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Review Article

Emerging Neurotechnologies: Implications for Professional Relations and Communication

Hrishikesh Suresh[1,2], Nebras M. Warsi[1,2], Tejas Sankar[3,4] and George M. Ibrahim[1,2,5,6]

[1]Division of Neurosurgery, Hospital for Sick Children, Toronto, Ontario, Canada, [2]Institute of Biomaterials and Biomedical Engineering, University of Toronto, Toronto, Ontario, Canada, [3]Division of Neurosurgery, Walter C. Mackenzie Health Sciences Centre, Edmonton, Alberta, Canada, [4]Department of Surgery, University of Alberta, Edmonton, Alberta, Canada, [5]Institute of Medical Science, University of Toronto, Toronto, Ontario, Canada and [6]Department of Surgery, University of Toronto, Toronto, Ontario, Canada

ABSTRACT: Rapid advances in neurotechnology and neurosurgery are positioned to revolutionize care for patients suffering from debilitating neurological and psychiatric disease. Enthusiasm for the adoption of these technologies is tempered by ethical dilemmas regarding resource allocation, provision of care, communication with patients and other providers, and other potential pitfalls. In the present work, we discuss bioethical implications of novel neurotechnologies for medical practice. In particular, we examine the implications of neurotechnological advancement through the lens of professional communication. Emerging challenges within this domain are presented in the context of physician interactions with four key partners: (i) patients; (ii) other physicians; (iii) industry; and (iv) society-at-large. Anticipated issues as well as mitigation strategies are discussed as they relate to communication with these stakeholders.

RÉSUMÉ : La neurotechnologie de pointe et ses incidences sur les relations et les communications professionnelles. Les progrès rapides réalisés en neurotechnologie et en neurochirurgie sont tels qu'ils peuvent révolutionner les soins aux patients atteints d'affections neurologiques débilitantes ou de troubles mentaux. L'enthousiasme que soulève l'adoption de ces nouvelles techniques est tempéré par les dilemmes éthiques que posent l'allocation des ressources, la prestation de soins, les communications avec les patients et d'autres fournisseurs ainsi que le risque potentiel d'autres embûches. Il sera question, dans le présent article, des répercussions bioéthiques de la neurotechnologie de pointe sur la pratique médicale, et plus particulièrement de l'incidence des progrès neurotechnologiques sur les communications professionnelles. Les nouveaux « défis » qui se profilent à l'horizon dans le domaine sont présentés dans le contexte des interactions entre les médecins et quatre intervenants clés, soit les patients, d'autres médecins, le secteur de l'industrie et la société en général. Ainsi, les problèmes appréhendés et les stratégies d'atténuation feront l'objet de discussion sous l'angle des relations avec tous ces intervenants.

Keywords: Neurosurgery; Neuroethics; Ethics; Professional relations; Neurological practice; Neural plasticity; Neuro-aids; Doctor-patient relationship

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Introduction

In 1965, renowned Montreal neurosurgeon and neuroscientist Dr Wilder Penfield famously declared the existential problem of neurology, namely "to understand man himself."[1] Through neurosurgical and neuroscientific training under renowned mentors including Charles Sherrington and Santiago Ramón y Cajal, Penfield developed an early appreciation for the intersection between the natural sciences and humanities embodied in the practice of neurology and neurosurgery.[2] Armed with a keen inclination toward translational research, Penfield leveraged contemporary advances in anesthesia, microsurgery, and stereotactic neurosurgery to transform his operating theater into a laboratory that would spark decades of research into the neural correlates of health, disease, and even the nature of humanity itself. As a testament to its uniquely Canadian roots, modern neurotechnology is widely credited to have arisen from the pioneering work of Penfield and his collaborators.[1–3]

Practice at the leading edge of neurotechnology thus represents the continuation of a decades-long tradition for the Canadian medical profession. Today, novel neurotherapeutics grounded in the principles of translational research hold the potential to revolutionize the management of a wide range of conditions. For instance, deep brain stimulation (DBS), which was once most commonly utilized for movement disorders, has more recently been employed to treat epilepsy and neuropsychiatric disorders such as anorexia, depression, and obsessive-compulsive disorder.[4–9]

