

## ARTICLE

# Clinical Neuroscience in Practice: An Experiential Learning Course for Undergraduates Offered by Neurosurgeons and Neuroscientists

G. R. Simonds<sup>1,2,3</sup>, E. A. Marvin<sup>2,3</sup>, L. S. Apfel<sup>2,3</sup>, Z. Elias<sup>2,3</sup>, G. A. Howes<sup>2,3</sup>, M. R. Witcher<sup>2,3</sup>, E. N. Weaver<sup>2,3</sup>, J. C. Fraser<sup>2,3</sup>, J. J. Synkowski<sup>2,3</sup>, J. T. Prickett<sup>2,3</sup>, C. M. Rogers<sup>2,3</sup>, C. M. Busch<sup>2,3</sup>, M. J. Benko<sup>2,3</sup>, N. Sou<sup>2</sup>, M. J. Churning<sup>3</sup>, D. C. Summers<sup>3</sup>, & H. Sontheimer<sup>1,2</sup>

<sup>1</sup>School of Medicine and Research Institute, Virginia Tech. Roanoke, VA; <sup>2</sup>Virginia Tech. School of Neuroscience;

<sup>3</sup>Carilion Clinic, Roanoke, VA.

Many pre-health students pursue extracurricular shadowing opportunities to gain clinical experience. The Virginia Tech School of Neuroscience introduced a formal course that provides a clinical experience superior to that received by many medical students. This course is composed of weekly 75-minute seminars that cover diseases affecting the nervous system, their diagnosis and treatment, complemented by weekly half-day intensive clinical experiences with unprecedented access to a team of neurosurgeons (in hospital operating rooms, Intensive Care Units, emergency room, angiographic suites, and wards). In the operating rooms, students routinely “scrub-in” for complex surgeries. On hospital rounds, students experience direct patient care and receive in-depth exposure to modern nervous system imaging. Students participate in two 24-hour “on-call” experiences with team providers. After call, students participate in cognitive and psychological studies to assess physiological and

psychological effects of call-related sleep deprivation. Students prepare weekly essays on challenging socioeconomic and ethical questions, exploring subjects such as the cost of medicine and inequalities in access to health care. Towards the end of the course, students meet with the admission dean of the Virginia Tech Carilion medical school; they prepare a personal statement for medical school/graduate school applications, and attend a half-day block of mock medical school/graduate school interviews delivered by experienced clinicians. In lieu of a final exam, each student presents to the entire neurosurgery department, an in-depth clinical analysis of a case in which they participated. We provide details on implementation, challenges and outcomes based on experiences from three semesters with a total enrollment of approximately 60 students.

*Key words: Neurosurgery, shadowing, health care, medical school, on-call, grand rounds*

## INTRODUCTION

The reader of this Journal is familiar with the increasing interest that undergraduates express in attaining a degree in Neuroscience (Ramos et al., 2011). To address student demand, about 150 U. S. colleges and universities, and particularly smaller liberal arts colleges have created interdisciplinary majors drawing expertise from disciplines like Psychology, Biology, Physics and Chemistry (Ramos et al., 2016). Virginia Polytechnic Institute and State University also known as Virginia Tech (VT) is a large public land grant university in Southwestern Virginia, a largely rural part of the state. VT introduced a Neuroscience major in 2014 and launched the School for Neuroscience in 2015 as the disciplinary home for the degree. Within only two years, enrollment grew to approximately 180 students annually with over 550 students enrolled as of this writing (9/2017). To better serve the diverse interests of students, VT Neuroscience divided the Neuroscience (NS) degree into four distinct majors: Clinical NS, Experimental NS, Behavioral & Cognitive NS and Computational & Systems NS. Students in all four NS majors share a common introductory curriculum that includes a freshman orientation course, and two semesters of introduction to NS with a required two semester introductory laboratory. Major-specific specializations occur in the students’ junior and senior years of study where they take major specific electives. Of note, in their freshman year, well over 50% of

students consider themselves “pre-health” students, although career paths for neuroscientists are considerably more varied, and could include at a minimum Research, Business, Finance, Law, Industry, Marketing, Policy and Politics (Price, 2011). In our experience, very few students articulate their pre-health interest based on actual familiarity with a clinical profession, and students are often somewhat naïve regarding the required course of study and selectivity of the career path. We muse over the effect that TV shows such as “House” may have had on the increasing interest in careers in healthcare.

