Establishing a surgical skills laboratory and dissection curriculum for neurosurgical residency training

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Surgical education has been forced to evolve from the principles of its initial inception, in part due to external pressures brought about through changes in modern health care. Despite these pressures that can limit the surgical training experience, training programs are being held to higher standards of education to demonstrate and document trainee competency through core competencies and milestones. One of the methods used to augment the surgical training experience and to demonstrate trainee proficiency in technical skills is through a surgical skills laboratory. The authors have established a surgical skills laboratory by acquiring equipment and funding from nondepartmental resources, through institutional and private educational grants, along with product donations from industry. A separate educational curriculum for junior- and senior-level residents was devised and incorporated into the neurosurgical residency curriculum. The initial dissection curriculum focused on cranial approaches, with spine and peripheral nerve approaches added in subsequent years. The dissections were scheduled to maximize the use of cadaveric specimens, experimenting with techniques to best preserve the tissue for repeated uses. A survey of residents who participated in at least 1 year of the curriculum indicated that participation in the surgical skills laboratory translated into improved understanding of anatomical relationships and the development of technical skills that can be applied in the operating room. In addition to supplementing the technical training of surgical residents, a surgical skills laboratory with a dissection curriculum may be able to help provide uniformity of education across different neurosurgical training programs, as well as provide a tool to assess the progression of skills in surgical trainees.

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KEY WORDS surgical skills laboratory; residency education; anatomical dissection
essment in a controlled and safe atmosphere may be in
an anatomical dissection laboratory. Anatomical dissec-
tion laboratories have long been a part of the training pro-
cess for neurosurgeons wishing to master microsurgical
techniques.12,16 Although many neurosurgeons have used
the dissection laboratory to develop their skills, structured
dissection curricula have yet to become a staple in medici-
eal education. There are multiple barriers to instituting a
surgical skills curriculum, including space, funding, and
equipment.13

Our institution (Cleveland Clinic) recently conducted
a survey of all (100) neurosurgical program directors in
the US to assess the current role of anatomical dissection
in residency training.11 Of the 65 training programs (65%)
that responded to our survey, 61 (93.8%) had cadaveric or
animal dissection available in their training program, but
only 58.3% had scheduled dissection sessions with addi-
tional laboratory availability for independent study. Of the
responders, 95.4% believed that an anatomical dissection
curriculum should be an integral part of surgical training,
and 89.2% would support the creation of a uniform nation-
al dissection curriculum for all programs. Thus, there does
appear to be a role for anatomical dissection, but it has yet
to become implemented across all training programs.

In this paper we have outlined our experience in con-
structing a fully equipped surgical skills laboratory for
anatomical dissection, established predominantly from ex-
tradepartmental sources. We have also been able to design
and incorporate a dissection curriculum into the residency
educational curriculum, creating a structured learning
system for surgical approaches that we believe should be
mastered by all neurosurgical residency graduates. We also
report a survey completed by Cleveland Clinic neurosur-
gical residents who have completed at least 1 year of the
dissection curriculum to assess the impact of incorporating
a dissection curriculum into the surgical education experi-
ence. This impact was also measured through a survey of
neurosurgical attending physicians at our institution.

Methods
Laboratory Environment

Initial expansion of the surgical skills laboratory was
performed with minimal departmental startup funds. We
obtained most of our equipment by applying for in-kind
donations from industry. We also applied for educational
grants from industry as well as internal institutional pro-
grams to obtain funding to purchase equipment that was
not available through donations.

Securing adequate space is possibly the most crucial,
yet difficult, step in establishing a surgical skills labora-
tory. One of the keys to a successful surgical skills labora-
tory is the ability to accommodate multiple dissections,
with no more than 2 surgeons per station. For new dissec-
tion laboratories, obtaining space in or near an exist-
ing wet laboratory that might also share these facilities
increases efficiency. A proper wet laboratory space that is
equipped to handle chemical compounds and biohazard-
ous materials should possess proper ventilation, a sink for
cleaning instruments, and freezers or cold rooms reserved
cadaveric specimen storage.

