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Interventional Psychiatry: How Should Psychiatric Educators Incorporate Neuromodulation into Training?

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Abstract

Objective—Interventional psychiatry is an emerging subspecialty that uses a variety of procedural neuromodulation techniques in the context of an electrocircuit-based view of mental dysfunction as proximal causes for psychiatric diseases.

Methods—The authors propose the development of an interventional psychiatry-training paradigm analogous to those found in cardiology and neurology.

Results—The proposed comprehensive training in interventional psychiatry would include didactics in the theory, proposed mechanisms, and delivery of invasive and noninvasive brain stimulation.

Conclusions—The development and refinement of this subspecialty would facilitate safe, effective growth in the field of brain stimulation by certified and credentialed practitioners within the field of psychiatry while also potentially improving the efficacy of current treatments.

Keywords

Psychiatric residency; Subspecialty education; Didactics; Brain stimulation; Milestones

Brain stimulation technologies are becoming increasingly common in the treatment of psychiatric illness. Psychiatrists who employ these methods have been described in procedure-specific terms such as ECT practitioner, TMS provider, or somatic therapist. Unfortunately, these labels fail to encompass the scope and procedural nature of brain stimulation. In order to facilitate the training and certification of those who perform these highly specialized interventions, we propose the term “interventional psychiatrist” and offer a plan to develop training paradigms for this blossoming subspecialty within the field of psychiatry [1] and alongside the emerging training milestone project [2].

When using the term *interventional*, our intent is not to imply that traditional psychiatric interventions do not affect significant change. Instead, our intent is to use the term *interventional* in a manner analogous to how it is used in fields like cardiology, radiology,

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and neurology. In these fields, the term *interventional* describes physicians who are certified, by nature of training and experience, to perform interventions that are procedural and typically more invasive than general medical care within that specialty [3].

Although we recognize the need for a minimum level of knowledge, skill, and experience necessary for an interventional psychiatrist, we realize that this level is best achieved through working in concert with existing clinical training paradigms and the emerging milestones project [2]. We can envision using the current clinical training paradigms and existing centers of expertise. The incorporation of interventional psychiatry into resident education is best achieved through the current clinical and research infrastructure in an effort to support the movement of the evolving expertise. This paper will briefly outline the scope and rationale for such training paradigms and attempt to integrate these concepts within particular components of the milestones [2].

The Electric Brain and Biophysics of Brain Stimulation

The brain is an electrochemical organ that can be intervened upon both chemically and electrically. In order to safely and effectively deliver electrical interventions, interventional psychiatrists must understand basic principles of both neuroscience and physics. Aside from understanding the circuits and native electrical properties of the human brain, interventional psychiatrists must also understand the circuits and native electrical properties of the techniques used to influence the brain.

Stimulating the Brain

The field of interventional psychiatry is emerging. Within the last 50 years, classical neuromodulation techniques have been refined and newer interventions have been developed. Electroconvulsive therapy research has continued to modify treatment parameters to optimize treatment, while reducing side effects. In 2005, vagus nerve stimulation (VNS) became the first invasive neuromodulation device approved as a treatment for a neuropsychiatric disorder by the Food and Drug Administration (FDA). In 2008, the FDA approved transcranial magnetic stimulation (TMS) for treatment-resistant depression [4]. As recently as 2009, the FDA granted a somewhat controversial humanitarian device exemption for use of deep brain stimulation (DBS) for obsessive-compulsive disorder (OCD). DBS, like many experimental and FDA-approved stimulation techniques, is now being investigated for the treatment of various neuropsychiatric conditions such as Gilles de la Tourette syndrome and depression [5]. From noninvasive to invasive neuromodulation, the field of interventional psychiatry is growing and expanding in a manner similar to interventional growth in other specialties as new approaches and technologies arose [6].

The Basis for Interventional Psychiatry: Dysfunctional Neural Circuitry

Interventional psychiatry is an area of psychiatry that was born out of the interplay between functional neuroimaging, neurophysiology, and focal brain stimulation. The aim of such a field is to begin to understand the causality of behaviors [7]. An interventional psychiatrist must understand the neural circuitry associated with psychiatric disorders and recognize the behavioral changes that result from focused manipulation of those circuits [6]. These skills are critical for delivering current treatments and for developing future treatments. For example, interventional psychiatrists currently are able to identify and modulate neuronal activity within dysfunctional brain circuits and subsequently monitor both patient response [8] and neurophysiologic response [9–11]. Thus, interventional psychiatry may generate new brain stimulation targets and potentially offer insights into biomarkers for psychiatric disease.

The Evolution of Interventionalism

Advances in diagnostic modalities and therapeutics have given rise to interventional subspecialties [12]. This is an expected and natural transition when standard medical treatments fail and patients become treatment resistant. Cardiology was the first medical specialty to grow an interventional subgroup, borrowing techniques from radiology (fluoroscopy) and using them to image vascular occlusions [3]. Simultaneously, cardiology also developed electrical interventions in order to convert aberrant electrical rhythms back to normalcy.