Students in all four NS majors are expected to do hands-on research beyond the required two-semester research course. At a minimum, students spend one semester in a laboratory but can obtain up to 12 laboratory credits, equivalent to four semesters of study. Opportunities for research are relatively straightforward to implement through undergraduate research credit earned by students working alongside graduate students or postdocs and presenting an abstract or co-authoring a paper. Such research experience is often a requirement for future admission to graduate school and is desirable, albeit not required for students pursuing a medical career. Obtaining clinically relevant experience that can inform a students’ career path and admissibility into medical or physician assistant (PA) school is often more challenging and typically not part of a college curriculum.

Upon establishing a distinct major in clinical NS, we felt

a need to address this gap by implementing a formal experience learning activity that would enhance the student experience in a clinical setting and their success in achieving their career goal. Hence, we developed an experiential learning course that caters specifically to pre-health students in NS. This course, now in its third iteration, is entitled “Clinical Neuroscience in Practice (NEUR 4594)” and has been a tremendous success. This article describes the course, its objectives, implementation, outcomes and our observation and recommendations with the hope that we can stimulate other colleges and universities to implement a similar course or generate their own version.

## Course Description

The overarching objective of this course was to provide a meaningful experiential learning opportunity for students to observe the clinical care provided to individuals suffering from injury or diseases affecting the nervous system. It was not intended to be merely a shadowing experience, but an intensive immersion that provides in depth understanding of the disease process that includes coverage of underlying pathology, approved treatments, treatment outcomes, as well as discussions of ethical, socioeconomic, and provider well-being issues related to the current state of health care delivery.

### Specific objectives included:

- To experience neurological illnesses in a clinical setting.
- Exposing students to currently available techniques and approaches to medical and surgical management of brain and spinal cord injury and neurological illnesses.
- Engaging students in discussion on current issues in health care and society.
- Exposing students to the emotional and psychological stressors of high-level tertiary care.
- Providing a deep and reflective experience to soul search whether their desire to pursue Medicine is genuine.
- Providing an “on-ramp” to medical school/dental school/PA School admission.

Prior generations of pre-health students who shadowed physicians reported that exposure to neurological illnesses were difficult to attain, with most students shadowing primary care physicians. We deliberately chose to focus on Neurosurgery for this course since all patients undergoing a neurosurgical procedure have a known illness affecting the nervous system. This illness is most often well defined with stroke, tumors, epilepsy, Parkinson disease, herniated disks, and aneurysms being excellent examples. Also, strategies for surgical treatment are well advanced and, in most instances, extensive literature is available regarding current standard of care. Most disorders also have a wealth of related ongoing experimental trials that can be examined and discussed.

While at first glance this setting may seem to be far too specialized to provide undergraduates with a broader and more balanced experience in Medicine, nothing could be further from the truth. Neurosurgery is a complex team effort that involves a variety of clinical specialties and multiple professions that students can witness and interact within the

care setting. For example, all patients are sedated by an anesthesiologist or nurse anesthetist; many procedures, for example deep brain stimulator implants (DBI), involve Neurology prior to or during surgery. All patients undergo imaging by a radiologist prior to or during surgery, and many minimally invasive procedures such as coiling of aneurysm are done by interventional radiologists. Many patients arrive through the emergency room having suffered trauma, and are initially cared for by emergency room physicians. Some procedures, such as pituitary surgery, involve Otolaryngology. Furthermore, well over half of the medical personnel are not physicians but rather medical technologists or advanced care providers (ACPs) that include nurse practitioners and physician assistants. Students also receive experience in post-surgical follow-up that often includes conversations with the patients and family members. Given the nature of the conditions witnessed, such conversations frequently involve social workers and palliative care specialists. Hence, during this course, students are exposed to and witness the work of a comprehensive list of physicians and non-physician health care professionals. One-on-one interactions with each of these providers allow students to gauge their interest in any of these professions. Most importantly, however, students will reliably experience neurological illness cases every time they attend this class. There is no idle time in a level 1 trauma center!