Corresponding author: Tejas Sankar, MDCM, PhD, FRCSC, FAANS, Division of Neurosurgery, Walter C. Mackenzie Health Sciences Centre, Department of Surgery, University of Alberta, 8440-112 Street NW, Edmonton, AB, Canada T6G 2B7. Email: tsankar@ualberta.ca

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Opportunities for Action
Physician-patient relationships
Mitigate therapeutic misconception in the context of experimental neurotechnologies through honest and explicit communication.
Physician-physician relationships
Facilitate access to neurotechnologies and emphasize information sharing among professionals and within training curricula.
Physician-industry relationships
Critically appraise the nature and involvement of industry and promote transparency to all stakeholders.
Physician-society relationships
Strive for effective, honest, and conscientious dissemination of information, including through social media.

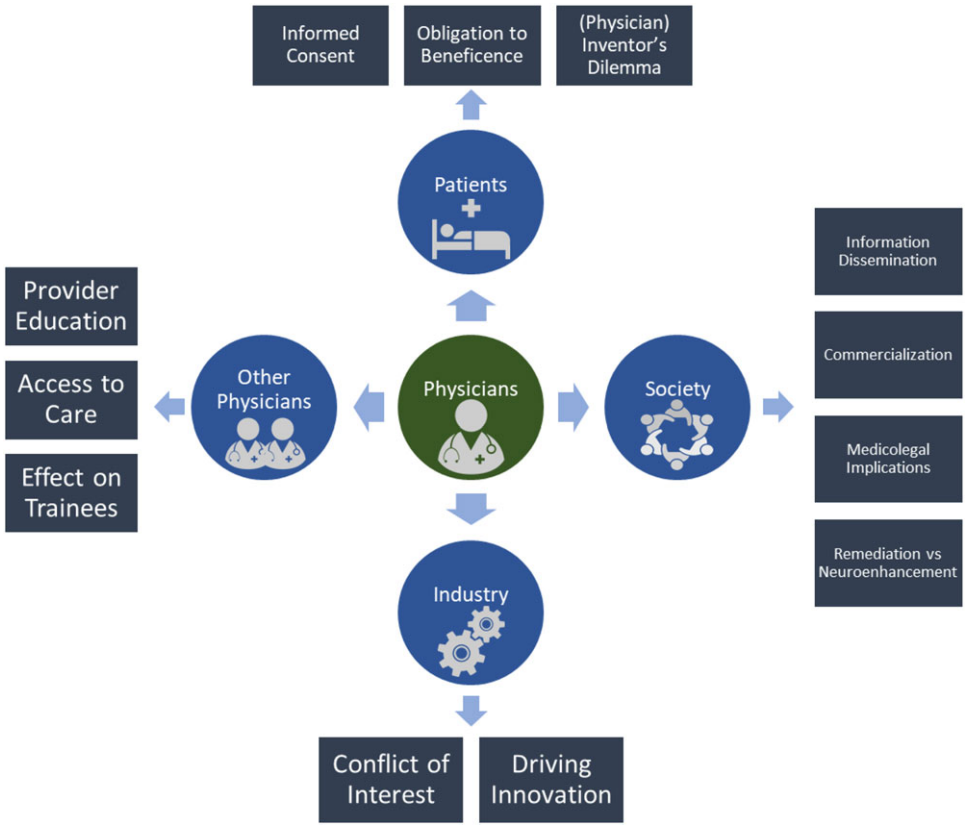

Figure 1: Schematic overview illustrating key physician-stakeholder relationships and the respective concerns expected to arise through the introduction of novel neurotechnologies.

Modern neurotechnologies further include non-invasive brain stimulation such as transcranial magnetic stimulation and magnetic resonance-guided focused ultrasound; the latter of which can now facilitate opening of the blood-brain barrier[10] and even potentially treat a variety of neuropsychiatric conditions in a minimally invasive manner.[11]

However, as Pandora from Greek mythology learned a millennia ago, great hope in medicine can rarely be found in the absence of unwelcome partners.[12] As a stark example, the physician-scientist António Egas Moniz – initially lauded with the 1949 Nobel Prize in Physiology or Medicine – was later discredited for the poorly studied and deleterious effects of early psychosurgery such as the prefrontal lobotomy.[13] In the present landscape, a moral imperative therefore exists for the medical community to ensure that potentially powerful neurotechnologies are wielded solely toward the benefit of patients and society-at-large.

