Neurosurgery residency and fellowship education in the United States: 2 decades of system development by the One Neurosurgery Summit organizations

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The purpose of this report is to chronicle a 2-decade period of educational innovation and improvement, as well as governance reform, across the specialty of neurological surgery. Neurological surgery educational and professional governance systems have evolved substantially over the past 2 decades with the goal of improving training outcomes, patient safety, and the quality of US neurosurgical care. Innovations during this period have included the following: creating a consensus national curriculum; standardizing the length and structure of neurosurgical training; introducing educational outcomes milestones and required case minimums; establishing national skills, safety, and professionalism courses; systematically accrediting subspecialty fellowships; expanding professional development for educators; promoting training in research; and coordinating policy and strategy through the cooperation of national stakeholder organizations. A series of education summits held between 2007 and 2009 restructured some aspects of neurosurgical residency training. Since 2010, ongoing meetings of the One Neurosurgery Summit have provided strategic coordination for specialty definition, neurosurgical education, public policy, and governance. The Summit now includes leadership representatives from the Society of Neurological Surgeons, the American Association of Neurological Surgeons, the Congress of Neurological Surgeons, the American Board of Neurological Surgery, the Review Committee for Neurological Surgery of the...
Harvey Cushing founded the Society of Neurological Surgeons (SNS) in 1920, marking the inception of neurosurgical discipline and medical specialty.¹ ² Neurosurgery achieved many important organizational landmarks early, including the foundation of the American Board of Neurological Surgery (ABNS) in 1940³ and of the Journal of Neurosurgery in 1944.⁴ In contrast, in 1999, neurological surgery was the last US medical specialty to require any form of renewed or ongoing board certification following training and primary certification.⁵ By the 1990s, neurosurgery had developed a reputation within organized medicine as demanding and technologically advanced, but lagging in pedagogical practices and oversight.

In the 2 decades that have followed, neurosurgical educational, leadership, and governance organizations launched a series of innovative educational projects and coordinated structural reforms that positioned neurosurgery as a leader in North American surgical education. Advances have included: 1) introducing neurosurgery-specific training for postgraduate year 1 (PGY1); 2) creating a structure of shared governance through coordinating leading national neurosurgical professional and educational organizations; 3) creation by the SNS of a series of nationally coordinated resident courses to ensure systematic training of simulated skills and behavioral competencies; 4) supporting the professional development of residency directors, teaching faculty, and program administrators; 5) creating a standardized national “Matrix” neurosurgical curriculum; 6) pilot participation in developing uniform national training milestones by the Accreditation Council for Graduate Medical Education (ACGME); 7) introducing residency training standards for surgical case minimums and academic activity; 8) developing a new system of accreditation for neurosurgical fellowship training; and 9) promoting training in research (Table 1).

In each case, these advances were driven by the foundational aims of neurosurgery: patient safety, quality clinical outcomes, technical and scientific excellence, and compassionate care of patients and their families. The early leaders of the specialty, including Harvey Cushing (1869–1939), Ernest Sachs (1879–1958), and Walter Dandy (1886–1946), were personally influenced by their exposure to the structured apprenticeship model implemented at Johns Hopkins Hospital by Sir William Osler (1849–1919) and William Halsted (1852–1922).⁶ In contrast, the organizational complexity of the modern health care system demands team-based leadership skills, while the rapidly evolving technological complexity of neurosurgical practice requires a modern pedagogy that incorporates lifelong learning. In this article, the authors describe the principal steps taken over the past 2 decades to create a coordinated and intentional system of neurosurgical education and a governance structure capable of advancing this system over time to meet the changing needs of neurosurgical patients and society.

**Incorporation of the PGY1 Training Year**

Historically, the PGY1 year for neurological surgery trainees occurred as a preliminary year under the supervision of a general surgery program director. Many trainees and neurosurgical residency directors felt that the bulk of individual PGY1 rotations, reading curricula, and didactic conferences were not relevant to neurosurgery and yielded very little basic surgical skills training. Between July 2007 and May 2009, the SNS sponsored a series of four education summits drawing on the leadership of the American Association of Neurological Surgeons (AANS), the Congress of Neurological Surgeons (CNS), the ABNS,
The ACGME Review Committee (RC) for Neurological Surgery, and the AANS/CNS Joint Washington Committee.7 The summits considered many alterations to US neurosurgery residency training, ultimately leading to the incorporation of the PGY1 year into neurosurgery residency in 2009, after approval by the ACGME and the ABNS. This change allowed educational leaders to design a PGY1 year that achieves specific neurosurgery training goals, including extensive experience in neurocritical care and endovascular neurosurgery. In 2012, a second result emanating from the education summit discussions was standardizing the length of neurological training to 7 years, which previously was 6 or 7 years depending on individual program preference.