Intervention Within the Brain

Cardiology's electrical interventions were soon adapted for use in patients with treatment-resistant neurologic disease. The interventional neurologist emerged, utilizing a modified version of the toolset of cardiology combined with a refined understanding of the functional neurologic state of their patients [3]. As with cardiology, neurology realized and harnessed the electrochemical nature of the brain. TMS emerged as a noninvasive tool to focally and noninvasively probe cortical excitability and neurophysiological function in the brain [13]. Some neurologists have used electroconvulsive therapy (ECT) to reverse medically resistant abnormal cortical synchrony [14].

The concept of the pacemaker was first translated into neurology with the implantable vagus nerve stimulation (VNS) [15] and, more recently, with the development of responsive neurostimulation (RNS) [16]. Invasive neuromodulatory interventions implanted as deep brain stimulating (DBS) electrodes through functional stereotactic neurosurgery have been shown to modify regional brain circuitry and therefore symptomatically treat neurological disease [17].

As these technologies were used for neurologic indications, it became evident that there were psychiatric side effects and benefits associated with their use. TMS, when applied to the prefrontal cortex, was found to alleviate some forms of depression [18]. VNS, when implanted for medically refractory epilepsy, was shown to also improve comorbid depression [15]. DBS, when placed in a limbic target, was shown to significantly reduce obsessions and compulsions [19]. These neurological interventions became neuropsychiatric interventions and, combined with ECT, gave rise to modern interventional psychiatry.

The Interventional Psychiatrist Emerges

Interventional psychiatry is a reconceptualization of work performed over the past century. Although interventional psychiatric procedures have been explored in the past, the gross nature of early interventions such as frontal lobotomies marred psychiatry with a stigma that has taken nearly 50 years to overcome [20]. In order to avoid past mistakes, interventional psychiatry needs to be formally recognized and developed as a subspecialty within psychiatry, with strong training and appropriate knowledge of the ethics of brain stimulation. For example, there are nearly a dozen forms of brain stimulation in development or currently approved for neuropsychiatric disease. There is also a journal devoted exclusively to the field [21].

The Rationale for Formalized Training

To date, there is no firm definition or clear training pathway for interventional psychiatry. Surprisingly, and despite APA Task Force recommendations, ECT has not been consistently incorporated into psychiatric residency education. Current ACGME psychiatry training regulations require minimal knowledge and awareness of the use of ECT, but no level of basic clinical competence is specified or tested [22]. The latest version of the proposed *psychiatry milestones* is more specific regarding knowledge and risks and contains sub-milestone ratings across the five levels of professional development [2]. Our recommendations do not conflict but, rather, support a defined educational approach from initial resident exposure, competency, and advanced practice. Despite its increasing prevalence and large body of literature, TMS has also not been required in resident education in any consistent manner. The training gaps in psychiatry are even more pronounced when one considers invasive procedures like DBS and VNS.

The new milestones give an initial educational layout of the somatic therapies and clinical neuroscience. The purpose of this article is to further delineate how these concepts can be integrated into general psychiatry education. In order to extend past these basic requirements and create a pathway to mastery, we suggest elective track and fellowship training experiences. The proposed track and one-year fellowship would provide opportunities for the interventional psychiatry trainee to develop the knowledge, skill, and attitudes required to provide safe, ethical, and appropriate interventions for their patients. We propose modifying fellowship training models in already established interventional subspecialties in neurology [23] and adapting them to fit within interventional psychiatry’s focus. We believe that developing three levels of training for interventional psychiatry will allow for a trainee to develop the treatment planning and management skills defined in the psychiatry milestones (Table 1).

Interventional Psychiatry Training/Tools

Probing Neural Circuits

Neuroimaging—Although neuroimaging currently serves limited diagnostic or prognostic purpose for psychiatrists, although that appears to be changing, [24], various structural imaging modalities are utilized by interventional psychiatrists for stimulation localization and troubleshooting, while functional imaging modalities have improved understanding of the circuitry underlying psychiatric disorders and may help to select a treatment that will be efficacious [24]. Knowledge of when to order structural brain imaging helps the interventional psychiatrist determine if a device is malfunctioning, while more sophisticated

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structural imaging, such as magnetic resonance imaging (MRI), may help the interventional psychiatrist determine the most appropriate location for stimulation. Functional MRI (fMRI) has become a useful tool with which to understand the effects of offline (outside of the scanner) and online (interleaved) TMS [9]. A full-time equivalent (FTE) credit in neuroimaging rotation that includes exposure to modalities such as head radiographs, CT, MRI, fMRI, diffusion imaging, positron emission tomography (PET), and single-photon emission computed tomography (SPECT) should be part of the training of an interventional psychiatrist. Such training would allow for the level of competency suggested in levels 4–5 of the neuroscience medical knowledge section of the psychiatry milestones (Table 2). This is similar to the ABPN requirement for neurology residents and is embedded within neurology fellowship training [25].

