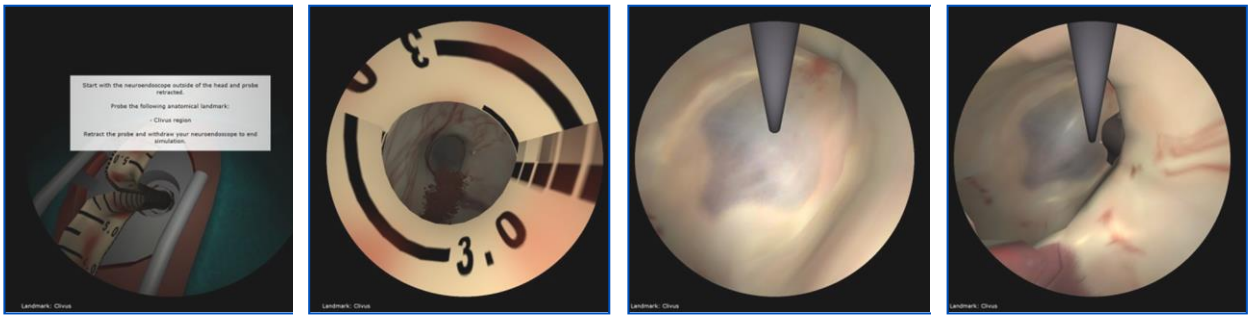
To use a Neuroendoscope to navigate without error along the ventricular system until the target landmark is located. This is to be demonstrated consecutively three times (once per day over three separate days).

	Performance Metrics
Outcome	▪ Landmark localization (yes/no)
Efficiency	▪ N/A
Error	▪ Contact with tissue or critical structure during navigation in ventricular system (yes/no)

Description

"Endoscopic Ventricular Test" permits practice of navigating the ventricular system with a Neuroendoscope in one hand. The main challenges are learning the unfamiliar anatomy and maintaining spatial orientation to recognize both the anatomy and location of the instrument.

The exercise involves dilated ventricles with a transparent ventricular floor. The peel-away tube and Burr Hole are already in place. Currently, the target landmark is fixed as the clivus, although future versions will randomly assign the desired anatomical structure. Performance hinges on correctly navigating to the target landmark without touching and potentially damaging other anatomical structures. Inadvertent contact with even one critical structure can negate the points gained from probing the desired landmark.



Suggested technique for the exercise:

- Begin with the Neuroendoscope outside of the head model and the probe retracted. Insert the instrument into the existing Burr Hole and rotate the handle to correctly orient the view.
- Identify the foramen of Monro and direct the scope to it, taking care not to contact the surrounding structures
- Advance the probe through the Neuroendoscope with your free hand and carefully direct it to the target landmark (currently fixed as the clivus). Use care so as not to contact the other anatomical structures in the vicinity.
- When you have held the probe steady in the desired region, retract the probe and gently withdraw the Neuroendoscope from the mannequin head to view your score

Performance – Endoscopic Ventricular Test

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Target landmark (clivus) reached?	-	yes no	100 0	100%
Perforated critical structure (hypothalamus, perforator/ arterial branch, ventricle wall, basilar artery, mammillary bodies, or pons)?	-	yes no	100 0	-100% for each structure perforated

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Endoscopic Nasal Navigation Exercise

Objectives

1. To handle an endoscope with indirect view onscreen
2. To learn the anatomy and recognize nasal anatomical landmarks
3. To locate the sphenoid ostium

Intended User

PGY-3 neurosurgery resident or any person desiring to practice endoscopic skills.

Training Goal

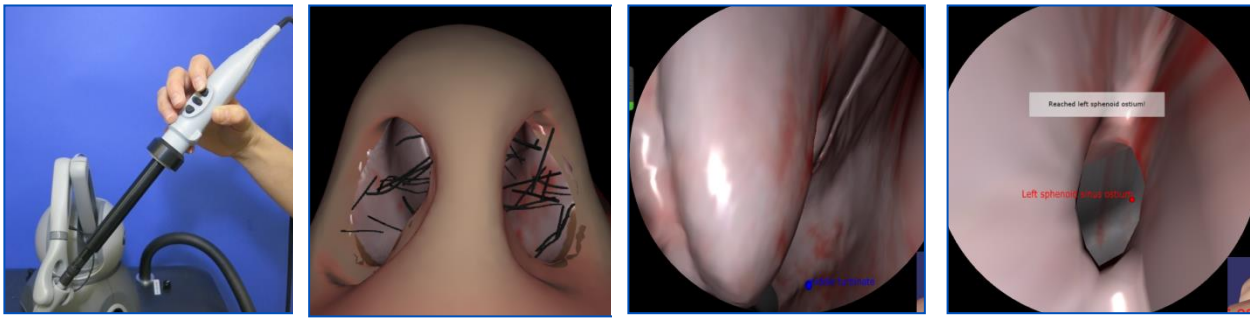
To use an endoscope to navigate without error along the nasal cavity until the ostium of the sphenoid sinus is located. This is to be demonstrated consecutively three times (once per day over three separate days).

	Performance Metrics
Outcome	▪ Sphenoid ostium localization (yes/no)
Efficiency	▪ Time to complete the task
Error	▪ Use of excessive force (duration)

Description

"Endoscopic Nasal Navigation" permits practice of navigating the nasal passages with an endoscope in one hand. Like the ventricular navigation exercises, the main challenges are learning the unfamiliar anatomy and maintaining spatial orientation to recognize both the anatomy and location of the instrument. The goal of the exercise is to locate and identify the sphenoid ostium. This task was selected because it integrates endoscopic challenges and permits the user to become familiar with the major anatomical landmarks in the approach to the sphenoid ostia.

The training exercise consists of inserting the endoscope and advancing it along the nasal cavity. Navigation of the endoscope can take place in either nostril of the simulated nose with each ostium as targets. Interactive models of the nasal cavities are used, complete with the required landmarks and anatomic labels for the inferior, middle and superior turbinates, as well as the nasal septum. To practice proper scope handling, the user is required to manoeuvre through the narrow surgical corridors of the nose. The virtual endoscope view can become blurred when in contact with tissue or become covered with blood if applied forcefully on tissue. As such, the user can practice keeping the view clear by using the pedal to rinse the lens. Errors include improper tool handling or using too much force. Performance is optimal when the ostium is located with efficient handling of the endoscope without error. The simulation automatically captures a successful outcome if the user is able to locate the ostium and hold it in the centre of the virtual endoscopic view.



Blurred view **Blood on lens** **Rinse** **Clean Lens**

Suggested technique for the exercise:

- Insert the endoscope into the nostril at approximately 25 degrees cephalad. Rotate the scope handle to correctly orient the view
- Locate the inferior turbinate and advance the scope until the choana can be seen
- At this point the endoscope should be angled up (~35°, approximately 1.5 cm) until the spheno-ethmoid recess is located
- Retract the middle turbinate such that the endoscope can be advanced until the ostium of the sphenoid sinus is seen. Generally, a dissector is used; however, the simulation is presently only available as a one-handed exercise. Thus, use the endoscope itself as a retractor by advancing the endoscope gently through the passage between the middle turbinate and the nasal septum.
- Localize and hold the ostium at the centre of the endoscopic view

Performance – Endoscopic Nasal Navigation

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Right sphenoid ostium localization	-	yes no	100 0	50%
Left sphenoid ostium localization	-	yes no	100 0	50%
Time to complete the task	s	0 180 ≥380	0 0 100	-100%
Excessive force applied to tissue (duration)	s	0 1 ≥4	0 0 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Bimanual Endoscopy – an Introduction to Minimally Invasive Techniques

The shift towards endoscopic approaches to the skull base has increased the need for new training methods, akin to the introduction of laparoscopy as an alternative to open surgery for cholecystectomies. Endoscopic procedures require the use of different optics and instruments compared to procedures performed under the operating room microscope. The traditional microsurgery tools are adapted to be longer because they are used in long, narrow surgical corridors such as the nostril or through a cannula inserted into the brain, consequently changing the ergonomics.

Rather than the stereoscopic view of the operating field from the microscope in open craniotomies, the endoscopic view is indirectly displayed in 2D onscreen. The surgeon must form a 3D mental map from a 2D view to maintain orientation of the endoscope, adapting to the loss of depth perception and using other cues as guides.

Nasal Debridement Exercise

Objectives

1. To practice using the microdebrider in coordination with the endoscope
2. To remove soft polyps using a microdebrider

Intended User

PGY-1 ENT residents or any person desiring to practice endoscopic skills.

Training Goal

To use an endoscope to navigate without error along a narrow corridor until a polyp is located. Use microdebrider to remove polyp without damaging any other structure. Repeat until all polyps have been cleared away. This is to be demonstrated consecutively three times (once per day over three separate days).

Performance Metrics

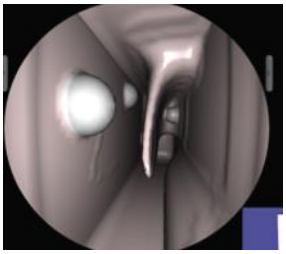
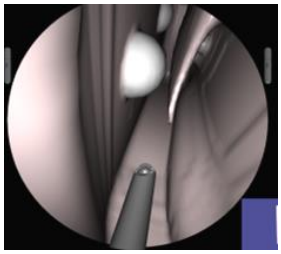
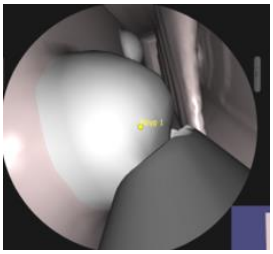
Outcome	▪ % polyps removed
Efficiency	▪ N/A

Error	▪ Damage to mucosa
	  ○ Use of excessive force (duration)
	  ○ Removal of mucosa
	▪ Use of excessive force on polyps (duration)

Description

"Nasal Debridement" permits familiarization of one of the most commonly used instruments in ESS, the microdebrider. The main challenge is using the microdebrider in coordination with the endoscope. The goal of the exercise is to locate the polyps in a nasal-like passage and to remove them carefully with the microdebrider. This task was selected because it provides a relatively simple geometry to permit the user to focus on practicing the bimanual technique of debridement.

The training exercise consists of inserting the endoscope and then to bring the microdebrider tool tip into view. Both instruments are then to be advanced along the corridors. To practice proper bimanual scope handling, the user is required to manoeuvre throughout the entire geometry to locate each of the polyps while keeping the microdebrider in view. Once a polyp is located, the user must properly position the microdebrider tool tip before resecting the polyp. The microdebrider tool tip can be rotated using the knob on the physical tool handle and is activated via a foot pedal. Proper microdebrider alignment will avoid inadvertent damage to the underlying mucosa. Errors in the exercise are related to damage to mucosa which can be caused either by applying too much force with the surgical instrument or its removal with the microdebrider.

Suggested technique for the exercise:

- Perform the procedure with the microdebrider in the dominant hand and the endoscope in the other hand
- Hold the endoscope like a pen and bring the instrument to the right nostril using the small view in the bottom corner of the screen (picture in picture view)
- Insert the endoscope against the topmost portion of the nostril and use this surface as a guide to steadily introduce the scope
- Introduce the microdebrider on the right side or inferior to the scope
- Advance the microdebrider parallel to the endoscope using the shaft of the scope as a guide
- Keep the microdebrider tip in view at all times to avoid inadvertent damage to structures
- Once a polyp is visible, bring microdebrider tool tip in proximity
- Rotate tool tip such that polyp is aspirated into its opening and back side (atraumatic) is facing away from the normal lining of the nasal cavity
- Activate microdebrider via foot pedal
- To minimize damage to mucosa, choose to draw tissue into the microdebrider using suction rather than pushing the instrument towards the tissue. Continue debriding polyp until it has been completely removed.
- Repeat for remaining polyps

Performance – Nasal Debridement

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
% of polyps removed	%	0 75 80 90 98 100	0 50 75 85 95 100	100%
% of mucosa removed	%	0 10 20 60 80 100	0 40 60 80 90 100	-50%
Excessive force applied to mucosa (duration)	s	0 1 10 ≥20	0 0 50 100	-50%
Excessive force applied to polyps (duration)	s	0 1 10 ≥20	0 0 50 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Tumour Debulking – an Introduction to Meningioma Debulking

Debulking is a common microsurgical technique used in tumour resection where the inside of the tumour is cored out, leaving only the outer capsule. The major goal of debulking is to decrease the amount of pressure that the tumour is putting on the subarachnoid space. This step is usually done *a priori* to tumour dissection from healthy tissue because the resulting void creates an operating space where tumour tissue can be safely retracted, facilitating the separation of the tumour without damaging the pial surface of the brain.

Debulking begins once the craniotomy has been performed, the dura opened and the Meningioma has been sharply incised. The dura can be left attached to the tumour and used as a retractor. Meningiomas are typically stiff tumours and therefore often require the ultrasonic aspirator for debulking, generally in the surgeon's dominant hand. The tumour is grasped and the ultrasonic aspirator placed inside the tumour via the incision to core out the tumour. The ultrasonic aspirator vibration and suction pressure are adjusted to be strong enough to remove the tumour, but not so strong that the tissue cannot be removed in a controlled manner. Debulking is carried out until an approximately 5-mm margin tumour-tissue interface is reached. This region is the "capsule" of a Meningioma. It is often discerned from visual cues because the capsule looks different and is typically softer than the tumour. As tumour tissue is removed, suction is used at medium power (~0.2 atm) to keep the operating field clear of blood.

The level of difficulty is related to the level of familiarity with the instruments as well as the anatomy at hand. As such, this task first requires that the user become comfortable with each tool and coordinating them bimanually prior to moving on to debulking a Meningioma in a procedure. A major error is injury to healthy brain, which can occur by debulking straight through the capsule by breaching the margins, using improper settings on the ultrasonic aspirator or using too much force when retracting or grasping.

Suggested Reading:

1. Maxwell R, Chou S. Convexity Meningiomas and general principles of Meningioma surgery. In: Schmidek H, Sweet W, eds. Operative Neurosurgical Techniques, Indications and Methods. Philadelphia: W.B. Saunders Company, 1988:555-562.
2. Steinmetz MP, Krishnaney A, Lee JH. Surgical Management of Convexity Meningiomas. In: Neuro-Oncology, Badie, ed. New York: Thieme, 2006:145-152.

Debulking 101-104 Exercises

Objectives

1. To learn the Meningioma debulking technique
2. To handle the ultrasonic aspirator and suction in coordination
3. To discriminate tumour from healthy brain using visual and tactile cues
4. To perform microsurgery under stereoscopic view

Intended User

PGY-3 to senior neurosurgery resident.

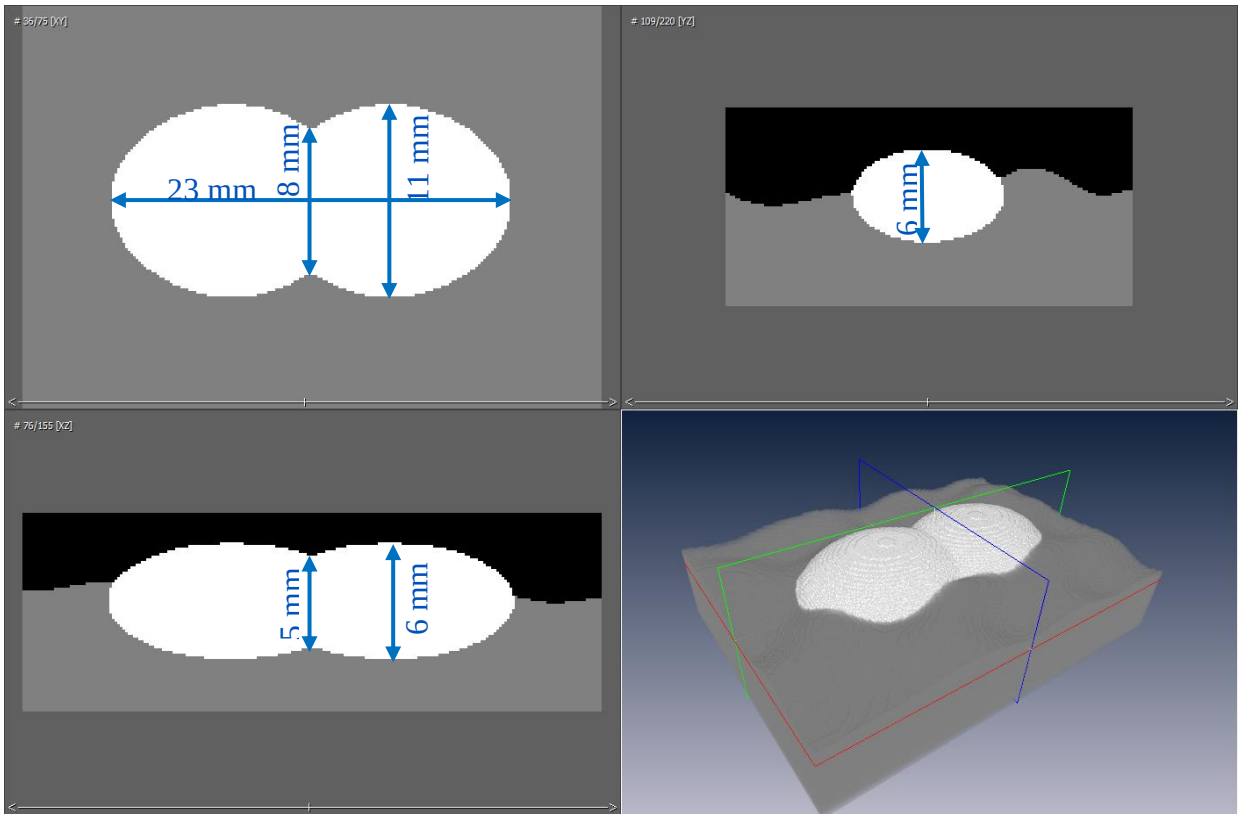
Training Goal

Using the ultrasonic aspirator, target a gross total resection of stiff tumour without error. This is to be demonstrated consecutively three times (once per day over three separate days).