The dissection stations should mimic the operating
room environment. This includes an operating microsco-
pe, vacuum aspirator, high-speed electric drill, May-
field head clamp with a tabletop mount, and basic surgical
and microsurgical instruments. We believed it imperative
that one of the surgical stations could serve as a “master
station,” to be used for demonstration purposes. The
microscope at this station was attached to a beam splitter
and camera, which projected the microscopic view onto
a large monitor. Also attached was a video capture unit
to allow for recording of both still images and video for
archival purposes. Much of this equipment can be pur-
chased as refurbished products from local distributors at a
significantly discounted price.

Operating Microscopes

A functioning operating microscope with good optics
and adequate lighting is the keystone of a surgical skills
laboratory dissection station. There are several methods
of obtaining a microscope on a budget. The easiest is to search
for older models that have been retired within one’s insti-
tution. Alternatively, microscope distributors often have a
stock of older models that they receive when a hospital pur-
ches a new microscope. If a hospital has a relationship
with these distributors, they may be willing to refurbish
and either discount or donate these microscopes to a labo-
atory. Finally, microscope manufacturers or distributors
may be willing to donate a new tabletop microscope when
an institution purchases a new microscope. In our labora-
tory, we were able to obtain 2 refurbished microscopes
from our local distributor at no charge. We were also able
to obtain 2 retired microscopes from our institution.

High-Speed Drills

High-speed electric drills with multiple attachments
are necessary to simulate skull base drilling. Many com-
panies are willing to donate refurbished drills. Drill bits
may be obtained through donations. In addition, lightly
used bits from the operating room may be a possibility.
One method to reduce the variety of drill bits needed is
to use drills that use a single-length drill bit that fits all
attachments. In our laboratory, we use the Stryker CORE
Universal drill system (Stryker Corporation). This system
accommodates different-length attachments on the drill
handle while using the same-length drill bit. This allows
one to use the same type of bit for drilling at different
lengths, from short to endonasal drilling. Automated ir-
gration attachments for drills are also invaluable for deep
skull base drilling.

Additional Components

Other components necessary for the dissection station
can be obtained through donations or purchase. Wall suc-
tion is ideal but can be substituted with portable electric
aspirators. We use portable electric aspirators (Schuco
Aspirator Model S330A) with reusable canisters, which
provide adequate suctioning during skull base drilling.
Mayfield head frames and tabletop clamps are needed
to secure the head in the desired position for dissection,
although foam padding can be used. Basic surgical and
microsurgical dissection instruments can generally be acquired through donations. Another cost-saving alternative is to purchase instruments from veterinary surgical instrument companies, particularly those offering microinstruments for veterinary ophthalmological surgery.

**Cadaveric Specimens**

Freshly embalmed and injected cadaver specimens are the key to maximizing the dissection experience. Injected cadaveric specimens can be obtained from the state anatomy board or from private companies who prepare specimens for dissections. Certain companies offer latex injection of the vasculature. Most medical centers associated with a medical school have arrangements for specimen cremation of their cadavers. The ability to use these services reduces return shipping and cremation costs. The key to an excellent vasculature injection is early washing (within 24 hours) of the vascular tree postmortem. If purchasing specimens from a company, it is prudent to inquire about the usual postmortem interval before vascular washing and fixation. The other key to a good injection is assessment of the specimen’s vasculature during washing. For example, severely stenotic vertebral arteries may benefit from a thinner injection solution unless there is brisk flow across the posterior communicating artery during carotid artery washing. Good injections can be obtained with either silicone or latex.\(^2,14,15\)

To maximize specimen use, we have experimented with different methods of specimen storage for future use. Freezing the specimen between uses requires thawing of the specimen several days prior to the laboratory session, and there is clear degeneration of the tissue. In our experience, optimal storage was obtained using 66% ethyl alcohol solution in a bucket and placed into a cooler at 40°–50°F. Specimens lasted significantly longer when placed in a cooler and were sufficiently malleable when removed several hours prior to dissection. We also kept a number of specimens in ethyl alcohol at room temperature for resident ad hoc use. When higher concentrations of ethyl alcohol were used (90%–100%), we found that parenchymal volume loss was accelerated. Ethyl alcohol also has a tendency to stiffen parenchyma. In lightly fixed specimens, this was advantageous, but if using heavily fixed specimens, one may need to either reduce the concentration of ethyl alcohol or add fabric softener.\(^10\)

**Dissection Curriculum**

To incorporate the skills laboratory into the residency educational curriculum, we reserved 4 hours of protected time each month for the laboratory. We divided the residents into junior- (postgraduate year [PGY] 2–3) and senior-level (PGY 4–5) resident groups and created a dissection curriculum tailored to each group. The junior curriculum was tailored to focus on anatomy and basic surgical techniques and approaches. The senior curriculum focused on advanced skull base approaches. The dissection curriculum was designed to provide a comprehensive, anatomically oriented approach to the cranial cavity from anterior to posterior. Each session begins with a 45-minute didactic session reviewing the pertinent anatomy and techniques, followed by the dissection portion.