Paired-Pulse TMS—Paired-pulse TMS (ppTMS) is a sophisticated tool for probing neural circuitry. This method has been used in psychiatric patients to determine either the native neurophysiologic parameters thought to be associated with their psychiatric disease or the effect of medications and/or stimulation on a given psychiatric condition. The interventional psychiatrist must have knowledge of the principles behind and experience in the delivery of ppTMS because it is proving to be an important biomarker in psychiatric disease and recovery [26]. Such training would allow for the level of competency suggested in levels 4–5 of the neuroscience medical knowledge section of the psychiatry milestones (Table 2).

Electroencephalography—A background in the basics of electroencephalography (EEG) is essential for the interventional psychiatrist because ECT, a core treatment modality for treatment-resistant neuropsychiatric disease, involves generating a therapeutic seizure. Although the EEG used in ECT contains fewer channels than conventional EEG, the principles of seizure appearance and postictal suppression are the same. The interventional psychiatrist must have a basic understanding of how to interpret EEG recordings. The interventional psychiatrist must also understand which clinical variables affect seizure threshold and modify electrical dosing accordingly. Quantitative EEG has had mixed results as a biomarker of psychiatric disease or treatment efficacy, but emerging EEG applications are showing promise [10]. We suggest that interventional psychiatry trainees be exposed to EEG as a part of their ECT experience along with a neurology rotation equivalent to one FTE. During this rotation, the trainee should have some exposure to the more sophisticated EEG techniques through didactics and hands-on training. Such training would allow for the level of competency suggested in levels 4–5 of the neuroscience medical knowledge section of the psychiatry milestones (Table 2).

Noninvasive Neuromodulation Treatments

Noninvasive psychiatric interventions use devices that function to provide temporary neuromodulation, typically while in a medical setting, and many times result in durable changes to the affected neurocircuitry of an individual’s psychiatric disease [27].

ECT—ECT has been used for nearly a century, and advances in the way it is delivered have greatly reduced side effects. Shorter pulse widths and unilateral electrode configurations have reduced the cognitive side effects of ECT, and changing the method of delivery of the electrical pulse has been explored. ECT is a very effective treatment for a wide array of neuropsychiatric diseases [28]. Training is important not only in the indications but also in the length/timing of treatment, whether or not to place the patient on maintenance ECT, and what medical and neurological conditions are relative contraindications.

Newer invasive brain stimulation techniques for related or unrelated conditions may pose an additional challenge [29]. Newer forms of seizure therapy are on the horizon, with much improved cognitive outcomes such as focal electrically administered seizure therapy (FEAST) and magnetic seizure therapy (MST) [30, 31]. Improper training in ECT can lead to poor treatment decisions, which may result in suboptimal cognitive outcomes [28] and, potentially, fatalities. We propose that those training in interventional psychiatry, and being nationally certified, have exposure to not only ECT treatment delivery but also brain stimulation consultation and didactics in ECT theory/use. Models for this training are already developing within medical education [32], and we suggest an expansion of these ideas (Tables 3 and 4).

TMS—Repetitive transcranial magnetic stimulation (rTMS) involves an electromagnetic device that delivers transcranial-pulsed magnetic fields of sufficient magnitude to induce neural action potentials. In many patients, repeated daily induction of neural action potentials in the prefrontal cortex (PFC) over several weeks can treat the symptoms of major depressive disorder [8]. In 2008, the FDA cleared one rTMS device for the acute treatment of depressed patients who have failed at least one antidepressant medication. TMS was developed for depression on the theory that there is hypofunction of the left PFC and its governing role over deeper limbic regions and that repeated TMS-induced neural action potentials over many days may be sufficient to reverse this functional deficit and therefore improve mood [18, 33]. Although rTMS for treating depression is generally safe and well tolerated in routine clinical practice, the interventional psychiatrist must be trained in those medical and neurologic diagnoses that would exclude a patient as a candidate for the treatment, particularly the risk of inducing seizures. The interventional psychiatrist also needs training to ascertain appropriate candidates for rTMS in depression. Furthermore, an interventional psychiatrist needs to ascertain an accurate motor threshold and precise treatment location for consistent implementation across different patients. Thus, training in interventional psychiatry for rTMS should incorporate didactics, consultation, and hands-on practice in acquiring motor thresholds and treatment delivery parameters (Tables 3 and 4).

Transcranial Direct Current Stimulation—Transcranial direct current stimulation (tDCS) involves an energy source that delivers constant, weak (typically ≤1 mA) electrical current through scalp electrodes. Although tDCS is currently just an investigational tool, studies have shown that it may also have therapeutic applications [4]. Interventional psychiatrists should be familiar with the basic concepts of tDCS and knowledgeable about potential uses for this evolving technique (Tables 3 and 4).

Invasive Neuromodulation Treatments

Invasive psychiatric interventions are those that require surgical implantation of permanent devices that function to provide constant or near constant neuromodulation.