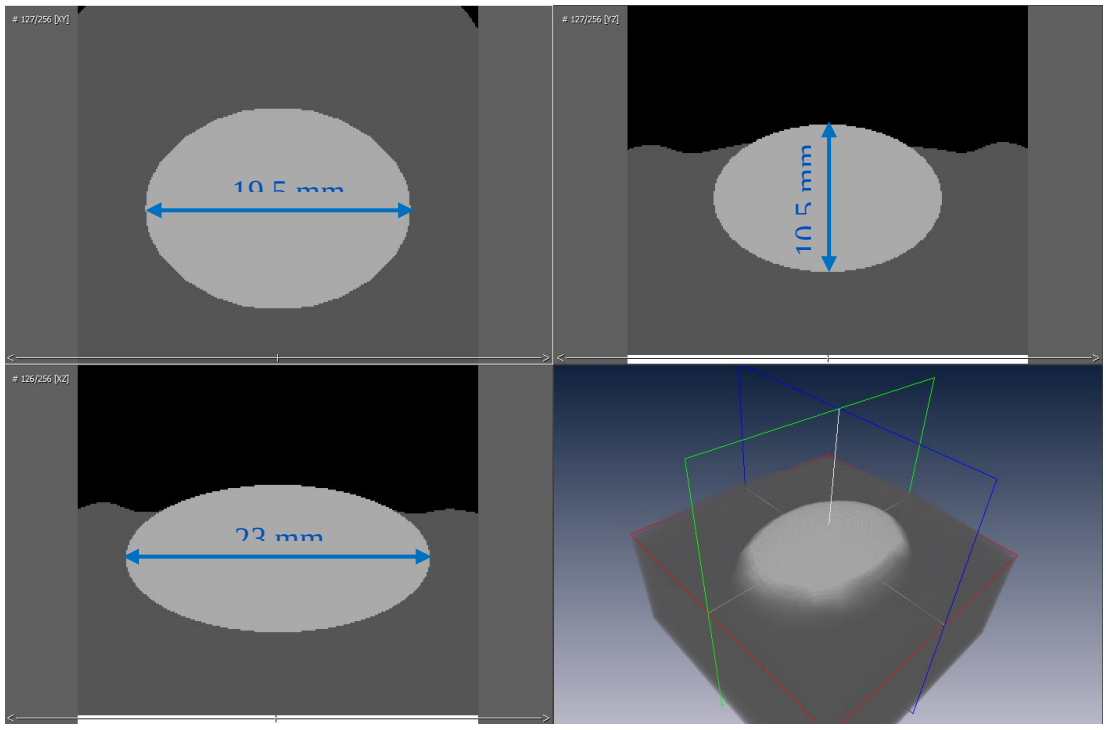
Performance Metrics

Outcome	▪ % tumour resection
Efficiency	▪ N/A
Error	▪ Removal of healthy tissue ▪ Use of excessive force (duration) ▪ Volume of blood remaining in surgical field ▪ Total blood loss ▪ Hemostasis achieved (yes/no)

Debulking 101: Removal of Meningioma-like Inclusion (Easy to Access)



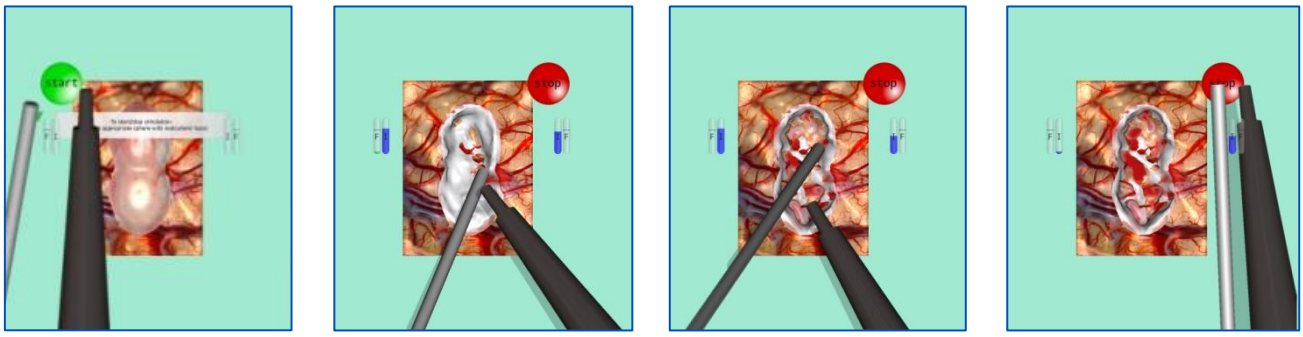
Debulking 102: Removal of Meningioma-like Tumour (Difficult to Access)



Description

"Debulking 101" is a task to practice using surgical aspirators, as well as to practice bimanual coordination of tools under the operating microscope. In the Debulking 101, 102 and 103 exercises, the simulated tumours do not have capsules. Rather, the user is instructed to debulk a Meningioma-like inclusion until the underlying healthy brain tissue is reached. As tissue is removed, suction is used to clear the operating field of blood. The inclusion is discerned from healthy tissue by its colour and by how it feels (stiffer than brain). Errors include injury to or removal of healthy brain, which can occur by debulking into healthy brain, using improper settings on the ultrasonic aspirator or using too much force when retracting. A proficient level in skill is achieved when a maximum of tumour is removed efficiently without damage to healthy brain.

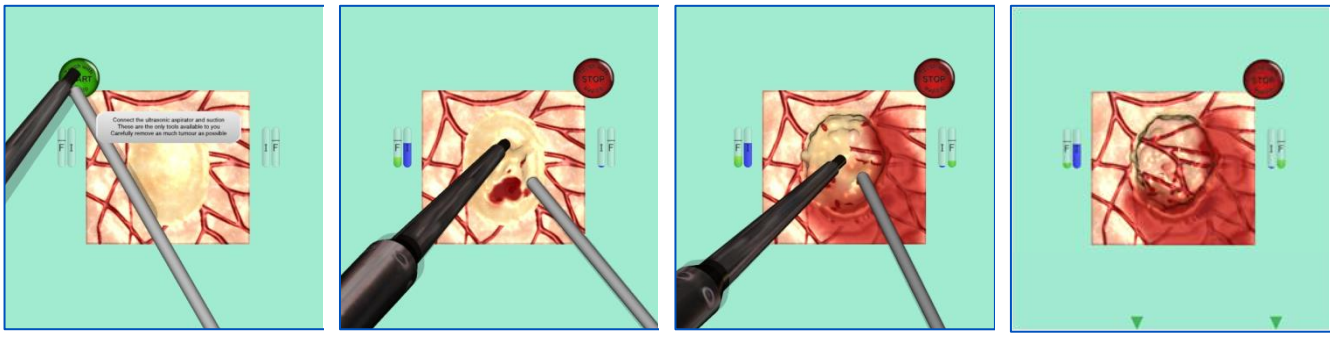
The training requires the use of both hands. The simulator is equipped with a realistic handle allowing the suction to be turned on/off via a thumb switch in the handle. The ultrasonic aspirator is activated via a foot pedal and its power can be adjusted. The module includes performance metrics of the percentage of tumour resected with penalty if any healthy tissue is removed or if any excessive force was applied on tissue. Feedback on the management of bleeding is also provided.



Suggested technique for the exercise:

- As practiced in the "Ultrasonic Aspirator" exercise, start with a relatively high aspiration power in the centre of the tumour, moving towards the margins.
- Typically, the tumour is debulked until approximately a 5-mm margin of tumour (i.e., the capsule) is left at the tumour-tissue interface. For this exercise, the simulated tumour does not have a capsule. Instead, debulk until the healthy underlying cortex is first seen.
- Then, decrease power to proceed at a slower pace to avoid injury to surrounding healthy tissue.
- To avoid accidental removal of healthy brain, the tissue to be removed must be clearly visualized. Use suction constantly to keep the view clear of blood and gently retract tissue at the interface if needed.

"Debulking 102" requires debulking a Meningioma-like inclusion as in the previous exercise but with the added difficulty that the tumour is difficult to visualize in its entirety.

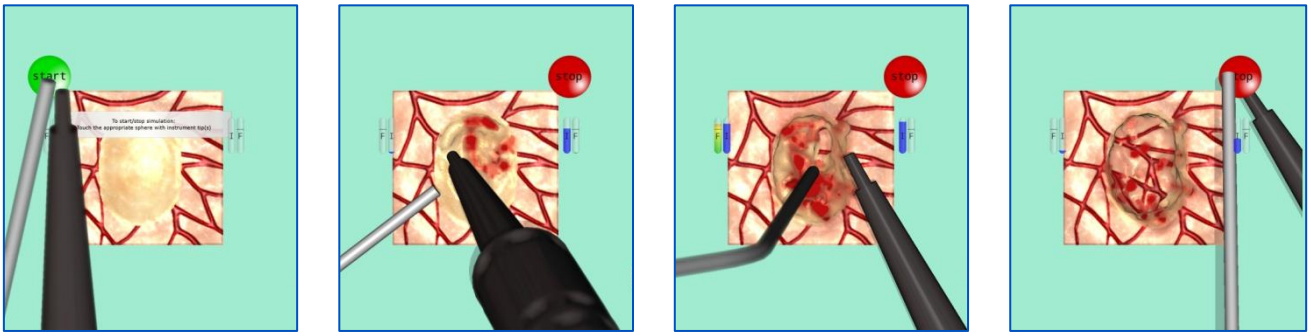


Suggested technique for the exercise:
The suggestions for this exercise are the same as for Debulking 101 with additionally:

- Use retraction in combination with the microscope (rotation and zoom) to clearly visualise the tissue to be removed
- The increased difficulty in accessing the tumour necessitates good use of suction to keep the field clear of blood

"Debulking 103"

Builds on the Debulking 102 Exercise in that the tumour stiffness is inhomogeneous.



Suggested technique for the exercise:
The suggestions for this exercise are the same as for Debulking 101 and 102 with additionally:

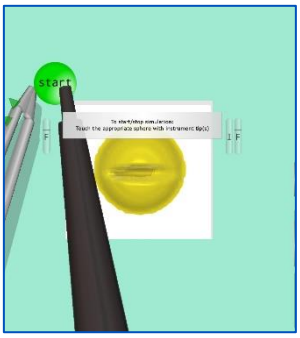
- Carefully adjust the intensity level of the instruments, especially the ultrasonic aspirator, according to the localized stiffness of the tumour and efficiently remove it without exerting undue force

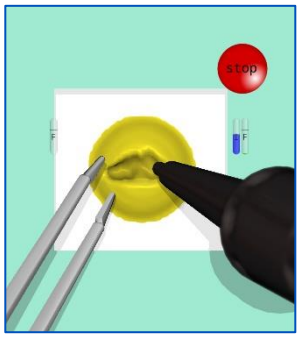
Performance – Debulking 101, 102, and 103

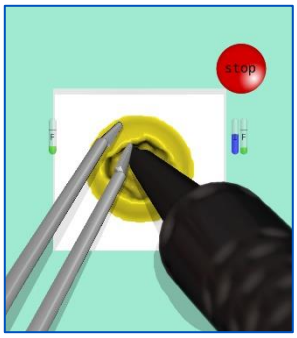
Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 50 80 90 98 100	0 50 75 85 95 100	100%
Volume of healthy brain removed	cc	0 0.09 0.2 0.5 ≥1	0 0 20 45 100	-100%
Excessive force applied to brain (duration)	s	0 1 ≥10	0 0 100	-50% for each hand
Excessive force applied to tumour (duration)	s	0 1 ≥10	0 0 100	-10% for each hand
Volume of blood remaining in operative field	cc	0 0.01 0.15 ≥0.5	0 0 50 100	-50%
Total blood loss (Debulking 101 only)	cc	0 1 ≥3	0 0 100	-50%

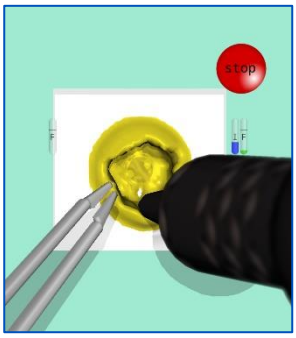
The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

"Debulking 104" requires the simultaneous use of the ultrasonic aspirator and bipolar in order to debulk a tumour inside a capsule. The exercise starts with the capsule incision already made.









Suggested technique for the exercise:

In addition to the techniques developed in the previous three exercises:

- Use both tools to carefully retract the capsule and remove tumour
- Do not feel constrained to preserve capsule material at the expense of a better view of the tumour; the objective is tumour removal. A reasonable amount of capsule may be removed without penalty
- When debulking the tumour, be aware of the force being exerted on the tumour as well as white material. Adjust the instrument intensity accordingly.

Performance – Debulking 104

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 100	0 100	100%
Volume of white material removed	cc	0 ≥0.01	0 100	-100%
Volume of capsule removed	cc	0 0.09 ≥0.37	0 0 100	-50%
Excessive force applied to white material (duration)	s	0 1 ≥4	0 0 100	-50% for each hand
Excessive force applied to tumour (duration)	s	0 1 ≥5	0 0 100	-10% for each hand
Excessive force applied to capsule (duration)	s	0 1 ≥5	0 0 100	-10% for each hand

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Tumour Resection – an Introduction to Soft Tumour Resection

Soft tumours such as gliomas are often resected using suction. Gliomas are typically highly vascular, soft tumours with non-distinct tumour-brain interfaces which make them challenging to remove. Typically, much of the procedure is carried out with suction in one hand and Bipolar forceps in the other. Tissue colour and feel are used as surgical cues to distinguish tumour tissue from healthy brain. However, such tumours are often difficult to discern and as such, intraoperative navigation can be used. This is especially the case for gliomas that are infiltrative or low grade (malignant cells have not significantly changed).

