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Original Article

On the balance beam: facing the challenges of neurosurgical education in the third millennium

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Received: 23 December 2023
Accepted: 26 February 2024
Published: 22 March 2024

DOI
10.25259/SNI_1014_2023

Quick Response Code:

ABSTRACT

Background: Neurosurgery is one of the most complex and challenging areas of medicine, and it requires an ongoing commitment to education and expertise. Preparing young neurosurgeons with comprehensive education that can allow them to achieve high professional standards is a pivotal aspect of our profession.

Methods: This paper aims to analyze the current scenario in neurosurgical training identifying innovative methods that can guarantee the highest level of proficiency in our specialty.

Results: Given the inherent high-stakes nature of neurosurgical procedures, there is a significant burden of responsibility in ensuring that neurosurgical training is of the highest caliber, capable of producing practitioners who possess not just theoretical knowledge but also practical skills and well-tuned judgment.

Conclusion: Providing high-quality training is one of the major challenges that the neurosurgical community has to face nowadays, especially in low- and middle-income countries; one of the main issues to implementing neurosurgery worldwide is that the majority of African countries and many areas in Southeast Asia still have few neurosurgeons who encounter enormous daily difficulties to guarantee the appropriate neurosurgical care to their population.

Keywords: Mentorship, Microsurgery laboratory, Neurosurgery, Neurosurgical education, Training

INTRODUCTION

From the birth of neurosurgery, the standards for education in this surgical specialty have been unwaveringly high. Neurosurgery undoubtedly ranks among the most complex and challenging

areas of medicine; considering the inherent high-stakes nature of neurosurgical procedures, there is a significant burden of responsibility in ensuring that neurosurgical training is of the highest caliber, capable of producing practitioners who possess not just theoretical knowledge but also practical skills and well-tuned judgment.[13] Hence, providing young neurosurgeons with a comprehensive education that can allow them to achieve high professional standards is a pivotal aspect of our profession and has always been a main concern for seniors. Nevertheless, with the continuous progress in medical and surgical technology and the ever-increasing complexity of neurological cases, the demand for enhanced neurosurgery education has become even more urgent.[17,29] Moreover, the rapid pace of advancements requires a constant upskilling of even experienced neurosurgeons, further underlining the importance of continuous education in this field; the pursuit of novel and improved methods of neurosurgery education must also ensure that it does not dilute the expertise of the practitioners in the process. In other words, while it is crucial to enhance the educational process, it is equally vital to uphold and maintain expert proficiency.[16] It is, therefore, essential to find an optimal balance between the integration of innovative training methods and the preservation of the time-tested principles and practices of neurosurgery. Neurosurgical education in the third millennium faces new, unprecedented challenges that require reshaping our current didactical methods, especially when considering the different scenarios of high- and low- and middle-income countries (LMICs). The first consideration is that the neurosurgical curriculum is not homogeneous and varies from country to country;[13,27,31] however, residents usually start their training performing simple procedures under close supervision, and with the progressive development of their surgical skills, they undertake more complex procedures; at the end of their residency, young neurosurgeons should be expected to be able to perform the whole spectrum of basic neurosurgical procedures without supervision. Most of the young neurosurgeons will choose to refine their skills and subspecialize (e.g., pediatric neurosurgery, neuro-oncology, or vascular neurosurgery); fellowships usually past 1–2 years. However, residency and fellowships are only the beginning of their professional journey; neurosurgeons must constantly keep up with learning new techniques and increase their knowledge to provide the best service to their patients. How can we ensure that trainees are educated while seniors maintain and further improve their proficiency? And how can we guarantee a homogenous neurosurgical education, despite the unequal socioeconomic settings worldwide?

In this article, we try to analyze the possible options for improving this equilibrium to eventually achieve the ultimate goal of enhancing patient care and safety.