Vagus Nerve Stimulation—The FDA has approved vagus nerve stimulation (VNS) for the treatment of medically resistant depression. In the initial VNS depression study, which looked at efficacy in patients with treatment-resistant depression (TRD), 40 % of patients were shown to be responders at 12 weeks [34]. In contrast to ECT and TMS, VNS does not work acutely but, rather, takes several months to reach peak clinical effects. Unfortunately, the FDA approved VNS before any class 1 evidence of efficacy; thus, insurance companies have been reluctant to reimburse for the implant [4]. Despite this setback, the effects of VNS appear to be remarkably durable [34, 35].

The interventional psychiatrist must be trained in the indications for the device and must be aware of the potential side effects produced by the device. The interventional psychiatrist must know how to program the device in order to reduce these side effects and optimize its effect [36]. Additional VNS training in the epilepsy clinic may increase exposure to VNS for the interventional psychiatry trainee, particularly in a center that has a low volume of depression patients with VNS implantation. We feel that seeing a minimum of three individuals with VNS for depression along with a rotation in an epilepsy clinic with exposure to epilepsy patients with VNS implantations would be an adequate level of exposure.

Deep Brain Stimulation—DBS facilitates reversible focal neuromodulation of altered circuits through implantation of an electrode. DBS for OCD involves implantation of bilateral deep brain stimulation electrodes into a limbic target such as the ventral internal capsule/ventral striatum. Typically, the patients who receive DBS for OCD have failed clomipramine + SSRIs + CBT and have a Yale–Brown Obsessive Compulsive Scale of around 30 [19]. TRD has also been treated successfully with DBS. Both the reward circuitry [37] and the subcallosal cingulate [38] appear to be useful targets. Training for an interventional psychiatrist must include instruction in the initial DBS evaluation and postoperative programming. In many centers, the interventional psychiatrist is also involved in evaluating DBS candidacy for neurologic disorders, particularly for Parkinson disease [39].

The interventional psychiatrist must also be trained in the initial and subsequent programming of implantable pulse generators (IPGs). This training can be gained through direct programming of psychiatric patients with DBS or through a combination of psychiatric and neurologic patients with DBS. The latter is suggested because of the relative rarity of psychiatric DBS patients, as well as the benefit of learning many of the established protocols within neurologic DBS [40]. The psychiatrist must be able to determine and troubleshoot DBS device malfunction, because there are potential hardware complications. The interventional psychiatrist must also be trained in the ethics and proper use of these devices, making sure not to misuse the humanitarian device exemption [20]. We feel that the interventional psychiatry trainee should be exposed to a minimum of three cases of DBS for psychiatric disorders. This exposure should be coupled with a rotation in a movement disorder DBS programming clinic and several intraoperative exposures to DBS placement for movement and psychiatric indications.

Summary

Interventional psychiatry, though still in its infancy, is an exponentially growing subspecialty within psychiatry that needs to be recognized and developed. Although many brain stimulation tools are currently in the realm of research, the FDA has approved at least three brain stimulation treatments (ECT, VNS, TMS) as therapeutic interventions in traditional psychiatric illnesses. Currently the target population of these experimental treatments primarily consists of treatment-resistant psychiatric patients, but this is likely to change. It is important to recognize formally and promote the training of interventional psychiatrists because the field of brain stimulation is rapidly becoming more clinically relevant, more widely available, and more complex. The dearth of physicians who are trained to implement brain stimulation for treatment-resistant patients with psychiatric disorders is troubling. These training deficits are compounded with the reality that invasive treatment of psychiatric disorders is one of the most controversial subjects in medicine, a topic that raises significant moral, ethical, and socioeconomic issues [41]. As a field, we need to make sure these methods are used thoughtfully and appropriately integrated into person-centered care and mental health recovery paradigms. Through ethical and procedural pairing, we can avoid the missteps and abuses of treatment from previous generations.

In order to capitalize on recent developments in the fields of invasive and noninvasive brain stimulation, we propose that interventional psychiatry be both recognized and introduced into training at three levels: a core curriculum of knowledge and experience during psychiatry residency training, a defined noninvasive neuromodulation track as an elective component of psychiatry residencies, and a formal interventional psychiatry fellowship that leads to an approved subspecialty certification from the American Board of Medical Specialties (ABMS).

Base Resident Education—At some point in the future, psychiatry trainees should have exposure to a circuit-based understanding of human behavior along with a basic exposure to both noninvasive and invasive psychiatric interventions. This basic exposure would improve understanding for patient referrals and consultations for brain stimulation interventions, increase creative thinking about treatment options, and reinforce an updated perspective of the neurobiology of psychiatric disease (consistent with levels 1–3 of the neuroscience milestones). Ideally, all psychiatric residents would have a core didactic and experiential curriculum including participation in brain stimulation consultation and observation of ECT/TMS (consistent with levels 1–3 of the somatic therapies milestone). See Tables 1, 2, 3, and 4 for the proposed requirements for general psychiatry.