**Course Implementation:** The course is offered as a 3-credit hour class and currently has a capacity limit of 20 students. The class meets twice weekly following a regular schedule (Table 1). Each week a 75-minute classroom lecture/discussion session presents a new disease problem led by one of the clinicians. This session is divided into five 15-minute segments. During the first 15 minutes the clinician presents the clinical case in the format of a “grand rounds” presentation (Rigby et al., 2012), a ritual of medical education, consisting of presenting the medical problems and treatment of a particular patient to an audience consisting of doctors, residents and medical students. During the next 15-minute segment students devise and discuss a treatment strategy for the patient. In the third 15 minutes, the actual treatment approach taken is presented along with a discussion of why and how this is considered the standard of care. In the fourth 15-minute block, two students will present the clinical evidence for the most effective treatment approach that justifies this as the “standard of care” using an important clinical trial paper as the source. The final 15 minutes are devoted to discussing the ethical and socioeconomic issues the particular case or disease may present.

The experience learning component of the course happens in the hospital. For logistical reasons, we divide students into two groups of 10 who either attend on Wednesday or Friday morning typically from 8-12pm. Roanoke Memorial Hospital is a regional level 1 trauma center that has nine attending neurosurgeons, 11 ACPs and seven Neurosurgery residents on staff. Six Neurosurgery operating suites remain busy throughout the week with a combination of elective and emergency surgeries. Typically,

Week	Activity	Assignment
1	Clinical Kickoff Meeting – Meet the Team	Self Introduction
2	Class – How to get into the Head <a href="#">Surgical Theater</a>	Question of the week
3	History of Clinical NS/Neurosurgery <a href="#">Surgical Theater</a>	Question of the week
4	Class - CNS Anatomy/Radiology/Diagnosis <b>Case Topics: Brain Metastasis</b> <a href="#">Surgical Theater</a>	Question of the week
5	Class - Stroke <b>Case Topic: Basal Ganglia Hemorrhage</b> <a href="#">Surgical Theater</a>	Question of the week
6	Class - Trauma <b>Case Topic: Severe Closed Head Injury</b> <a href="#">Surgical Theater</a>	Question of the week
7	Class - Tumor <b>Case Topic: Acoustic Neuroma</b> <a href="#">Surgical Theater</a>	Question of the week
8	Class - Vascular/Interventional Radiology <b>Case Topic: Aneurysm Rupture</b> <a href="#">Surgical Theater</a>	Question of the week
9	Class- Spine <b>Case Topic: L4 L5 HNP</b> <a href="#">Surgical Theater</a>	Question of the week
10	Class - Functional Neurosurgery <b>Case Topic: Refractory Seizure</b> <a href="#">Surgical Theater</a>	Question of the week
11	Class - Medical School Application Process (Do's and Don'ts) <a href="#">Surgical Theater</a>	Personal Statement
12	Class - Pediatric Neurosurgery <b>Case Topic: Baby with Hydrocephalus</b> <a href="#">Surgical Theater</a>	Question of the week
13	Socioeconomics of Neuroscience and Healthcare - Student Discussion Session <a href="#">Surgical Theater</a>	Question of the week
14	Class - Cervical Spine <b>Case Topic: Cervical Fracture/Dislocation</b> <a href="#">Surgical Theater</a>	Question of the week
15	Grand Rounds Presentations	My Patient Case

Table 1. A typical one-semester for the class.

we divide students into groups of two to three to attend one of the ongoing surgical cases (Fig. 1, Table 2) or round with a clinician on pre- or postsurgical consults. From time to time, we allow more students in the same operating room to witness particularly educational procedures, for example, the placement of a DBI in an awake procedure to treat Parkinson's disease. Given the volume of surgical cases, we can ensure that students can sample a comprehensive list of illnesses. Table 2 contains examples based on diaries that were maintained by students over the course.

All students were required to obtain HIPPA training and to have up to date vaccinations as well as a recent negative TB test. Patient privacy, interactions with patients, professional conduct and dress code were discussed prior to the first clinical session. Moreover, students are required to have advanced NS knowledge and have taken at a minimum six credit hours of Introduction to NS with laboratory, 3 credits hours Cellular & Molecular NS, and 3 credit hours of Diseases of the Nervous System. Students that attend the course have an average GPA of >3.5 and are destined to apply to medical, dental or PA schools.