Although the medical profession is predicated on effective communication,[14] the implications of emerging neurotechnologies on this fundamental pillar have rarely been discussed. To this end, this work aims to assess the present and future impact of neurotechnological advances upon professional conduct and particularly communication between physicians and four critical stakeholder groups: (i) patients; (ii) other physicians; (iii) industry collaborators; and (iv) society-at-large (Figure 1). As increasingly advanced neurotherapeutics become part of the physician's armamentarium, a fundamental understanding of the impact these technologies may have on professional communication is a critical first step toward avoiding ethical pitfalls and supporting optimal patient care.

Physician-Patient Relationships

The many ethical issues surrounding physician-patient relationships as they relate to novel neurotechnologies are beyond the scope of the current work. The issue of professional communication between physicians and patients relating to these advances is, however, understated and encompasses many themes in modern

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neuroethics. The challenges and pitfalls relating to consent, therapeutic misconception, and the junction of clinical and research pursuits are well described.

As it relates to professional conduct and communication, recognizing the inherent vulnerability associated with seeking or receiving treatment with an emerging neurotherapeutic serves as the cornerstone of effective physician-patient communication. By virtue of the severity, chronicity, and commonly intractable nature of their disorder, many patients seeking advanced care will have already failed to respond to various front-line treatment options.[15] The accumulating fatigue and desperation in search of much-needed therapies renders these patients, and their caregivers, especially vulnerable to internalizing unrealistic appraisals of the risks and benefits of an emerging or experimental therapeutic while the true magnitude of expected risk and reward might remain poorly understood.[16,17] This tendency, termed therapeutic misconception, poses a significant challenge to obtaining free and informed consent. Barriers to informed consent are further exacerbated in the context of neurosurgical interventions, which commonly promise greater reward at the cost of significantly higher upfront risks.[18] Consent discussions in the realm of psychiatric surgery, which focuses on an especially vulnerable segment of society, may be further complicated by comorbid capacity limitations, as explored by several authors in dedicated works.[2,19]

Sensitivity toward the internal and external pressures that may bias patient perception and decision-making is therefore critical for medical practitioners to support optimal physician-patient communication. A critical first step in this process is to recognize and disclose one's own vested interests in a therapy or procedure, whether personal, financial, or related to academic recognition. In the context of emerging neurotherapeutics, wherein physician-scientists commonly serve as both treating physicians and lead investigators, such conflicts of interest are especially common.[19,20] In addition to full disclosure of potential conflicts of interest, the use of objective language represents another strategy by which physicians can support individual autonomy during consent discussions. It is widely reported that for many patients, whatever is new is automatically perceived as better.[20] Consequently, describing experimental neurotherapeutics as "non-validated," rather than "novel," may serve to counter preconceived notions of therapeutic superiority.[20,21] These considerations are also relevant when industry is directly involved in the development of novel therapeutics, which we address in a later section. The duty toward transparent communication also extends to general practitioners providing neurotherapeutic referrals, who must be cautious to clearly communicate the potentially experimental nature of neurosurgical and study-related referrals; otherwise, patients may assume that they are being offered a widely accepted medical therapy with a high chance of success [21]. Finally, given the potential for significant confounders of patient capacity and informed consent in the context of various neurological disorders, particular attention should be paid toward professional communication in discussing surgery for psychiatric indications. To this end, some have argued that obtaining third-party consent, such as from duly informed family or caregivers, should be a routine component of pre-intervention discussions with these patients.[22] Family members and caregivers, however, can also be subject to significant biases. Either as a result of caregiver burden or burnout, or being motivated to provide relief to loved one.[22] In this, some have argued that research ethics boards (REBs) are another option for providing oversight during the informed consent process.[23]

