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Title: Simulator Training for Endovascular Neurosurgery

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Author Questionnaire

1. Microscopy: Does your protocol involve video microscopy, such as filming a complex dissection or microinjection technique? **N**

2. Software: Does the part of your protocol being filmed demonstrate software usage? **Y**

Videographer: All screen captures to be filmed or recorded on day of shoot

3. Filming location: Will the filming need to take place in multiple locations (greater than walking distance)? **N**

Introduction

1. Introductory Interview Statements

REQUIRED:

1.1. **J. Scott Pannell**: Simulation training is increasingly important for learning complex, high-risk skills. This endovascular neurosurgery simulator protocol tests trainee anatomical knowledge and provides haptic catheter-system feedback in a consequence-free environment **[1]**.

1.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

REQUIRED:

1.2. **J. Scott Pannell**: Our protocol provides stepwise guidelines for trainees of varying levels **[1]**.

1.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

Introduction of Demonstrator on Camera

1.3. **J. Scott Pannell**: Demonstrating the procedure will be Robert Rennert, a Neurosurgery resident and former endovascular fellow **[1][2]**.

1.3.1. INTERVIEW: Author saying the above

1.3.2. Named demonstrator(s) looks up from workbench or desk or microscope and acknowledges camera

Ethics Title Card

1.4. Procedures involving human subjects have been approved by the Institutional Review Board (IRB) at UCSD.

Protocol

2. Simulator Setup

2.1. Before beginning a procedure, assemble and power on the simulator **[1-TXT]**.

2.1.1. WIDE: Talent #1 approaches assembled simulator, then powers on simulator **TEXT: See text for simulator equipment list**

2.2. Select the patient scenario in the software interface on the attached laptop **[1]** and select the appropriate arterial sheath size from the drop-down menu **[2]**.

2.2.1. Talent #1 selecting scenario, with monitor visible in frame
2.2.2. SCREEN: Sheath size being selected

2.3. Select the appropriate catheter, guidewire, and/or microsystem based on the specific scenario and turn on the A and B plane fluoroscopy **[1]**.

2.3.1. SCREEN: Tool(s) being selected, the fluoroscopy being turned on

2.4. Activate the fluoroscopy with the foot pedals **[1]** and use the joysticks to adjust both the patient and image intensifier positions until the correct posteroanterior and lateral views are obtained **[2]**.

2.4.1. Talent #1 activating fluoroscopy with foot pedal(s), with monitor visible in frame as possible
2.4.2. Talent #1 adjusting positions with joystick, with monitor visible in frame

3. First Patient Scenario: Four-Vessel Angiography

3.1. For a four-vessel cerebral angiogram simulation, select a 5-French femoral sheath **[1]**, a 0.035-inch guidewire, and a 4-French diagnostic catheter from the drop-down menu as tools to be used in this simulation **[2]**.

3.1.1. WIDE: Talent #1 selecting sheath, with monitor visible in frame
3.1.2. SCREEN: Tool(s) being selected Vid NOTE: can also use 2.2.2 and/or 2.3.1

3.2. Insert the guidewire into the simulator machine **[1]** until it registers on the simulation screen, signaling that access has been gained **[2-TXT]**.

3.2.1. Talent inserting guidewire

3.2.2. SCREEN: Guidewire registering on screen **TEXT: Here 52-year-old male with unruptured left carotid terminus aneurysm shown**

3.3. Advance the guidewire until it is visualized in the descending thoracic aorta and continues into the aortic arch **[1]**.

3.3.1. SCREEN: Guidewire visualized in aorta/continuing into aortic arch Vid NOTE: DNS, Use 3.2.2.

3.4. When the guidewire is safely in the aortic arch, hold the guidewire in place and insert a diagnostic catheter over the guidewire through the simulated femoral sheath to the aortic arch **[1]**.

3.4.1. Shot of guidewire being held in place, then catheter being inserted

3.5. Remove the guidewire **[1]** and gently depress the contrast syringe plunger to use the fluoroscopy puff technique to simulate contrast injection **[2]** and briefly opacify the vessels as the catheter is advanced into the desired artery **[3]**.

3.5.1. Guidewire being removed *Videographer: Important step*
3.5.2. Syringe being depressed Vid NOTE: do not use tk1 or tk2
3.5.3. SCREEN: Vessels being opacified/catheter advancing

3.6. Next, create a roadmap guide by injecting contrast with the contrast syringe **[2]** while the roadmap fluoroscopy foot pedal is depressed **[3]**.

~~3.6.1. SCREEN: Feature being selected~~
3.6.2. Contrast being injected Vid NOTE: do not use tk1 or tk2; can also use 3.5.2 tk1
3.6.3. Talent depressing foot pedal *Videographer: Important step*

3.7. Reinsert the wire to selectively catheterize the desired vessel, advancing the catheter over the wire **[1-TXT]** to catheterize the right and left internal and external carotid arteries and the left and right vertebral arteries **[2]**.