MATERIALS AND METHODS

An evolving curriculum: Adapting neurosurgical education for the future

In the first place, a strong background in neurosciences is mandatory to build up a thorough neurosurgical knowledge and expertise. Comprehensive knowledge of neuroanatomy, neurophysiology, and neuropathology is an essential prerequisite to understanding complex neurological conditions and the underpinnings of surgical interventions.[24] Procedural skills and surgical knowledge are key. An ever-growing array of surgical techniques necessitates a curriculum that judiciously balances traditional methods with innovative approaches, thereby producing neurosurgeons capable of selecting the most fitting technique based on the patient's specific needs.[2,23] An essential aspect of the learning curve is related to the exposure to the highest number of procedures and, especially, to the quality of those procedures. Repeated practice of surgeries coupled with constructive feedback from mentors and consistent self-reflection play a pivotal role in the development of surgical skills.

Besides clinical practice, hands workshops have traditionally represented an essential part of training when learning new surgical techniques; unfortunately, this kind of training is not always available to everyone. These workshops are often difficult to organize as they can take place only in specific venues and are burdened by high costs due to the preparation of the cadavers.

RESULTS

Neurosurgical education in LMICs: The importance of local training

The Lancet Commission on Global Surgery estimated that over 66% of the global population lacks access to surgical care. Among numerous contributing factors, a critical issue stems from an insufficient number of healthcare professionals. It has been estimated that 2.2 million surgeons, anesthetists, and obstetricians are required to bridge the healthcare gap between high- and low-income countries. Neurosurgery, in particular, grapples with a severe scarcity of professionals across many low- and middle-income nations, resulting in the denial of neurosurgical treatment to millions of patients. Globally, there are roughly 50,000 neurosurgeons. High-income countries maintain an average ratio of 1 neurosurgeon/80,000 population, while low-income countries witness this ratio plummet to 1 neurosurgeon/1 million inhabitants.[13] An alarming 33 countries lack any neurosurgeons, and vast expanses, predominantly in Africa and Southeast Asia, possess a paltry number of neurosurgeons concentrated mainly in urban pockets.[22] Numerous rural areas within Africa lack

access to basic medical services, let alone the prospect of neurosurgical treatment.

In 2019, a study gauging the capacity and deficiency in delivering vital neurosurgical care deduced that around 5 million essential neurosurgical cases remain unmet in LMICs. The study further calculated that an additional 23,000 neurosurgeons would be required to bridge this chasm.[30] Traumatic injuries and congenital malformations constitute a substantial share of neurosurgical pathology in these regions. Road traffic and industrial accidents, exacerbated by a lack of safety measures and ongoing conflicts plaguing underdeveloped regions, are significant contributors to trauma cases. Over the past decades, a progressive surge in traumatic injuries to the brain, spine, and peripheral nerves has been observed. In regions devoid of neurosurgeons, orthopedic and general surgeons may tend to urgent cases; however, it is important to note that their expertise lacks sub-specialization, rendering them incapable of handling intricate cases. In settings devoid of neurosurgeons, patients are deprived of access to critical procedures such as interventions for bleeding aneurysms,[6] tumor excisions, and intricate spine surgeries. Even in instances where a few neurosurgeons are available within a country, certain subspecialties of neurosurgery (such as functional neurosurgery and peripheral nerve surgery) might be absent.

Until recent years, the integration of neurosurgery into many low-income countries was primarily facilitated by the pioneering efforts of professionals from nations where the field of neurosurgery was well-established. For example, the French neurosurgeon René Chetonier relocated to Kabul and, in collaboration with an Afghan colleague (Dr. Abdul Hamid Rahimi), initiated neurosurgical procedures. Alternatively, local physicians ventured abroad to study neurosurgery and eventually returned to their home countries to practice. However, relying on foreign training is often viable only for a limited number of professionals. In addition, a substantial concern is the phenomenon of brain drain, which detrimentally impacts many low-income nations. After undergoing training in countries offering improved quality of life and professional prospects, numerous young professionals exhibit reluctance to return to their home countries and establish their practices there.