An entire 9-session cranial curriculum can be designed around a minimum of 2 sets of cranial specimens (Table 1). If funding permits, designing the curriculum around 3–4 specimens allows for residents to practice on unused sides on their own time. When designing a curriculum, there are some important considerations. First, approaches involving dissection of parenchyma (e.g., an interhemispheric transcortical approach) should be performed early after specimen arrival. Pure bone dissections (e.g., a posterior petrosal approach) should be performed last. Materials should be planned accordingly. For example, we placed a session on carotid endarterectomy and microvascular anastomosis after pterional and peripheral nerve sessions to allow radial artery harvest and to have the carotid and middle cerebral artery exposures already completed. Complexity should be alternated to allow for even spacing of PGY 2–3 and 4–5 sessions. Finally, if available at one’s institution, collaboration with neurootologists and rhinologists for posterior petrosal and endoscopic endonasal sessions, respectively, can be of major educational value.

After the first year, we expanded the curriculum to include dissections in the spine and peripheral nerves. Peripheral nerves, in particular, are an area of neurosurgery to which many residents have insufficient exposure. Laboratory dissection is an avenue by which programs can help supplement deficiencies. We obtained 3 fresh-frozen torso specimens that were intact from the head to the pelvis with a single arm (approximately $2500/specimen + shipping). We arranged 5 dissection sessions around this single set of specimens covering the occiput to ilium (Table 2). Sessions were pooled into weekly sessions over 5 weeks. Specimens were placed in a 4°C cooler in between sessions. Combining too much material in 1 or 2 sessions results in mental fatigue and poor recall. We found this arrangement to be a good balance between allowing time for preparation, learning, and specimen preservation.

**Resident and Faculty Survey**

The dissection curriculum at the Cleveland Clinic Neurosurgery Program has been instituted since the 2011–2012 academic year. We collected an anonymous survey from all the residents who have participated in the curriculum since its inception. We also surveyed attending neurosurgeons in the department that have been faculty since the inception of the dissection curriculum regarding their assessment of changes in surgical skill level of the residents in the operating room.

**Results**

The dissection curriculum was implemented in the 2011–2012 academic year. The curriculum consisted of 4 sessions for junior residents and 5 sessions for senior residents. In the second year, we incorporated peripheral nerve and spinal instrumentation sessions (Fig. 1).

We collected results from all current residents in our program who had undergone the dissection curriculum since its inception (Fig. 2). Twelve residents responded to the survey. They ranged from PGY 2 to PGY 7 at the time of taking the survey. All the residents agreed that dividing the sessions by junior- and senior-level groups was appro-
<table>
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<tr>
<th>Specimen 1</th>
<th>Specimen 2</th>
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### Session I: Basics of craniotomy, pterional approach (PGY 2–3)
- Pinning and positioning
- Temporals muscle anatomy and dissection
- Pterional craniotomy

### Session II: Orbitozygomatic craniotomy (PGY 4–5)
- 1- vs 2-piece orbitozygomatic craniotomy
- Pretemporal approach
- Extradural anterior clinoidectomy
- Transsylvian approach and circle of Willis anatomy

### Session III: Far-lateral and telovelar approach (PGY 2–3)
- Suboccipital craniectomy and C-1 laminectomy
- Telovelar approach to the 4th ventricle
- Far-lateral craniectomy
- Vertebral artery and cerebellomedullary anatomy

### Session IV: Carotid endarterectomy, microvascular anastomosis (PGY 4–5)†
- Anterior cervical neck carotid anatomy
- Carotid endarterectomy technique
- Microvascular anastomosis‡

### Session V: Retrosigmoid approach (PGY 2–3)
- Venous sinus anatomy
- Retrosigmoid craniectomy
- Cerebellopontine anatomy

