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SIMULATION IN NEUROSURGICAL RESIDENCY TRAINING: A NEW PARADIGM

Simulation in Surgical Training

In the era of duty hour restrictions and increasing medico-legal pressures, surgical simulation offers a viable alternative to bridge the gap in experience and knowledge of residents. The value of simulation for the re-creation of invasive procedures has a rich history in cadaveric dissection and animal experimentation. While these exposures provide a valuable experience and do not require sophisticated technological support, cadavers and laboratory animals are a scarce and expensive resource. Three years ago, we established a 'fundamental skills laboratory' funded by educational grant support. The course was run by our faculty and senior level residents and provided an educational experience to the junior level residents. The course involved intensive hands-on exercises designed to familiarize the trainees with fundamental bedside procedures and operative skills such as external ventricular drain and intracranial pressure bolt placement, suturing, drilling and turning a craniotomy flap. This course was extremely successful and was the forerunner to the SNS Boot Camp that will be offered for its second consecutive year in July 2011 for all incoming post-graduate year 1 (PGY1) neurosurgery residents.

Technological advancements have made possible the transition from these laboratory experiences to a 'clean' environment that relies entirely on technology and no preserved tissue specimens. Simulation in this setting is now widely accepted for enhancing the resident training experience in other specialties including surgical training of laparoscopic procedures, endoscopy, colonoscopy, thorascopy, cataract surgery, peripheral vascular endovascular interventions and airway management. These simulation systems replicate procedures that involve two-dimensional visualization. The application of simulation in the realm of neurosurgical training and education has lagged somewhat compared to other specialties, likely

Figure 1: Residents and fellows perform an endovascular coil embolization of a posterior communicating artery aneurysm on the Simbionix simulator (Simbionix USA Corp, Cleveland OH). Simbionix provides an interactive and realistic biplanar fluoroscopy to perform both diagnostic and interventional procedures on a number of 'patient' case scenarios with unique vasculatures. A broad selection of groin sheaths, diagnostic catheters and glidewires may be selected and the software incorporates the unique mechanical properties of each. Patient vital signs are continuously monitored during the session.

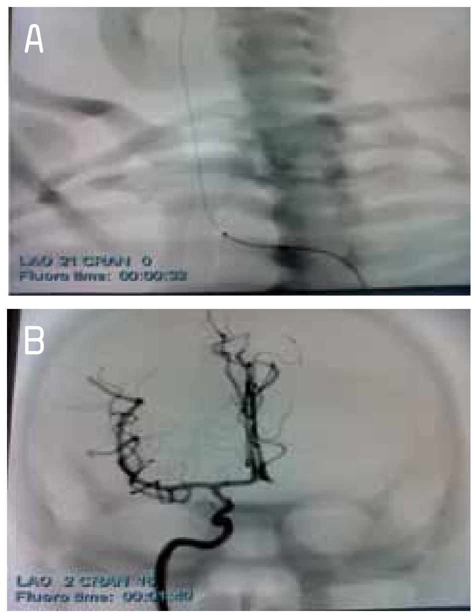

Figure 2: A) Trainees advance a 5F diagnostic catheter over an 0.035" guidewire to cross the arch and then selectively catheterize the right internal carotid artery (RICA). B) A selective RICA angiogram is then performed as shown in this fluoroscopic view.

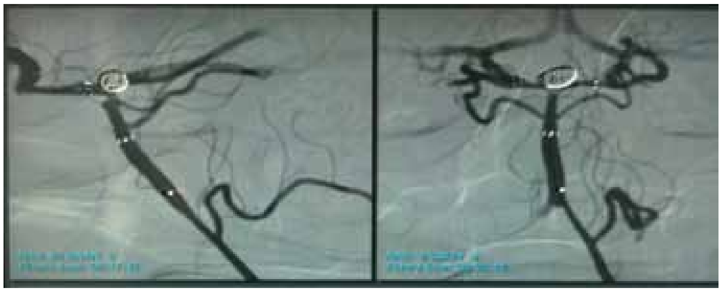

Figure 3: Trainees perform a stent-assisted coil embolization of a basilar apex aneurysm using the "Y-stent" configuration, as demonstrated in this digitally subtracted view. In this technique, the first open-cell design stent is placed from the mid basilar artery to a posterior cerebral artery (PCA). The second open-cell stent is then placed from the basilar artery through the twines of the first stent into the contralateral PCA. The microcatheter is then navigated through the stents into the aneurysm. The stent reconstruction maintaines the growing coil mass within the aneurysm.