To enhance the operating room experience, all our students also receive four hours of "scrub training" and periodically "scrub in" to enter the sterile surgical field next to the surgeon (Fig. 1). Those students who witness the surgery outside the surgical field typically find outstanding visual vantage points from the head side of the table where the anesthesiologist sits, or by following the procedure on the monitor above the surgery table projecting images from an operating microscope. Students are prompted to ask questions throughout most procedures with the obvious exception of awake craniotomies. Students are also encouraged to spend time with the electrophysiology technicians who continuously monitor nerve function. This is a particularly exciting opportunity for students to see the very EEG and EMG recordings that they obtained on each other during their introduction to NS laboratories, being applied in a patient care setting.

Each student attends at least two "rounding" experiences with an attending physician. Here the morning is spent moving from patient room to patient room, where students witness the physician's interaction with the patient and family, as well as see physical exams being performed. The rounding physician explains routine mental status and motor exams and reflexes. These include tests of language, pupillary reflex, pursuit eye movement, tone in arm or legs, pronator drift, finger to nose, and reflexes involving biceps, triceps, knee, ankle and plantar responses (i.e., Babinski). Typically, the mobile computer systems are used to view patient records, and most importantly brain images if available. The rounding physician reviews the patient treatment in the context of his or her medical history. Through this experience students become quite familiar with interpreting a number of imaging

<b>Vascular</b>	Aneurysm in various locations with clipping, coiling & stenting Strokes, particularly hemorrhagic, subarachnoid, epidural, parenchymal Cavernoma, an AV malformation & treatment by Cyberknife Diagnostic Angiograms
<b>Trauma</b>	Head trauma due to fall from tree, car accidents, no seatbelts, with decompressive craniotomies Adult fall from ladder causing serious brain trauma 24-year-old killed by gunshot to the head
<b>Spine</b>	Suboccipital decompression due to Arnold Chiari malformation in 11-year-old Slipped disks, herniated, fractured, with fusions and many rods and screws Osteoporosis requiring spine fusions Pediatric spine surgery in 13-year-old injured playing football 14-year-old with spine fracture from horseback riding BMX accident with Fracture upper neck, C1 anterior fracture Facet joint fracture in an elderly nursing home patient Kyphoplasty
<b>Tumors</b>	Primary brain tumors, ranging from pilocytic astrocytomas to glioblastomas Meningiomas and Ependymomas One recurrent glioma with Gliadel wafer treatment Metastatic brain tumors, of breast, kidney, colon, melanoma Transnasal removal of pituitary tumor Pediatric tumors causing hydrocephalus
<b>Functional</b>	Parkinson disease, placement of DBS in awake procedure Cervical Dystonia, placement of DBS
<b>Other</b>	Cysts and infections, often associated with IV drug use Pediatric hydrocephaly, shunts and Shunt repairs

Table 2. Examples of clinical cases observed by the students.

modalities that include CT and MRI of the brain and spine, angiography, CTA, MRA, and more. By the end of the course, students know how to interpret hyper- and hypodensities on CT versus MRI scans, understand the differential intensity of water versus tissue on T1 and T2 weighted MRIs, and should understand the utility of diffusion and perfusion images in evaluating the penumbra in a stroke patient.

#### On Call Experience:

To enhance the clinical experience, we require each student to spend one 12-hr. night shift on call. Early in the semester they pick suitable times, which could be any day of the week including the weekend. Students check in with a resident at 7pm and stay awake until 7am the following morning. The intensity of the experience obviously depends on the case load and has ranged from a relatively eventless night to one that they would describe as organized chaos - where middle of the night emergency surgeries were required on trauma, stroke, or gunshot victims. Many of our students elected to add additional on-call experiences throughout the semester. To gain some insight into the effect that staying awake for 24 hrs. has on a person's ability to perform their duties, we paired this student experience with a motor and cognitive performance assessment. This entailed a battery of quantitative fine motor/dexterity tests, cognitive tests and mood assays (analyzing strain on resilience). The findings of these assessments will eventually be analyzed across a larger participant group with the objective of comparing the

performance data between naïve student volunteers and experienced surgeons. However, even in their preliminary self-assessment, it is eye opening for students to see a notable decrease in performance in all cognitive measures.