The additional benefit derived from the education summit work was recognition of the value of cooperation between the major neurological educational and professional organizations, which led, in part, to these groups initiating a more general, permanent Neurosurgery Summit mechanism in 2010.

Governance (One Neurosurgery Summit)

Following the success of education summits organized by the SNS from 2007 to 2009, the SNS proposed holding regular meetings of leaders from each of the major neurological organizations with a stake in national education and governance. The first annual Neurosurgery Summit meeting was held in October 2010, in conjunction with the CNS Annual Meeting. Participants included the President and President-Elect of the SNS, AANS, and CNS; the Chair, Secretary, and Executive Director of the ABNS; the Chair of the RC for Neurological Surgery; the Secretary of the SNS to manage the agenda; and the principal administrator of each organization. The SNS President also presides at Summit meetings. Eventually, the Chair and Executive Director of the AANS/CNS Washington Committee and the President and Research Committee Chair of the American Academy of Neurological Surgery (AAcNS) were added (Table 2). Beginning in 2012, the Summit was held twice annually at the CNS and AANS annual meetings. Since July 2014, an additional annual Summer Summit meeting has been devoted to specialty-wide strategic planning. The name “One Neurosurgery Summit” was adopted in 2016 to reflect the focus of participating organizations on advancing the interests of the entire profession of neurological surgery on behalf of patients and society.

The One Neurosurgery Summit leaders work on a consensus basis and make nonbinding decisions, which nonetheless have profoundly influenced the choices of its member organizations and the direction of the specialty. Nominations to major national bodies or policymaking panels are routinely discussed at the Summit. The Summit also commonly appoints task force members to draft national policy proposals and responses, such as ACGME resident duty-hour standards, GME funding, quality goals formulation, standards of professional conduct, and priorities for federally funded research. The Summit provided a major forum for the design of an integrated specialty accreditation and certification system involving the ABNS, ACGME, and SNS Committee on Advanced Subspecialty Training (CAST; see below), and also hosted strategy discussions for using clinical outcomes registry data to support quality, patient safety, and professional certification. Perhaps most importantly, the Summit has focused on the evolving definition of neurological surgery as a specialty of medicine and surgery, including the coordination of education, residency and fellowship training, program accreditation, and individual certification in upholding the highest standards of clinical practice, innovation, and discovery.

The minutes of One Neurosurgery Summit meetings are distributed to and approved by its member societies. Responsibility for gathering information and opinion, generating consensus, and communicating more broadly back to members of the profession falls to each of these individual member societies.

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Resident Courses

Most neurosurgical trainees lost access to general surgery orientations, including basic hands-on skills training such as suturing and instrument use, with the incorporation of the PGY1 into neurological residency in 2009. In response, various neurological programs launched pilot hands-on skills courses for their PGY1 residents in 2009, including regional cooperative courses held in Portland, Oregon, and Chicago, Illinois.8

In 2010, these “PGY1 boot camp” courses were held nationally at 6 regional centers and included participation by 100% of entering neurological residents in the US.9 All 6 sites utilized a uniform curriculum supervised by the SNS, representing academic department chairs and residency directors. This curriculum incorporated basic neurological surgical skills, such as suturing, bone drilling and plating, and dural closure; model-based simulation of a comprehensive array of emergency department and intensive care unit–based neurological procedures, such as intubation, lumbar drain and ventriculostomy placement, and cervical traction;10 and behavioral simulations related to professionalism and communications.11 The national boot camp courses were funded by a multiyear unrestricted educational grant from medical device industry.
sponsors. Sponsors agreed to funding via regulated educational grants and also deidentified their loaned equipment to maintain a strict focus on basic safety, skills, and professionalism training without any element of marketing.