Interventional Psychiatry Track—We propose that those trainees interested in performing noninvasive neuromodulation, particularly in the community setting, be allowed to have a dedicated track within participating psychiatric residencies. This track would diminish inconsistencies in training and improve delivery of brain stimulation in community settings. We propose that those psychiatrists currently performing noninvasive neuromodulation be grandfathered into this designation. Under this proposal, interested residents would have requirements for both ECT and TMS and have an opportunity to participate in initial evaluations/consultations and ongoing management of acute and maintenance forms of each treatment (allowing for the trainee to achieve competence in milestone levels 4–5 within the realms of somatic therapies).

Additionally, trainees would be able to participate in hybrid rotations that include clinical neurophysiology and neuroradiology, allowing for a more neuroanatomically informed understanding of brain-behavior relationships (and allowing for the trainee to achieve competence in milestone levels 4–5 within the realm of neuroscience). We suggest that the track span all 4 years, with the final year being dedicated to completing the requirements for the track the majority of time (Tables 1, 2, 3, and 4).

Interventional Psychiatry Fellowship—A psychiatry trainee interested in interventional psychiatry would ideally be trained in a dedicated fellowship that exposed the trainee to all of the aforementioned neuromodulation paradigms and provided opportunities for patient management. This training would be hosted at an institution with a robust noninvasive and invasive psychiatric neuromodulation program in collaboration with neurology, neurosurgery, and neuroradiology. The trainee should receive hands-on exposure in established and emerging neuromodulation technologies and have the opportunity to manage patients being treated with each modality. See Tables 1, 2, 3, and 4 for the proposed requirements for this training pathway (mastery in both neuroscience and somatic therapy sections defined within the psychiatry milestones along with additional requirements).

There is a bright future for neuromodulation in psychiatric disorders, but academic centers must provide adequate resident/fellowship training to those who will be providing these interventions in order to avoid mistakes of an earlier era [20]. The implementation and certification of the aforementioned training opportunities should not be delayed, because the exponential nature of these neurotechnologies must be met with a properly trained cohort of interventional psychiatrists ready to meet the challenges of treatment-resistant psychiatric disease.

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References

1. Stetka BK, Edward, Williams Nolan. A new psychiatry subspecialty? Medscape Psychiatry. 2013 APA 2013 issue.

2. The Psychiatry Milestone Project. 2013.
3. Lakhan SE, Kaplan A, Laird C, Leiter Y. The interventionalism of medicine: interventional radiology, cardiology, and neuroradiology. Int Arch Med. 2009; 2(1):27. English. [PubMed: 19740425]
4. George MS, Aston-Jones G. Noninvasive techniques for probing neurocircuitry and treating illness: vagus nerve stimulation (VNS), transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS). Neuropsychopharmacol: Off Publ Am Coll Neuropsychopharmacol. 2010; 35(1):301–16. PubMed PMID: 19693003. Pubmed Central PMCID: 3055429. Epub 2009/08/21.eng.
5. Benabid AL. What the future holds for deep brain stimulation. Expert Rev Med Devices. 2007; 4(6): 895–903. PubMed PMID: 18035954. [PubMed: 18035954]
6. Sackeim HA, George MS. Brain stimulation—basic, translational, and clinical research in neuromodulation: why a new journal? Brain Stimul. 2008; 1(1):4–6. English. [PubMed: 20633365]
7. Silvanto J, Pascual-Leone A. Why the assessment of causality in brain-behavior relations requires brain stimulation. Journal of cognitive neuroscience. Feb 20.2012 English.
8. George MS, Lisanby SH, Avery D, McDonald WM, Durkalski V, Pavlicova M, et al. Daily left prefrontal transcranial magnetic stimulation therapy for major depressive disorder: a sham-controlled randomized trial. Arch Gen Psychiatry. 2010; 67(5):507–16. PubMed PMID: 20439832. Epub 2010/05/05. eng. [PubMed: 20439832]
9. Siebner HR, Bergmann TO, Bestmann S, Massimini M, Johansen-Berg H, Mochizuki H, et al. Consensus paper: combining transcranial stimulation with neuroimaging. Brain Stimul. 2009; 2(2): 58–80. PubMed PMID: 20633405. Epub 2009/04/01. eng. [PubMed: 20633405]
10. Broadway JM, Holtzheimer PE, Hilimire MR, Parks NA, DeVylder JE, Mayberg HS, et al. Frontal theta cordance predicts 6-month antidepressant response to subcallosal cingulate deep brain stimulation for treatment-resistant depression: a pilot study. Neuropsychopharmacol: Off Publ Am Coll Neuropsychopharmacol. 2012; 37(7):1764–72.
11. Priori A, Berardelli A, Rona S, Accornero N, Manfredi M. Polarization of the human motor cortex through the scalp. Neuroreport. 1998; 9(10):2257–60. PubMed PMID: 9694210. Epub 1998/08/07. eng. [PubMed: 9694210]
12. Wagle Shukla A, Okun MS. Personalized medicine in deep brain stimulation through utilization of neural oscillations. Neurology. 2012; 78(24):1900–1. PubMed PMID: 22592364. [PubMed: 22592364]
13. Barker AT, Jalinous R, Freeston IL. Non-invasive magnetic stimulation of human motor cortex. Lancet. 1985; 1(8437):1106–7. PubMed PMID: 2860322. Epub 1985/05/11. eng. [PubMed: 2860322]
14. Kamel H, Cornes SB, Hegde M, Hall SE, Josephson SA. Electroconvulsive therapy for refractory status epilepticus: a case series. Neurocrit Care. 2010; 12(2):204–10. eng. [PubMed: 19809802]
15. Elger G, Hoppe C, Falkai P, Rush AJ, Elger CE. Vagus nerve stimulation is associated with mood improvements in epilepsy patients. Epilepsy Res. 2000; 42(2-3):203–10. English. [PubMed: 11074193]
16. Morrell MJ. Responsive cortical stimulation for the treatment of medically intractable partial epilepsy. Neurology. 2011; 77(13):1295–304. [PubMed: 21917777]
17. Benabid A-L, Vercucil L, Benazzouz A, Koudsie A, Chabardes S, Minotti L, et al. Deep brain stimulation: what does it offer? Adv Neurol. 2003; 91:293–302. English. [PubMed: 12442687]
18. George MS, Wassermann EM, Williams WA, Callahan A, Ketter TA, Basser P, et al. Daily repetitive transcranial magnetic stimulation (rTMS) improves mood in depression. Neuroreport. 1995; 6(14):1853–6. PubMed PMID: 8547583. Epub 1995/10/02. eng. [PubMed: 8547583]
19. Greenberg BD, Gabriels LA, Malone DA Jr, Rezai AR, Friehs GM, Okun MS, et al. Deep brain stimulation of the ventral internal capsule/ventral striatum for obsessive-compulsive disorder: world-wide experience. Mol Psychiatry. 2010; 15(1):64–79. PubMed PMID: 18490925. [PubMed: 18490925]
20. Fins JJ, Rezai AR, Greenberg BD. Psychosurgery: avoiding an ethical redux while advancing a therapeutic future. Neurosurgery. 2006; 59(4):713–6. English. [PubMed: 17038936]

