Bioethics and Neurosurgery: An Overview of Existing and Emerging Topics for the Practicing Neurosurgeon

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Key words
- Bioethics
- Brain computer interfaces
- Ethics
- Health equity
- Informed consent neurosurgeons
- Neurosurgery

Abbreviations and Acronyms
BCI: Brain—computer interface
DBS: Deep brain stimulation
ICH: Intracranial hemorrhage
TBI: Traumatic brain injury

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Neurosurgery is a field with complex ethical issues. In this article, we aim to provide an overview of key and emerging ethical issues in neurosurgery with a focus on issues relevant to practicing neurosurgeons. These issues include those of informed consent, capacity, clinical trials, emerging neurotechnology, innovation, equity and justice, and emerging bioethics areas including community engagement and organizational ethics. We argue that bioethics can help neurosurgeons think about and address these issues, and, in turn, the field of bioethics can benefit from engagement by neurosurgeons. Several ideas for increasing engagement in bioethics are proposed.

INTRODUCTION

Neurosurgeons often care for gravely ill patients who may be unable to communicate their wishes and lack decision-making capacity. Furthermore, neurosurgeons operate on the central nervous system, viewed by many as the nexus of one's sense of selfhood. Complex ethical issues are inherent to the day-to-day practice of neurosurgery and the advancement of the field.[1-3]

Bioethics is a multidisciplinary field that applies moral theories to problems in health, medicine, and technology, and empirically and theoretically examines these issues with a focus on application. Neuroethics explores ethical issues that arise from neuroscience and its applications, including those within neurosurgery.[4]

We aim to provide an overview of key and emerging ethical issues in neurosurgery with a focus on issues relevant to practicing neurosurgeons. This is not meant to be an exhaustive list of all ethical issues, rather we hope to illustrate the breadth of ethical issues in the field and argue that neurosurgeons would benefit from engaging with bioethics and—in turn—bioethics could be more responsive to the needs and realities of neurosurgery.

KEY ISSUES

Informed Consent and Capacity

The ability to provide informed consent for surgical intervention is defined by decision-making capacity, which is evaluated in the context of a specific decision. The patient or surrogate decision-maker must understand the options and risks and have stable reasoning that is not unduly impacted by impaired brain function, a mood disorder, or medical condition.[5] Given the risk and complexity associated with decision-making about neurosurgical interventions, informed consent is of key importance in neurosurgical patients.[5-7]

In neurosurgical patients, cognition, comprehension, and thus decision-making capacity may be impacted by their condition in a stable or fluctuating way. Certain intracranial lesions may affect cognition that can impair a person's ability to engage in medical decision-making.[8-12] Patients with brain edema may have fluctuating decision-making capacity as it subsides or increases.[13]

Adequately assessing capacity can be challenging. In brain tumor patients, capacity may be overestimated by physicians with few patients undergoing formal capacity assessment, which is distinct from cognitive testing.[12-14] The history of psychiatric surgery (e.g., on incarcerated and institutionalized individuals) serves as a reminder of the risk of coercion in neurosurgery, and that context matters for assessing the ethics of neurosurgical interventions.[15,16]

In neurosurgical patients who lack capacity, substituted judgment via surrogate decision-making is the standard of care.[13] However, surrogates have been shown to not always make decisions concordant with the patient's wishes.[17] Significant discordance between clinician and surrogate perceptions of communication has also been reported, complicating goals of care discussions.[18,19] Surrogate decision-making also applies to pediatric patients who require neurosurgical intervention.[20,21] Surrogates are often faced with complex decisions that need to be made rapidly in the setting of an uncertain prognosis, especially in cases of traumatic brain injury (TBI) and severe intracranial hemorrhage (ICH).[22,23] Decision aids are interactive videos or written tools designed to help patients or surrogates account for their values when making an informed choice, and have been developed for some conditions including TBI and ICH.[24,25]

Clinical Trials and Research Ethics

Informed consent is an ethical standard and legal requirement for human subject research. *Therapeutic misconception*, in which the potential research participant inappropriately expects a personal therapeutic benefit from a research study, is a challenge to obtaining truly informed consent.[26,27] This concept is not unique to neurosurgery research, but may be heightened in patients with severe illness and in situations where existing treatments offer only minimal benefit (e.g., high-grade tumors, TBI).[26,28]

Trial design for neurosurgery poses additional challenges. Randomized controlled trials for a surgical intervention require *clinical equipoise* between the 2 treatments—a lack of consensus between experts in the field on which treatment is superior—to avoid the possibility of withholding a treatment with a known, superior benefit.[29] Using sham surgery as a placebo group in deep brain stimulation (DBS) trials can pose significant risk to patients, such as general anesthesia and infection, without possibility of benefit.[30,31] This risk can potentially be mitigated by crossover study design.[30,31] Research studies involving implantable technology raise questions about post-trial care of patients with trial-related implants, including who should fund the management of this device after the study period ends.[32-36]