#### Professional Development Activities:

Since many of the enrolled students (>80%) are striving for admission to medical school, we include three activities that educate and inform them along this career path. Firstly, we



Figure 1. The operating room experience. Students are up-close with the surgery team.

devote one classroom session to discuss medical training and the medical school application process. This session is led by the Dean of Admission of the Virginia Tech Carillion Medical School. The feedback for this 75-minute session has been universally positive even among those students who assumed that they already knew the process. The second activity is preparation, review and revision of an actual personal statement to be included with the application to medical school. This is a graded assignment. Finally, each student participates in a mock medical school interview that is modeled after the “multiple mini interview” schema adopted by many medical schools. Each student has eight interviews and receives both feedback and a numerical grade for each.

**Assignments and Evaluation:**

We elected to grade students on homework assignments that are informed by their clinical experience. Specifically, students have to answer the “question of the week,” examples of which are listed in Table 3. Some of these questions appear trivial at first glance, yet most require thoughtful deliberation. Students are strongly encouraged to discuss their answers with the physicians or residents. In total, these account for 40% of the final grade.

Ten % of the grade is given to the personal statement and another 10% to their final grand rounds presentation.

<p>What do you think were the most pronounced changes and advances in surgical care including neurosurgery in the past 20, 50, and 100 years?</p> <p>How good are our diagnostic tests?</p> <p>Cranial nerves: What are they and what do they do?</p> <p>What disease am I most afraid of and why?</p> <p>How is brain death being determined?</p> <p>When should care for a patient be stopped? Who should decide?</p> <p>How would you go about delivering very bad news?</p> <p>What is your reaction to being so near to death and tragedy?</p> <p>If you screw up care of a patient and they are badly hurt, how will you respond?</p> <p>How do you deal with all the tragedy around you? People dying or permanently disabled many due to poor decisions they made?</p> <p>Now that you have seen a number of surgeries, is there anything unexpected and surprising?</p> <p>What was the scariest thing you saw and how did it affect you?</p> <p>What was the saddest movement?</p> <p>Are we spending health care dollars wisely?</p> <p>Work Life Balance. Is it possible?</p> <p>Has this experience changed me, my plans, or my opinion about clinical Neuroscience?</p>
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Table 3. Examples for the “Question of the week.”

For this activity, described as terrifying by some, each student has to present an actual clinical case they experienced to the entire clinical staff in their regular weekly grand rounds forum. Students are mentored by a resident and provided with de-identified biological and imaging data. As would be the case for a resident doing the same, the students are questioned throughout the presentation. Indeed, the students will have practiced and extensively rehearsed the case with one of the residents. The attending physicians assigns a grade for each student’s performance.

While 10% each are devoted to participation in class and in the clinical setting, 20% of the grade is devoted to a diary maintained by the student throughout the course in which they detail the de-identified patient cases, with diagnosis, treatment approach, successes and failures, and their own thought about each case.

Table 2 shows a listing of the various cases that students had the opportunity to observe close-up.

**Example Cases**

Case 1: The first clinical case that was presented in last year’s grand-rounds was of a 45-year-old woman, who presented with new onset seizures and was found to have a contrast-enhancing mass on MRI of the brain (Fig. 2A). She suffered from breast cancer two years earlier that was treated with surgery, radiation and chemotherapy, and the patient was thought to be in remission. This patient’s history, when paired with the MRI, was highly suspicious of a brain metastasis, which would indicate that remnants from the primary cancer had spread microscopically to the brain.