The SNS PGY1 boot camp courses have improved systematic learning of fundamental knowledge, skills, and behaviors necessary for optimal performance and patient safety during the initial stages of neurosurgical training. Their success led to the addition of a second national course, held at 3 regional centers, for trainees entering the 1st year of “junior residency” (PGY2). The junior resident courses concentrate on model-based simulation of more complex, integrated surgical tasks, including taxing operative emergency scenarios (Fig. 1). The courses also teach more challenging and advanced communication, professionalism, and leadership skills, such as breaking bad news, using safety checklists, performing clinical handoffs, and leading an interdisciplinary team. Finally, more recently the SNS added a pregraduation course covering the transition to practice for chief residents.

Based in part on the US effort, boot camp courses at the inception of neurosurgical training have been adopted in other countries and regions, including Canada, Great Britain, Southeast Asia, Africa, and South America.

In the US, other procedural specialties have initiated boot camps with design input from the SNS, including general surgery, pediatric surgery, emergency medicine, radiation oncology, and otolaryngology.

The SNS also sponsors a long-standing course supporting research training and grant development: the Research Update in Neurosurgery and Neuroscience (RUNN) course. Established in 1984, the RUNN course has been organized and administered by the SNS since 1999. The 1-week course is held each year at the Woods Hole Oceanographic Institution in Falmouth, Massachusetts. Distinguished neuroscientists from inside and outside of neurosurgery provide a series of intensive research lectures as well as both scientific and practical advice to a large audience of residency trainees interested in careers as clinician-scientists.

Professional Development for Residency Directors, Faculty, and Administrators

Evolution of the national neurosurgery boot camp courses required training course leaders and faculty in the use of a growing collection of model-based surgical and procedural simulators. Therefore, as part of the 2011 SNS Annual Meeting in Portland, Oregon, an afternoon hands-on “Teach the Teachers” workshop was held, incorporating faculty training for all boot camp course simulator stations. This professional development workshop was expanded to a full day in 2012 and invited participation by all residency program directors, academic department chairs, and other SNS members. The neurosurgery residency program administrators organization (now the Association of Residency Administrators for Neurological Surgery) had traditionally held their annual meeting in the same city as the SNS Annual Meeting each year, on the preceding 2 days. Beginning in 2012, program administrators were also invited to attend this daylong Saturday SNS professional development session with their program directors, to facilitate interprofessional learning and innovation for individual residency programs.

The 2012 Saturday seminar focused on introducing the ACGME’s Next Accreditation System, as well as a seminar on teaching the basics of evidence-based medicine. Since that time, the Saturday morning sessions have concentrated on more in-depth updates for ACGME accreditation functions. The afternoon sessions have focused on professional development topics, including: introduction, review, and revision of the ACGME Milestones project; best practices for Clinical Competency Committees; residency training in clinical outcomes and quality science; remediating the problem resident; best practices for resident wellness; effective assessment strategies (in collaboration with the ACGME); best practices in preparing for RC program review; professional development strategies for neurosurgical educators; and introduction of the ACGME Program Director Patient Safety and Quality (PDPQ) pilot curriculum. Over the past decade, these Saturday professional development sessions have become the most widely attended element of the SNS Annual Meeting. The content is considered “must-have” information particularly for residency directors, associate directors, and program administrators.

In 2007, the SNS created an online “Tool Kit” for residency program directors and administrators. Designed to assist with program administration, residency education, and episodic accreditation functions, the Tool Kit contains an evolving compendium of best practice documents, policies, forms, and curriculum examples, as well as links to critical online resources. As ACGME accreditation practices have changed, the Tool Kit has undergone multiple major content revisions.

Matrix Curriculum

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Curriculum Committee (later organized as the Curriculum Subcommittee of the Committee on Resident Education) began work on a comprehensive, subspecialty-focused curriculum that year, drawing in part on previous curricula created by the CNS and various individual residency programs. In 2011, the Committee married the core curriculum to the ABNS primary examination knowledge categories and attempted to identify the limited available objective tools for measurement of resident performance in various curricular areas. The Committee also incorporated a tool for assessing stages of physician cognitive and skills development. The resulting “SNS Matrix Curriculum” covers medical knowledge and patient care in each subspecialty area of neurological surgery, as well as the four ACGME “general competencies”: systems-based practice, practice-based learning, professionalism, and interpersonal skills and communication. Presently, in collaboration with the AAcNS, the Committee is adding a specific curriculum for basic and clinical research methodologies.