The pivotal shift in the implementation of neurosurgery within low-income countries has been the establishment of local training programs. These initiatives have catalyzed the development of a network of neurosurgical centers, which have gradually extended their coverage from capital cities to encompass larger geographic regions within the respective countries.

A prime exemplar of the potency of a successful local training program is unequivocally reflected in Nepal. Mirroring the trajectory of most LMICs, the emergence of neurosurgery in Nepal has a relatively recent chronicle. Commencing with a solitary neurosurgeon in 1989 and swelling to 12 by 2007, Nepal's neurosurgical landscape underwent a transformative leap with the inception of a local training program in 1999. In the years since, Of 116 neurosurgeons currently practicing in the country, 47 (40.5%) are homegrown, a cohort inclusive of two practitioners currently serving in the Maldives.[7,27] Furthermore, Nepal serves as a magnet for international neurosurgery residents and medical students hailing from Germany, Bangladesh, the UK, the USA, Switzerland, and Japan, among others, who opt to undertake neurosurgery electives within its precincts.

While the shortage of neurosurgeons persists, with an estimated demand for 300 based on a 1/100,000 ratio, Nepal presently harnesses a workforce of 116 neurosurgeons dispersed across nearly all major regions of the country. Impressively, nearly 40% of these professionals have undergone local training.[27]

The resonance of this successful model is palpable in other Asian and African nations as well. Local training initiatives not only yield an augmented number of professionals but also act as a bulwark against the brain drain phenomenon, bolstering the workforce and progressively expanding the neurosurgical network of the country. An additional advantage lies in the aptitude that local training confers on young professionals to operate within the constraints of available resources. This stands in contrast to those who pursue education abroad and subsequently return home, often grappling with disparities in equipment and setting between their training location and their homeland.

Remote mentorship and distant learning: A new concept evolved during the pandemic

The past few decades have witnessed significant technological advancements, with a notable emphasis on its application in education, particularly in the past 3–4 years. In 2019, the outbreak of the COVID-19 pandemic prompted global lockdowns, serving as a significant setback for neurosurgical education worldwide. The reverberations of this disruption were felt across the globe, affecting not only medical education but all facets of learning. In the realm of neurosurgery, residents experienced a marked decline in the time dedicated to patient interactions and clinical education due to the pandemic.[3,12,28]

The imperative to discover novel avenues for expanding neurosurgical knowledge was partially addressed through innovative technology, specifically the evolution of simulations and virtual reality during this period.[19,28] The COVID-19 pandemic, in retrospect, acted as a turning point in neurosurgical education, marking the true inception of virtual learning.[3] Previously unfamiliar online platforms

such as Zoom, Teams, and Google Meet quickly infiltrated our daily lives, transforming into essential tools for remote education, benefiting neurosurgery residents and numerous other medical learners.[25]

Remote learning opened avenues for young individuals, enabling them to access cutting-edge neurosurgical knowledge from esteemed global experts virtually. This mode of education fostered interactions between residents from LMICs and renowned faculties, a feat that would have been otherwise challenging. The global neurosurgery community united during these challenging times to contribute to the global education of budding neurosurgeons.

Two coauthors of this paper actively committed themselves to providing opportunities for remote learning. Starting from May 2020, under the guidance of one coauthor, a series of webinars were organized under the aegis of the World Federation of Neurosurgical Societies. As of the present date, more than 200 webinars have been conducted, spanning various subspecialties. This webinar series serves as an exemplary model for virtual learning, boasting exceptional success with over a thousand participants regularly engaging in these bi-weekly sessions. Both webinar series continue to enjoy immense popularity and have become an integral component of global neurosurgery education. Even after the pandemic abated and in-person meetings resumed, remote learning persisted as a cornerstone of neurosurgical education. The advent of hybrid conferences marked a significant advancement in remote learning. This hybrid approach has now evolved into a standard practice driven by the realization of its potential to connect with neurosurgery residents worldwide. The neurosurgical community must persist in embracing the newer tools in neurosurgical education, such as simulations, Virtual Reality, and Hybrid conferences, even beyond the COVID-19 era, to further enhance learning in the third millennium.[11,20,24]