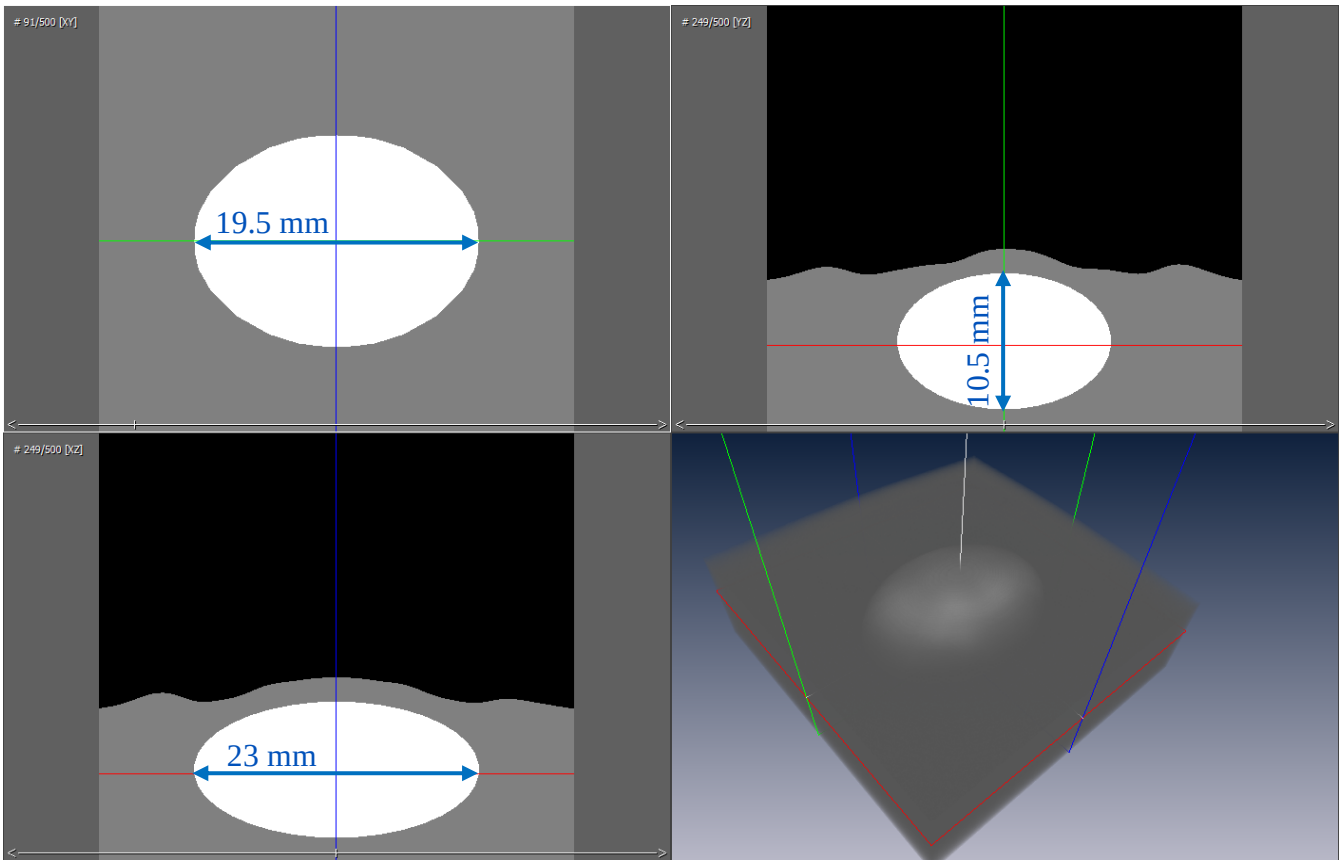
Resection begins once the tumour is exposed. Generally, an incision is made in the cortex to gain access to the tumour, which is removed via microsurgical techniques. These techniques permit a small and direct approach to the tumour with the preservation of structures. The location of the underlying tumour dictates the microsurgical technique to be employed:

1. Through the crown of the gyrus (subcortical tumour)
2. Transsulcal / transsulcal to side of gyrus (subcortical tumour)
3. Long narrow white matter tunnel (subgyral tumour)
4. Transfissural (e.g., near Sylvian fissure)

Suggested Reading:

1. Salcman M, Kempe LG, Heros RC. Hemispheric Gliomas. In: Kempe's Operative Neurosurgery. Vol 1, 2nd ed. New York: Springer-Verlag, 2004.
2. Pia HW, Microsurgery of gliomas. Acta Neurochirurgica 80:1-11, 1986.

Resection 101-102: Removal of Ellipse within Cube, Retraction Required, without Bleeding (101) and with Bleeding (102)



Resection 101-102 Exercises

The exercises in this module focus on the resection of hemispheric glioma-like inclusions to be accessed via the first of the microsurgical techniques:

1. Through the crown of the gyrus
2. Long narrow white matter tunnel for deep subcortical tumour
3. Transsulcal / transsulcal to side of gyrus
4. Transfissural

Objectives

1. To coordinate handling of the Bipolar forceps and suction simultaneously
2. To discriminate tumour from healthy brain using visual and tactile cues in glioma resection
3. To locate and manage bleeding vessels with bipolar forceps
4. To perform microsurgery under stereoscopic view

Intended User

PGY-3 to senior neurosurgery resident.

Training Goal

Remove as much of the soft tumour as possible without error. This is to be demonstrated consecutively three times (once per day over three separate days).

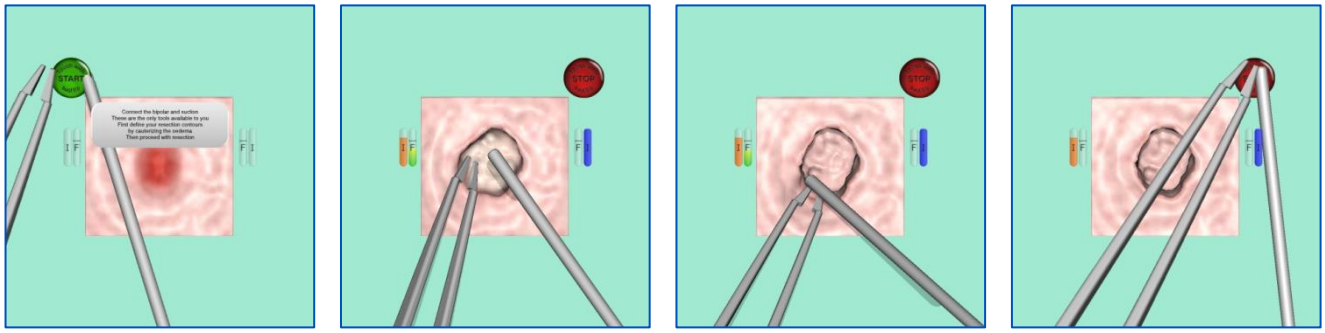
Performance Metrics

Outcome	▪ % tumour resection
Efficiency	▪ Total blood loss (if bleeding is present)
Error	▪ Removal of healthy tissue ▪ Use of excessive force (duration) ▪ Hemostasis achieved if bleeding is present (yes/no)

Description

"Resection 101" was designed to practice simultaneous use of the Bipolar forceps and suction under the operating microscope to access a hemispheric glioma-like inclusion. The basic task is to use the suction tool to first expose the underlying tumour and then to remove it. This scenario does not have any active bleeding to focus on discerning tumour from healthy tissue and practising tissue retraction with the tool shaft.

The training task begins with the exposed surface of the brain in the operating view. The location of the glioma is delineated by an abnormal region at the surface directly above it. The user is instructed to remove this region of brain using suction at its maximum aspiration power. The glioma is discriminated from healthy tissue based on colour and that it feels softer to the touch. Errors include injury to healthy brain when too much force is applied when retracting. A proficient level in skill is achieved when a maximum of tumour is removed efficiently without damage to healthy brain.



Suggested technique for the exercise:

- Place the bipolar in your dominant hand and suction tool in the other
- Use the abnormal region at the surface of the tissue as the margins for your corticectomy
- Remove abnormal tissue using suction at high aspiration, slowly creating a cavity as the abnormal tissue is removed
- Once the abnormal region is removed, begin resecting the tumour that has been exposed (whitish hue). Begin at tumour centre.
- Should any tissue prove difficult to access, use your bipolar tool shaft to gently retract tissue
- Be mindful not to apply too much force. If tissue remains difficult to access despite the use of retraction, use the zoom and rotation settings of the microscope for optimal operative view throughout
- This sequence is continued until the entire tumour is removed beginning from its centre to its margins

Performance – Resection 101

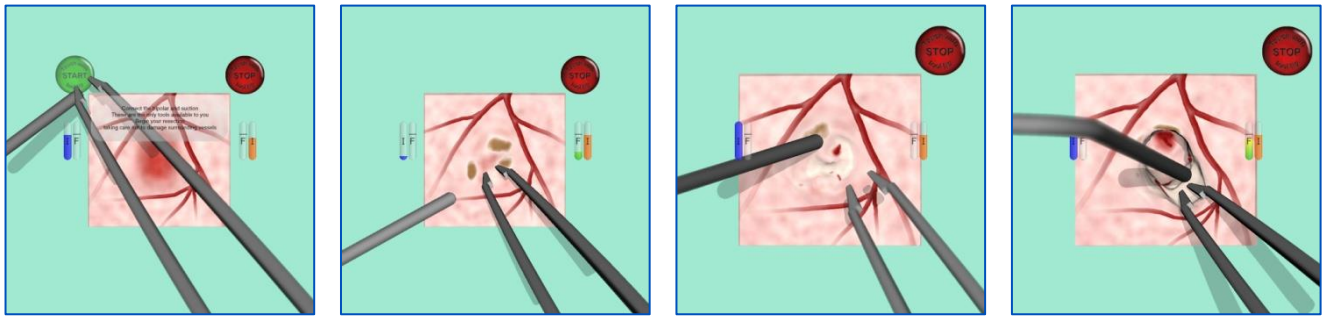
Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 50 80 90 ≥98	0 50 75 85 100	100%
Volume of healthy brain removed	cc	0 0.15 ≥0.65	0 0 100	-100%
Excessive force applied to brain (duration)	s	0 4 ≥14	0 0 100	-50%
Excessive force applied to tumour (duration)	s	0 4 ≥14	0 0 100	-10%

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

"Resection 102" practices resection of a glioma-like inclusion as in the previous exercise with the added difficulty that bleeding is present. As such, practice using the suction tool for three functions:

1) remove tissue
2) use tool shaft as a retractor
3) clear the view of blood

Any bleeding is stopped by coagulating the site with Bipolar forceps at the low-medium setting. Suction at a minimum power is used to aspirate blood to keep the field of view clear. A proficient level in skill is achieved when a maximum of tumour is removed efficiently without damage to healthy brain while managing all bleeding sites.



Suggested technique for the exercise:

The suggestions for this exercise are the same as the previous with additionally:

- Begin by cauterising the surface oedema to avoid excessive bleeding at the start
- Any bleeding is managed by using suction at low aspiration to remove blood and reveal the bleeding source
- Cauterise the blood vessel using the bipolar forceps. Ensure that a low power setting is used

Performance – Resection 102

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 50 80 90 ≥98	0 50 75 85 100	100%
Volume of healthy brain removed	cc	0 0.15 ≥0.65	0 0 100	-100%
Excessive force applied to brain (duration)	s	0 4 ≥14	0 0 100	-50%
Excessive force applied to tumour (duration)	s	0 4 ≥14	0 0 100	-10%
Total blood loss	cc	0 0.3 ≥0.6	0 0 100	-100%
Hemostasis achieved	-	yes no	0 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Hemostasis – an Introduction to Bleeding Management with Suction and the Bipolar

Achieving hemostasis is essential to any surgical procedure. If not dealt with promptly, bleeding can accumulate at rapid rates and completely flood the operating space. When the surgical field is obscured, it is no longer safe to continue operating until the blood has been cleared and the bleeding site located and coagulated. As such, the surgeon is continually aiming to manage bleeding with every surgical step taken.

There are a number of ways to control bleeding:

1. Bipolar forceps to cauterise and seal bleeding site
2. Suction to aspirate the blood
3. Cotton patties to absorb blood or to safely apply pressure with an instrument tip onto the bleeding site to stop bleeding
4. Vascular clip application
5. Suture to close a blood vessel opening
6. Packing the bleeding site with a hemostatic agent such as Surgicel or Gelfoam
7. Flush the site with saline until bleeding eventually comes to a stop on its own

The technique used depends on the location of the bleeding site and the degree of bleeding at hand.

Suggested Reading:

1. Yasargil M. Instrumentation and Equipment, in: Microneurosurgery of CNS tumours IVB. Stuttgart, George Thieme Verlag, 1996.

Bleeding Source 101-103 Exercises

These exercises practice the first two of the seven techniques in bleeding management:

1. Bipolar forceps to cauterise and seal bleeding site
2. Suction to aspirate the blood
3. Cotton patties to absorb blood or to safely apply pressure with an instrument tip onto the bleeding site to stop bleeding
4. Vascular clip application
5. Suture closed a blood vessel opening
6. Packing the bleeding site with a hemostatic agent such as Surgicel or Gelfoam
7. Flushing the site with saline until bleeding eventually comes to a stop on its own

Objectives

1. To cauterise a bleeding site with the bipolar forceps
2. To learn the bimanual hemostasis technique with suction
3. To recognize bleeding points
4. To perform microsurgery under stereoscopic view

Intended User

PGY-3 neurosurgery resident

Training Goal

To use suction to clear away blood until bleeding site is exposed and the Bipolar forceps to coagulate until it can be executed without error. This is to be demonstrated consecutively three times (once per day over three separate days).

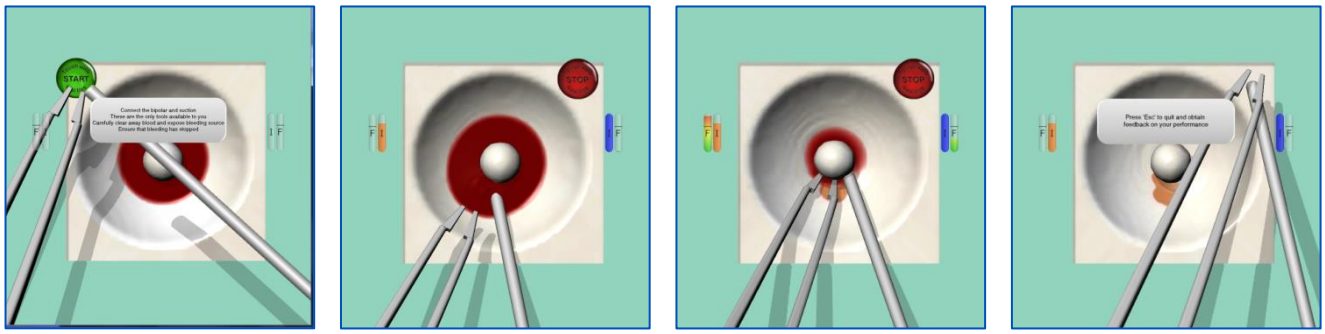
	Performance Metrics
Outcome	▪ Hemostasis achieved (yes/no)
Efficiency	▪ Total blood loss
Error	▪ Blood remaining in surgical field ▪ Use of excessive force (duration) ▪ Removal of healthy tissue ▪ Burning healthy tissue

Description

"Bleeding Source 101" was defined to practice hemostasis with the Bipolar forceps and suction. The challenges are to locate the bleeding site, to keep the view clear of blood and stop the bleeding. Mastery of proper technique is required when coagulating. The forceps must be gently applied over the bleeding site rather than pinching forcefully on the blood vessel.

The training module was designed to practice cauterisation of blood vessels as well as to train the bimanual coordination required. First, suction is used to aspirate blood to reveal the bleeding site and maintain a clear field of view. Then, the Bipolar forceps are used to stop the bleeding. A bleeding site is sealed only if proper technique is used. This must be repeated until all bleeding has been dealt with for a successful outcome. Potential errors include removal of healthy tissue (sphere), over-cauterisation and excessive blood loss occurring when too much time is taken to successfully stop the bleeding.

Performance metrics include whether the bleeding has successfully been stopped, as well as tracking the volume of blood remaining and total blood loss. Feedback on errors includes any healthy tissue removed and the time spent in the excessive force zone.



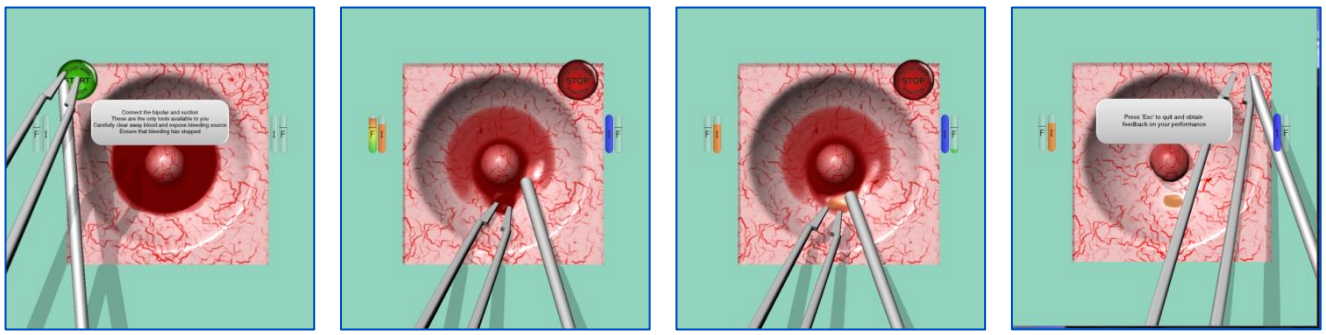
Suggested technique for the exercise:
Use suction to decrease the level of blood present, adjusting the aspiration either at the source with the power knob or at your thumb. Use care to avoid touching any of the soft spherical "tissue" at the centre of the operating field. Continue clearing the blood until the bleeding source is located. Coagulate precisely to seal the source. Clear away the remainder of blood and make sure that the bleeding has stopped prior to ending the exercise. To check that the bleeding has stopped, use your inactivated suction tool as a retractor to check around the sphere. Finally, wait a moment to check for any signs of blood accumulating.

Performance – Bleeding Source 101

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Hemostasis achieved	-	yes no	100 0	100%
Volume of healthy tissue (sphere) removed	cc	0 ≥0.12	0 100	-100%
Excessive force applied to bowl (duration)	s	0 7 ≥20	0 0 100	-50%
Excessive force applied to sphere (duration)	s	0 7 ≥20	0 0 100	-50%
Total blood loss	cc	0 0.15 ≥1	0 0 100	-50%
Volume of blood remaining in operative field	cc	0 0.05 ≥0.1	0 0 100	-100%
Surface of tissue substantially over-cauterised	mm^2	0 ≥20	0 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

"Bleeding Source 102" practices hemostasis with the bipolar and suction as in the previous exercise, but with the added difficulty that the bleeding site is difficult to discern. As such, the blood must be meticulously cleared away to uncover it.