Milestones (1.0 and 2.0)

The focus of the SNS Matrix Curriculum on developmental stage assessment and educational outcomes was well aligned with a contemporaneous effort at the ACGME to create a unified national system of “milestones” specifying measurable intended educational outcomes at various stages of residency training in each medical and surgical specialty. Therefore, in August 2011, neurosurgery was added as a seventh “early adopter” specialty to draft national milestones for residency educational outcomes, a year ahead of the majority of ACGME-represented specialties.26 The SNS appointed members to an ACGME Neurosurgery Milestones Working Group. The group then worked for 2 years at in-person and virtual meetings to craft the neurosurgery milestones. During this process, drafts of the new milestones system were evaluated by a survey of SNS members, by two successive small pilot projects, by the review of educational specialists at the ACGME, and by attendees at a national program directors’ workshop held in conjunction with the October 2012 CNS Annual Meeting. The SNS and ACGME gave final review and approval of the Neurosurgery Milestones. The Milestones were published in March 201332 and implemented on July 1 of that year.

The response of neurosurgery program directors, faculty, and residents to the Milestones was generally highly positive.28 From its inception, the Milestones data discriminated residents’ level of progress through their training, which had not been true of standard rotation evaluation data. A study combining stakeholder structured interviews and surveys revealed that the neurosurgical milestones increased the specificity and granularity of assessment, identified problem residents early, and assisted in the development of focused mitigation plans for struggling residents. Most importantly, the milestones generated transparent and constructive discussions between residents and faculty members about progress, both individually and through feedback from a milestones-focused clinical competency committee.28 Because mandatory Milestones reporting twice a year for all US residents represented a major organizational and cultural shift, release of the milestones was accompanied by a detailed and ongoing rollout project that began in May 2013. This effort included symposia at 4 CNS and 4 SNS annual meetings, 2 ACGME sponsored webinars, and 1 interspecialty ACGME milestone meeting.

In 2016, recognizing opportunities for further improvement, the Neurosurgery Milestones Working Group submitted a proposal to the ACGME to jump-start a Milestones 2.0 pilot project 2 years earlier than previously envisioned. As the lone early adopter in this second phase of development, neurosurgery concentrated on a reduction in the breadth of the milestones, eliminating milestones that were not helpful in discriminating resident developmental progress. The medical knowledge milestones were abbreviated significantly, reflecting only the cognitive developmental stage without any specific disciplinary information. The number of general competency milestone sets was actually increased, including a teaching competency unique to neurosurgery. However, each of these general competency developmental assessments was focused on a single exemplary skill set, markedly reducing the overall documentation burden without sacrificing accuracy. Finally, the level 5 (postresidency) milestones were aligned with the fellowship training requirements promulgated by the SNS-CAST (see below).

Development of the Neurosurgery Milestones 2.0 involved participation by an expanded committee, including both a resident trainee and a public member, over the course of 5 meetings (4 in-person and 1 videoconference) between May 2016 and November 2017. Once again, input was derived from professional educators at the ACGME as well as from program directors through an SNS survey. The new milestones were published in April 2018,29 reviewed at the SNS Annual Meeting in May 2018, and implemented on July 1, 2018 (Fig. 2). Other ACGME-recognized specialties followed with Milestones 2.0 revisions 1–2 years later.

ACGME Collaboration

Over the past 2 decades, the ACGME has undertaken extensive reforms to the system of accreditation for North American residency training, including the introduction of the Milestones, the Next Accreditation System,30 resident duty-hour restrictions,31 and a single accreditation pathway for North American allopathic and osteopathic residencies.32 Within this setting, the RC for Neurological Surgery has also developed a record of substantial, specialty-level innovation.