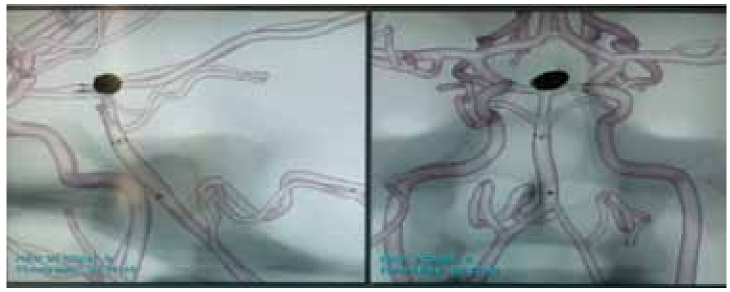

Figure 4: The simulator software provides a three dimensional roadmap view of the vasculartture which can be turned on and off during an procedure to aid the trainee in understanding the relevant anatomy.

due to the challenge inherent in replicating a complex three-dimensional reality with a sharp contrast between neural elements and their surrounding skeletal support system.

However, improvements in computer processing power, volume rending, graphics and haptics have facilitated the creation of sophisticated, albeit limited simulation, systems for neurosurgical applications.[1] Some centers have adapted resources for three-dimensional volume rendering intended for diagnostic and intraoperative navigation purposes towards simulation and educational efforts. The benefit of this strategy is that it utilizes specific patient's imaging data. There is evidence that employing computed tomography angiography (CTA), magnetic resonance angiography (MRA), 3-D stereoscopic imaging and other virtual reality systems to interact and familiarize one's self with a particular patient's anatomy can be beneficial towards surgical planning. This method can aid in establishing a good surgical strategy, enhancing intra-operative spatial orientation and increasing the surgeon's confidence in a wide range of surgical scenarios. The drawback of this strategy is that it does not provide feedback to the trainee.

Endovascular Simulation

A high fidelity simulation system equipped with haptic feedback is available for angiography-based procedures that is based on a more simplified two-dimensional visualization than open neurosurgery. Angiography and the growing field of neurointervention are playing a rapidly evolving role in the care of neurosurgical patients. Neurointervention requires a very unique skill set that is not transferable from open domains taught in neurosurgical training programs. An unintended consequence of the rapid evolvement and adaptation of endovascular techniques is that residents are currently not completing training programs with a sufficient endovascular experience to practice that specific skill set beyond. As a result, present-day neurosurgery resident graduates lack the comprehensive capacity of prior generations of neurosurgeons. In an attempt to begin to close that gap we strongly encourage the active participation in the angiography suite by residents and are exploring new and safe methods for our trainees to acquire endovascular skills. With this purpose in mind, we studied the feasibility and utility of simulated diagnostic cerebral angiography among neurosurgical residents and fellows using an endovascular biplane angiography simulator.

We recruited trainees into a pilot study approved by the institutional review board of the Cleveland Clinic. Neurosurgical residents in their post-graduate years one through five (PGY 1-5) and first and second year endovascular neurosurgery fellows were recruited into a standardized training protocol consisting of a didactic, demonstration and hands-on learning environment. A pre- and post-task survey was performed; designed to assess a participant's baseline knowledge, attitudes and beliefs regarding the educational merit of the training curriculum.

The Simbionix simulator (Simbionix USA Corp, Cleveland OH), was employed. Simbionix provides an interactive biplanar fluoroscopic display to perform both diagnostic and interventional procedures on a number of 'patient' case scenarios with unique vasculatures. A broad selection of groin sheaths, diagnostic catheters and glidewires may be selected and the software incorporates the unique mechanical properties of each. While the behavior of the catheter in the vessel is simulated, actual catheter and wire manipulations are incorporated by motion tracking sensing capabilities in the hardware component of the simulator. Information such as angulation, friction and forward-loading are all incorporated into the algorithm to produce haptic feedback and allow the catheters to navigate in a realistic fashion. Contrast can be administered during both simulated real time fluoroscopy and digital subtraction angiography. Roadmap assistance for navigation can also be simulated.