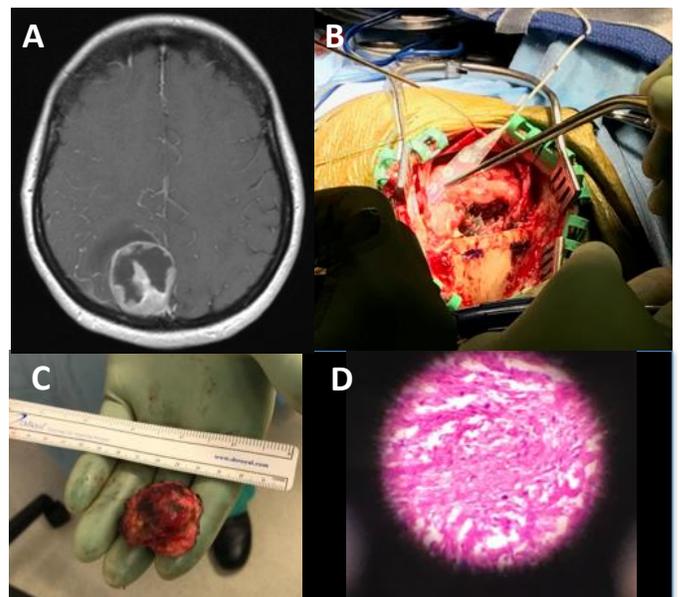


Figure 2. Removal of meningioma from patient with prior history of breast cancer. (A) Preoperative MRI scan shows an enhancing lesion in the tight occipital lobe. (B) Image with exposed brain during the operation. An access pathway has been created to extract the tumor as a single mass. (C) Tumor mass after extraction. (D) Image taken through the eye-piece of the pathology microscope showing distinct cellular details of the extracted and sectioned tumor tissue.

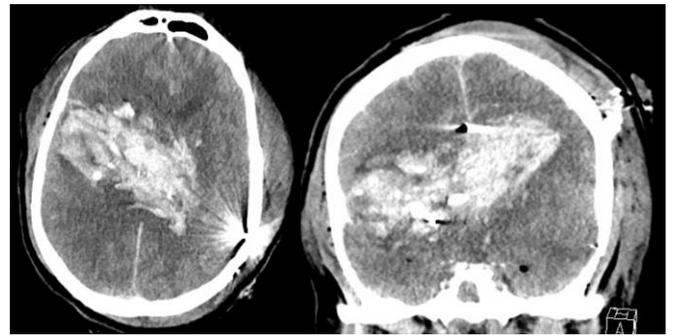
This tumor would have then grown to a size that would make it symptomatic. It would require surgery, radiation, and chemotherapy and nonetheless would portend a poor prognosis. Six students observed the surgery start to finish, literally from anesthesia induction, to positioning, to scalp incision and craniotomy, to tumor removal (Fig. 2B) and closure, and to the patient's transfer to the recovery unit.

They also witnessed the surprise of the surgeon when the mass that was removed lacked the typical consistency of a metastatic tumor but rather had a rubbery consistency with clearly defined margins (Fig. 2C). The subsequent "frozen section" histology, also observed under a microscope by the students, revealed features common in meningioma, a benign primary brain tumor of the coverings of the brain. These features included a swirling cellular pattern of the neoplastic meningeal cells (Fig. 2D). These tumors are entirely unrelated to metastatic cancer, and are considered surgically curable. This was a happy outcome as this patient had developed a benign and curable tumor completely unrelated to her breast cancer, suggesting that the breast cancer indeed remained in remission. This case triggered hours of discussion among the students as to how a prior health condition, the breast cancer in this case, can strongly bias a suspected diagnosis. It also illustrated one of the best-case scenarios where surgical intervention alone can prove to be curative, somewhat of a rarity in Neurosurgery.

**Case 2:** The second case was of a 24-year-old woman, who was admitted to the emergency room after a gunshot wound to the head. The victim was breathing independently but was in coma. Pupillary and corneal reflexes were initially present. The patient moved semi-purposefully to painful stimuli. An emergency CT scan revealed extensive cortical damage along the trajectory of the bullet, fragments of which were still present in the left parietal lobe (Fig. 3). The brain was diffusely swollen and showed massive bleeds along the trajectory. The patient rapidly deteriorated with her pupils becoming dilated and unresponsive to light, indicating probable brain herniation. Given the extensive damage and location of the injury the surgical team elected not to intervene. The patient continued to decline and was declared dead two days later.

The students learned that a young child who found a loaded assault rifle on the kitchen table and, in playing pulled the trigger, inflicted the gunshot. The gunshot accidentally hit the mother who was sitting on the couch watching TV in another room. Not surprisingly much discussion centered on the irresponsible use of guns in society and efforts that could be taken to prevent such tragic accidents. Safe-keeping of guns, and fingerprint readers on triggers were among the solutions offered, albeit some students went further in questioning the utility of the second amendment (the right to bear arms) in this day and age. Other discussions explored the culpability of the patient's boyfriend who left the loaded rifle out in the open.