The ACGME led a robust regulatory response to public concern about the quality of care delivered in the US residency training environment, including the introduction of duty-hour limitations for resident trainees introduced in 2003, revised in 2011, and further revised and supplemented with supervision standards in 2017. Importantly, the 2017 revision also established new standards for the support and teaching of physician wellness during training.33 Neurosurgery has been a leader in evaluating the effectiveness of duty-hour and supervision standards for
improving surgical and educational outcomes, as well as implementing best practices for effective compliance.\textsuperscript{34-37}

During the 2012–2013 academic year, the RC for Neurological Surgery also introduced surgical case category minimums in each major area of training and practice, as well as overall residency case minimums, ensuring a depth and breadth of training preparing residents for safe independent practice. Based on patterns of practice in the specialty, such as a shift toward lower volumes of open vascular cases and increased volumes of endovascular cases, these minimums have been adjusted to reflect the availability of clinical case material as well as the need to add new skills. The RC for Neurological Surgery has also been conspicuous for various efforts to ensure the academic quality of the training environment, such as requiring minimum levels of demonstrated faculty scholarly activity (including peer-reviewed publications) each year. Finally, neurological surgery is currently one of four specialties participating in the ACGME’s national pilot of the PDPQ initiative, designing a national quality curriculum for ultimate adoption by all US residency training programs in all specialties.

Fellowship Training (CAST and RFP)

Facing the rapid differentiation of surgical technology in various areas of neurosurgery and increasing subspecialization among neurosurgeons in practice, the SNS in 1999 created the Committee for Accreditation of Subspecialty Training, which later changed its name to the Committee on Advanced Subspecialty Training (CAST; maintaining the same acronym). Early areas of differentiation included pediatric neurosurgery (which formed the Accreditation Council for Pediatric Neurosurgery Fellowships [ACPNF] in 1992), functional and stereotactic neurosurgery, spine surgery, and neuroendovascular surgery. As fellowship training after residency became common in these and other areas of neurosurgery, CAST sought to improve the quality and outcomes of such training, which the ACGME has mostly not regulated.

Currently, CAST accredits well over 200 fellowships in the following areas of subspecialty training: cerebrovascular neurosurgery, central nervous system endovascular surgery, neurocritical care, neurosurgical oncology, pediatric neurosurgery (with the ACPNF), stereotactic and functional neurosurgery, peripheral nerve surgery, and spine surgery. Beginning in 2013, CAST created fellowship review committees in each practice area, which advise CAST on appropriate program requirements in each specialty and also review applications from relevant programs. In several specific areas, CAST partnered with other specialty organizations to accredit programs that train specialists whose core discipline may be outside of neurosurgery (including neurology and radiology for central nervous system endovascular surgery,\textsuperscript{38} and neurology for neurocritical care). The fellowship review committees for these two areas now include interdisciplinary representation from those disciplines. As CAST accreditation gained wider, multispecialty recognition, the SNS entered into a unique formal agreement for CAST to utilize the software infrastructure of ACGME accreditation systems. This arrangement facilitates the efficient tracking of faculty rosters, participating sites, and other basic program information by both CAST and the RC for Neurological
Surgery, providing oversight of the impact of hosting fellowship programs on residency training.

In 2014, CAST began certifying the completion by individual neurosurgeons of CAST-accredited fellowships in endovascular neurosurgery and neurocritical care. Over time, CAST coordinated closely with and ultimately transferred its certification functions to the ABNS. Participation in CAST-accredited programs is now a key component of recognition of focused practice (RFP) in an individual practitioner’s board certification (currently available for central nervous system endovascular surgery, pediatric neurosurgery, and neurocritical care). In part to coordinate and align the work being done to accredit fellowship programs and to recognize the focused practice of individual neurosurgeons, the CAST administrative office was co-located with the ABNS headquarters in Rochester, Minnesota, in 2019. The innovations undertaken by CAST over the past 2 decades have provided a successful model for surgical subspecialty training accreditation that is also likely to influence progress in other ACGME-recognized specialties.

Research

In the summer of 2018, the One Neurosurgery Summit added representatives from the AAcNS to assist with systematic coordination of research training and funding efforts across neurological surgery. For example, research leaders from the AAcNS are currently creating a comprehensive research training curriculum for inclusion in the SNS Matrix Curriculum, which will complement the in-person research methods teaching and mentoring taking place at the annual SNS RUNN course. Saturday professional development seminars at the SNS Annual Meeting provide a forum for educating residency directors and administrators about best practices for teaching evidence-based medicine or other research-related topics. Finally, the SNS and RC for Neurological Surgery collaborated on the inclusion of specific research training milestones as part of the educational goals of all US trainees.