Recently, the introduction of modern training tools like simulators has offered the possibility to train young neurosurgeons in a risk-free environment, facilitating skill development and reducing the learning curve.[10] Neurosurgery continuously progresses, with ongoing developments in technology and an expanding understanding of neurological diseases. Consequently, neurosurgical curricula need adaptation in response to this evolving scenario.[31] The increasing importance of technology in neurosurgery must be taken into consideration; from intraoperative imaging to robot-assisted surgery, technology is revolutionizing neurosurgical practice. Therefore, it becomes mandatory to integrate technological literacy in the neurosurgical curricula to provide the trainees to proficiently utilize these tools and understand their potential advantages and limitations.[8] The development of critical thinking and decision-making skills must also be a focal point of an evolving curriculum. The high-stakes, complex decision-making environment of neurosurgery necessitates these abilities.[13] Innovative teaching methods such as clinical case discussions, problem-based learning, and ethical debates can be integrated to foster these skills.

Nowadays, research has also become essential for modern neurosurgeons. With the rapid pace of advancement in neurosurgery, the ability to conduct and interpret research enables neurosurgeons to remain at the forefront of their field. Encouraging student engagement in research projects and teaching principles of research methodology and critical appraisal can enhance this capacity.[13] Communication and interpersonal skills should be a significant part of neurosurgical education. Neurosurgeons must effectively communicate with patients, families, and healthcare teams.[1] Patient-centered care, empathy, and ethical conduct should form integral parts of the curriculum.[27] An evolving curriculum in neurosurgical education should aim to develop not just the knowledge and skills but also the attitudes and values that are pivotal to the practice of neurosurgery. This holistic approach will prepare neurosurgeons who are skilled clinicians, empathetic healers, critical thinkers, lifelong learners, and effective collaborators, ready to navigate the ever-evolving landscape of neurosurgery.

Mentorship and collaborative learning: Cornerstones of neurosurgical education

Mentorship plays a pivotal role in neurosurgical education, serving as a critical factor in shaping the future generations of neurosurgeons. Mentors offer not only technical expertise and clinical acumen but also valuable insights into professionalism, work-life balance, and ethical considerations, thereby influencing the overall growth and development of their mentees. Mentors may also guarantee that no discrimination occurs, and they should contribute to creating a setting conducive to open dialog and idea exchange, fostering a culture of inquiry and critical thinking. Mentorship aids novices in honing their technical skills, making intricate clinical decisions, and navigating the complexities inherent in neurosurgical practice.[8] Moreover, the mentor-mentee relationship often evolves into a lifelong professional partnership that continues to contribute to the mentee's ongoing advancement. Beyond its impact on individual mentees, mentorship also extends its influence to foster a collaborative learning atmosphere. By cultivating a nurturing and intellectually stimulating environment, mentors encourage collaborative learning, which involves the exchange of knowledge and skills among peers, thereby enriching the overall learning experience.[4]

Various forms of collaborative learning are evident in neurosurgery, including case discussions, journal clubs, and joint research projects. These platforms facilitate mutual

learning, the sharing of experiences, and the attainment of a comprehensive perspective on neurosurgical practice. In addition, collaborative learning environments foster essential attributes such as teamwork and communication skills, which are paramount for the multidisciplinary nature of effective neurosurgical care.[8] To ensure the enduring impact of mentorship and collaborative learning, it is imperative to extend their influence beyond the formal training period. Professional networks and societies offer opportunities for continued mentorship and collaboration, facilitating lifelong learning and sustained professional growth.[8]

In conclusion, mentorship and collaborative learning are indispensable components of neurosurgical education, shaping the well-rounded development of neurosurgeons. These elements not only contribute to the refinement of clinical and technical proficiencies but also foster the development of professional attitudes, effective communication skills, and a steadfast commitment to continuous learning.