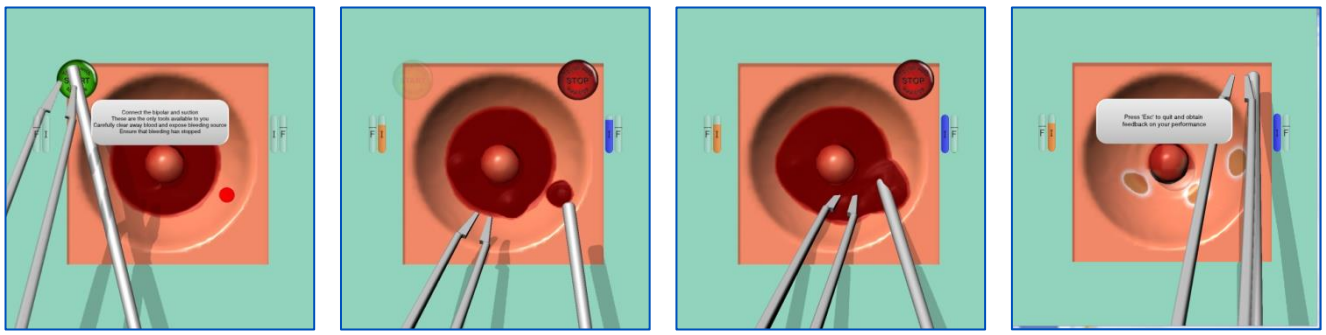
Suggested technique for the exercise:
The technique is the same as that of the exercise above with the added challenge that penalties are applied for erroneous cauterisation. Make sure that a given vessel is actually bleeding prior to cauterising.

Performance – Bleeding Source 102

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Hemostasis achieved	-	yes no	100 0	100%
Volume of sphere removed	cc	0 ≥0.12	0 100	-100%
Excessive force applied to bowl (duration)	s	0 7 ≥20	0 0 100	-50%
Excessive force applied to sphere (duration)	s	0 7 ≥20	0 0 100	-50%
Total blood loss	cc	0 0.05 ≥1	0 0 100	-50%
Volume of blood remaining in operative field	cc	0 0.05 ≥0.1	0 0 100	-100%
Surface of tissue substantially over-cauterised	mm^2	0 80 ≥160	0 0 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

"Bleeding Source 103" practices hemostasis with the bipolar and suction as in the previous exercise, but with the added difficulty that there are numerous bleeding sites present. The blood level is rapidly rising in the surgical field.



Suggested technique for the exercise:
The technique is the same for the previous exercises. In this exercise, however, it is important to maintain your composure despite the fact that the blood levels are rapidly rising.

Performance – Bleeding Source 103

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Hemostasis achieved	-	yes no	100 0	100%
Volume of sphere removed	cc	0 ≥0.12	0 100	-100%
Excessive force applied to bowl (duration)	s	0 7 ≥20	0 0 100	-50%
Excessive force applied to sphere (duration)	s	0 7 ≥20	0 0 100	-50%
Total blood loss	cc	0 1 ≥3	0 0 100	-50%
Volume of blood remaining in operative field	cc	0 0.05 ≥0.1	0 0 100	-100%
Surface of tissue substantially over-cauterised	mm^2	0 80 ≥160	0 0 100	-50%

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Exposure – an Introduction to Tissue Separation using Microscissors

In various microsurgical procedures, the area of interest is exposed for treatment via careful separation of tissue using tools such as suction or Bipolar forceps to grasp and gently pull tissue, and cutting membrane or fibres with Microscissors. For example, such techniques are mentioned in publications for exposure of the internal auditory canal, lower cranial nerves, vertebral artery, and aneurysm sites.

An aneurysm is a blood-filled dilation of a blood vessel caused by a weakening of the vessel's wall. Aneurysms typically develop because of the general wear and tear of blood pressure on the arteries' walls, called hemodynamic forces. A weak spot in the artery wall bulges out, giving way to the pressure of the blood flow, and forming a sac.

The treatment decisions for aneurysms are made based on the size, location and shape of the aneurysm as well as the patient's symptoms and general health. Treatment of aneurysms currently consists of three main options:

- Short- and long-term monitoring without operating
- Microsurgical Clipping
- Endovascular Coiling

Surgical clipping is the most common technique and requires a craniotomy, after which the neurosurgeon navigates with the aid of a microscope past the exterior of the brain tissue, without cutting into it, to gain access to the arteries and the aneurysm. The aneurysm is exposed from the surrounding brain and the artery it arises off, and microsurgical techniques are used to dissect the aneurysm neck free from the feeding vessels without rupture. A surgical aneurysm clip is placed around the neck of the aneurysm, obliterating flow into the aneurysm without compromising the adjacent vessels or small perforating branches of these vessels.

Possible complications include infection at the incision site, rupturing the aneurysm during surgery, damage to the artery and bleeding into the brain which could result in brain damage.

References:

The Aneurysm and AVM Foundation
http://www.taafonline.org/ba_about.html)

Massachusetts General Hospital Neurosurgical Service
http://neurosurgery.mgh.harvard.edu/Interventional/INRgdc.HTM

American Heart Association / American Stroke Association
http://www.strokeassociation.org/STROKEORG/AboutStroke/TypesofStroke/HemorrhagicBleeds/What-You-Should-Know-About-Cerebral-Aneurysms_UCM_310103_Article.jsp

Medscape from WebMD
http://emedicine.medscape.com/article/252142-overview#aw2aab6b8

Fibre Exposure and Cutting Exercise

This exercise practices simultaneous use of the Bipolar forceps for grasping and Microscissors for cutting fibres connecting tissues.

Objectives

1. Grasp and carefully retract tissue to expose the underlying fibres
2. Differentiate fibres to be cut from vital fibres such as arteries
3. Manipulate the Microscissors between fibres to cut only the general connecting fibres
4. Avoid pulling forcefully on tissue

Intended User

PGY-3 neurosurgery resident

Training Goal

The suggested practice for this exercise is until the trainee can consistently separate the tissue and cut fibres, without error, consecutively three times (once a day over three separate days).

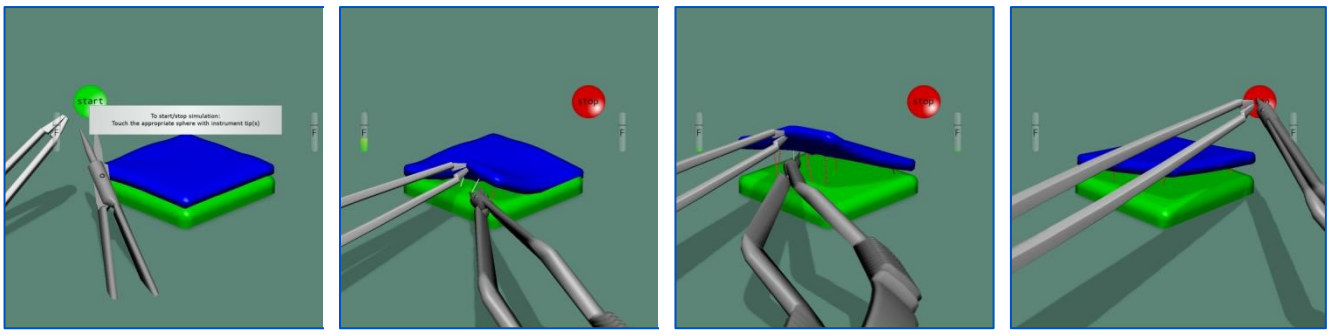
	Performance Metrics
Outcome	▪ Connecting fibres successfully cut
Efficiency	▪ N/A
Error	▪ Use of excessive force (duration) ▪ Arteries severed

Description

"Fibre Exposure and Cutting" practices the simultaneous use of the Bipolar forceps and Microscissors to practice some of the skills required to detach tissue, such as a tumour from surrounding healthy tissue, or expose an aneurysm. The Bipolar forceps are used to grasp and gently pull tissue to expose any thin fibres connecting the two regions. Microscissors are manipulated to cut the fibres.

The exercise depicts two squares (blue and green) representing different types of tissue, one on top of the other and connected by red and white fibres. The Bipolar forceps are used to partially lift the blue square, exposing the fibres. Microscissors are used to cut the general connecting (white) fibres while leaving the arteries (red fibres) intact. Care with both instruments is necessary, as excessive pulling or undue force will break all fibres.

Performance metrics include the number of general (white fibres) successfully cut. Feedback on errors includes any arteries (red fibres) severed and the time spent in the excessive force zone.



Suggested technique for the exercise:

- Place the Microscissors in the dominant hand and the Bipolar forceps in the other
- Gently grasp the top (blue) square with the Bipolar forceps and partially lift it, exposing the red and white fibres in the vicinity of the grasping point
- Advance the Microscissors, carefully avoiding contact with the red fibres, to increase the separation between the top and bottom squares
- Position and manipulate the Microscissors to snip any white fibres. Progress from the closer edges of the square to the centre and farther edges until all white fibres have been located and cut
- Avoid pulling too hard on the blue square with the Bipolar forceps as this will break all fibres in the area

Performance – Fibre Exposure and Cutting

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Number of white fibres cut	-	0 16	0 100	100%
Excessive force applied to tissue (duration)	s	0 0.5 1 ≥3	0 0 5 100	-50%
Number of arteries (red fibres) cut	-	0 9	0 100	-100%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Aneurysm Exposure Exercise

Objective

Practice bimanual coordination of the Microscissors, suction and bipolar instruments to expose the entire aneurysm.

Intended User

Senior neurosurgery resident.

Training Goal

To cut the arachnoid membrane, dissect the Sylvian fissure valley, and sever all target (green) arachnoid fibres to expose the aneurysm.

Performance Metrics

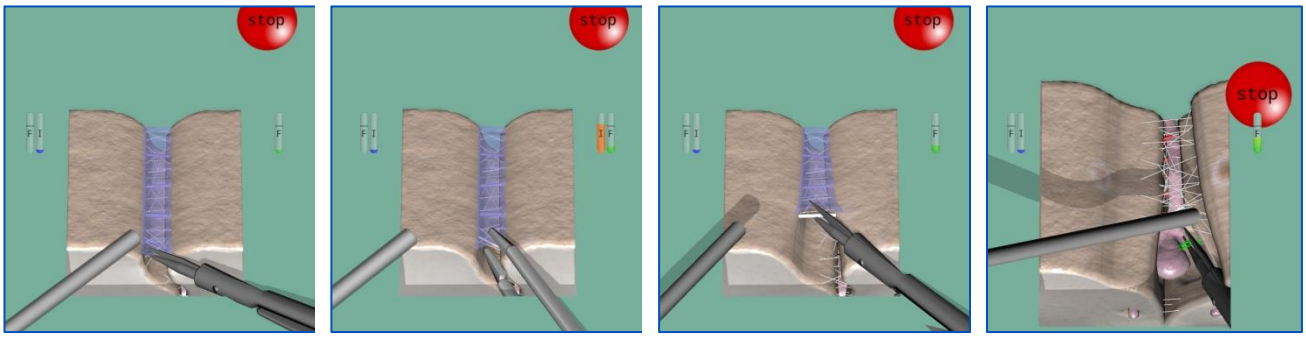
Outcome	▪ Number of target (green) fibres cut ▪ Number of white fibres cut
Efficiency	▪ N/A
Error	▪ Severing arteries and veins ▪ Use of excessive force (duration)

Description

"Aneurysm Exposure" represents one of the three main challenges in this delicate microsurgical procedure, following positioning of the head, and preceding clipping.

The geometry represented in the exercise consists of the frontal and temporal lobes, the Sylvian fissure valley, the artery with a bifurcation of different diameters, and the aneurysm site located within the bifurcation area. Several important techniques can be practiced using multiple instruments, such as cutting the transparent arachnoid membrane and connecting fibres to access and separate the Sylvian fissure, minimization and control of bleeding, and precise tool positioning with minimal use of force to reach and dissect the aneurysm neck.

Dissection of the entire Sylvian fissure valley provides the best view of the aneurysm site and the target (green) arachnoid fibres. Performance hinges on cutting a sufficient number of white fibres and the target arachnoid fibres. Errors include exerting too much force on the lobes, artery and aneurysm, as well as severing veins or the small (red) arteries connecting the main artery to the frontal and temporal lobes.



Suggestions for the exercise:

- At the start, the Microscissors are generally in the dominant hand and the suction tool in the other. Be prepared to switch to the bipolar for cauterisation
- Use the keyboard keys to adjust the virtual microscope rotation and zoom to put the membrane and fibres in clear view so as to access them without applying too much force on the tissue
- Cauterise the purple veins (turn to white) before cutting them to avoid bleeding
- The suction tool may be used to gently nudge tissue and better expose the target fibres
- This procedure is time-consuming; do not rush as it will likely result in exerting excessive force

Performance – Aneurysm Exposure

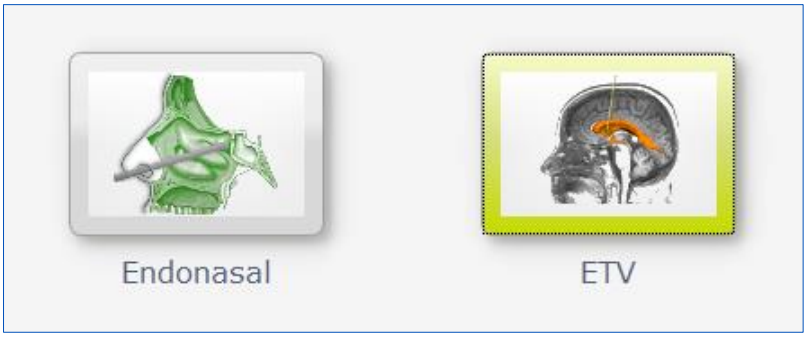
Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Number of target (green) fibres cut	-	0 ≥10	0 100	75%
Number of white fibres cut	-	0 ≥30	0 100	25%
Excessive force applied to temporal lobe (duration)	s	0 1.8 ≥6	0 0 100	-50%
Excessive force applied to frontal lobe (duration)	s	0 1.8 ≥6	0 0 100	-50%
Excessive force applied to artery (duration)	s	0 1.5 ≥10	0 0 100	-10%
Excessive force applied to aneurysm (duration)	s	0 1.5 ≥10	0 0 100	-1%
Number of arteries cut	-	0 ≥5	0 100	-200%
Number of veins cut	-	0 ≥20	0 100	-200%

***The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight"**.

Endoscopic Surgery Module

The endoscopic techniques introduced in the Fundamental Skills module are applied to surgical exercises in this module. Minimally invasive techniques have been successively applied to various conditions and are commonly employed in gastrointestinal, gynecological, heart, spine, vascular and urological surgical interventions, as well as treatment of tumours such as in the pancreas, liver, lungs, gallbladder, skull base and prostate, to name a few.

Currently, this module provides opportunities to practice the endonasal approach as well as endoscopic third Ventriculostomy procedures.



Endonasal Surgery

In endoscopic sinus surgery (ESS), the main challenge is obtaining a solid understanding of the structures of the nose and paranasal sinuses. In this domain, skills training targets familiarization with the anatomy along with practice of basic bimanual endoscopic techniques. As in any endoscopy specialty, the ability to work in long narrow corridors, a good sense of orientation, the identification of all relevant anatomic landmarks and an aptitude for drawing a 3D mental map from 2D feedback onscreen are essential for a good surgical performance.

ESS is indicated for many disorders of the sinus and nasal cavity, including the operative treatment of chronic rhinosinusitis which affects 10% of the population in North America. The procedures can be challenging not only due to the complex anatomy but also due to the proximity of vital structures such as the carotid artery, eye (orbit), the optic nerve, carotid artery and brain. Given that ESS requires the use of high speed drills and powered microdebriders, potentially dangerous situations can arise if the instruments are used improperly. Proper use is characterized by a firm grip to permit fine movements despite the vibration of the tools. Operative treatment should target maximal preservation of mucosa, periosteum and bone as well as gentle tissue handling. It is critical to maintain a clear operative view to decrease the risk of complications. Errors can occur if the operative site is approached too rapidly, which can cause loss of spatial depth or increase risk of inadvertently damaging fragile anatomical structures. Complications can include CSF leakage, injury to the orbit and skull base.

Suggested Reading:

1. Bakker NH, Fokkens WJ, Grimbergen CA. Investigation of training needs for functional endoscopic sinus surgery (FESS). Rhinology 43:104-108, 2005.
2. Levine HL, Clemente MP. Sinus surgery: endoscopic and microscopic approaches. In: Clemente MP, editor. *Surgical Anatomy of the Paranasal Sinus.* Stuttgart: Thieme; 2003.
3. Castelnuovo P, Endoscopic cadaver dissection of the nose and paranasal sinuses: an anatomical-Operative tutorial on the basic techniques of endoscopic nasal and paranasal sinus surgery, Endo-Press, Germany, 2006.

