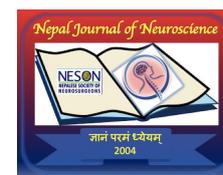


Maximising Neurosurgical Residency Training: Integrating Skill, Cognition, and Resilience

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Date of Submission: 10th January 2026

Date of Acceptance: 3rd February 2026

Date of Publication: 15th March 2026

Abstract

Neurosurgical residency training is uniquely demanding, requiring mastery of technical skills, advanced cognitive decision-making, and emotional resilience. Contemporary training faces additional pressures from duty-hour regulations, rapid technological advancement, subspecialization, and increasing emphasis on trainee well-being. This perspective reviews the evolution of neurosurgical training from classical apprenticeship models to modern, competency-based paradigms incorporating simulation, structured feedback, mentorship, and global collaboration. We provide a vision for a residency that balances surgical skill acquisition with reflective practice, professional identity formation, and resilience, aiming to produce neurosurgeons who are technically proficient, intellectually mature, and sustainable in the long term.

Key words: Neurosurgical education, residency training, simulation, mentorship, resilience

INTRODUCTION

Neurosurgical training has historically been rooted in apprenticeship, shaped by pioneers such as Sir William Osler, Harvey Cushing, and Walter Dandy. Their legacy emphasizes mentorship, progressive responsibility, and the integration of scientific knowledge with hands-on experience. Osler's aphorism—"He who studies medicine without books sails an uncharted sea, but he who studies without patients does not go to sea at all"—continues to define the essence of surgical education.¹

However, modern residency training has evolved within a dramatically altered landscape. Duty-hour restrictions, increasing procedural complexity, rapid sub-specialization, and heightened patient safety expectations have reduced uniform operative exposure. Simultaneously, technological advances have transformed surgical workflows. The central challenge is not whether neurosurgical training must adapt, but how it can

evolve without sacrificing depth, humanism, and excellence.²

Skill acquisition and deliberate practice

Technical mastery in neurosurgery is achieved through deliberate practice—repetitive, goal-directed training that incorporates immediate feedback and progressively increasing difficulty.³ Skill acquisition follows a staged trajectory, beginning with anatomical understanding, advancing through simulation-based rehearsal, cadaveric dissection and culminating in supervised clinical performance. (Table 1)

Table 1: Time frame for enhanced learning and training

Category	Typical Time Frame	Knowledge and skill acquirement
Surgical Anatomy Orientation	PGY-1 to PGY-2 (Primary Focus)	Basic neurosciences, neuroanatomy, and clinical localization via didactic lectures and clinical rotations.
Simulation Training	PGY-1 to PGY-3 (Basic Training)	Micro-suturing, high-speed drilling, and instrument handling using synthetic or virtual models. Basic spine instrumentation and navigation guidance.
Cadaver Dissection	PGY-4 to PGY-6 (Advanced Training)	Complex craniotomies, skull base approaches, and vessel anastomosis. Advanced spine instrumentation.

Access this article online

Website: <https://www.nepjol.info/index.php/NJN>

DOI: <https://doi.org/10.3126/njn.v23i1.91788>

HOW TO CITE
Makkina, C. Maximising Neurosurgical Residency Training: Integrating Skill, Cognition, and Resilience. NJNS. 2026;23(1):3-5

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ISSN: 1813-1948 (Print), 1813-1956 (Online)

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Simulation has become an indispensable adjunct to operative training. Cadaveric dissection remains essential for anatomical realism, while virtual and augmented reality platforms enable repeated rehearsal of complex or infrequent procedures in a risk-free environment. Three-dimensional printed models offer tactile feedback for spinal and cranial procedures, while digital platforms provide low-cost, global access to educational resources. Evidence consistently demonstrates that simulation improves technical performance, confidence, and patient safety, serving as a bridge between theory and operative autonomy.⁴⁻⁵ (Table 2)

Table 2 : Simulation modalities and training

Modality	Primary application	Key advantage
Cadaveric dissection	Skull base, bypass surgery	High anatomical fidelity
Virtual/Augmented reality	Aneurysm clipping, ETV	Safe repetition
3D-printed models	Spinal instrumentation	Hands-on tactile learning
Digital platforms	Neuroanatomy, planning	Global accessibility

Cognitive training and feedback

Neurosurgery is as much a cognitive discipline as a technical one. Surgical decision-making requires integration of anatomy, physiology, pathology, and risk anticipation. Mental rehearsal, contingency planning, and reflective case analysis enhance precision and judgment under pressure.