21. Sackeim HA, George MS. Brain stimulation-basic, translational, and clinical research in neuromodulation: why a new journal? Brain Stimul. 2008; 1(1):4–6. PubMed PMID: 20633365. [PubMed: 20633365]

22. Fink M, Abrams R, Bailine S, Jaffe R. Ambulatory electroconvulsive therapy: report of a task force of the association for convulsive therapy. Association for Convulsive Therapy. Convuls Ther. 1996; 12(1):42–55. PubMed PMID: 8777654. [PubMed: 8777654]

23. Hassan A, Okun MS. Emerging subspecialties in neurology: deep brain stimulation and electrical neuro-network modulation. Neurology. 2013; 80(5):e47–50. PubMed PMID: 23359377. Pubmed Central PMCID: 3590054. [PubMed: 23359377]

24. McGrath CL, Kelley ME, Holtzheimer PE, Dunlop BW, Craighead WE, Franco AR, et al. Toward a neuroimaging treatment selection biomarker for major depressive disorder. JAMA Psychiatry. 2013; 70(8):821–9. PubMed PMID: 23760393. [PubMed: 23760393]

25. Brillman J, Kasdan R, Wechsler LR. The neurologist as neuroimager. Neurology. 1997; 48(2): 303–6. PubMed PMID: 9040710. [PubMed: 9040710]

26. Fitzgerald PB, Brown TL, Daskalakis ZJ. The application of transcranial magnetic stimulation in psychiatry and neurosciences research. Acta Psychiatr Scand. 2002; 105(5):324–40. PubMed PMID: 11942939. [PubMed: 11942939]

27. Higgins, ES.; George, MS. Brain stimulation therapies for clinicians. American Psychiatric Pub; 2009.

28. Sackeim HA, Prudic J, Nobler MS, Fitzsimons L, Lisanby SH, Payne N, et al. Effects of pulse width and electrode placement on the efficacy and cognitive effects of electroconvulsive therapy. Brain Stimul. 2008; 1(2):71–83. [PubMed: 19756236]

29. Ducharme S, Flaherty AW, Seiner SJ, Dougherty DD, Morales OG. Temporary interruption of deep brain stimulation for Parkinson's disease during outpatient electroconvulsive therapy for major depression: a novel treatment strategy. J Neuropsychiatry Clin Neurosci. 2011; 23(2):194–7. PubMed PMID: 21677249. [PubMed: 21677249]

30. Nahas Z, Short B, Burns C, Archer M, Schmidt M, Prudic J, et al. A feasibility study of a new method for electrically producing seizures in man: focal electrically administered seizure therapy [FEAST]. Brain stimulation. Mar 16.2013 PubMed PMID: 23518262.