**Case 3:** This was an elective procedure to reduce the tremors in a 62-year-old woman who was diagnosed with



*Figure 3.* Gunshot victim. CT scans showing the trajectory with bullet entry on the right frontal lobe and fragments near the parietal skull. Left, axial; Right, Coronal section

Parkinson disease. The students were able to witness an awake procedure in which a guide cannula was placed through a small hole drilled in the skull and into the brain, and an ultra-thin electrode was advanced deep into the brain to the subthalamic nucleus. The electrode placement followed a pre-determined path mapped out using a highly precise stereotactic targeting system affixed to the patient's skull. Such a system allows for the selection of trajectories that avoid damage to major arteries and eloquent brain areas. Initially, this microelectrode was passed to test the target area for suitability. Electrical signals of individual cells indicated appropriate positioning. A larger electrode system embedded into a thin silicone-based tube was then passed down the same tract. Once the electrode system was placed in the vicinity of the target, it was stimulated in increasing increments and a neurologist monitored the patient for reduction in hand tremors. He also monitored for unwanted facial twitches and visual changes - implying the electrode was not in an ideal lie. On the first pass, only non-specific responses could be elicited with the patient complaining of visual field disturbances. A new approach angle was calculated, the electrode advanced to the target location, and the stimulation re-initiated. This time, the patient's tremors quieted down to almost none. The patient broke out in tears of joy. For the first time in years, she was able to voluntarily control her hand. A remarkably emotional scene!

In this case we took full advantage of explaining the direct and indirect movement control pathways of the deep brain nuclei and how these predict that placement of a stimulation electrode downstream from the lesioned dopaminergic neurons in the substantia nigra could restore balanced activation. The case illustrated the potential promise of "functional" surgery. In this case the patient was in and out of hospital in a matter of hours and experienced long-term symptom relief. It also illustrated the power of a collaborative approach to complex neurological disorders between multiple medical specialists, technologists, medical equipment representatives and the treating surgeon.

## Student Feedback

As of this writing, two cohorts of 20 students have completed this course, and 20 more are currently enrolled. Student demand has been overwhelming and the experience

universally positive. Many students rated the course as the most valuable and insightful experience they had in their college career. Several students described this course as “life altering.” Examples of actual student testimonials are illustrated in Table 4. Three students who had been pursuing careers in nursing or PA schools, and had already prepared application materials, changed their mind and took the MCATs instead in order to apply to Medical School. Two students who were unsure as to whether to attend graduate or medical school elected the former. We consider both positive outcomes, as there was no attempt to bias students’ perspective but rather to inform them through real world experience. A more comprehensive assessment analysis will be attempted once we have achieved a sufficient number of course completions.

*Without being too dramatic, this is the single best class I have taken in my academic career. It has provided me with invaluable experience that I will remember for the rest of my life. This unique program has exposed me to the world of medicine in a way few other opportunities could.*

*It is a completely different level of learning when you get to witness the patient / doctor relationship first-hand. Although the class was time consuming in comparison with my other classes, it was definitely the class that I learned the most in this semester - possibly even the most in my time at Virginia Tech.*

*How many other undergrads can say they have scrubbed in and have been present on the surgical field of a spinal surgery? I imagine not many.*

*This semester has been nothing short of amazing for me. From a clinical perspective, I have learned such an immense amount. I can now look at a CT and give a (decent, basic) interpretation of what I’m looking at and how the patient may have developed those pathologies. Not to mention how to treat these pathologies through surgery. That experience has been absolutely incredible to see these surgeries happen right in front of you.*

*The opportunity to participate in this course was a once in a lifetime experience in which I forsook other classes to take. I grew not only professionally, but also morally and emotionally. I learned about a field which I had virtually no experience about, and created problems for myself by creating several options about what to do with my life.*

*This class was hands-down the best class I have ever taken. Not only have I learned more about the brain than I thought I would, but I also learned more about myself and the career I want to pursue. I can now say with confidence that I want to be a physician and that all specialties are on the table, including neurosurgery. It’s amazing what a semester can do in affecting your views and decisions.*

*I learned from the course that I do not want to go into neurosurgery. I find it fascinating to follow a case from first consult, to the OR, and then through their recovery, but I know I would not be happy dedicating such a huge chunk of my life to my work.*

*Sadly, I have learned that neurosurgery is not the profession for me. It appears as if surgeons are constantly surrounded by death or people that are severely disabled, whether it is mentally or physically. But, honestly, I think that I have learned more this semester from this class than I have in my five years of college.*