The potential benefit of learning this invasive procedure that requires fluoroscopy and cumulative radiation doses on a simulator is that it involves a no-risk environment for both the patient and the trainee. The simulator was

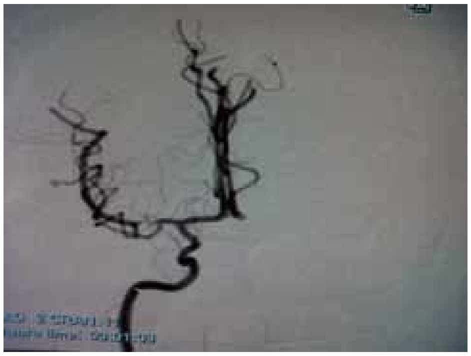

Figure 5: Digital subtraction angiography of a simulated patient case scenario of a man who presented with right middle cerebral artery (MCA) distribution ischemic symptoms demonstrates a critical stenosis of the M1 segment of the MCA just distal to the origin of the anterior temporal artery.

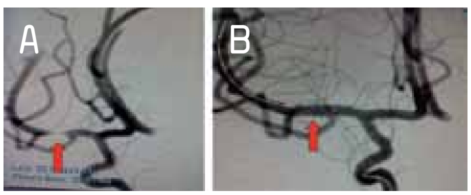

Figure 6: Pre (A) and Post (B) balloon angioplasty and stenting of the lesion demonstrates restoration of the diseased vessel caliber.

rated favorably for both visual display and mechanical/haptic feedback properties by experienced fellows for the training of residents in diagnostic cerebral angiography. Residents reported that both the hands-on and didactic components of the training session were valuable to the learning process. The results of our pilot simulation program demonstrated significant improvements in procedural and fluoroscopic times among neurosurgical residents reflecting improved catheter technique for four vessel angiography on a simulator over a short period of time. Residents who lacked formal training and experience in angiography were able to complete the task in a time approaching that of the experienced fellows at the completion of the training. Further study will be directed at testing the hypothesis that performance on the simulator correlates with angiography suite performance. The next step will be to fully incorporate the endovascular simulator into the resident curriculum and follow aptitude and level of comfort as residents perform procedures in the angiography suite.

Simulation in Residency Training: Moving Forward

Simulation of surgical procedures such as laparoscopy has been fully incorporated into the training of general surgery residents. In fact, general surgery training programs are required under the Accreditation Council for Graduate Medical Education to provide a simulation and skills laboratory for trainees. The role of simulation in neurosurgical education is yet to be defined. There are two main components to a procedure that simulation can reinforce. First, the order of steps required to successfully perform any given procedure can be rehearsed under different scenarios. For example, one can perform A then B then C and await the outcome of this management algorithm. After the outcome is identified by the simulation system (adverse or desired), another treatment algorithm can be employed in a reiterative manner. This learning environment could be very beneficial and efficient, particularly for relatively rare yet vital occurrences in real-world patient encounters, such as critical resuscitation. There is evidence that simulation of cardiopulmonary resuscitative efforts, for example, can improve performance and subjective perceptions of self competence among trainees. An intensive, curriculum-based simulation module can be as beneficial as six months of clinical ward experience.

Secondly, simulation of technical procedures can also be of benefit by providing a no-risk environment for rehearsal of mechanical skills required. These findings reflect a transfer of skills acquired from the simulator to an actual patient encounter. It would be expected that the closer a simulation can mimic an actual procedure, the more readily the skills can be transferred. Strategies employing simulation into training must also incorporate periodic retraining of skills to avoid deterioration over time.

Conclusions

Surgical simulation provides a zero-risk setting in which skills can be acquired through repetition. Advanced anatomically and technically accurate simulation systems that provide haptic feedback can further aid the trainee in developing and refining the mechanical skills required for the procedure. In addition, exposure of trainees to long and complex procedures could help to develop the mental preparedness to withstand their real-life counterparts. Ultimately, the best metric for determining simulator effectiveness is an objective assessment of the efficacy of skill acquisition derived from simulation usage and the transfer of this information to actual real-life procedures.

The role of simulation in neurosurgical residency training will be established by a handful of leading programs that are committed to providing a rich environment for their trainees and outlining protocols and curricula with objective outcomes to track an individual's performance over time. To this aim, we should demand and drive future technological advances towards this worthwhile endeavor.

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