Summit organizations also support various mechanisms to fund neurosurgical research experience for trainees and early-career faculty, including the flagship National Institutes of Health (NIH) K12 Neurosurgeon Research Career Development Program (NRCDP) that provides grant funding and structured mentorship to select junior faculty. The first NRCDP scholars were funded in 2013 and the program was expanded in 2016 when the CNS committed to providing ongoing grant support to fund an additional awardee via the National Institute of Neurological Disorders and Stroke (NINDS)/CNS K12 Getch Scholar Award. In 2018, the AAcNS Emerging Investigator Mentoring Program was established to complement the K12 program by providing intensive longitudinal grant writing and research mentoring by established neurosurgical clinician scientists to a broader group of promising junior faculty investigators. The AANS also funds numerous training and early-career research opportunities through its Neurosurgical Research and Education Foundation (NREF), some of which are cosponsored by the AAcNS.

Finally, the leadership of the One Neurosurgery Summit groups have supported strategic planning for proposals to the NIH regarding priorities for federally funded neurosurgery research and also hosted strategy discussions for the use of clinical outcomes registry data to support quality, patient safety, and professional certification. Together, these coordinated efforts of the One Neurosurgical Summit organizations have also increased the successful achievement of initial NIH R01 funding by neurological surgeons at a pace exceeding that of any other specialty.

Response to COVID-19

The substantial investments in coordinated governance by the specialty of neurosurgery over 2 decades proved extremely valuable during the outbreak of the COVID-19 pandemic. In the first few months of the outbreak, One Neurosurgery Summit organizations moved their critical meeting content to online forums, concentrating on mission-focused needs. For example, the SNS provided just-in-time information for residency program directors and academic chairs in its first virtual national symposium, as well as moved critical safety and professionalism boot camp courses to a hybrid online and local program-based hands-on simulation model for incoming PGY1 residents. The SNS Medical Student Committee coordinated input from educators and Summit leaders in launching and communicating a national policy for equity and safety during the neurological surgery residency subinternship rotation and interview season (neurosurgery was one of the first three specialties in the nation to do so). The CNS and AANS provided continuing education for practicing neurosurgeons using both synchronous and asynchronous online forums, created online forums to share real-time information about the impact of the pandemic on patient and surgeon safety, and communicated staffing, educational, and safety best practices for COVID-19 through journal rapid e-publications. The ABNS pivoted to provide both written and oral certification examinations remotely to maintain practice standards without delaying the pipeline of vitally needed new practitioners. Program accreditation by the ACGME and SNS-CAST continued uninterrupted using online databases and meeting functionality.

Future Directions

Recognizing that the most effective educational and professional systems must constantly evolve, work continues in various areas, including: connecting neurosurgical curricula to the various modern online learning tools that have evolved within the specialty, defining the scope of mandatory core neurosurgery training, and revising the overall structure of the neurosurgical residency to incorporate some variable or specialty experience for every trainee.

An unusually rich collection of online learning resources is available to support the US neurosurgical curriculum. In 2003, the CNS launched the Self-Assessment in Neurological Surgery as an interactive online tool with rich links to a growing ecosystem of digital learning resources available on the worldwide web. In subsequent years, the ABNS has converted its written examination to an online format, launched specialty-specific respon-
Conclusions

US neurological surgery has a century-old history of training rigor and excellence, based on a traditional, structured apprenticeship model. Over the past 2 decades, as the specialty evolved, neurosurgery has become an acknowledged leader in innovative pedagogy, curriculum design, educational systems, and governance. Key to progress has been strategic coordination at the level of national neurological leadership organizations through the One Neurosurgery Summit mechanism. Important tactics have included incorporating the PGY1 training year into neurosurgery residency, introducing nationally organized foundational courses with shared simulation and professional experiences, providing professional development for residency program leaders and administrators, creating a national curriculum, defining educational outcomes milestones, introducing residency training standards for surgical case minimums and academic activity, codifying fellowship and other specialty training standards, and promoting training and early-career development in neurosurgical research. Related advances during this time period in certifying the training of individual neurosurgeons have complemented these educational efforts in raising US practice standards.

Based on this strong foundation of cooperation and achievement, the future of neurosurgical education in the US is auspicious. As a specialty, neurosurgery remains committed to and focused on leadership in educational innovation that both complements and facilitates clinical and scientific progress in the specialty.

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Disclosures

Dr. Selman reports ownership in Surgical Theater. Dr. Friedman has direct stock ownership in astar1.

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