Sphenoid Ostium Drilling Exercise

Objectives

1. To practice using the microdrill in coordination with the endoscope to enlarge the sphenoid ostium
2. To navigate to the sphenoid ostium and through to the sphenoid sinus

Intended User

PGY-3 ENT residents or any person desiring to practice endoscopic skills.

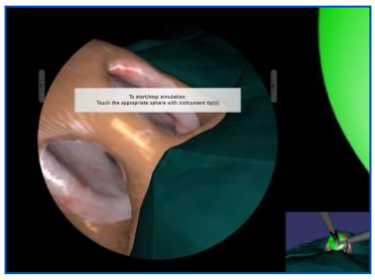
Training Goal

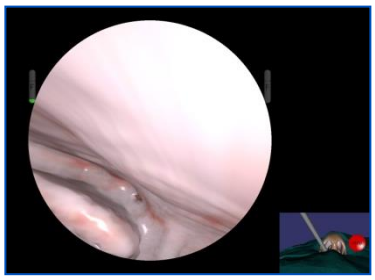
To use an endoscope to navigate without error along the nasal cavity until the ostium of the sphenoid sinus is located, then enlarge the opening using the microdrill to access the sphenoid sinus. This is to be demonstrated consecutively three times (once per day over three separate days).

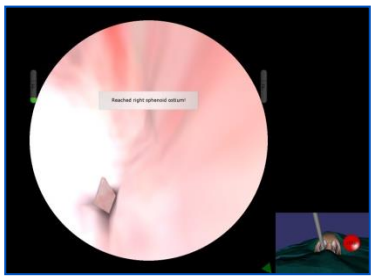
	Performance Metrics
Outcome	▪ Landmark localization (yes/no)
Efficiency	▪ N/A
Error	▪ Navigation into other areas ▪ Use of excessive force (duration) ▪ Removal of tissue in other areas

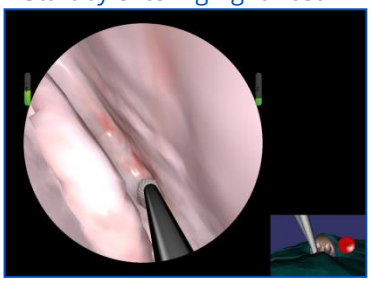
Description

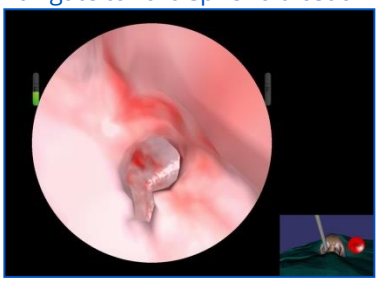
"Sphenoid Ostium Drilling" practices the approach to the sphenoid sinus by enlarging the sphenoid ostium without removing other tissues and while minimizing trauma to the nasal mucosa. Currently the exercise is fixed on the right nostril only.

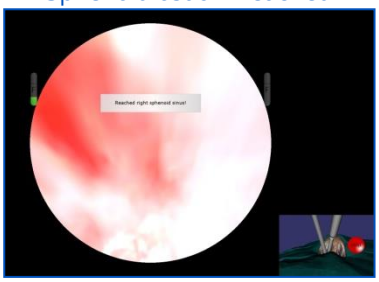

Start by entering right nostril


Navigate toward sphenoid ostium


Sphenoid ostium reached


Microdrill introduced


Enlarged opening


Endoscope at final target

Suggested technique for the exercise:

- Gently direct the endoscope through the right nostril and orient it to navigate past anatomical landmarks toward the sphenoid ostium. Use the foot pedal to rinse your "lens" as necessary.
- When the message appears on screen that you have successfully reached your target, introduce the microdrill through the same nostril and pathway. You may need to slightly retract your endoscope to permit a better view and allow space for the drill.
- When the drill is in the correct location, depress the foot pedal and carefully guide it to enlarge the opening. You are aiming to remove between 35-90% of the neighbouring tissue.
- Withdraw the drill from the opening and advance only the endoscope to move into the sphenoid sinus. An onscreen message will indicate you have reached your target.
- Avoid excessive force at all times

Performance – Sphenoid Ostium Drilling

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Reached right sphenoid ostium with endoscope?	-	yes no	100 0	50%
Reached right sphenoid sinus with endoscope?	-	yes no	100 0	50%
Reached left or right sphenoid sinus with drill?	-	yes no	100 0	-100% for each
Excessive force applied to tissue (duration)	s	0 1 ≥4	0 0 100	-50% for each hand
Percentage of tissue surrounding ostium removed	%	0 35 90 100	100 0 0 100	-50%
Volume of other tissue removed	cc	0 0.064 ≥0.2	0 0 100	-100%

****The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".***

Ethmoidectomy (Right and Left Sides) Exercise

Objectives

1. To practice using the microdebrider in coordination with the endoscope
2. To navigate from the nasal vestibule to the nasopharynx
3. To perform a complete Ethmoidectomy
4. To perform a wide Sphenoidotomy

Intended User

PGY-3 ENT residents or any person desiring to practice endoscopic skills.

Training Goal

To use an endoscope to navigate without error along the nasal cavity until the ostium of the sphenoid sinus is located. This is to be demonstrated consecutively three times (once per day over three separate days).

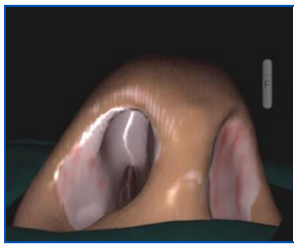
	Performance Metrics
Outcome	▪ % ethmoid removed ▪ % anterior sphenoid wall removed
Efficiency	▪ N/A
Error	▪ Use of excessive force (duration) ▪ % tissue removed from no-go zones

Description

"Ethmoidectomy" permits practising a different approach to the sphenoid sinus. In endoscopic sinus surgery, the sphenoid ostium can be localized through the posterior ethmoid cells. In this approach, the middle turbinate is medialized, rather than lateralized as in the "Endonasal navigation" exercise. This task was selected because it permits the user to become familiar with the major anatomical landmarks of accessing the ostium from the ENT perspective.

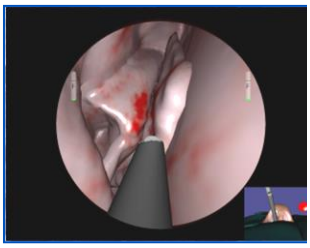
The training exercise consists of inserting the endoscope and microdebrider and advancing into either nasal cavity. The model of this cavity is interactive, complete with 18 anatomical structures. The user is required to perform a complete Ethmoidectomy followed by a wide Sphenoidotomy. Performance is optimal when both the ethmoid and anterior wall of the sphenoid sinus have been debrided away without error. Errors include the damage to any other structure including the use of high forces or inadvertent debridement.

Anatomical structures in Ethmoidectomy Model	
Septum	Posterior wall of sphenoid sinus
Inferior turbinate	Skull base
Middle turbinate	Orbit (with orbital fat)
Superior turbinate	Planum sphenoidale
Lamina papyracea	Fontanelle
Anterior ethmoid cell	Optic nerve
Posterior ethmoid cell	Carotid artery
Ground basal lamella	Clivus
Anterior wall of sphenoid sinus	Intersinus septum

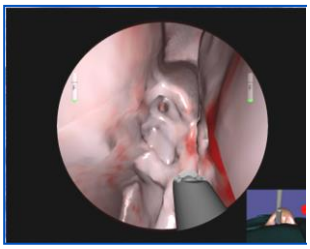


Enter right nostril

Middle turbinate



Middle turbinate medialized



Begin resection of ethmoid bulla

Suggested technique for the exercise:

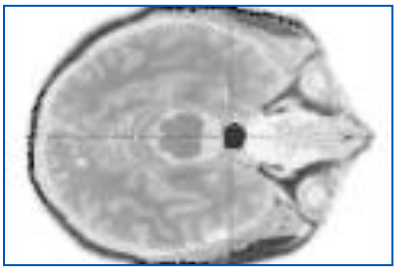
- Locate the middle turbinate and retract it towards the septum
- Localize the main anatomical landmark for performing an Ethmoidectomy: the ethmoid bulla
- Begin resection of the bulla beginning inferiorly and medially to avoid damage to the fragile lamina papyracea, orbit and skull base
- Continue to perform an anterior Ethmoidectomy, the resection of the anterior cell(s) to a single compartment until the basal lamella is visualized (mucosa can be seen)
- Enter the basal lamella and then the posterior cell(s) of the ethmoid. Again, proceed inferiorly and medially.
- Remove the posterior ethmoid cells until the anterior wall of the sphenoid sinus is seen
- Perform a wide Sphenoidotomy by locating the ostium of the sphenoid sinus and enlarging the opening
- Choose to open the sphenoid in inferior and medial direction which is safer
- Enter sphenoid sinus and visualize the optic nerve (above) and carotid artery (below)

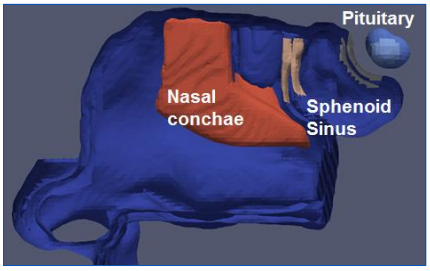
Performance – Ethmoidectomy (Right or Left)

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
% of sphenoid face removed	%	0 40 50 60 70 ≥80	0 75 80 85 90 100	50%
% of anterior ethmoid removed	%	0 40 50 60 70 ≥80	0 50 75 80 90 100	25%
% of posterior ethmoid removed	%	0 40 50 60 70 ≥80	0 50 75 80 90 100	25%
Excessive force applied (duration): superior turbinate, lamina papyracea, orbital fat, skull base, septum, inferior turbinate, sphenoid posterior wall, sphenoid face, optic nerve, carotid artery, middle turbinate, ground lamella or other tissue	s	0 10 15 ≥20	0 10 20 50	-50% for each hand
% of no-go zone tissue removed: septum, lamina papyracea, orbital fat, sphenoid posterior wall, optic nerve, carotid artery, or skull base	%	0 10 20 60 80 100	0 40 60 80 90 100	-100% for each no-go zone

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Pituitary Adenoma Exercise





Objectives

To practice resecting a pituitary adenoma using an endoscopic transsphenoidal approach.

Intended User

Any person desiring to practice endoscopic skills.

Training Goal

1. Identify the sphenoid ostium on each side
2. Enlarge the sphenoid ostia to visualize the contents of the sphenoid sinus
3. Remove the sphenoidal rostrum from the posterior portion of the nasal septum
4. Extend the Sphenoidotomy and remove sphenoid septum as required
5. Carefully open the floor of the sella turcica
6. Carefully resect the tumour with the suction tool

	Performance Metrics
Outcome	▪ Percentage of pituitary adenoma, nasal septum, sphenoid face, sphenoid septum, and sella turcica removed
Efficiency	▪ N/A
Error	▪ Volume of pituitary gland or other healthy tissue removed

Description

Pituitary adenoma are primary tumours that occur in the pituitary gland and are one of the most common intracranial neoplasms. Depending on their size they are broadly classified into pituitary microadenoma, less than 10 mm in size, or pituitary macroadenoma, greater than 10 mm in size. Size can affect clinical presentation, treatment options, surgical approach and imaging challenges, as may be expected for small intra-pituitary lesions versus larger lesions that extend into the suprasellar region.

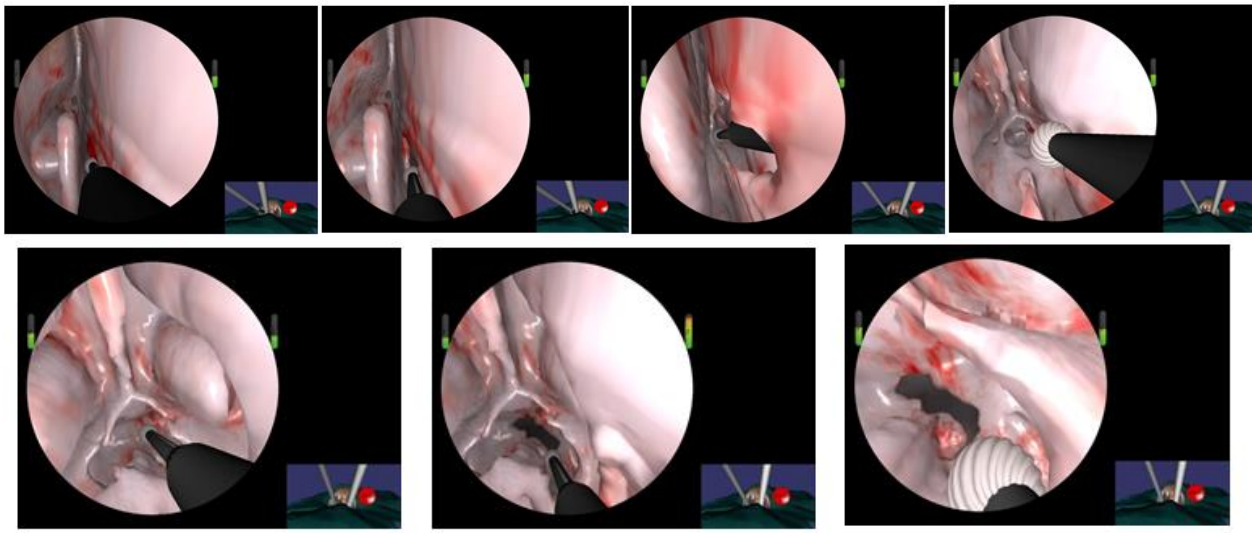
A pituitary microadenoma is confined to the sella, and as such has no scope to produce symptoms due to mass effect. As such they are most frequently diagnosed as the result of investigating hormonal imbalance. Patients with macroadenoma typically exhibit symptoms of local mass effect on adjacent structures (especially the optic chiasm). Some may present hormonal imbalance, with symptoms of hypopituitarism (from compression) or secretion. Pituitary carcinoma are very rare.

Medical and surgical treatments of pituitary adenoma are common. Symptoms related to mass effect will often necessitate surgical decompression regardless of cell type. The most commonly employed approach to pituitary masses is transsphenoidally, whereby the floor of the pituitary fossa is accessed via the nasal cavity. In large tumours other approaches, such as craniotomy, may be necessary.

An endoscopic transsphenoidal approach allows the surgeon to see through a small incision that is made in the back of the nasal septum. The surgeon passes instruments through normal nasal passages and opens the sphenoid sinus to reach the pituitary gland and remove the adenoma. The use of this technique is limited by the tumour's position and the shape of the sphenoid sinus.

References:

http://radiopaedia.org/articles/pituitary-adenoma
http://www.nice.org.uk/guidance/IPG32
http://www.cancer.org/cancer/pituitarytumors/detailedguide/pituitary-tumors-treating-surgery



Suggested technique for the exercise:

- Establish access through both nostrils by removing the posterior nasal septum (septectomy)
- Remove the anterior wall of the sphenoid sinus and the sphenoid rostrum to allow a panoramic view of the surgical area

Performance – Pituitary Adenoma

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of pituitary adenoma removed	%	0 100	0 100	40%
Percentage of nasal septum removed	%	0 100	0 100	15%
Percentage of sphenoid face removed	%	0 100	0 100	15%
Percentage of sphenoid septum removed	%	0 100	0 100	15%
Percentage of sella turcica removed	%	0 100	0 100	15%
Volume of pituitary gland removed	cc	0 0.06 ≥0.2	0 0 100	-50%
Volume of other tissue removed	cc	0 2 ≥4	0 0 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Endoscopic Third Ventriculostomy

As discussed earlier, ETV represents a relatively recent development in treatment for hydrocephalus and an alternative to placement of a shunt or drain. This procedure is typically performed in patient cases presenting with obstructive hydrocephalus and requires specialized training to perform it.

Following the selection of the perforation site using anatomical landmarks, generally, forceps or a Fogarty balloon is used to enlarge the opening. Once the fenestration has been performed, the scope is advanced through the opening to determine whether the Liliequist membrane is present. If it is, a second perforation is performed. Finally, the scope is retracted to assess the fenestration. The adequacy of the fenestration is indicated by the presence of CSF flow.

The level of difficulty is related to the anatomy, in particular, the state of the ventricular floor. A more transparent membrane will make the selection of the perforation site easier since the anatomical landmarks can be discerned. In the case of the ventricular floor being opaque or scarred, one may need to rely on the Doppler for alternative cues. As well, the management of bleeding caused during the procedure can lead to waiting times. Bleeding is usually managed by flushing the area for several minutes.

Suggested Reading:

Farin et al. Endoscopic third Ventriculostomy. J Clinical Neuroscience 13:763-330, 2006.