A final point as it relates to the physician-patient relationship is the duty to respect informed patient decisions even in the presence of high potential risk.[24] Therefore, despite the potential barriers toward informed consent we have outlined, we must stress that the role of practitioners is not to decide on a patient's behalf, but rather to ensure that each patient is able to make an informed decision regarding their care without undue influence from the allure of novelty and potentially high-reward therapeutics. In concordance with this role for physicians, an overwhelming majority of patients undergoing investigational surgery for neuropsychiatric disease believe that, as long as they are fully aware of potential risks and willing to accept them, they should be free to participate regardless of the burden of risk.[25]

Physician-Physician Relationships

The pedagogical and collaborative underpinnings of modern medical practice are rooted in Canadian medical history. Sir William Osler, a close mentor of Penfield, is widely considered to be one of the forefathers of modern medical education.[26] Specifically, Osler led the implementation of practical, apprenticeship-based teaching of medical students and residents that would later be widely popularized by the Flexner report in 1910.[26] More than a century later, a key component of physician-physician relationships remains the pedagogical exchange between experienced physicians and junior trainees. However, as neurotechnological complexity grows, challenges arise in the communication and professional practices associated with teaching and acquiring the skills required for safe therapeutic delivery.[27–29] Indeed, the breadth and extent of modern neurotechnology – from deep brain stimulation to vagus nerve stimulation to transcranial magnetic stimulation – pose several challenges to the medical profession.

Through apprenticeship models of medical education, practical experience and supervision by experienced providers are necessary for trainees to acquire relevant skills prior to providing a given treatment.[30] Skill acquisition also depends on sufficient exposure to a variety and volume of clinical material during medical school and residency training in particular; however, trainee exposure to many commonly employed neurotechnologies is already lagging behind the pace of development – a disparity expected to widen with further neurotechnological development.[31] Furthermore, when specific neurotechnological training for residents is available, individual hospitals commonly provide only a fraction of available neurotherapeutic services and, in the case of neuromodulatory devices, tend to use devices from single manufacturers.[32] The broad implications of these by-products of neurotechnological innovation are far reaching. Inequities in access to care, conflicts of interest, and monopolies or oligopolies of neurotechnology companies pose serious ethical concerns. Specific to the medical profession and inter-professional communication, these issues significantly impact the ability of trainees to effectively engage in and provide neurotherapeutic care. For now, focused fellowship training, such as in functional neurosurgery or interventional psychiatry, represents the leading approach to strengthen provider education and facilitate care delivery, though eventually an ideal strategy would include the percolation of relevant knowledge and skills into more basic training at the medical school and residency levels.

On a professional level, the transition to increasingly subspecialized care has been associated with a concentration of expertise within select tertiary and quaternary centers which may lead to

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detrimental upstream effects on rural and remote populations. Within the Canadian context, these patients already carry a significantly greater burden of disease and associated complications than their urban counterparts.[33,34] At the provider level, several solutions have been proposed to help bridge this gap. First, consistent with an increasing focus toward competency-based medical education, the inclusion of high-yield neurotherapeutic objectives, such as transcranial magnetic stimulation for major depression or DBS for movement disorders, is expected to facilitate national access to neurotherapeutic care.[35] Furthermore, close collaborations between subspeciality practitioners and community physicians will be critical to support care delivery to these populations. An example of success in this domain relates to the continued growth in surgical referrals for DBS from within North American rural and remote populations.[36]

Inter-professional communication in the setting of neurotechnological therapy can be facilitated by the development of consensus-based guidelines addressing the appropriate application of novel neurotechnologies. These guidelines are a moving target since the field is, by nature, constantly evolving. Large-scale collaborative efforts are required to keep the profession current on novel advances. Increasingly, larger working groups are being established both to measure the impact and inform the application of neurotechnologies within the broader medical profession.[37] One such example is the Pan Canadian Neurotechnology Ethics Collaboration (PCNEC), which recognizes the need for multi-sectoral consultation in the development and advancement of neurotechnologies.[38]

