Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Letter to the Editor "Incorporating Telehealth to Improve Neurosurgical Training During the COVID-19 Pandemic"

Letter:

Training in neurologic surgery has evolved significantly since its formalization in 1953.[1] Training is highly regulated, both by the Accreditation Council for Graduate Medical Education (ACGME) and the American Board of Neurological Surgery, and curricular structure has evolved over the years to accommodate changes in health care and ensure proficiency on graduation.

In 2003, the ACGME mandated that all residents must work no more than 24 hours per shift, 80 hours per week, and required 1 day per week without patient care responsibilities.[2] At the time, residents and faculty thought this mandate would make it difficult for residents to be adequately trained,[3] but in the time since 2003, residency programs and national organizations have adapted to ensure that resident experience was not hindered by limitations on available training hours. On the national level, standardization across programs became the primary focus, with the introduction of resident boot camp in 2009, the Milestones project in 2012, and mandated 7-year training in 2013.[4]

Similar to the ACGME work hour restrictions in 2003, the COVID-19 outbreak presents a significant challenge to residency training in neurosurgery. As an initial response to the COVID-19 pandemic in the United States, the American College of Surgeons recommended suspension of all elective surgical procedures.[5] Furthermore, in an attempt to manage both health care provider personal protective equipment and human-to-human contact, outpatient clinics at many institutions have been substantially reduced, or pivoted to telehealth. These measures have almost immediately eliminated the traditional educational experiences available to neurosurgical residents. This communication aims to outline how one academic department has adapted to meet the highest standards of neurosurgical education possible given the unique circumstances of the COVID-19 pandemic.

ACGME NEUROLOGIC SURGERY MILESTONES

At present, education in neurosurgery is based primarily on the Neurological Surgery Milestones, a document created by the ACGME to guide evaluation of resident performance.[6] The Milestones are multifaceted, focusing on attitudes, skills, knowledge, and other attributes included within the ACGME developmental framework (**Table 1**). Each milestone is arranged in levels, from 1 to 5, which signify movement from novice to expert in the given subcompetency. These milestones do not necessarily correlate with postgraduate year, and residents can potentially advance early or even regress in their milestones based on their performance. Level 4 is considered a goal for resident graduation, whereas level 5 is considered an expert resident or fellow level, above the expectation for graduation in a given subcompetency.[6] Although operative training is the main focus of most patient care subcompetencies, with specific procedures detailed by subspecialty, many of the other educational objectives can be met despite the limitations dictated by the COVID-19 crisis. With limited operative time available for trainees, it is exceedingly important for residency programs to optimize all available learning opportunities. At our institution, we have leveraged telehealth to focus on clinical experiences that are traditionally underrepresented in residency training, using educational theory as the underpinning for our activities.

EDUCATIONAL MODELS FOR SURGICAL TRAINING

A number of educational theories are relevant to training in surgical subspecialties,[7] and these remain applicable during the COVID-19 era, despite limited in-person patient interaction. For example, surgical educators are well aware that trainees develop expertise through deliberate practice and regular reinforcement (Ericsson's theory), with guidance from more experienced experts (Vygotsky's theory), and by sharing their knowledge within communities of practice (Lave and Wenger's theory).[8,9] Because time in the operating room has grown scarce, we have found that these ideas can easily be applied to education outside of the operating room as well.

It is easiest to conceptualize educational models by grouping them either into explicit mastery models of instruction that lead to expertise or implicit constructivist models that consider the cognitive and social perspectives of the learner.[10] Mastery models are readily apparent in surgical training, in which skills acquisition and technical proficiency are primary goals. For instance, Ericsson's theory outlines that deliberate practice is a key factor in achieving expertise, with the specific intention and motivation to improve, as opposed to rote repetition. However, it is often underappreciated that this approach is most effective when coupled with constructivist strategies, including experiential learning methods that include targeted feedback from instructors.