Emerging Technologies

Modern neurosurgery is inextricable from evolving neurotechnology. Brain—computer interfaces (BCI) include systems that measure and record neural activity ("read") or introduce change via stimulation to an area of the brain ("write"). These advanced neurotechnologies could revolutionize treatment of movement disorders and has potential utility in psychiatric disorders.[37,38] Beyond restoring impaired function, neurotechnologies could eventually be used to enhance normal function, such as memory or cognition. What constitutes so-called *enhancement* and where the line between acceptable and unacceptable therapeutic gain lies is an area of long-standing debate.[39,40]

A BCI that can pick up real-time neural activity and respond in some fashion by providing stimulation is considered a closed-loop system and could feasibly run without external, human oversight.[39] While the possibility of a closed-loop system may lead to more effective, precise neuromodulation and minimize side effects, it could also alter cognition, mood, and memory, raising complicated questions about identity, free will, autonomy, data storage, and privacy.[33]

Neurochips, neuroprostheses, applications of brain organoids in brain and spinal cord injury, and use of artificial intelligence and machine learning in practice are other areas that deserve attention.[41,42] Neurosurgeons have a unique vantage point and should be part of the ethical discussion of these technologies given their scientific and procedural expertise.[43] While a philosophical discussion on the nature of identity, self, and autonomy seems esoteric, patients may discuss these topics with their neurosurgeons as therapies become available.[40,44]

Finally, some argue the cost of developing new treatments that will only benefit select or well-resourced patients instead of being directed towards improving access to existing, cheaper treatments.[43] There is a possibility of direct-to-consumer BCI products, an idea popularized by the creation of Elon Musk's company, NeuraLink.[20] Clinicians will likely be faced with questions from patients about how to act on data generated by these direct-to-consumer products.

Innovation in the Operating Room

The "gray zone" between surgeon-specific variation in technique and introduction of major new technologies in the operating room presents challenges to oversight, regulation, and liability.[45-47] Guidelines for device assessment, such as the IDEAL framework, which proposes criteria for each step of a new device: Idea, Development/Exploration, Assessment, Long-term study (IDEAL), are a strategy for regulation in this sphere.[45]

Patients should be presented with the risks and benefits of the novel technology; however, lack of robust and long-term data for recently introduced technologies make it difficult for both patients and clinicians to have a complete understanding.[48] Every effort should be made to communicate the uncertainty of new technology versus the standard of care in the consent process.[48,49]

Device representatives are often present in the operating room to assist in deploying and troubleshooting technology. Presence of and dependence on device representatives may be inevitable and could improve outcomes by ensuring consistent use of technology; however, there is not clear consensus on how much neurosurgeons should rely on representatives' knowledge.[50] Device representatives' presence and evolving autonomy of surgical devices may raise concerns if something goes wrong.[51] As robots become a bigger part of neurosurgical practice, the possibility of semi and fully autonomous robots raises ethical and legal questions. Finally, neurosurgeons' relationships with industry create conflicts of interest. Conflicts of interest are not in and of themselves problematic but need careful attention to mitigate risk of inadvertent bias and exploitation.[46,47,52]

Equity and Justice

Historically, medical bioethics focused primarily on interactions between providers and patients—which can be thought of as *medical microcosms* (i.e., on a small scale). Equity and justice are relevant to microcosm interactions, such as ensuring fair and equitable treatment of post-operative pain, offering treatments in an unbiased fashion, and decision-making in the setting of prognostic uncertainty.[53] Decisions about withdrawing life-sustaining treatment in patients with devastating brain injury are likewise

