The Interface of Global Neurosurgery and Technological Innovation: A Vision for The Future

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The altruistic pursuit of international neurosurgical equity is evolving from its neocolonialist roots in purely surgical mission trips to more collaborative capacity building endeavors. Inevitably, these projects incorporated in-person components requiring travel, concomitant expenses and time away from one's practice for both parties, all presumed requirements of participation that have been quoted as barriers to involvement despite popular interest. While travel restrictions disrupted many capacity-building initiatives, they also highlighted possible solutions to ensuring evolution away from the neocolonialism that may belie some partnerships, as well as establishing and enhancing collaborations while minimizing barriers to involvement. This solution at least partially lies in technological innovation. The Global Action Framework of the Global Neurosurgery Committee in the World Federation of Neurological Societies (WFNS) encompasses objectives that are already achieved through digital hubs: amplification of access, alignment of activity, advancing collaborations, and assimilating initiatives into broader systems. We suggest that the new wave of international neurosurgical collaboration requires an accessible, comprehensive and evidence-based technological resource framework and propose a vision for such a system.

This framework would encompass six domains reflective of current needs in neurosurgical education, mentorship and skill acquisition: personal education, surgical simulation, intersurgeon connectivity, clinical assistance, research collaboration and optimization of surgical equipment sharing (**Table 1, Figure 1**):

Domain	**Definition**	**Metric**
Self-Education	Study materials available for personal use, including text, video, recorded lectures, and interactive modules that increase clinical knowledge.	-Usership -Web Metrics -Pre/Post knowledge assessments
Surgical Simulation	A physical, digital, or virtual imitation of a clinical situation that allows for safe repetition and early skill set acquisition.	-Time Spent -Haptic Metrics

		-Pre/Post knowledge assessments -OSATS -NEVAT
Virtual Mentorship	Person-to-person clinical training and assistance using distance technology such as video conference or virtual or augmented reality.	-Patient Care -Mortality, complication rates -Cases performed
Connectivity	Strategically linking individuals and organizations with aligned interests seeking to foster collaboration and align resources with needs.	-Usership -Connection metrics
Research Collaboration	Mutual support of research efforts utilizing online platforms for data exchange, statistical support, and publication seeking equitable authorship and research infrastructure development	-Publications -Authorship metrics (LMIC 1st, 2nd, last) -Bibliometrics
Surgical Equipment Sharing/Support	Leveraging technological advances and industry relationships to make surgical and perioperative equipment available and maintainable in resource constrained areas.	

Table 1: Summary of Key Domains of Technology and Innovation in Neurosurgical training with definitions and proposed outcome metrics

Figure 1: Illustrative diagram of wheel-and-spoke concept for digital hub to facilitate hybrid neurosurgical education

The personal educational spoke would provide access to resources for up to date neurosurgical literature by including links to webinars, virtual lectures, courses, online versions of conferences and atlases with a centralized event calendar.

The earliest in its development, the surgical simulation spoke, would provide a space for safe repetition of technical skill acquisition and familiarity of procedural steps. Surgical simulators span platforms such as physical models, digital simulation and virtual or augmented reality. The strategic use of simulation for specific Bellwether procedures in high-need regions could significantly bolster workforce development.

The ability to access and connect with various mentors remains central to the development of any early practicing neurosurgeon. A hub for virtual neurosurgical mentorship would, similar to current social media platforms, expand such connectivity. Those with aligned clinical interests will be able to more easily find and collaborate with each other allowing mutual involvement in a wide variety of daily activities; from pre-operative patient selection to virtual tumor and epilepsy boards to intraoperative consultation using virtual and augmented reality.

Similarly, research collaboration is strengthened by increased availability of digital communication, cloud-based data repositories, and encourages local partners to present their findings via virtual conference unencumbered by the financial burdens of attendance.

Lastly, availability of imaging and maintenance of equipment can be a rate-limiting step to advancing capacity for surgical care. As part of this global neurosurgical connectome, we envision an opportunity to link design engineers with high-yield equipment needs thus minimizing associated disparities in access secondary to equipment availability and upkeep.

With increasing recognition of the need for equitable access to surgical care arises an opportunity to connect a fragmented network of individuals and organizations ultimately pursuing similar goals. The above-described use of technological innovation to drive global neurosurgical collaboration seeks to maximize connection and minimize redundancy. In practice, we first plan to collate current tools available for each domain by methodologically rigorous systematic review and determine their respective effectiveness using validated metrics. Secondly, a needs assessment conducted with a representative sample of international neurosurgeons from both developed and developing health systems will help to determine areas of greatest demand within the above framework. Finally, frequent solicitation and application of user feedback will be required with the evolution of this digital hub to ensure relevant application to the growing global neurosurgical community (**Figure 2**). Inherently this will require constant self-re-evaluation as a community to ensure agreed-upon ethical guidelines for digital resources in surgical capacity building are followed.

Figure 2: Summary of WFNS Global Neurosurgery Committee Action Plan on Technology and Innovation

Critics of this vision may argue that virtual options for surgical education, mentorship and consultation are no substitute for in-person guided development. We fully recognize the value of traditional in-person education, hospital based-residency training, peer evaluation processes and board certification. However, the addition of digital communication tools, simulation models and augmented/virtual reality systems can be synergistic, providing a scalable addition to current training systems that can more rapidly increase neurosurgical expertise worldwide. The power of digital technology for didactic teaching, case review, research collaboration, and focused surgical skill development has already been highlighted in the setting of current travel restrictions. Implementing technological innovation in global neurosurgical endeavors remains the natural

evolution of our international neurosurgical community, and it is time we create a means to enter into this new phase connected, together.

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