### Session VI: Approach to the lateral and 3rd ventricle (PGY 2–3)
- Anterior interhemispheric transcallosal approach
- Posterior interhemispheric transcallosal approach
- Contralateral transfalcine transprecuneal approach to the atrium
- Lateral and 3rd ventricular anatomy

### Session VII: Middle fossa approach (PGY 4–5)
- Temporal craniotomy and dural dissection
- Middle fossa anatomy
- Anterior petrosectomy

### Session VIII: Endoscopic endonasal approach to the sella (PGY 2–3)
- Nasal anatomy
- Endoscopic endonasal approach
- Sellar and parasellar anatomy
- Expanded transplanum approach

### Session IX: Posterior petrosal approach (PGY 4–5)
- Temporal bone anatomy and drilling technique
- Retrolabyrinthine approach
- Translabyrinthine approach
- Transcochlear approach

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* Two is the minimum number of specimens needed to complete the entire curriculum. If funding allows, additional specimens can be used and unused portions may be saved for additional resident practice.
† Injected fixed specimens still allow good practice in suturing technique, but if funding allows, consider using fresh noninjected specimens to better mimic tissue characteristics when performing anastomosis.
‡ We use a radial artery harvested from the torso laboratory series and practice high-flow internal carotid artery to middle cerebral artery anastomoses using exposed arteries from prior pterional/orbitozygomatic laboratory dissections.
The residents were also surveyed regarding their thoughts on duty-hour restrictions (Fig. 3). Only 4 residents (33%) believed that duty hours had hindered their ability to develop their surgical skills. Of those residents, all stated that the dissection laboratory effectively supplemented the operating experience.

Nine attending neurosurgeons in the Department of Neurosurgery responded to the faculty survey (Fig. 4). Five surgeons (55.6%) indicated a significant improvement in operative skill level since the implementation of the dissection curriculum, 3 (33.3%) noted a slight improvement, and 1 (11.1%) stated there was no change. Areas of improvement that were noted were use of the high-speed drill, followed by understanding of 3D anatomy and general microsurgical techniques. Areas in which the surgeons would most like to see further improvement through utilization of the laboratory included understanding of 3D anatomy and surgical-approach planning. Five of the 9 respondents stated that they used a dissection laboratory during their residency, but all agreed that it should be part of the current training program and that residents should demonstrate proficiency with skills and/or procedures in the laboratory prior to performing them in the operating room (Fig. 4).

**Discussion**

Anatomical dissections have always provided an avenue for fully trained neurosurgeons to enhance their anatomical knowledge and microsurgical skills. Yaşargil noted that, as a young surgeon, he had a mental barrier to skull base surgery because he felt uncomfortable and inexperienced with skull base anatomy and high-speed drill technology, which he ameliorated through his experience in the dissection laboratory. It is only logical that this component of training should become a component of the surgical educational experience. For training programs without a surgical skills laboratory already in place, the establishment of one may seem onerous. We have outlined a strategy to do so using our experience with minimal starting resources.

The addition of a surgical skills laboratory can augment the surgical training experience. Trainees will be able to gain a better understanding of surgical anatomy and approaches without the constraints of the operating room atmosphere. For advanced-level trainees, a surgical skills laboratory can help to better prepare them prior to performing a complex procedure in the operating room, thus maximizing the learning potential for less commonly performed procedures. In our survey of residents who have participated in the dissection curriculum since its inception at our residency program, nearly all of the participants agreed that the dissection sessions could be beneficial in this regard. We believe the keys to achieving this are to divide the sessions by resident training level and to maintain a low resident-to-cadaver ratio, which allows for adequate hands-on dissection time.

Nearly all of the attending surgeons noted improvements in surgical skill level since the introduction of the dissection curriculum, although the subjectivity of this assessment method makes it difficult to adequately judge the impact of the curriculum. Standardized motor-skill assessment tools may be implemented in the future to fully assess whether a dissection curriculum truly has an impact. Despite the fact that nearly half of the attending surgeons

### TABLE 2. Sample curriculum for a single-torso cadaver with 1 upper extremity

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TLIF = transforaminal lumbar interbody fusion.