3.7.1. Wire being reinserted/catheter being advanced **TEXT: Remove wire for subsequent angiography runs**
3.7.2. SCREEN: Arter(ies) being catheterized

3.8. When each of the vessels is selectively catheterized, use the diagnostic catheter and the simulator contrast syringe to perform angiograms of each of the vessels **[1]**, obtaining high-magnification views of the aneurysm, as necessary **[2]**.

3.8.1. Contrast agent being injected

3.8.2. SCREEN: Shot of aneurysm

3.9. Review the angiograms for adequacy before removing the catheter **[1]** and remove the diagnostic catheter from the simulation sheath **[2-TXT]**.

3.9.1. Talent reviewing angiograms, with monitor visible in frame
3.9.2. Catheter being removed **TEXT: Simulated femoral arteriotomy site closure not performed**

4. Second Patient Scenario: Carotid Terminus Aneurysm Coiling

4.1. For carotid terminus aneurysm coiling simulation select a 6-French guide catheter, a 0.035-inch guidewire, and a 4-French diagnostic catheter from the drop-down menu **[2]**.

4.1.1. WIDE: Talent #1 selecting sheath, with monitor visible in frame Vid NOTE: use throughout section 4
4.1.2. SCREEN: Tool(s) being selected

4.2. Insert a diagnostic catheter over a guidewire into the aortic arch **[1-TXT]** and insert a guide catheter over the diagnostic catheter through the femoral access site to the aortic arch **[2]**.

4.2.1. Talent #2 inserting diagnostic catheter **TEXT: Here a 52-year-old male with known ruptured left carotid terminus aneurysm, severe headache, nonfocal exam, and Glasgow Coma Scale of 15 shown**
4.2.2. SCREEN: Guide catheter being inserted

4.3. Remove the guidewire **[1]** and create a roadmap guide of the left common carotid artery in the software **[2]**.

4.3.1. Guidewire being removed Vid NOTE: do not use tk1 or tk2
4.3.2. SCREEN: Roadmap guide being created

4.4. Depress the fluoroscopy foot pedal to inject contrast with the contrast syringe **[1]** and reinsert the guidewire **[2]** to facilitate selective catheterization of the left common carotid artery and the internal carotid artery **[3]**.

4.4.1. SCREEN: Contrast being injected Vid NOTE: DNS, use 4.3.1-4.3.2
4.4.2. Guidewire being inserted Vid NOTE: do not show wire go off screen
4.4.3. SCREEN: Arter(ies) being catheterized

4.5. When the guide catheter is within the internal carotid artery, remove the diagnostic catheter **[1]** and depress the fluoroscopy pedal while injecting contrast to allow the performance of angiographic runs of the left internal carotid cerebral circulation **[2]**.

4.5.1. Catheter being removed
4.5.2. SCREEN: Contrast being injected Vid NOTE: can be reused for other syringe injection shots

4.6. Measure the aneurysm using the calculation option **[1-TXT]** and select a microcatheter or microwire and an appropriately sized coil **[2]**.

4.6.1. SCREEN: Aneurysm being measured **TEXT: Coil diameter should be 1 mm wider than mean aneurysm diameter**
4.6.2. Talent #1 selecting microcatheter/microwire and coil NOTE: This was filmed as part of 4.1, but please put it here. Vid NOTE: use 4.1.1-4.1.2

4.7. Insert a microcatheter and microwire through the femoral access site **[1]** and, under roadmap guidance, selectively catheterize the aneurysm with the microsystem **[2-TXT]**.

4.7.1. Catheter and/or microwire being inserted *Videographer: Important step*
4.7.2. SCREEN: Aneurysm being catheterized **TEXT: Controlled micromovements key to preventing inadvertent rupture**

4.8. Remove the microwire **[1]**, insert the previously selected coil through the femoral access site **[2]**, and slowly advance the coil into the aneurysm **[3]**.

4.8.1. Microwire being removed *Videographer: Important step*
4.8.2. Coil being inserted *Videographer: Important step*
4.8.3. SCREEN: Coil being advanced

4.9. Once the coil is fully inserted, perform a diagnostic cerebral angiogram **[1]** and assess the patency of the parent artery and aneurysm filling **[2]**.

4.9.1. SCREEN: Angiogram being performed
4.9.2. SCREEN: Patency being assessed

4.10. With patency of the parent artery preserved **[1]**, detach the coil and remove the coil wire **[2]**. Place additional coils as needed until complete embolization of the aneurysm or sufficient coverage of the dome is achieved **[3]**.

4.10.1. SCREEN: Shot of embolization Vid NOTE: DNS, use 4.9.1-4.9.2
4.10.2. SCREEN: Coil being detached
4.10.3. Coil being removed **TEXT: Repeat with additional coils until approximately 30% aneurysm occlusion obtained**

4.11. After final post-coiling angiography, remove the microcatheter and guide catheter from the simulation sheath site **[1-TXT]**.

4.11.1. Catheter(s) being removed **TEXT: Simulated femoral arteriotomy site closure not performed** Vid NOTE: post coiling angiography filmed per author's pref

4.11.2. Added shot: catheter being removed

5. Third Patient Scenario: Left Middle Cerebral Artery Thrombectomy

5.1. For a left middle cerebral artery thrombectomy simulation, select a 6-French guide catheter, a 0.035-inch guidewire, and a 4-French diagnostic catheter, from the drop-down menu **[2]**.