Quality of care and patient safety: The central goals of neurosurgical education

Ensuring high-quality care and patient safety remains the paramount objective of medical practice, and neurosurgery is no exception. Given the rapidly evolving nature of the field, characterized by increasing complexity and sophistication, an unwavering dedication to these principles becomes imperative. Notably, the quality of neurosurgical education directly correlates with the standard of patient care and safety outcomes. The multifaceted nature of care in neurosurgery encompasses precise diagnosis, effective surgical planning, meticulous execution of procedures, and diligent postoperative management. These aspects are directly influenced by the neurosurgeon's knowledge, technical skills, decision-making abilities, and commitment to continuous professional development. As such, the development and constant honing of these competencies serve as pivotal components within neurosurgical education.[15]

Patient safety closely intertwines with care quality, especially in a field where interventions profoundly impact patients' lives. Neurosurgical education must instill a profound understanding of potential complications and strategies to prevent them while fostering a culture that prioritizes patient safety.[8]

For instance, comprehensive surgical simulation training, offering a risk-free environment for practice, plays a significant role in enhancing patient safety. Such simulations enable learners to attain proficiency in complex procedures and effectively manage potential complications before encountering them in real-world clinical scenarios.[5] Moreover, communication and teamwork skills bear vital importance in ensuring patient safety. Interprofessional education, which facilitates learning with, from, and about other health-care professionals, enhances communication, collaboration, and, consequently, patient safety.[18,21] The pivotal role of neurosurgical education in elevating care quality and patient safety is underscored by its emphasis on a robust knowledge base, technical proficiency, critical thinking, patient safety, and effective communication, all of which directly contribute to better patient outcomes.

Young neurosurgeons face diverse challenges during their transition from training to independent practice. These challenges encompass acquiring surgical skills, adapting to professional and lifestyle changes, and navigating the complexities of the job market. Key challenges faced include:

1. Acquiring Surgical Skills: Given the broad scope of neurosurgery and the myriad of procedures involved, mastering complex surgical techniques poses a steep learning curve and a significant challenge [31]
2. Transition to Independence: The shift from being a supervised trainee to an autonomous surgeon responsible for critical decision-making and patient outcomes can be daunting. Young neurosurgeons must learn to manage this responsibility while continually refining their clinical judgment and decision-making skills [8]
3. Work-Life Balance: Neurosurgery's demanding nature often entails extended and irregular working hours, necessitating a delicate balance between personal life and professional commitments. Burnout becomes a significant risk;[14]
4. Financial Pressure: Escalating medical education costs can burden young neurosurgeons with considerable student debt. Coupled with relatively low income during residency, this leads to financial stress [14]
5. Job Opportunities: The job market for young neurosurgeons can prove challenging, with certain regions experiencing an oversupply of neurosurgeons while others face shortages. In addition, aligning available opportunities with specific subspecialty interests can present difficulties.[31]

Addressing these challenges underscores the necessity of comprehensive training programs that not only foster technical expertise but also prepare young neurosurgeons for the professional and personal obstacles that they may encounter. Mentorship, well-being initiatives, financial planning education, and career guidance all play instrumental roles in supporting young neurosurgeons in their journey toward becoming proficient and well-rounded neurosurgeons.

DISCUSSION

The dynamic and demanding nature of modern neurosurgery requires an ongoing evolution of the educational framework

to ensure that neurosurgeons can face the challenges of managing an increasingly complex patient population effectively. At the same time, maintaining the proficiency of experienced practitioners is crucial; they bear the responsibility of delivering expert care and guiding the next generation of neurosurgeons. Achieving this delicate balance between enhancing neurosurgery education and preserving expert proficiency requires a comprehensive, innovative, and measured approach.