Floor Perforation Exercise

Objectives

1. To handle a Neuroendoscope with indirect view onscreen
2. To identify and use landmarks to maintain orientation
3. To localize ventricular structures for effective floor perforation

Intended User

PGY-3 neurosurgery resident or any person desiring to practice endoscopic skills.

Training Goal

To enter the existing Burr Hole with peel-away tube and navigate to the third ventricle until the floor is located and the ideal perforation site located and executed. This is to be demonstrated consecutively three times (once per day over three separate days).

Performance Metrics

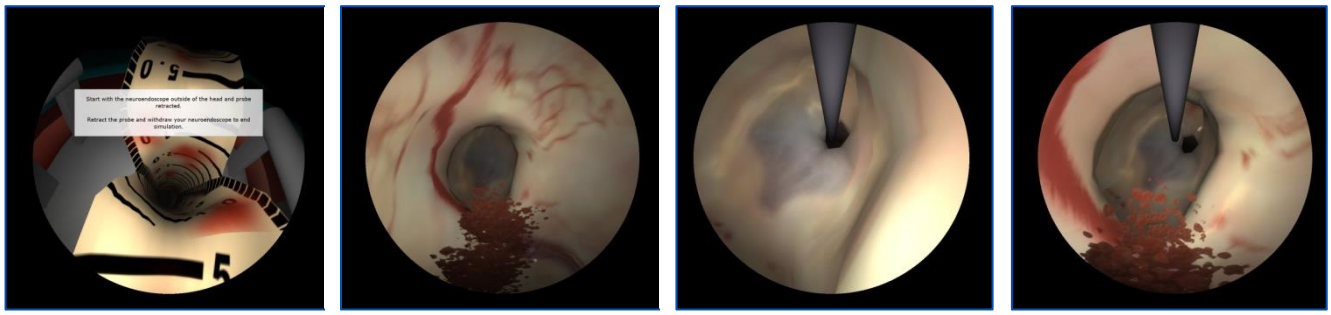
Outcome	▪ Floor perforation achieved (yes/no)
Efficiency	▪ N/A
Error	▪ Contact with tissue/structures during navigation in ventricular system (yes/no) ▪ Perforation executed in incorrect zone (yes/no)

Description

"Floor Perforation" practices skills related to endoscopic procedures such as Neuroendoscope navigation within the ventricular system.

The challenges for this simulated exercise are learning the ventricular anatomy and maintaining spatial orientation while properly navigating the scope. The goal is to locate and identify an ideal perforation site on the ventricular floor. This exercise involves dilated ventricles with a transparent ventricular floor. The peel-away tube and Burr Hole are already in place. The Neuroendoscope is inserted and advanced along the ventricular system until the foramen of Monro is seen. The anatomical landmarks, the thalamostriate and septal veins are used to identify the foramen borders. Once oriented, the scope must be advanced carefully so as not to touch the borders of the foramen of Monro, in particular the fornix, until the third ventricle is reached. Using anatomical landmarks, such as the infundibular blush and mammillary bodies for guidance, a perforation site is selected on the ventricular floor. After perforation, advance the scope to the opening and inspect the anatomy posterior to the floor, namely the basilar artery and clivus.

The ergonomics of an endoscopic procedure are recreated in this simulation via a haptic system which represents the scope and provides force feedback while observing the 2D view onscreen. Ending the simulation gives automatic feedback on the quality of the fenestration site selection while errors include damage to critical structures, such as the basilar artery.



Suggested technique for the exercise:

- Start the exercise with the endoscope outside of the mannequin head. Once the simulation has started, begin by inserting the instrument into the Burr Hole opening. Once the endoscope has been inserted, shift your gaze onscreen.
- With your free hand, pull on the probe handle (already placed in the channel of the endoscope) and make sure it is pulled out at its maximum. This assures that the probe is in the retracted position (cannot be seen onscreen).
- Advance the scope along the peel-away tube. Continue advancing the scope until the foramen of Monro is located. Use the choroid plexus, thalamostriate and septal veins to orient the scope and identify the foramen borders.
- Advance the scope carefully without touching the borders of the foramen, in particular the fornix, until the floor of the third ventricle is seen. Use the infundibular blush and the opening of the fourth ventricle to align yourself.
- On the floor select a site between the infundibular blush and the mammillary bodies to perforate. To perforate, use your free hand to slowly advance the probe through the Neuroendoscope and against the ventricular floor to perforate it.
- Retract the probe and withdraw the scope from the head model

Performance – Floor Perforation

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Probed ideal perforation site?	--	yes no	100 0	25%
Perforated ideal site?	--	yes no	100 0	75%
Touched ventricle wall?	--	yes no	100 0	-100%
Perforated critical structure (infundibulum, hypothalamus, pons, mammillary bodies, perforator/arterial branch or basilar artery)?	--	yes no	100 0	-100% for each structure perforated

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Floor Perforation and Enlargement Exercise

Objectives

1. To handle a Neuroendoscope with indirect view onscreen
2. To identify and use landmarks to maintain orientation
3. To localize ventricular structures for effective floor perforation
4. To enlarge the original perforation to a suitable size and shape

Intended User

PGY-3 neurosurgery resident or any person desiring to practice endoscopic skills.

Training Goal

To execute floor perforation as in the previous exercise, using the existing Burr Hole with peel-away tube and navigating to the third ventricular floor, then to enlarge the perforation using the Neuroendoscope probe. This is to be demonstrated consecutively three times (once per day over three separate days).

Performance Metrics

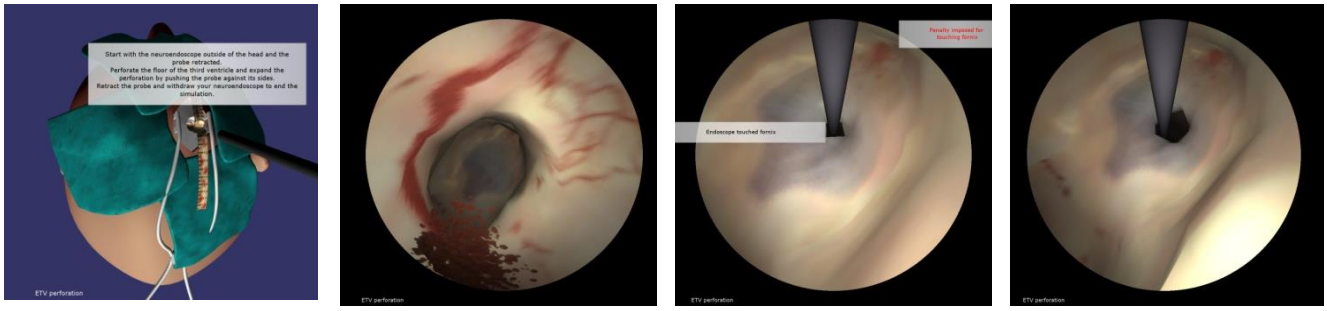
Outcome	▪ Floor perforation achieved (yes/no)
Efficiency	▪ N/A
Error	▪ Contact with tissue/structures during navigation in ventricular system (yes/no) ▪ Perforation executed in incorrect zone (yes/no) ▪ Deviation of perforation shape from ideal

Description

"Floor Perforation and Enlargement" begins with the same steps as the previous exercise to perforate the ventricular floor, and then practices the additional step of enlarging the perforation.

As mentioned above, forceps or Fogarty balloons are commonly used for enlargement; in this simulation, the tip of the probe is pressed against the sides of the original incision to create a larger opening. The shape and size of the enlargement is compared to an ideal perforation for quantitative evaluation.

Challenges specific to this exercise are to avoid touching the scope shaft or probe to any of the critical structures. Contact with certain critical structures, or perforation in these regions, may incur greater penalty as outlined in the table of performance metrics. Any unnecessary contact results in the display of a warning box during the exercise.



Suggested technique for the exercise:

- Approach the ventricular floor using the Neuroendoscope in the same manner as for the Floor Perforation exercise, except using even greater care not to contact critical structures in the vicinity
- Once perforation has been executed, use the probe to gently widen the original opening. Try to create a circular opening of at least 6 mm in diameter.
- When you are satisfied with the size and shape of the perforation, retract the probe and withdraw the scope, using equal care to avoid touching critical structures

Performance – Floor Perforation and Enlargement

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Probed ideal perforation site?	--	yes no	100 0	25%
Perforated ideal site?	--	yes no	100 0	75%
Touched wall of lateral ventricle, wall of third ventricle, mammillary body, clivus region, infundibulum recess, supraoptic recess, mesencephalon, pons or pons region?	--	yes no	100 0	-10% for each structure reached
Touched basilar region, arterial branch region or choroid plexus?	--	yes no	100 0	-50% for each structure reached
Touched fornix or basilar artery?	--	yes no	100 0	-100% for each structure reached
Perforated clivus?	--	yes no	100 0	-30%
Perforated wall of lateral ventricle, wall of third ventricle, mammillary body, clivus region, infundibulum recess, supraoptic recess, mesencephalon, pons or pons region?	--	yes no	100 0	-50% for each structure perforated
Perforated fornix, basilar region, basilar artery, or arterial branch region?	--	yes no	100 0	-100% for each structure perforated
Similarity of perforation shape to ideal	--	0 0.7 1	100 0 0	-30%

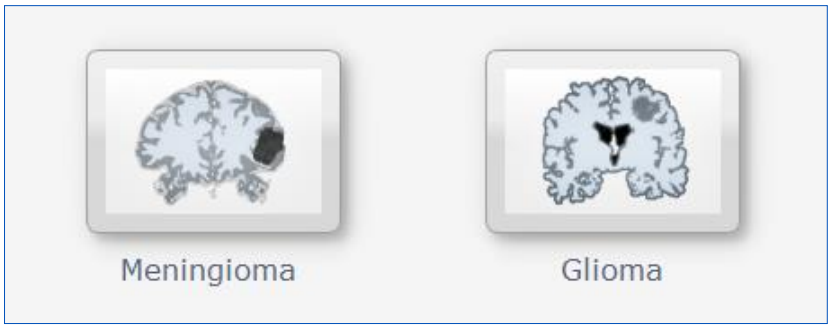
The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Microsurgery Module

Microsurgery contains exercises which lend to procedures rather than particular techniques because the instruments (suction, ultrasonic aspirator, and bipolar) can be exchanged for one another throughout.

This training module addresses the resection of Meningiomas and gliomas, which account for the majority of primary brain tumours, as well as the exposure of an aneurysm site prior to clipping.

Brain tumour surgeries are done in three steps: approach, tumour exposure/removal and closure. The Meningioma and glioma training scenarios provided in this module are derived from medical images of actual patient cases. They focus on practising the tumour exposure and/or resection portion of the procedures.



Meningioma – an Introduction

Meningiomas are the most commonly occurring primary brain tumours. They are typically benign and develop from the meninges (dura, arachnoid and pia mater) rather than the brain itself. Symptoms result from pressure from the tumour pushing onto the surface of the cortex. These tumours are extrinsic, commonly distinct from the brain, thus a gross total resection for a complete cure in the patient can be obtained. The approach to these tumours is dictated by its size, location and extent of dural involvement.

Common locations for Meningiomas include:

1. Falx and parasagittal (25%)
2. Convexity without falx or sinus involvement (20%)
3. Sphenoid wing (20%)
4. Olfactory Groove (10%)
5. Suprasellar (10%)
6. Posterior Fossa (10%)

Meningioma removal often involves debulking followed by dissecting its capsule from the pial layer. Tumour is discerned from healthy tissue by how it feels (generally stiffer than healthy brain), its colour and the CSF space between the Meningioma and the brain. To enhance debulking, it is important to coagulate the dural feeders to make the tumour less vascular.

Once debulked, the plane between the tumour capsule and pia/arachnoid is established. The vessels (from the pia and arachnoid) are identified, coagulated and divided as the capsule is circumferentially dissected from the pia. The majority of the pia/arachnoid should be left intact. The space between tumour and underlying brain is not always clearly defined. In more complicated cases, there is tumour invasion of the surrounding brain and small pial blood supply can be parasitized by the tumour. This is important when determining how much tissue to remove because the risk of injuring healthy brain is related to the degree of adhesion.

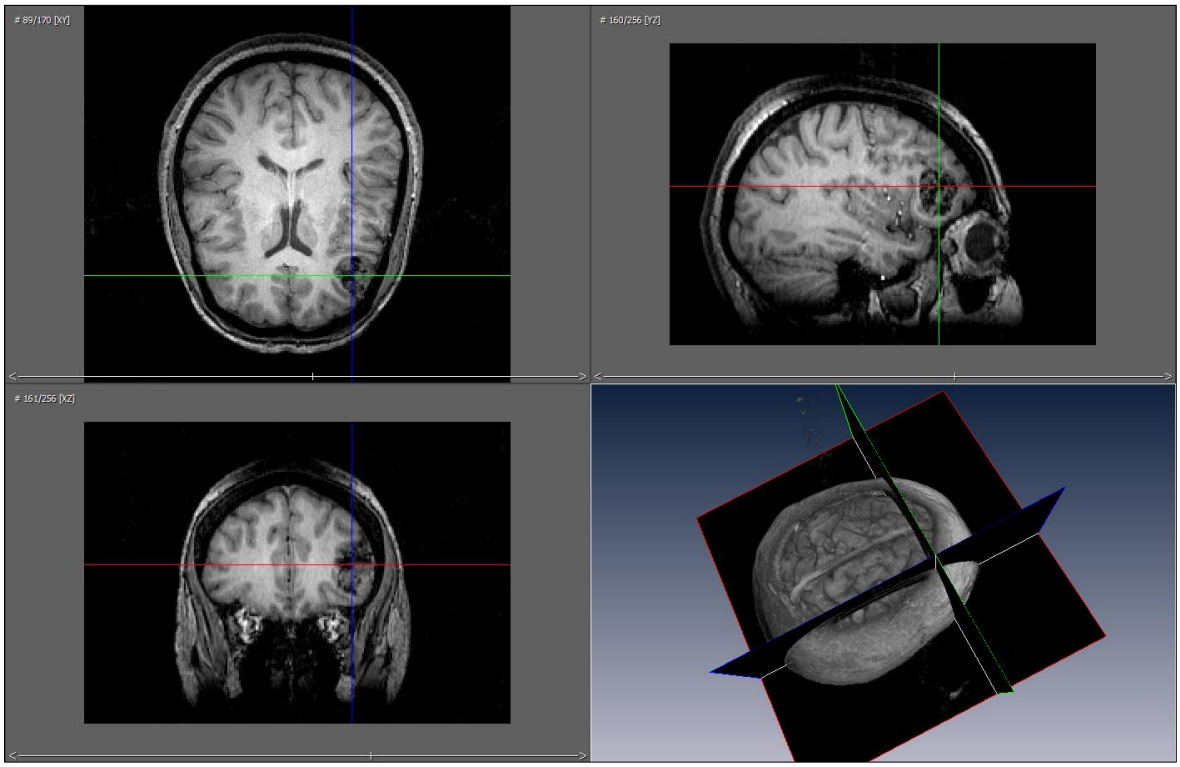
A major risk of the operation is causing cortical injury by breaching the arachnoid and the pia into the oedematous grey matter underneath the tumour. If one strips away the pia from the cortex this can result in cortical injury either related to direct trauma, vascular injury (ischemia) or both, depending on the tumour's location. The patient can be left with neurological deficit.

Suggested Reading:

1. Yasargil M. Instrumentation and Equipment, Microneurosurgery of CNS tumours IVA. Stuttgart, George Thieme Verlag, 1996.

Patient Cases: Removal of a Frontal Convexity

Meningioma (Derived from Medical Images): Minimally Vascular (Case 1) and Highly Vascular (Case 2)



Meningioma Convexity Case 1-4 Exercises

The exercises in this module focus on the second of the six common locations of Meningiomas:

1. Falx and parasagittal
2. Convexity without falx or sinus involvement
3. Sphenoid wing
4. Olfactory Groove
5. Suprasellar
6. Posterior Fossa

Objectives

Surgically treat a patient presenting with a frontal convexity Meningioma. Remove as much tumour as possible while preserving function i.e., without risking damage to healthy brain.

Intended User

Senior neurosurgery resident.