Physician-Industry Relationships

The aim of positively advancing neurotechnologies demands commensurate financial support that is exceedingly challenging to obtain without significant industry collaboration. While physician-industry collaborations crucially underpin the development advanced neurotherapeutics, coexisting physician-investigator conflicts of interest, inconsistent regulatory oversight, and the fundamental reliance of these technologies on the medical device industry is rife with potential for dubious ethics. Industrial support comes in many forms, including, but not limited to, the provision of research grants, provider incentives, travel grants to facilitate the dissemination of positive study results, and perhaps most importantly, device manufacture.[39] Furthermore, in the Canadian context, authorizations for investigational testing have until recently required the presence of an industry partner through the Medical devices active license program.[40] With regard to monitoring, stringent regulations commonly applied toward pharmaceutical development are not directly portable to the device development context, leading to a relative laxity in oversight.[40] Potential ethical pitfalls in physician-industry collaboration clearly warrant continued engagement of the medical profession and cautious inter-professional communication.

Given the practical requirements for industry partnerships in device development, one potential risk remains the direction of public research priorities by privately owned corporations.[39] This risk is perhaps best illustrated through a case study of antibiotic development, which remains predominantly pharmaceutical-led. In this domain, despite the growing patient and societal costs of antibiotic resistance, novel antibiotic discovery continues to decline year-over-year.[41] Rising development costs coupled with dwindling economic returns have been cited as a driving force behind this phenomenon.[41] A similar trend has been observed within neuromodulation, in which the utilization of existing hardware, such as DBS systems, to target a growing array of brain regions using largely empirical approaches extrapolated from experience in the treatment of movement disorders, seems to be implicitly preferred over the development of more costly, disease-specific approaches to DBS.[42] The professional conduct of the medical profession at large must remain free of undue industry influence on research priority-setting and ensure that the driving force for such research remains primarily directed by the interests of patients, their caregivers, and society-at-large. We propose two communication strategies by which the potential detrimental influence of industry priorities may be minimized. First, communicating real or perceived influences ought to be a standard practice in proceedings, and professional medical societies need to actively monitor the potentially detrimental effect of industry on medical priorities. Second, barriers to innovation must be minimized without compromising patient safety. To this end, regulatory organizations should collaborate with providers and industry to standardize and streamline how new technologies are to be developed, and their efficacy validated. The combination of transparency and streamlined development would aim to balance the priorities of providers and industry while ensuring that societal benefit is kept in focus. To some extent, this has been a recent priority of the FDA, though achieving appropriate oversight without stifling innovation remains an ongoing challenge.[42] Naturally, given the multifaceted and complex nature of the problem at hand, communication strategies alone are unlikely to achieve significant success and additional mitigation strategies beyond the scope of this paper are likely going to be needed.

Physician-Society Relationships

When considering the societal role of the medical profession, effective communication, duty to care, and health advocacy as outlined in the CanMEDS framework are of paramount importance.[43] There are several influences on the relationship between physicians and society-at-large. The rise of social media as a tool for health information is a timely example, and one which stands to deeply transform how physicians interact and engage with society-at-large. Other influences on physician-society relations include the trend toward expansion of artificial intelligence applications in healthcare, with implications surrounding the extent to which medical practitioners may be held responsible for adverse outcomes associated with treatments under algorithmic control.[44] Finally, societal implications of potential human enhancement through advanced neuromodulation merit considerable analysis and discussion.

Over the course of the last decade, social media has come to play a significant role in communicating medical information to the general public.[44–46] However, the ubiquity of this largely unregulated tool as a means of accessing and promoting health information remains an ethical concern. Given the lack of rigorous scientific oversight, study results and medical information shared through social media platforms demonstrate a significant positivity bias, wherein the putative benefits of a therapeutic approach are significantly over-stated.[44,47] From the perspective of researchers and providers, who commonly utilize these platforms to share their latest research, an awareness of potential public misconceptions is warranted.[48] Indeed, as members of the general public increasingly rely on social media to obtain health information, the risks of therapeutic misconception and potential harm increase significantly.[49]