Experiential learning theory involves learning through direct encounter, reflecting on experiences to develop concepts, and receiving feedback; therefore, behaviors can be modified for application to new situations. Vygotsky's theory identifies a zone of proximal development (ZPD), in which learning tasks that are outside of the learner's current abilities are achievable with guidance from a more knowledgeable teacher, who provides observation and feedback that serves as a scaffold for progression through the ZPD, before deliberately fading when no longer needed.[7,10] These concepts are beginning to be used more formally by neurosurgery programs for procedural training: Duke Neurosurgery has recently implemented a surgical autonomy program that applies the ZPD concept to the development of operative skills among their residents.[11]

This type of learning can be enhanced further within communities of practice, which allow for shared repertoire, joint enterprise, and mutual engagement among peers. As Lave and Wenger described, learning is not a process of individual experience, rather it is an integral aspect of social practice, achieved through increased knowledge, competency, and involvement in the surrounding community.[9]

Finally, during instruction, it is also important to consider individual learning styles of each student. There is precedent in general surgery and other disciplines for using the Kolb Learning Style Index, a 12-item questionnaire developed by David Kolb, to characterize individual learning styles into 4 groups:

Table 1. Neurologic Surgery Accreditation Council for Graduate Medical Education Milestones

Competency	Sub-Competency
Patient care	• Brain tumor • Surgical treatment of epilepsy and movement disorders • Pain and peripheral nerve disorders • Spine • Vascular • Traumatic brain injury • Pediatrics • Critical care
Medical knowledge	• Information gathering and interpretation • Critical thinking for diagnosis and therapy
Systems-based practice	• Patient safety • Quality improvement • Health care systems awareness
Practice-based learning and improvement	• Evidence-based practice • Mentorship and teaching • Research
Professionalism	• Well-being • Ethical behavior
Interpersonal and communication skills	• Communication in coordination of care • Patient and family communication

accommodating, assimilating, converging, and diverging.[12] Emotional and interpersonal relationships are the main features of the accommodating learning style, whereas assimilating learners thrive with abstract logic. Individuals categorized as converging learners work best by actively solving problems, whereas diverging learners excel through observation.[13]

Prior work has shown that optimal learning styles tend to be generalized across professional groups,[12] and can predict success in surgical residency.[14] Although general surgery trainees have been characterized by accommodating and converging learning styles, early work in Taiwan has shown that neurosurgical residents typically exhibit diverging learning styles and progress toward an assimilating learning style as training progresses.[15] Further study of learning styles in neurosurgical training is required for educators to generalize these findings to other settings.

TELEHEALTH CLINIC AND VIRTUAL RESIDENT CONFERENCES

At our institution, we have found that involving residents in telehealth clinic and supplementing this time with virtual, case-based conferences has already enhanced resident education, by taking learning models classically used in surgical skills training and applying them to surgical decision-making and management instead. It is well understood that some of these softer skills in residency training, just like surgical skills, are not necessarily natural abilities. However, these skills can also be taught, learned, and practiced in a structured fashion.[16]

Traditional neurosurgical training heavily emphasizes hands-on operative experience and associated inpatient care, limiting curricular space for outpatient clinical experience. As a result, neurosurgeons anecdotally report that one of the more difficult aspects of transitioning to independent practice is learning how to develop their style in clinic, including identifying appropriate candidates for surgery, engaging in shared decision-making, managing patient expectations, developing longitudinal patient relationships, managing complications in the short and long term, and so forth. The skills learned during inpatient care are not directly transferable to this setting because of the fragmented way in which care is delivered by residents coming on and off service, and the hierarchical nature of decision-making in the hospital. Clinic experience in residency is highly variable from program to program, and depends on attending availability and program logistics, including work hours, because most residents are primarily responsible for managing the inpatient service.

Nevertheless, outpatient clinical experience provides a critical opportunity for trainees to develop the nonoperative skills emphasized by the ACGME milestones, including information gathering and interpretation, evidence-based practice, critical thinking for diagnosis and therapy, and awareness of health care systems (Table 1). These skills are necessary to become certified as an attending neurosurgeon, as evidenced by the fact that the oral board examination itself requires candidates to apply their medical knowledge to sample case scenarios, and to review their own decision-making for patients they have taken care of, instead of asking candidates to perform surgical tasks. Although operative training is certainly required to become a neurosurgeon, these additional skills are necessary for a successful practice.