Training Goal

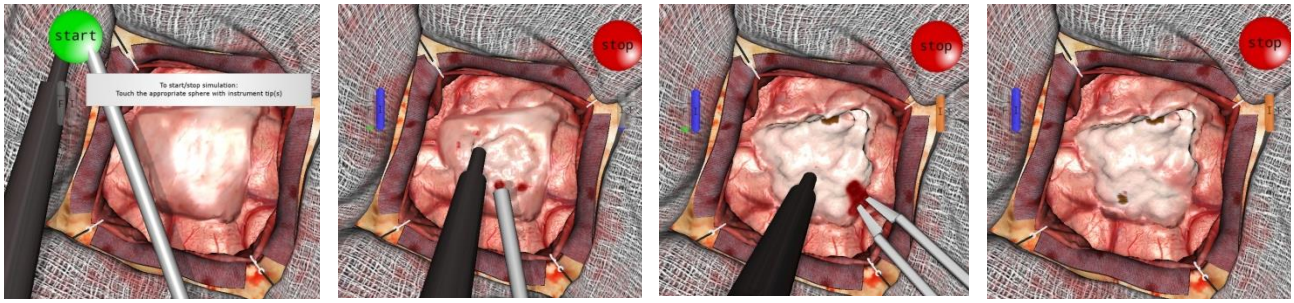
- Gross total resection (100%) for a well-circumscribed, non-adhesive, minimally vascular tumour, without removal of healthy tissue
- Greater than 90% for a diffuse, adhesive and/or vascular tumour, without removal of healthy tissue

Performance Metrics

Outcome	▪ % tumour resection
Efficiency	▪ N/A
Error	▪ Removal of healthy tissue ▪ Use of excessive force (duration) ▪ Hemostasis achieved (yes/no)

Description

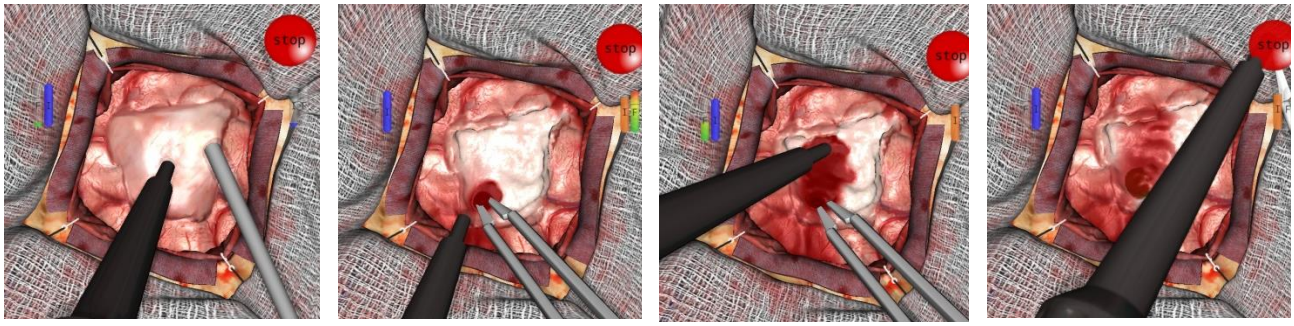
"Convexity Case 1" begins with the dura cut circumferentially around the tumour and the tumour exposed. There was no dural involvement. As such, the dura was dissected from the tumour and the dural feeders were coagulated. Therefore the tumour should not bleed profusely during the debulking stage.



Suggestions for the exercise:

- Check with your suction tool to see if the tumour is hard or soft. A soft tumour will deform under suction. In this case, use suction to debulk. Else, use the ultrasonic aspirator.
- Adjust the power of the aspirator. Keep in mind that you want to be able to remove tumour without too much tissue deformation.
- Begin as practiced in the previous debulking exercises by enucleating the centre of the tumour at high aspiration, slowly creating a cavity as the tumour is removed
- Any bleeding is managed by using suction at low aspiration to remove blood. It is important to keep the view clear of blood at all times to avoid inadvertent damage to healthy tissue.
- Should the bleeding prove too brisk to be cleared away with suction, switch to the bipolar. First reveal the bleeding source and then cauterise using the bipolar forceps. Ensure that a low power setting is used.
- Once bleeding has been managed, continue with debulking to a 5-mm margin of tumour at the interface
- Determine the tumour adherence to healthy tissue to decide on the amount of tumour that can be safely resected
- The simulated tumours presently do not include the arachnoid adhesions. As such, rather than proceeding to microdissecting the capsule, continue this sequence until desired extent of resection is achieved.
- Be mindful not to apply too much force on the tissue. If tissue is difficult to access, either gently retract tissue with your tool shaft or make use of the zoom and rotation settings of the microscope. This will permit optimal operative view throughout.

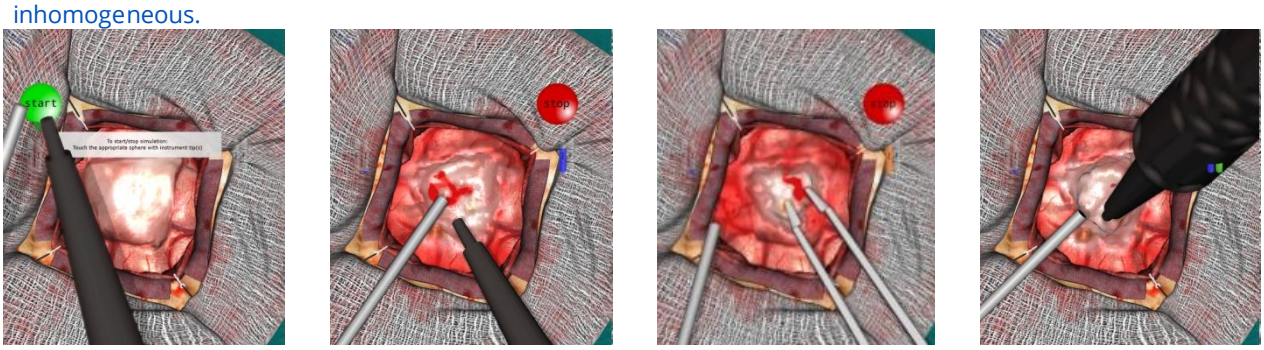
"Convexity Case 2" requires debulking the same tumour as in the previous exercise, except that the tumour is highly vascular.



Suggestions for the exercise:
The instructions are the same as the previous, except additionally:

- Promptly stop the onset of bleeding as it can accumulate rapidly to flood the entire operative views. Any delays will render location of the blood source more difficult and time-consuming. As well, the likelihood of injury to functional brain is increased.

"Convexity Case 3" builds on the Convexity Case 2 exercise in that the tumour stiffness is randomly inhomogeneous.



Suggestions for the exercise:
The instructions are the same as the previous, except additionally:

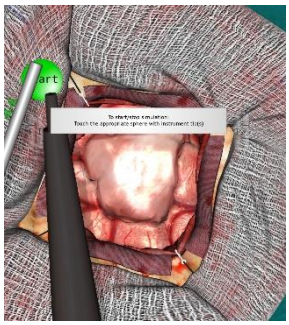
- Carefully adjust the intensity level of the instruments, especially the ultrasonic aspirator, according to the localized stiffness of the tumour and efficiently remove it without exerting undue force

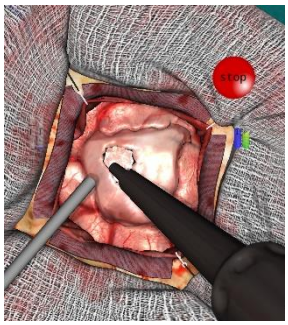
Performance – Convexity Meningioma Cases 1, 2, & 3

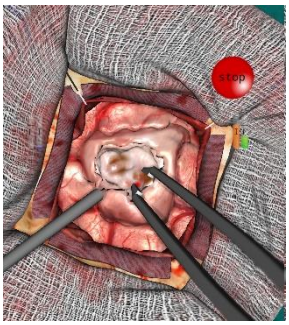
Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 75 80 90 98 100	0 50 75 85 95 100	100%
Volume of healthy brain removed	cc	0 0.05 ≥0.2	0 0 100	-100%
Total blood loss	cc	0 5 ≥10	0 0 100	-100%
Hemostasis achieved	--	yes no	0 100	-50%

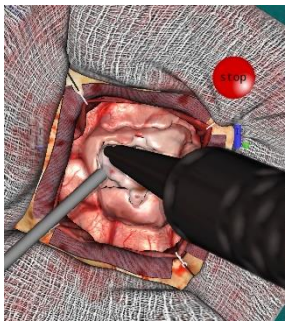
The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

"Convexity Case 4" requires the user to core out a convexity Meningioma as in the previous exercise, but with a tumour capsule.









Suggestions for the exercise:

The instructions are the same as the previous, except additionally:

- Be aware of the differences in stiffness between the capsule, tumour and healthy tissue and their influences on instrument intensity level to balance effective removal with potential tissue damage
- Remove as much of the capsule as you need to focus on removing most of the tumour, while avoiding damage to healthy tissue

Performance – Convexity Meningioma Case 4

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 75 80 90	0 50 75 100	100%
Volume of healthy brain removed	cc	0 ≥0.01	0 100	-100%
Total blood loss	cc	0 5 ≥10	0 0 100	-100%
Hemostasis achieved	--	yes no	0 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Glioma – an Introduction

Gliomas are the most common primary intrinsic brain tumours. They arise from the glial cells, the main types being:

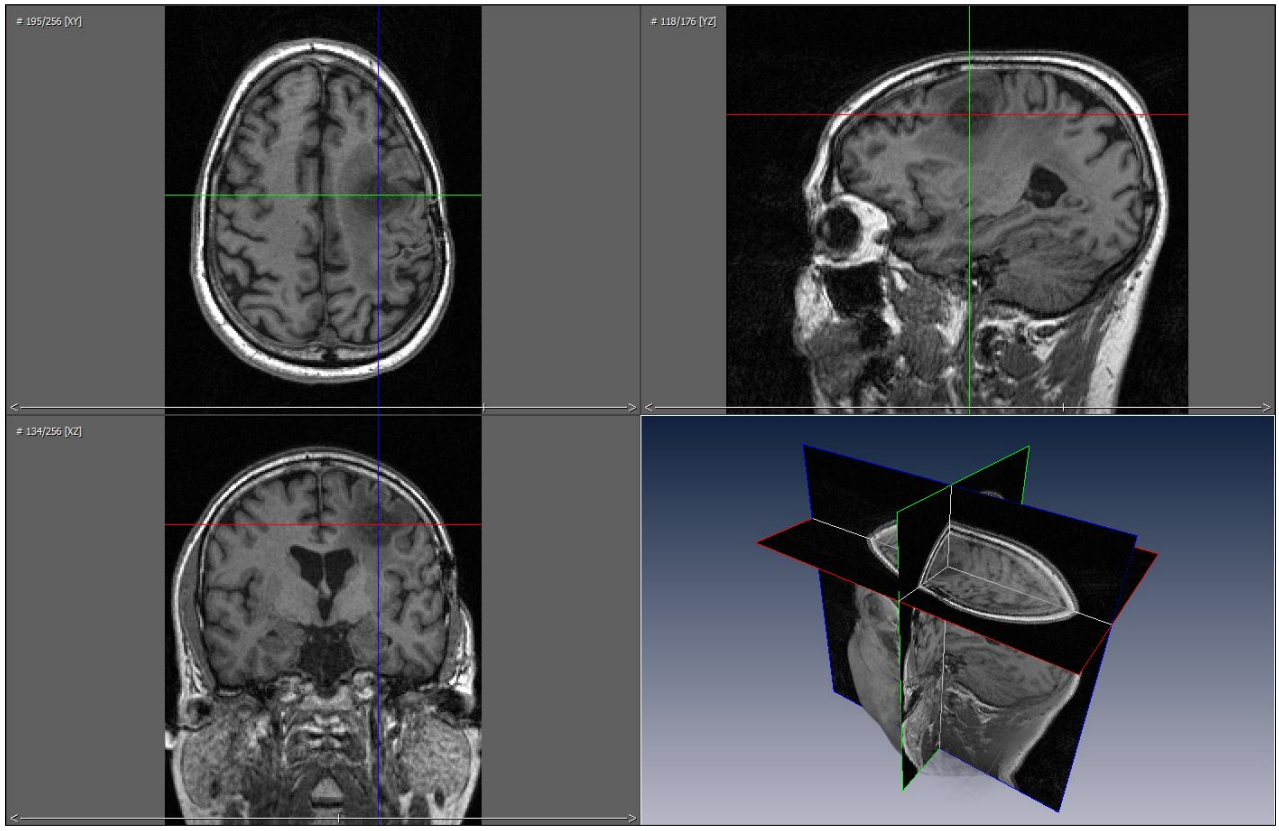
1. Oligodendromas
2. Astrocytomas
3. Ependymomas

Surgical treatment for these tumours depends on the location, the cell type and the grade of malignancy involved.

In the case of gliomas, the extent of resection has an impact on patient survival time so it is attempted to remove as much tumour as possible. Well-circumscribed gliomas are typically removed piecemeal, whereas partial resection or biopsy is the treatment preferred for low grade gliomas near eloquent cortex. A lobectomy can be performed for gliomas located at the pole of a lobe.

It has been found that a gross total resection of a glioma (greater than 98%) permits a longer patient survival time. However, when the tumour is highly infiltrative or if important structures are involved, only partial resections are possible. Incomplete tumour resections can also be due to the lack of any visual difference between tumour and healthy brain. Even when intraoperative navigation is used, brain shift diminishes its accuracy in identifying the tumour regions.

Patient Case: Left Frontal Subcortical Glioblastoma Multiforme (Derived from Medical Images)



Glioma Exercise

The exercise in this module involves the second of the three main types of gliomas:

1. Oligodendromas
2. Astrocytomas
3. Ependymomas

A glioblastoma multiforme (GBM) tumour is a grade IV astrocytoma, characterized as an aggressive and highly infiltrative tumour proving to be one of the most challenging to remove.

Objectives

Surgically treat a patient presenting with a left frontal subcortical glioma. Remove as much tumour as possible while preserving function i.e., without risking damage to healthy brain.

Intended User

Senior neurosurgery resident.

Training Goal

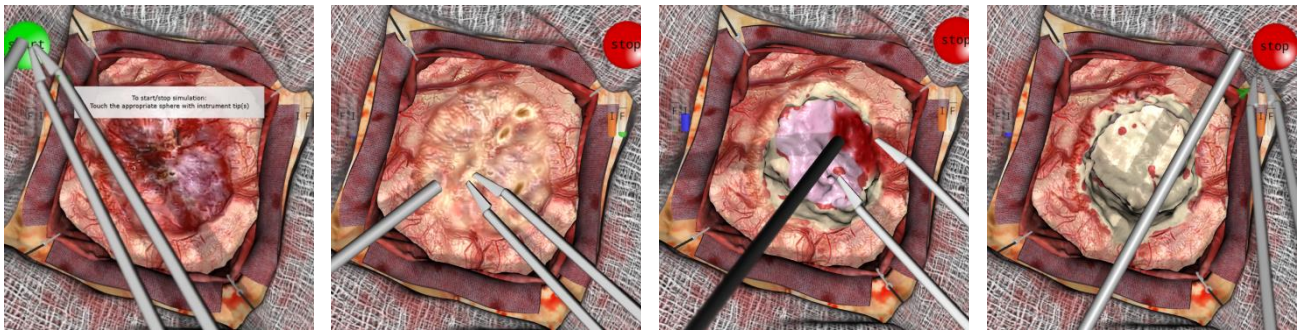
To remove as much of the soft glioma as possible until a gross total resection is achieved without removal of healthy tissue.

Performance Metrics

Outcome	▪ % tumour resection
Efficiency	▪ Total blood loss
Error	▪ Removal of healthy tissue ▪ Use of excessive force (duration) ▪ Hemostasis achieved (yes/no) ▪ Blood remaining in surgical field (yes/no)

Description

"Glioma (GBM Case 1)" begins with the dura cut circumferentially around the tumour with the exposed surface of the brain exposed in the operating view. The location of the glioma is delineated by an abnormal region at the surface directly above it.



Suggestions for the exercise:

- The bipolar is generally in the dominant hand and the suction tool in the other
- Begin by cauterising the surface oedema to avoid excessive bleeding at the start
- Remove abnormal tissue using suction at high aspiration, slowly creating a cavity as the tumour is removed
- Any bleeding is managed by using suction at low aspiration to reveal the bleeding source. The blood vessel is then cauterised using the bipolar forceps. Ensure that a low power setting is used.
- Should any tissue prove difficult to remove, switch the suction for the ultrasonic aspirator
- This sequence is continued until the entire tumour is removed. Begin at the centre and extend to the margins.
- Be mindful not to apply too much force on the tissue. If tissue is difficult to access, either gently retract tissue with your tool shaft or make use of the zoom and rotation settings of the microscope for optimal operative view throughout.

Performance – Glioma

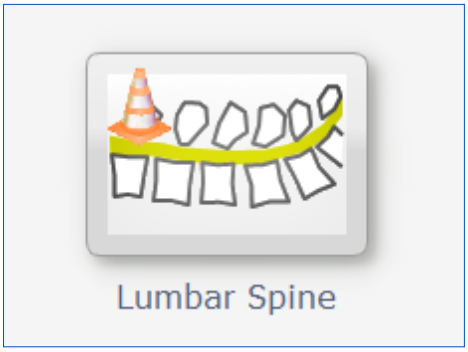
Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Percentage of tumour removed	%	0 75 80 ≥85	0 50 85 100	100%
Volume of healthy brain removed	cc	0 4.05 ≥8	0 0 100	-100%
Total blood loss	cc	0 5 ≥10	0 0 100	-100%
Hemostasis achieved	-	yes no	0 100	-50%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Spine Surgery Module

This training module addresses skills unique to spine surgery. Spine surgeries treat conditions of the cervical, thoracic and lumbar spine and involve complex spinal instrumentation.