~~5.1.1. WIDE: Talent #1 selecting sheath, with monitor visible in frame~~

5.1.2. SCREEN: Tool(s) being selected Vid NOTE: use throughout section 5

5.2. Insert the guide catheter into the left internal carotid artery **[1-TXT]** and perform angiographic runs of the left internal carotid cerebral circulation as demonstrated **[2]**.

5.2.1. Talent #2 inserting guidewire **TEXT: 64-year-old female with NIHSS score of 12 for aphasia and right-sided weakness shown**

5.2.2. SCREEN: Angiographic run being performed

5.3. Select a microcatheter or microwire and a stent retriever device from the drop-down menu. Insert a microcatheter **[2]**, and microwire into the simulated femoral access site **[3]** and into the left internal carotid artery **[4]** and, under roadmap guidance, advance the microwire and microcatheter into the left middle cerebral artery carefully past the area of occlusion **[5-TXT]**. NOTE: Selection of microcatheter was filed as part of 5.1, but please put it here.

~~5.3.1. Intermediate aspiration catheter being inserted *Videographer: Important step*~~

5.3.2. Microcatheter being inserted *Videographer: Important step*

5.3.3. Microwire being inserted *Videographer: Important step*

5.3.4. SCREEN: Material(s) being inserted into left internal carotid artery

5.3.5. SCREEN: Microwire and microcatheter being inserted into left middle cerebral artery **TEXT: Caution: Potential complications include vascular perforations and/or downstream clot embolization**

5.4. Replace the microwire with a stent retriever device **[1]** and advance the device into the artery distal to the occlusion **[2]**.

5.4.1. Device being inserted Vid NOTE: can also use 5.1.1-5.1.2

5.4.2. SCREEN: Device being advanced into artery

5.5. Remove the microcatheter, leaving the stent retriever in place at the level of the occlusion **[1]**.

5.5.1. Microcatheter being removed Vid NOTE: DNS, use 5.4.1-5.4.2 *Videographer: Important step*

~~5.5.2. SCREEN: Intermediate catheter being advanced~~

5.6. Turn on the simulated aspiration to the guide catheter in the software and pull back on the microwire to retract the stent retriever device into the guide catheter **[1]**.

5.6.1. SCREEN: Aspiration being activated, then microwire being retracted

5.6.2. Added shot: microwire being retracted

5.7. Remove the stent retriever from the simulated femoral access site **[1]** and perform an angiogram through the guide catheter to ensure removal of the occlusion **[2]**.

5.7.1. Retriever being removed Vid NOTE: use 5.6.2

5.7.2. SCREEN: Angiogram being removed

5.8. Remove the guide catheter from the simulation sheath site **[1-TXT]**.

5.8.1. Catheter(s) being removed **TEXT: Simulated femoral arteriotomy site closure not performed**

Protocol Script Questions

A. Which steps from the protocol are the most important for viewers to see?

3.5., 3.6., 4.7., 4.8., 5.3., 5.5.

B. What is the single most difficult aspect of this procedure and what do you do to ensure success?
4.7. Selectively catheterizing an aneurysm is both dangerous and challenging. Controlled micromovements are key to prevent inadvertent rupture.

Results

6. Results: Representative Performance Evaluations

6.1. Based on analysis of variance and Tukey's Honest Significant Difference testing **[1]**, statistically significant improvements were seen among all of the participants in specific performance metrics for all three procedures **[2]**, including contrast utilization **[3]**, fluoroscopy time **[4]**, and total procedural time **[5]**.

6.1.1. LAB MEDIA: Figure 2
6.1.2. LAB MEDIA: Figure 2 *Video Editor: please sequentially emphasize data bar groups from top to bottom of graph*
6.1.3. LAB MEDIA: Figure 2 *Video Editor: please emphasize grey data bars*
6.1.4. LAB MEDIA: Figure 2 *Video Editor: please emphasize orange data bars*
6.1.5. LAB MEDIA: Figure 2 *Video Editor: please emphasize blue data bars*

6.2. In addition, significantly increased Likert Scale scores were observed **[1]**, for which a score of 1 corresponded to failure and a score of 5 corresponded to excellence based on the procedural technique **[2]**.

6.2.1. LAB MEDIA: Figure 3 *Video Editor: please add asterisks or similarly emphasize significance for all data bars*
6.2.2. LAB MEDIA: Figure 3

Conclusion

7. Conclusion Interview Statements

7.1. **J. Scott Pannell**: In addition to possessing the relevant anatomical knowledge, one of the keys to a successful endovascular neurosurgery is a refined tactile sense to avoid vessel wall dissections and perforations **[1]**.

7.1.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera

7.2. **J. Scott Pannell**: While the simulator includes a haptic feedback system, modulation of the acceptable force vectors during real-world training is critical for the safe performance of the endovascular techniques **[1]**.

7.2.1. INTERVIEW: Named talent says the statement above in an interview-style shot, looking slightly off-camera