* These sessions are suitable for all PGYs 2–5.
† A PGY 4–5 session could include minimally invasive TLIF, Ponte osteotomies, pedicle subtraction osteotomy, and iliac screw fixation.
‡ Alternatively, this session can be completed using cranial specimens to allow easy transition from posterior to lateral to anterior positions.

priate for trainee skill level. The most valuable aspect of the sessions was mastering anatomical relationships and surgical approaches. This was followed by gaining more experience with surgical instruments and equipment, and gaining experience with less commonly performed procedures. Eleven residents (92%) agreed that the laboratory sessions improved their ability to understand anatomical relationships, and 8 residents (67%) believed that the dissection sessions improved their technical skills in the operating room. Eight residents (67%) stated that they have been able to apply concepts and techniques they learned in the dissection sessions in the operating room, and 11 residents (92%) believed that being able to perform a procedure in the dissection laboratory would enhance the learning experience prior to performing actual surgery. The residents were also surveyed regarding their thoughts on duty-hour restrictions (Fig. 3). Only 4 residents (33%) believed that duty hours had hindered their ability to develop their surgical skills. Of those residents, all stated that the dissection laboratory effectively supplemented the operating experience.

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Surgical skills laboratory for neurosurgical residency
in our survey did not have access to a dissection laboratory during their residency, all believed that it should be part of the current training program. Implementing such programs can lead the way to greater uniformity among training programs despite variations in surgical volume and expertise available at individual programs. Although nothing will replace the experience and knowledge gained from the actual operative experience, this method will

![Photograph of endoscopy (A), general skull base (B), peripheral nerve (C), and spinal instrumentation (D) dissection sessions in the surgical skills laboratory. Figure is available in color online only.](image)

**FIG. 1.** Photograph of endoscopy (A), general skull base (B), peripheral nerve (C), and spinal instrumentation (D) dissection sessions in the surgical skills laboratory. Figure is available in color online only.

![Results from the resident survey regarding the impact of the surgical skills laboratory and dissection curriculum, which was completed by residents in PGY 2–7 (n = 12) who had completed at least 1 year of the curriculum.](image)

**FIG. 2.** Results from the resident survey regarding the impact of the surgical skills laboratory and dissection curriculum, which was completed by residents in PGY 2–7 (n = 12) who had completed at least 1 year of the curriculum.
take a step toward creating minimal competencies that each trainee will be mandated to meet.

Finally, the resources of a surgical skills laboratory may become a necessary tool in the future assessment of neurosurgical trainees. In recent years, graduate medical education has trended toward more structured assessment of training competency. The ACGME has established core competency requirements that must be met for all training programs, breaking down the training experience into components that must be fulfilled. This has resulted in the need for a structured environment to refine and assess surgical skills. Some surgical training programs have already established a skills competency program to assess surgical education by having trainees achieve graduated milestones.5 In neurosurgery, the recent advent of milestones has forced training programs to be able to document a progression of learning to increase uniformity in training standards. These milestones will likely cross over into the assessment of surgical skills—which is far removed from the apprenticeship-based model in which graduation is a subjective assessment—to a model that focuses on meeting graduated competencies.5 Training programs in the future may be required to document the development and competency of the necessary skill sets to graduate as an adequately trained surgeon. A surgical skills laboratory can provide the environment for a systematic simulated component of surgical training and also provide a means of testing the proficiency of the skills acquired.

Conclusions

The obstacles to creating a surgical skills laboratory at any given institution may appear daunting but can be overcome at any academic institution, regardless of the initial resources available. Nearly 3 years after implementation of the dissection curriculum, we have found a positive response from the trainees. The ultimate gauge of effectiveness for a set curriculum will be from the attending surgeons’ assessment of whether trainees are better prepared for operative procedures and more completely trained at the conclusion of their training. This assessment is difficult to do given that it is subjective, which leads to the need for more uniform assessment of surgical training in the future.

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Author Contributions
Conception and design: Liu, Kshettry, Recinos. Acquisition of data: Liu, Kshettry. Analysis and interpretation of data: Liu, Kshettry. Drafting the article: Liu, Kshettry. Critically revising the article: Liu, Kshettry, Benzel. Reviewed submitted version of manuscript: Liu, Kshettry, Benzel. Approved the final version of the manuscript on behalf of all authors: Liu. Administrative/technical/material support: Liu, Kshettry. Study supervision: all authors.

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