In response to the COVID-19 outbreak, our department has pivoted quickly to develop a robust clinical pathway for outpatient evaluation using telehealth.[17] The telehealth format is optimal for seamlessly incorporating residents into clinic. With operative volume limited to emergencies at each of our clinical sites, residents have been reassigned to virtual clinics across a number of disciplines, from peripheral nerve and spine to brain tumor and vascular neurosurgery. Prior to COVID-19, the curriculum only allowed space for 2 required outpatient clinic rotations for all residents, both in spine. Under the current telehealth system, residents are assigned a clinic day for one faculty member at a time. After patients are screened by medical assistants and all of the relevant clinical data are collected by the outpatient coordinator, the resident is able to review the information and conduct telehealth appointments with each patient. Residents are asked to complete documentation in the electronic medical record using a standardized template that automatically incorporates the relevant clinical information and allows the learner to focus on recording their history, virtual physical examination, clinical assessment, and plan. Each case is then discussed one by one with the attending using these templates for efficient review of all clinical data, including imaging findings. The resident can then observe how the attending conducts each encounter with the patient by video conference. Senior residents have the option to take a more central role in the second encounter, depending on the resident's skill level and relationship with the patient. The format of gradually elevated responsibility used in our telehealth clinic is modeled after the ACGME milestones. Residents are provided

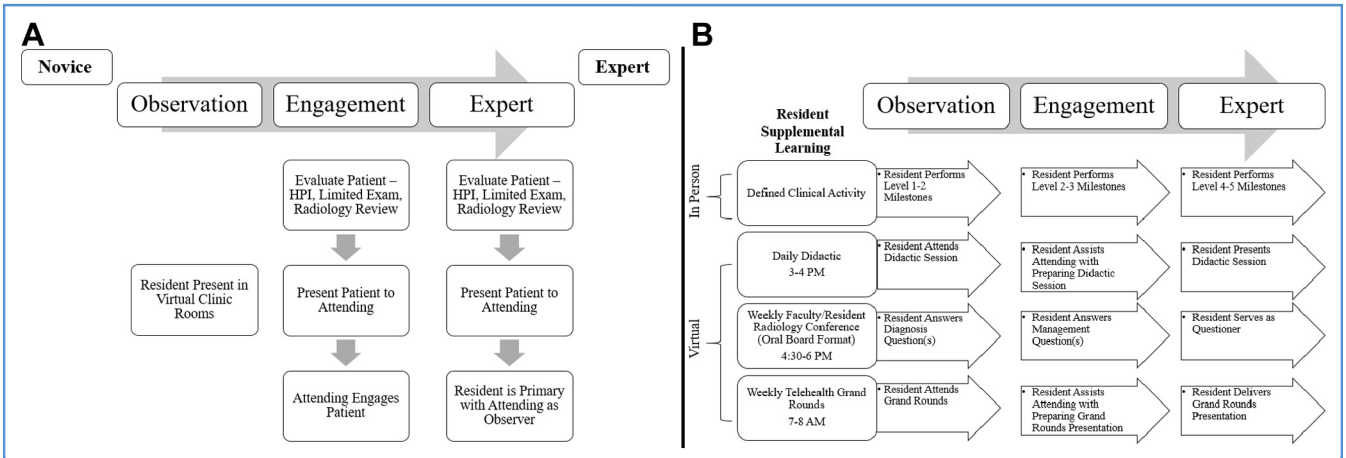

Figure 1. Projected implementation of alternative resident education structure during pandemic restrictions: (**A**) telehealth resident learning and (**B**) resident supplemental learning experience. HPI, History of Present Illness.

with the opportunity to go from novice level observation to expert level autonomy, in line with the training guidelines (Figure 1A).

In this format, telehealth outpatient clinic manifests many of the principles offered by educational theory for the development of expertise. Residents have the autonomy to conduct clinical encounters and deliberately practice their approach (Ericsson's theory, mastery learning model). They then can receive direct feedback from faculty members and reflect on their performance, after either observing the attending conduct the same encounter, and or having the attending observe their performance in a follow-up encounter (Vygotsky's theory, experiential learning model). Furthermore, telehealth can easily be adapted to all 4 of Kolb's learning styles, affording observation for divergent learners, active problem-solving for convergent learners, logical clinical reasoning for assimilating learners, and relationship building—with both patients and faculty mentors—for accommodating learners. Because telehealth is likely going to remain an integral part of care even after the COVID-19 crisis subsides, this format is flexible for adaptation as surgical volume grows, and can even serve as the blueprint for a resident-run clinic (with attending oversight), which is typically difficult to arrange within most health systems.