## DISCUSSION

College education typically relies heavily on salaried faculty or instructors to deliver classroom lectures or laboratory experiences. This course moves the majority of learning out of the classroom and into the experiential world. Teaching is done on the fly and depends much on the inquisitiveness of the students. It also differs by the inclusion of medical professionals who volunteer their time. The neurosurgery team did so quite readily in this case. Such willing participation from busy clinicians may not be the norm, however. There is of course a financial disincentive to slowing down a bit to teach and not seeing a maximum amount of patients every day. The neurosurgery team, however, was quite tickled when they were rewarded for their efforts with adjunct academic titles at Virginia Tech. Such a gesture may act to incentivize more reluctant clinicians in similar situations.

All the participating physicians reported their involvement both in the classroom and in the clinical theater to be remarkably rewarding and energizing. For the residents it was a particularly welcome distraction from the daily grind. Furthermore, they valued being able to use their academic rank for their subsequent application to fellowship programs.

Critical to the success was the buy-in from the leadership of the Department of Neurosurgery and the hospital administration. In our instance, this was easy as the head of Neurosurgery co-developed the course and was the major brainchild of this endeavor (pun intended!). The hospital administration, too, was very supportive and considered this course as an important outreach component. They even created a documentary that is now used in advertisements (<https://www.youtube.com/watch?v=J4bh8bTOgk>).

Ultimately, an attitude of good will and a willingness to “pay it forward” is essential to implement such a course. We view this as a common attribute among clinicians, and therefore, encourage other interested parties to reach out to their clinical colleagues.

The biggest challenge for the future of this program will be to meet increasing student demand. Even as a year-round offering, we currently can only accommodate 40-50 students annually. We feel that not just pre-healthcare students would greatly benefit from the course. With our School of Neuroscience enrollment growing to ~200 freshman annually, we expect more than 100 students showing interest in the course. This will require either a creative approach to expanding this opportunity, or an equitable and fair mechanism of student selection. With regards to scaling, we are experimenting with the inclusion of other clinical NS services such as Psychiatry, Neurology, Anesthesiology, Radiology and Pathology.

The reader who is a faculty member at a college or university not affiliated with a medical school may hesitate to consider offering a clinical experience course, making the assumption that such a relationship would be required. However, this collaboration was established completely separate from the auspices of our medical school. This effort grew from a direct relationship between a busy clinical surgical department outside academia and our School of Neuroscience. In such, there need not be any barriers for

Table 4. Testimonials from participating students.

similar collaborations elsewhere. In fact, college programs pairing with departments at regional medical centers may be ideal. Physicians at these hospitals may find it difficult or too time-intensive to be affiliated with a medical school. Pairing with a local university program may offer a less structured and rigid path for intellectual stimulation and academic involvement. We should also point out that proximity might not be essential. Roanoke Memorial Hospital is 40 miles from the VT campus. Therefore, students had to travel 40 miles each way to obtain the clinical experience, and generally two of the clinicians had to travel the same distances for Tuesday didactic classes on the VT campus.

Finally, we ask the reader to consider the fact that nothing about this experience-learning course is uniquely restricted to NS or Neurosurgery. Indeed, we encourage college professors to partner with physicians in any number of clinical specialties. Many students are interested in cancer, diabetes or heart disease. Each of these diseases offers the richness of discussion that can be had when considering socioeconomic of health care, responsibility of the individual versus society, and the burden to society. For a student of the liberal arts, these types of discussions are of equal, or greater, importance as the medical experiences, but they are readily and vividly demonstrable in these clinical settings. We believe that through creative educational enterprises such as this, we will help students find their best paths, be they to careers in medicine or any other productive and fulfilling endeavor.

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Received September 29, 2017; revised December 07, 2017; accepted December 21, 2017.

This work was supported by NIH grant R01-NS036692. The authors thank the students in Neuroscience 4594 for their notes, submissions and feedback on this course.

Address correspondence to: Dr. Harald Sontheimer, Virginia Tech, School of Neuroscience, 300 Turner Street NW, 4500 North End Center, Blacksburg VA 24061. Email: [sontheimer@vt.edu](mailto:sontheimer@vt.edu)

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