31. Moscrip TD, Terrace HS, Sackeim HA, Lisanby SH. Randomized controlled trial of the cognitive side-effects of magnetic seizure therapy (MST) and electroconvulsive shock (ECS). Int J Neuropsychopharmacol / Off Sci J Coll Int Neuropsychopharmacologicum. 2006; 9(1):1–11. PubMed PMID: 16045810.

32. Li D, Hall SE, Tong LD, Rollins MD. The electroconvulsive therapy and anesthesia exercise (ECTAE): the creation of an interdisciplinary learning activity for medical students. J ECT. 2013; 29(3):214–8. PubMed PMID: 23377747. [PubMed: 23377747]

33. George MS, Wassermann EM, Kimbrell TA, Little JT, Williams WE, Danielson AL, et al. Mood improvement following daily left prefrontal repetitive transcranial magnetic stimulation in patients with depression: a placebo-controlled crossover trial. Am J Psychiatry. 1997; 154(12):1752–6. PubMed PMID: 9396958. Epub 1997/12/16.eng. [PubMed: 9396958]

34. Rush AJ, George MS, Sackeim HA, Marangell LB, Husain MM, Giller C, et al. Vagus nerve stimulation (VNS) for treatment-resistant depressions: a multicenter study. BPS. 2000; 47(4):276–86. English.

35. Berry SM, Broglio K, Bunker M, Jayewardene A, Olin B, Rush AJ. A patient-level meta-analysis of studies evaluating vagus nerve stimulation therapy for treatment-resistant depression. Med Devices. 2013; 6:17–35. PubMed PMID: 23482508. Pubmed Central PMCID: 3590011.

36. Liporace J, Hucko D, Morrow R, Barolat G, Nei M, Schnur J, et al. Vagal nerve stimulation: adjustments to reduce painful side effects. Neurology. 2001; 57(5):885–6. PubMed PMID: 11552021. [PubMed: 11552021]

37. Schlaepfer TE, Bewernick BH, Kayser S, Madler B, Coenen VA. Rapid effects of deep brain stimulation for treatment-resistant major depression. Biol Psychiatry. 2013; 73(12):1204–12. PubMed PMID: 23562618. [PubMed: 23562618]

38. Lozano AM, Giacobbe P, Hamani C, Rizvi SJ, Kennedy SH, Kolivakis TT, et al. A multicenter pilot study of subcallosal cingulate area deep brain stimulation for treatment-resistant depression. J Neurosurg. 2012; 116(2):315–22. PubMed PMID: 22098195. [PubMed: 22098195]

39. Rodriguez RL, Fernandez HH, Haq I, Okun MS. Pearls in patient selection for deep brain stimulation. Neurologist. 2007; 13(5):253–60. PubMed PMID: 17848865. [PubMed: 17848865]

40. Volkmann J, Moro E, Pahwa R. Basic algorithms for the programming of deep brain stimulation in Parkinson's disease. Mov Disord: Off J Mov Disord Soc. 2006; 21(Suppl 14):S284–9. PubMed PMID: 16810675.

41. Heller AC, Amar AP, Liu CY, Apuzzo MLJ. Surgery of the mind and mood: a mosaic of issues in time and evolution. Neurosurgery. 2006; 59(4):720–39. English. [PubMed: 17038938]

Implications for Educators

- Psychiatry training programs should develop training guidance for the ethical and patient-centered implementation of the evolving area of psychiatric procedures.
- Educators should phase in curricular changes aimed at increasing trainees' knowledge of clinically relevant neuroscience in an effort to effectively integrate the expanding neuromodulation science.
- Psychiatry program directors should consider a transition plan, likely requiring interdisciplinary cooperation with related fields such as neurology, neurosurgery, and neuroradiology as trained psychiatrist practitioners evolve.
- Psychiatry selection committees should prepare for a changing residency applicant pool requesting increased exposure and experience in practice-relevant neuromodulation and interventional techniques.

Implications for Academic Leaders

- Psychiatry leadership should augment clinical and academic faculty to moderate thoughtfully the evolving culture of procedural psychiatry.
- Academic institutions should consider the need for expanding clinical and research programs that amplify the relationship between psychiatry and other disciplines in the treatment of behavioral syndromes.
- Department chairmen should plan for cross-disciplinary agreements with neurology, neurosurgery, and neuroradiology.
- Interventional psychiatry leaders should develop a mechanism to support relationships between training programs with advanced interventional psychiatry programs and those with less early resources.