The evolution of neurosurgery education should be targeted and multifaceted, taking into account the diverse skill set that future neurosurgeons will require. A modern curriculum should not only establish a solid foundation in neurosciences but also incorporate the growing impact of technology in the field of neurosurgery. Equipping trainees with technological literacy and research acumen would enable them to navigate the rapidly changing landscape of neurosurgery. Moreover, the curriculum should emphasize the development of critical thinking skills, decision-making abilities, and communication proficiency, as these attributes are vital in delivering patient-centered, safe, and effective care.[25]

However, while technology and innovation play significant roles, traditional teaching methods, such as mentorship and collaborative learning, remain integral. Mentorship, in particular, plays a crucial role in shaping the professional growth and career trajectory of trainees. The mentor's influence extends beyond technical skills, imparting wisdom, professionalism, and ethical conduct that cannot be acquired solely from textbooks. Collaborative learning environments foster teamwork and effective communication, both essential in the multidisciplinary realm of neurosurgical care.[12]

Enhancing neurosurgery education should also prioritize patient-focused approaches, with an unwavering commitment to quality care and patient safety. Educational strategies should be geared toward improving patient outcomes and mitigating risks associated with neurosurgical procedures. Integrating comprehensive surgical simulation training can enhance patient safety by allowing trainees to gain proficiency in complex procedures and manage potential complications in a controlled environment.[25] In addition, incorporating interprofessional education into the training curriculum can enhance trainees' understanding of team dynamics and improve patient care.[9,18,26]

The transition from trainee to independent practitioner represents a critical phase in a neurosurgeon's career. It signifies a shift in responsibility, demanding a deeper understanding of the real-world implications of neurosurgical care. Preparing trainees for this transition should be a focal point in enhancing neurosurgery education. Providing support during this phase, such as mentorship, well-being initiatives, and career guidance, can significantly impact the trainee's professional growth and job satisfaction.[8] While new initiatives and innovative approaches are vital, maintaining the proficiency of established practitioners should not be overlooked. Continuous professional development and lifelong learning are essential to ensure that experienced neurosurgeons remain at the forefront of their field. Furthermore, these seasoned practitioners serve as mentors and role models for the next generation of neurosurgeons, emphasizing the importance of preserving their proficiency. An important mission is ensuring collaboration between the different continents in the process of neurosurgical education based on mutual benefits and respect. Many obstacles and challenges exist in LMICs, which hinder the promotion of neurosurgery significantly, which will definitely be reflected in the quality of training and trainees.[15] The neurosurgical community is committed to supporting neurosurgical education and training in the LMICs, to promote the standards of qualification of trainees, which will definitely have a positive impact on the quality of neurosurgical care provided to their patients. The field of neurosurgery stands at the brink of an educational evolution driven by advancements in technology, changes in the healthcare landscape, and the unrelenting pursuit of high-quality patient care. Although challenges abound, the potential to shape a new generation of highly skilled, adaptable, and empathetic neurosurgeons is substantial. Nevertheless, the enhancement of neurosurgery education requires judicious consideration, striking a balance between innovative integration and the preservation of traditional principles that underpin neurosurgical expertise.

CONCLUSION

The field of neurosurgery is a dynamic intersection of medical knowledge, technical precision, ethical considerations, and compassionate care. To keep up with its continuous evolution and demand for innovation, a multifaceted approach is necessary. Adapting the curriculum is crucial to equip future neurosurgeons with relevant skills while retaining foundational principles. Mentorship and collaborative learning play a key role in nurturing lifelong learning and professional growth, emphasizing patient safety and high-quality care. Addressing challenges faced by young neurosurgeons is essential to prepare them for broader responsibilities and pressures, creating a new generation of resilient, empathetic, and proficient professionals. Ultimately, the goal is to improve patient care and safety, making the effort worthwhile.

Declaration of patient consent

Patient's consent is not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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How to cite this article: Encarnacion Ramirez MD, Montemurro N, Musa G, Chmutin GE, Nurmukhametov R, Rosario Rosario A, *et al*. On the balance beam: facing the challenges of neurosurgical education in the third millennium. Surg Neurol Int. 2024;15:102. doi: 10.25259/SNI_1014_2023