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Social media also allows for direct and public communication between patients and caregivers on the one hand, and physician researchers on the other. While these networks have the capacity to advance the development of neurotherapeutics by providing a direct lens onto patient experience and need, they may also lead to significant concerns. Firstly, there is considerable inequity in access to social media; consequently, the opinions and needs of a subset of patients may be disproportionately amplified.[50] As such there is a risk that the priorities of vulnerable communities may be less understood, studied, or recognized in treatment paradigms. Second, due to the public nature of social media communications, physicians may feel compelled to modify clinical or research approaches to mitigate negative publicity, contrary to their better judgement.[51] Professional societies have a responsibility, through the formulation of policies and monitoring agencies, to provide guidance and assistance for clinicians and scientists in navigating these complex and growing challenges. In this context, patient privacy and personal health information must always be securely protected. Given that neurotechnological innovations often involve a limited number of participants and the results may be broadly disseminated, there is indeed a high risk of exposure and compromise of patient data.[52]

The intersection between physician responsibility and society is being redefined by novel neurotechnologies. For example, the integration of artificial intelligence in clinical decision-making has the potential to impact a physician's duty to care and medical liability. In the Canadian legal context, medical liability requires four elements to be proven, namely: (i) a duty of care was owed to the patient; (ii) standard of care was violated; (iii) the patient suffered harm; and (iv) harm arose as a direct or proximate consequence of substandard provider conduct.[53] However, as progressively more therapeutic decisions are abstracted away by technology, who is to be held liable for a serious adverse event? And if physicians are not liable for device malfunction, is the device manufacturer? Practically speaking, based on established precedent it is challenging to hold *anyone* liable for such events.[54] These questions therefore continue to present a moral and legal quagmire in which patients may be left without potential recourse for justice. As long as this lack of clarity continues to exist, explicit communication of this potential concern should therefore be part-and-parcel of consent discussions surrounding these devices. Moreover, healthcare providers ought to play an active role in helping to delineate specific legal guidelines aimed at averting patient harm in these scenarios.

Within the broader context of society, the integration of novel neurotechnologies continues to obscure the definition of therapeutic interventions. When considering intended outcomes for novel neurotechnologies, a critical distinction exists between enhancement of function and remediation of deficits. Enhancement is defined as the augmentation of otherwise normal human function in the absence of medical need, whereas remediation refers specifically to medical treatment for an impairment or deficit.[55] However, these distinctions may be subjective and vary both across cultures and time; they have certainly long been debated in psychiatry.[56] As state-of-the-art medical devices present increasing potential to treat or augment previously intractable conditions and even alter one's personality,[43,57,58] the challenge for providers will be to define appropriate and reasonable applications for increasingly capable neurotherapeutics.

Given the fluidity between normal and pathological, some authors have argued that therapeutic applications for a given technology should focus on demonstrated need.[55] Once need has been established, researchers and providers should further ensure that candidate technologies appropriately balance the four complementary principles of bioethics.[24] An appropriate framework by which to assess the ethics of a novel neurotherapeutic would therefore consider: (i) medical necessity; (ii) ability to abide by the principles of beneficence, non-maleficence, and individual autonomy; and (iii) the potential to confer unfair advantages to some individuals due to supra-normal enhancement, which would compromise the principle of justice. The latter point is of particular importance in patient-centered perspectives: in a survey of neurosurgical patients, the vast majority supported neurotherapeutics applied toward remediation but not for supra-normal enhancement of human function.[25]

Conclusions

Novel neurotechnologies hold the potential to revolutionize treatments for patients with otherwise incurable and disabling neurological and psychiatric conditions. However, in addition to the tremendous need for continued development of these technologies, a robust discussion of potential ethical pitfalls is necessary to avoid inadvertent harm. Positioned at the forefront of neurotechnological innovation, medical practitioners are instrumental in the sound development and application of modern neurotechnological therapies and neuromodulatory devices in particular. We have addressed here some of the implications of novel neurotechnologies for intra-/inter-professional communication within the medical profession more generally (Table 1). Physician interactions with key allied groups, including patients, other physicians, industry, and society-at-large reveal both opportunities as well as significant ethical challenges to navigate. As novel neurotherapeutics increasingly enter the physician's armamentarium, healthcare providers should be aware of relevant issues and risk mitigation strategies in order to ensure optimal patient care.

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