Table 1

PC3 treatment planning and management

3.4/B Recognizes need for consultation and supervision for complicated or refractory cases	*4.2/A Integrates multiple modalities and providers in comprehensive approach*	**Helping to develop novel treatments and approaches**
Knows when it is appropriate to involve the interventional psychiatrist into the case	*5.2/A Integrates emerging neurobiological and genetic knowledge into treatment plan*	**Knowledge of how and when to interface with neurology, neurosurgery, and anesthesia for coordination of infusion-based and invasive psychiatric interventions**
3.2/A Applies an understanding of psychiatric, neurologic, and medical comorbidities to treatment selection	*4.1/A Devises individualized treatment plan for complex presentations*	**Understanding how to troubleshoot treatment failures in patients receiving psychiatric interventions**

The patient care-3 portion of the proposed milestones and treatment planning and management milestones targeted specifically at psychiatric intervention. The original milestones language is in italic and our proposed expansion is in bold

Table 2

MK3 clinical neuroscience

General resident	Interventional psychiatry track/fellowship	Interventional psychiatry fellowship
2.1/A Knows indications for structural neuroimaging (cranial computed tomography [CT] and magnetic resonance imaging [MRI]) and neurophysiological testing (electroencephalography [EEG], *evoked potentials, sleep studies)*	*4.4 Describes leading neuroscientific hypotheses of emotions and social behaviors*	**In depth knowledge of proposed circuitry involved in psychiatric disease**
2.4/E Identifies the brain areas thought to be important in social and emotional behavior	*4.2/A Knows clinical indications and limitations of functional neuroimaging*	**In depth knowledge of brain imaging and neurophysiological modalities**
3.1/A Recognizes the significance of abnormal findings in routine neurodiagnostic test reports in psychiatric patients	*5.1/A Integrates recent neurodiagnostic research into understanding of psychopathology*	**Training in the theory of EEG and qEEG**
3.2/B Knows indications for specific neuropsychological tests and understands meaning of common abnormal findings	*5.3/D Explains neurobiological hypotheses and genetic risks of less common psychiatric disorders to patients*	**Training in the theory of the presumed effects of ppTMS and rTMS**
4.1/A Explains the significance of routine neuroimaging, neurophysiological, and neuropsychological testing abnormalities to patients	*5.4/D Integrates knowledge of neurobiology into advocacy for psychiatric patient care and stigma reduction*	**Training in the theory of the neurophysiology of ECT as it pertains to a particular disease**

The medical knowledge-clinical neuroscience portion of the proposed milestones and neuroscience knowledge specific to psychiatric intervention. The original milestones language is in italic and our proposed expansion is in bold

Table 3

PC5 somatic (interventional) therapies

General resident	Interventional psychiatry track/fellowship	Interventional psychiatry fellowship
2.4/D Seeks consultation and supervision regarding potential referral for ECT treatments	*5.1/B Explains less common somatic treatment choices to patients/families in terms of proposed mechanisms of action*	**Learning the intraoperative and postoperative care of patients with invasive psychiatric interventions**
3.3/C Uses augmentation strategies, with supervision, when primary pharmacological interventions are only partially successful	*5.2/C Integrates emerging studies of somatic treatments into clinical practice*	**Displays mastery of educating patients on all aspects of interventional treatment including course, prognosis, anticipated risks/benefits at the individual level**
Watches administration of TMS and ECT during clinical training	**Demonstrates competency in delivery of TMS, tDCS, and ECT**	**Demonstrates mastery of implantable device programming and maintenance along with TMS/ECT administration**
Has session where there is basic exposure to the devices used by the interventional psychiatrist	**Ability to ascertain an accurate motor threshold and treatment location for TMS**	**Ability to read anatomical and functional scans for stimulation targeting**

The patient care-5 somatic (interventional) therapies portion of the proposed milestones and treatment planning and management milestones targeted specifically at psychiatric intervention. The original milestones language is in italic and our proposed expansion is in bold

Table 4

MK5 somatic (interventional) therapies

General resident	Interventional psychiatry track/fellowship	Interventional psychiatry fellowship
Describes indications for ECT	*5.1/B Explains less common somatic treatment choices to patients/families in terms of proposed mechanisms of action*	**Understands advanced programming algorithms of VNS and DBS devices**
2.4 Seeks consultation and supervision regarding potential referral for ECT	*5.2/C Integrates emerging studies of somatic treatments into clinical practice*	**Achieves mastery in the understanding of the presumed mechanisms of action of brain stimulation technologies**
3.2/C Monitors relevant lab studies throughout treatment and incorporates emerging physical and laboratory findings into somatic treatment strategy	**Understands basic programming algorithms of VNS and DBS devices**	**Knowledge of neuropsychiatric effects of DBS in neurologic patients (such as Parkinson's disease**
3.3/C Uses augmentation strategies, with supervision, when primary pharmacological interventions are only partially successful	**Understanding of the inclusion/exclusion criteria for brain stimulation interventions**	**Knowledge of emerging infusion-based treatments**

The medical knowledge-5 somatic (interventional) therapies portion of the proposed milestones and treatment planning and management milestones targeted specifically at psychiatric intervention. The original milestones language is in italic and our proposed expansion is in bold