Finally, we have augmented our traditional radiology case conference while operative case volume remains low. Prior to COVID-19, at our weekly case conference with all residents and faculty present, patients from each clinical site are presented and residents have the opportunity to simulate an oral boards examination, practicing surgical decision-making with each case scenario. Using videoconferencing, residents now conduct their own case-based conferences 3 times per week, with an introductory didactic to review a specific topic followed by case presentations, each moderated by a senior resident and a faculty member with relevant subspecialty expertise. So far, this approach has created a community of practice for social learning (Lave and Wenger's theory) that is primarily resident-driven, not only strengthening relationships between coresidents, but also allowing residents to develop their individual teaching styles while reviewing essential neurosurgical content together. In a manner similar to the telehealth learning structure, the alternative resident learning opportunities provide a means for gradual increasing responsibility, modeling the ACGME milestones (Figure 1B). Of note, the alternative education structure is designed with the capacity to expand as the pandemic deepens and regress as elective practices return to normalcy. Ultimately, this makes it possible for our department to maintain the standard of residency education while flexibly adapting to the ebb and flow of the current pandemic.

CONCLUSIONS

Neurosurgical training is complex and constantly evolving. The COVID-19 outbreak so far has posed a significant challenge to resident education by limiting the number of operative procedures and in-person encounters available for resident involvement. However, at our institution, efficient adoption of telehealth clinic and virtual technology has presented a unique opportunity to enhance resident training despite these constraints, by leveraging traditional educational theories.

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REFERENCES

1. Clark K. Accreditation and approval of residency positions in neurological surgery in the United States: an overview. *Neurosurgery*. 1981;9:601-603.
2. Friedman WA. Resident duty hours in American neurosurgery. *Neurosurgery*. 2004;54:925-933.
3. Fargen KM, Chakraborty A, Friedman WA. Results of a national neurosurgery resident survey on duty hour regulations. *Neurosurgery*. 2011;69:1162-1170.
4. Yaeger KA, Munich SA, Byrne RW, Germano IM. Trends in United States neurosurgery residency education and training over the last decade (2009-2019). *Neurosurg Focus*. 2020;48:E6.
5. American College of Surgeons. COVID-19: recommendations for management of elective surgical procedures. Avaliable at: https://www.facs.org/covid-19/clinical-guidance/elective-surgery. Accessed May 2, 2020.
6. Selden NR, Abosch A, Byrne RW, Harbaugh RE, Krauss WE, Mapstone TB. Neurological surgery milestones. *J Grad Med Educ*. 2013;5(1 suppl 1):24-35.
7. Chauvin SW. Applying educational theory to simulation-based training and assessment in surgery. *Surg Clin North Am*. 2015;95:695-715.
8. Sadideen H, Kneebone R. Practical skills teaching in contemporary surgical education: how can educational theory be applied to promote effective learning? *Am J Surg*. 2012;204:396-401.
9. Sadideen H, Plonczak A, Saadeddin M, Kneebone R. How educational theory can inform the training and practice of plastic surgeons. *Plast Reconstr Surg Glob Open*. 2018;6:e2042.
10. Nataraja RM, Webb N, Lopez PJ. Simulation in paediatric urology and surgery. Part 1: An overview of educational theory. *J Pediatr Urol*. 2018;14:120-124.
11. Duke Neurosurgery. Innovation and opportunity: expanding horizons for Duke Neurosurgery Residency Program. Avaliable at: https://neurosurgery.duke.edu/sites/neurosurgery.innovah.com/files/duke-neurosurgery-innovation-and-opportunity-issue.pdf. Accessed May 1, 2020.
12. Drew PJ, Cule N, Gough M, et al. Optimal education techniques for basic surgical trainees: lessons from education theory. *J R Coll Surg Edinb*. 1999;44:55-56.
13. Mammen JM, Fischer DR, Anderson A, et al. Learning styles vary among general surgery residents: analysis of 12 years of data. *J Surg Educ*. 2007;64:386-389.
14. Quillin RC, Pritts TA, Hanseman DJ, Edwards MJ, Davis BR. How residents learn predicts success in surgical residency. *J Surg Educ*. 2013;70:725-730.
15. Lai HY, Lee CY, Chiu A, Lee ST. The preferred learning styles of neurosurgeons, neurosurgery residents, and neurology residents: implications in the neurosurgical field. *World Neurosurg*. 2014;82:298-303.
16. Nakagawa S. Communication–the most challenging procedure. *JAMA Intern Med*. 2015;175:1268-1269.
17. Blue R, Yang A, Zhou C, et al. Telemedicine in the era of COVID-19: a neurosurgical perspective. *World Neurosurg*. 2020;139:549-557.