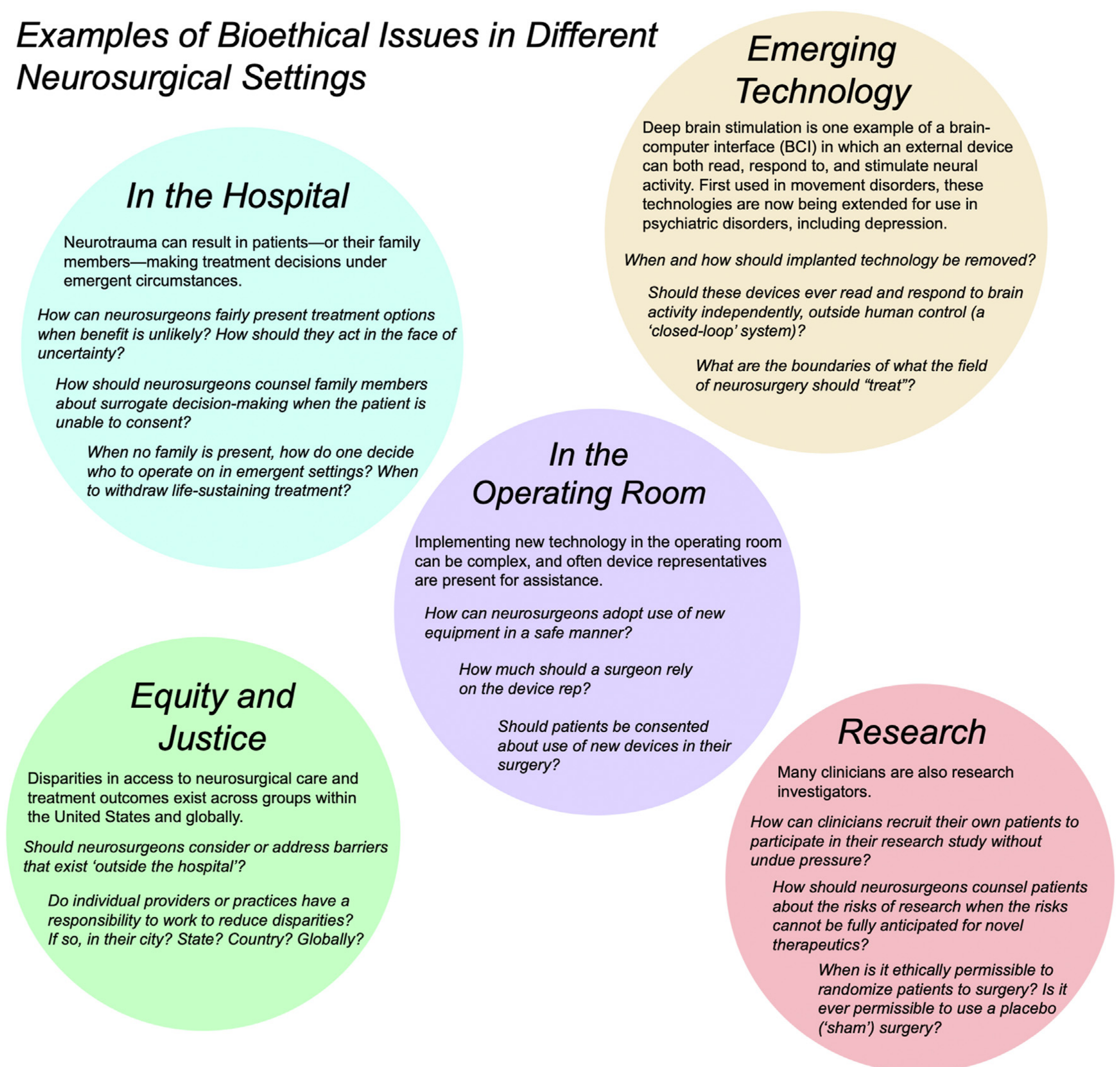

Figure 1. Examples of bioethical questions in different realms of neurosurgery.

ambiguous and vary across patients with different socioeconomic, demographic, and religious backgrounds.[54]

Advancing health equity also requires attention towards *medical macrocosms* (i.e., on a large scale)—the complex interplay between health systems, providers, patients, and society. Neurosurgical outcomes are not equivalent across income and race, and previous research has shown that social and structural determinants of health play a major role in these differences.[55]

Neurosurgical care is not distributed equally or justly.[56] For example, Hispanic and Native American people on average need to travel further to see a neurosurgeon in the United States than other racial/ethnic groups.[57] Even for those close to a neurosurgical center, cost can be prohibitive.[39,58] Dissemination of new technology across health care systems in the United States can be slow. Innovation is often clustered near academic research centers with highly trained specialists. Access to new technology lags in rural areas.[59]

While neurosurgical resources are disproportionately concentrated in high income nations, there is an enormous need for surgical care in developing nations and the Global South, with the need for an estimated 5 million essential neurosurgical cases are unmet each year.[60] There is an ethical imperative to expand neurosurgical capacity, and critically examining volunteer endeavors in global neurosurgery with a

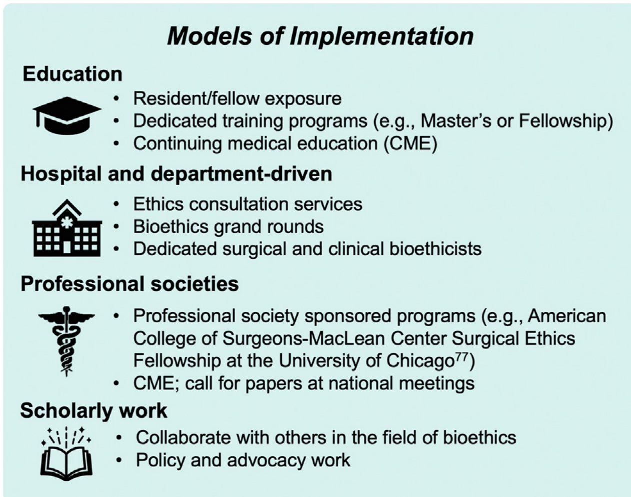

Figure 2. Proposal for integration of bioethics within neurosurgery.

bioethics lens can help ensure that these efforts are focused on capacity building, engaging local resources, and providing sustainable solutions, rather than medical "voluntourism."[61-65]

WHAT'S NEW IN BIOETHICS?