Structured feedback accelerates learning. Tools such as the Objective Structured Assessment of Technical Skills (OSATS) provide objective benchmarks, but equally critical is a departmental culture that promotes honest, constructive feedback and reflective improvement.⁶⁻⁷ A single focused question—“What could I do better next time?”—can transform experience into expertise.

Resilience, Teamwork, and Well-being

Resilience is integral to neurosurgical competence. Patient safety depends on effective teamwork with anesthesiologists, nurses, and technologists. Morbidity and mortality meetings, when reframed as quality-improvement exercises rather than blame forums, foster systems-based learning.

Psychological well-being is equally vital. Exposure to adverse outcomes places residents at risk of burnout and the “second-victim” phenomenon. Structured debriefing, peer support, and access to mental health resources mitigate emotional exhaustion and promote professional longevity.⁸ Work–life integration remains a significant challenge. The intensity of neurosurgical training strains personal relationships and family life, with studies reporting high levels of marital stress among trainees.⁹⁻¹⁰ Recognizing relationship preservation as part of professional development—through predictable scheduling, family-inclusive initiatives, and institutional support—enhances resilience and performance.

Mentorship, Technology, and Global Learning

Mentorship remains central to neurosurgical training. Effective programs provide complementary mentorship in technical

skills, cognitive decision-making, and academic development. Structured mentor–mentee engagement improves satisfaction, reduces burnout, and supports career progression.⁶

Technological innovation must be adopted judiciously. Exoscopes, navigation systems, and augmented reality enhance visualization and accuracy but should be integrated based on clinical need, validated training, and cost-effectiveness. Technology should augment—not replace—clinical judgment. Global neurosurgical education has expanded rapidly through webinars, digital atlases, and collaborative platforms, particularly benefiting low- and middle-income countries. The growing body of literature on neurosurgical education reflects this collective momentum toward shared learning.¹¹ (Fig 1)

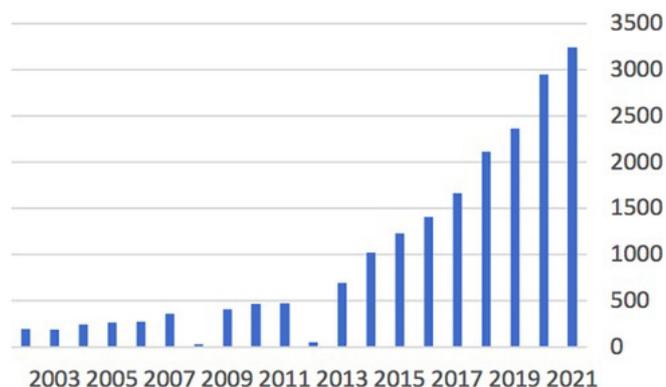


Figure 1: The rise in articles about neurosurgical education from 2003 to 2021

Conclusion

The neurosurgeon of the future is defined not by case numbers alone, but by the quality of learning, depth of judgment, and resilience of character. Deliberate practice supported by simulation fosters technical mastery; reflection and feedback cultivate wisdom; and balanced personal and professional lives sustain long-term excellence.

The enduring lessons of Osler, Cushing, and Dandy remind us that neurosurgical training is ultimately about shaping individuals. The next generation of neurosurgeons must emerge not only as skilled operators but also as thoughtful leaders—capable of embracing innovation without losing humanity and excellence without burnout.

ACKNOWLEDGEMENT

We are thankful to our department of Neurosurgery at CMC, Vellore

FUNDING: No funding was obtained for the study

DISCLOSURES: Authors have nothing to disclose.

CONFLICT OF INTEREST: None.

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