Back pain, resulting from aging, trauma, structural abnormalities, or improper body mechanics, may lead to a recommendation for spine surgery if non-surgical treatment such as medications and physical therapy fails to relieve symptoms. Surgery is only considered in cases where the exact source of pain can be determined, such as a herniated disc, scoliosis, or spinal stenosis. Traditionally performed as open surgery which creates a long incision to view and access the spinal anatomy, more and more spine conditions can be treated with minimally invasive techniques, leading to shorter operative and recovery times. Technological advances in preoperative and intraoperative imaging techniques have greatly advanced minimally invasive procedures, as they enable surgeons to accurately identify an anatomic lesion and operate with a high level of precision and safety.



Lumbar Spine – an Introduction

Lumbar surgery refers to any type of surgery in the lumbar spine, or lower back, between one or more of the L1-S1 levels. There are two general types of lumbar spine surgery that comprise the most common surgical procedures for the lower back: lumbar decompression and lumbar fusion.

Spinal stenosis is the single most common diagnosis that leads to spinal surgery, of which a laminectomy (spinal decompression) represents one component. The standard position of the patient is prone, with support to avoid pressure on the abdomen. While under general anesthesia, an incision is made in the middle of the back and hemostasis achieved with electrocautery. Spinal muscles are moved aside to expose the bony vertebra, and the arched portion of the vertebra, called the lamina, is removed using a high-speed drill to make lateral trenches and expose the spinal cord. Thickened ligaments and bone spurs are removed. The overgrown facet joints, located directly over the nerve roots, may be trimmed to give more room for the spinal nerves to exit the spinal canal. If there is a herniated disc, a discectomy may be performed. In patients with severe symptoms of lumbar spinal stenosis, decompressive surgery alone is effective approximately 80% of the time.

Hemilaminectomy is like bilateral lumbar laminectomy, but dissection is limited to one side of the interspinous ligament, which allows for a smaller initial skin incision. Supraspinous and interspinous ligaments and the contralateral hemilamina are preserved. Hemilaminectomy can be more demanding than bilateral laminectomy because decompression is performed through a more limited exposure, and is more dependent on feel (palpation) than by direct visualization.

References:

www.mayfieldclinic.com
www.spinehealth.com
www.spineuniverse.com

Atlas of Neurosurgical Techniques: Spine and Peripheral Nerves
Fessler RG and Sekhar LN, eds, Thieme, 2006.

The Adult and Pediatric Spine, Volume 1
Frymoyer JW and Wiesel SW, eds, Lippincott Williams & Wilkins, 2004.

Surgical Techniques for the Spine
Haher, TE and Merola AA, eds, Thieme, 2003.

Hemilaminectomy Exercise

Objectives

This exercise focuses on practising the spinal decompression portion of spine surgery with the following goals:

- Remove the lamina
- Avoid removing other tissue such as ligament or muscle, as well as bone from neighbouring segments
- Avoid touching the spinal cord
- Minimize bleeding

Intended User

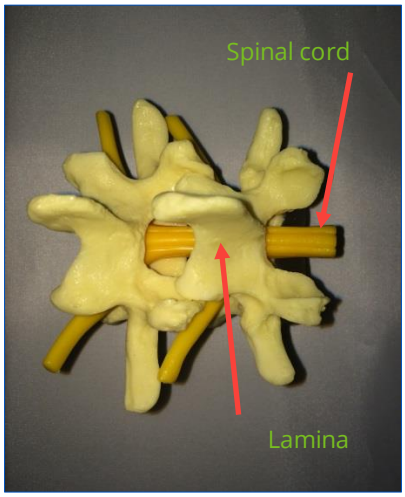
Senior neurosurgery resident.

Training Goal

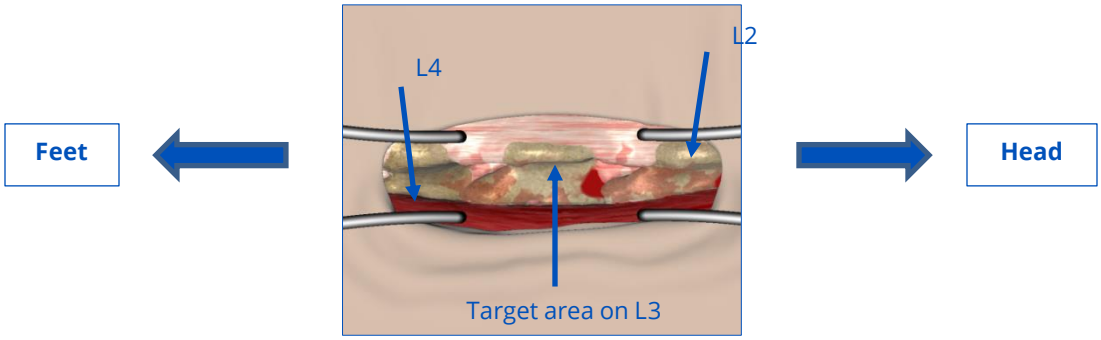
	Performance Metrics
Outcome	▪ Volume of L3 vertebra removed
Efficiency	▪ N/A
Error	▪ Removal of vertebra other than L3 ▪ Removal of spinal cord ▪ Removal of flavium ligament ▪ Removal of other tissue ▪ Use of excessive force (duration) ▪ Total blood loss

Description

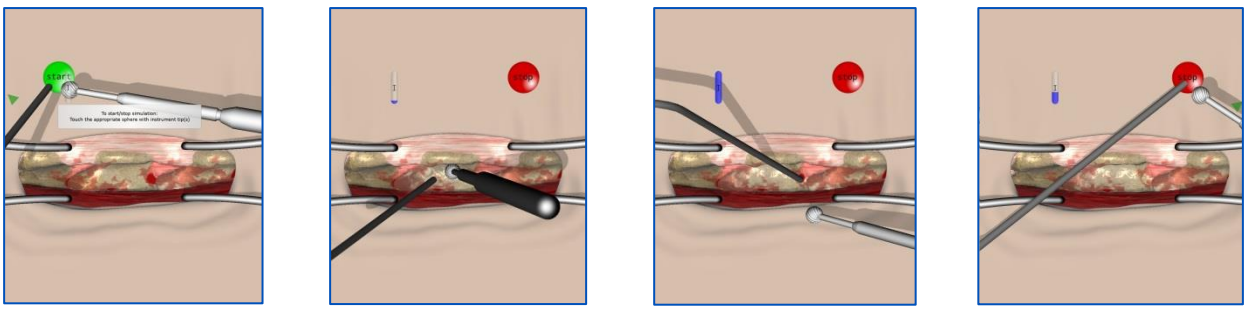
"Hemilaminectomy" is derived from real anatomical data. The spine section model pictured below indicates the target area, or lamina, of the vertebra and its proximity to the spinal cord, which in reality is further protected by layers of ligament and dura.



The onscreen representation (below) depicts the L3 vertebra in the centre, with L4 on the left and L2 on the right. This corresponds to the surgeon approaching the prone patient's right side. Muscle tissue is red and the pinkish tissue is ligament.



In its beta form, the exercise currently awards points for any material removed on L3. Note, however, that the target area is the lamina, below and on the underside of the protruding spinous process.



Suggestions for the exercise:

- Use suction to clear any bleeding evident at the outset
- Position the drill tip at the L3 vertebra and use the pedal to activate it. Use a gentle back-and-forth motion to gradually remove the bone. Limit drilling to bony areas as much as possible.
- Keep the drill away from the muscle on the lower side and the ligament above, as well as neighbouring vertebrae
- Continue to clear any blood using suction
- Avoid excessive force with both instruments

Performance – Hemilaminectomy

Metric	Unit	Thresholds*		Overall Score weight
		metric value	metric grade	
Volume of L3 vertebra removed	cc	0 1 1.2 ≥1.8	0 100 100 0	100%
Volume of spinal cord removed	cc	0 0.2 ≥1	0 0 100	-100%
Volume of vertebra other than L3 removed	cc	0 ≥0.1	0 100	-25%
Volume of flavium ligament (L4-L3) removed	cc	0 0.05 ≥0.1	0 0 100	-25%
Volume of flavium ligament (L3-L2) removed	cc	0 0.05 ≥0.1	0 0 100	-25%
Volume of other tissue removed	cc	0 0.07 ≥0.2	0 0 100	-25%
Excessive force to spinal cord (left and right hands)	s	0 ≥1	0 100	-50% for each hand
Total blood loss	cc	0 ≥0.05	0 100	-25%

The grade for any "metric value" is the linear interpolation between the two "metric grade" threshold points before and after it multiplied by the "score weight".

Additional Information:

Table 1A: Technical Skill Requirements for Graduation in Neurosurgical Oncology

1. Open and close scalp incisions
2. Perform Ventriculostomies, place lumbar drains and intracranial monitors
3. Position patients for craniotomy
4. Perform the opening and closing of craniotomies
5. Resect skull lesions
6. Perform image-guided biopsies
7. Demonstrate facility with the use of surgical instruments including operating microscope and endoscope
8. Identify interface between tumour and brain and use as operating plane for tumour resection
9. Identify anatomic landmarks, functional regions and major structures
10. Show how to minimize and control intraoperative bleeding
11. Perform resection of extra- and intra-axial brain tumours
12. Perform resection of supra- and infratentorial brain tumours
13. Perform resection of pituitary lesions
14. Perform basic skull base procedures
15. Detect and handle unexpected complications

Figure 1A: Cognitive Task Analysis of Entering the Sella

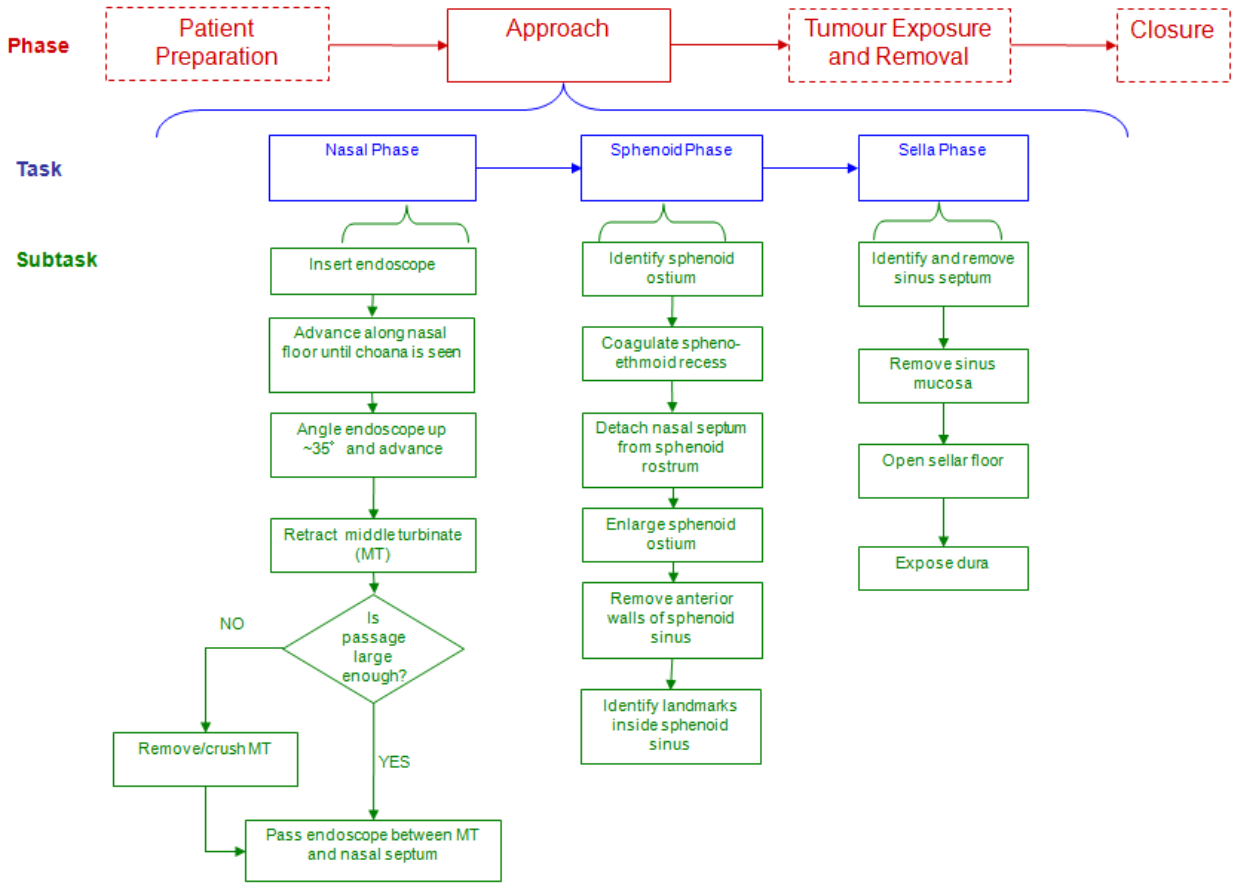
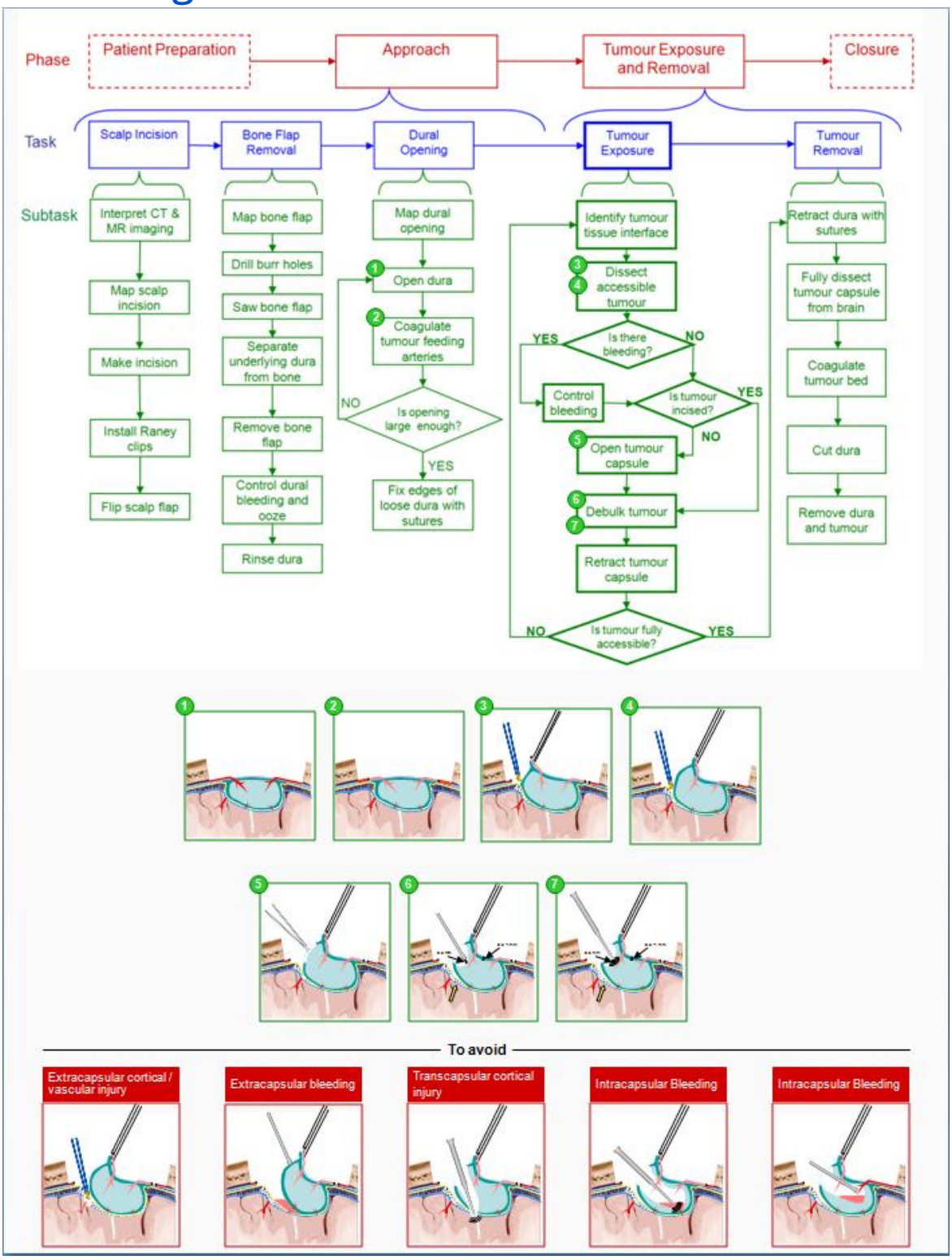


Figure 2A: Cognitive Task Analysis of Meningioma Debulking



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