Here we highlight two emerging areas of interest in the field of bioethics that have relevance to neurosurgery.

Community Engagement and Bidirectional Research

Engagement of patients, patient advocates, communities, and care providers in all stages of the research process is a strategy to incorporate patient and community values and interests in research aims, mitigate medical mistrust, promote the dissemination of research findings, and increase and diversify study enrollment.[66-69] A related concept is bidirectional research—the idea that patients should be included in each step of research.[70] While these approaches have benefits, they also raise questions about potential for conflicts of interest and coercion, differing sources and forms of expertise between patients and clinicians, and the unequal power dynamics between community members and medical professionals.[71]

Organizational Ethics

Organizational ethics refers to the set of values that guides the overall mission of an organization and the ethical issues that affect healthcare systems and healthcare delivery on a macroscopic level.[72-74] Neurosurgeons may engage in organizational ethics by advocating for the needs of neurosurgical patients, health equity, and justice. Organizational ethics—like shared professional values—can be used to guide the actions of the neurosurgery community as a whole, such as in oversight of neurosurgical practice via board certification or position statements on topics such as professionalism and harassment in organized neurosurgery.[75]

WHY SHOULD NEUROSURGEONS ENGAGE IN BIOETHICS?

As evidenced by this overview, neurosurgeons encounter ethical issues in every subspeciality and practice setting (**Figure 1**). The field of bioethics excels at identifying and describing ethical issues and offers both conceptual clarity and practical tools to approach these conundrums. For example, bioethicists may engage in empirical work, such as describing patient and clinicians' views on whether implanted DBS devices should be removed or kept and maintained following a research study.[34,36] Beyond just reporting descriptively how people view this issue, bioethicists may provide guidance based both on data and on principles such as beneficence, autonomy, non-maleficence, and justice. For example, guidance regarding removal or post-trial access and maintenance of implanted devices may not be a summary of the dominant view, but also consider and include the minority's views and concerns under the principal of justice.[33,34]

Neurosurgeons offer invaluable perspective to the field of bioethics. At the front lines of clinical work and research, neurosurgeons can share their first-hand experience and help ground theory-based conversations. Neurosurgeons' experience can help to structure, inform, and interpret social science research and ground bioethics discussions in data (an area of bioethics termed "empirical bioethics"). Often, bioethicists make recommendations on topics relevant to neurosurgeons; without neurosurgeons "present at the table", these recommendations may miss real-world details. Implementation and buy-in for these recommendations also likely lag without neurosurgeon representation.

Increasing Neurosurgeon Engagement in Bioethics

Involvement in bioethics can be accomplished at several levels (**Figure 2**). Professional neurosurgery organizations and funding bodies can promote research and investigation in bioethics by funding fellowships, grants, and calls for articles and abstracts. There may be a role for ethics education in neurosurgery residency, given that medical school curricula are not focused on the unique ethical dilemmas faced by neurosurgeons.[76] Neurosurgeons with a special interest in the field may pursue ethics fellowships or graduate training (e.g., the American College of Surgeons-MacLean Center for Ethics Fellowship Program).[77] In addition, there is opportunity for interdisciplinary collaboration with trained ethicists. Broad perspectives will only serve to enrich these discussions.[78] Some institutions have implemented initiatives such as "Bioethics Grand Rounds" to facilitate such conversations.

CONCLUSION

Ethical issues arise in neurosurgery clinic, the operating room, on the wards, and in research—both in patient–provider interactions and on the global health system level. Bioethics can better equip neurosurgeons to face these complex and essential issues, be that through multidisciplinary collaboration, novel research approaches to ethical dilemmas in neurosurgery, and education. There are many models of bringing bioethics into the clinical space—including formal training programs, continuing medical education, and collaboration with dedicated bioethicists. In turn, bioethics will be strengthened by neurosurgeon involvement, who can share their unique experience and expertise.

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Alexandra J. White: Conceptualization, Writing – original draft. **Margot Kelly-Hedrick:** Conceptualization, Writing – original draft. **Stephen P. Miranda:** Writing – review & editing. **Mariam M. Abdelbarr:** Writing – review & editing. **Gabriel Lázaro-Muñoz:** Writing – review & editing. **Nader Pouratian:** Writing – review & editing. **Francis Shen:** Writing – review & editing. **Brian V. Nahed:** Writing – review & editing. **Theresa Williamson:** Conceptualization, Writing – review & editing.

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