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NEUROSURGICAL TECHNOLOGIES IN MENTAL HEALTH CARE: SOCIETAL, WELL-BEING, AND PUBLIC POLICY IMPLICATIONS

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ABSTRACT

Introduction and purpose: Neurosurgery, traditionally focused on life-saving and functional preservation, also profoundly impacts mental integrity due to its direct interaction with the brain. Psychiatric neurosurgery, including deep brain stimulation and advanced stereotactic techniques, actively modulates dysfunctional neural circuits in treatment-resistant psychiatric disorders. This review examines how such interventions influence personality, cognition, and social functioning, highlighting their evolving role as evidence-based therapeutic options that extend beyond conventional clinical outcomes.
Materials and methods: The literature search was performed using PubMed, Scopus, Web of Science, and Google Scholar. Keywords included: "psychiatric neurosurgery", "deep brain stimulation", "DBS", "vagus nerve stimulation", "VNS", "auricular vagus nerve stimulation", "aVNS", "stereotactic neurosurgery", "treatment-resistant depression", "major depressive disorder", "obsessive-compulsive disorder", "OCD", "treatment-resistant psychiatric disorders", "personality changes", "cognitive changes", "neuropsychiatric outcomes", "quality of life", "social functioning", "employment", "cost-effectiveness", and "caregiver burden".
Conclusion: Psychiatric neurosurgery, including deep brain stimulation and vagus nerve stimulation, demonstrates significant clinical and socioeconomic benefits for patients with treatment-resistant psychiatric disorders. Beyond symptom reduction, these interventions can restore cognitive and emotional functioning, enhance quality of life, improve social integration, and facilitate professional reintegration. Additionally, they alleviate caregiver burden and may reduce long-term healthcare costs. While current evidence supports the safety and efficacy of these approaches, optimal targeting strategies, patient selection, and long-term outcomes require further research. Overall, psychiatric neurosurgery represents a transformative therapeutic option, bridging clinical treatment with broader psychosocial and economic impact.

KEYWORDS

Psychiatric Neurosurgery, Deep Brain Stimulation, Vagus Nerve Stimulation, Treatment-Resistant Psychiatric Disorders, Personality and Cognitive Changes, Quality of Life

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Introduction

Neurosurgery is predominantly considered a therapeutic modality focused on saving lives and improving quality of life. Nonetheless, it possesses a more profound significance, given its direct impact on the brain's structure. To this day, the effect of those interventions on patients' mental integrity remains a highly scrutinized area of research. Every incision on neural tissue is a potential source of change in how a person feels, thinks, and perceives the world. Because the brain acts as the physical part of the human persona, even minor modifications can be crucial in relation to a patient's life, potentially influencing their relationships, professional roles, and overall quality of life.

The intrinsic link between the human psyche and cerebral structure has been recognized for millennia, originating with primitive trepanations and evolving through the dark, controversial era of mid-20th-century lobotomies. Although these early, often radical attempts to alter psychological functioning were fraught with ethical failures, they inadvertently provided a substantial volume of data regarding the localization of brain function. These historical precursors have forced a rigorous re-evaluation of the connection between the mental and physical spheres. In recent years, we have witnessed a paradigm shift in psychiatric neurosurgery; it is rapidly transitioning from the last resort treatment into a sophisticated, evidence-based therapeutic option. Supported by a burgeoning body of research, this evolution is defined by a commitment to meeting the highest ethical standards while prioritizing the preservation of the "self" rather than mere clinical survival [1].

While the success of traditional neurosurgery is often measured by the anatomical removal of lesions or the preservation of motor functions, the focus of psychiatric neurosurgery is fundamentally different. It moves beyond the mere avoidance of iatrogenic trauma, seeking instead to actively modulate the dysfunctional neural circuits responsible for severe mental illness. Modern techniques, such as Deep Brain Stimulation (DBS) and advanced stereotactic procedures, leverage our growing understanding of neuroplasticity and brain connectivity to restore, rather than disrupt, psychological equilibrium. Consequently, the boundary between surgical intervention and mental health treatment is becoming increasingly blurred.

This review aims to assess the role of modern neurosurgical procedures as a therapeutic tool for treatment-resistant psychiatric disorders, focusing on how alterations in personality or cognition shape their later lives and social roles.

Methodology

A comprehensive literature search was conducted to identify studies evaluating the role of modern neurosurgical procedures in the treatment of psychiatric disorders and their impact on personality, cognition, psychosocial functioning, and socioeconomic outcomes. The search was performed using PubMed, Scopus, Web of Science, and Google Scholar. Keywords included: "psychiatric neurosurgery", "deep brain stimulation", "DBS", "vagus nerve stimulation", "VNS", "auricular vagus nerve stimulation", "aVNS", "stereotactic neurosurgery", "treatment-resistant depression", "major depressive disorder", "obsessive-compulsive disorder", "OCD", "treatment-resistant psychiatric disorders", "personality changes", "cognitive changes", "neuropsychiatric outcomes", "quality of life", "social functioning", "employment", "cost-effectiveness", and "caregiver burden". Additional relevant publications were identified through a manual review of the reference lists of selected articles.

Neurosurgical technologies

Deep Brain Stimulation (DBS)

The history of DBS is closely linked to the development of stereotactic neurosurgery, initially designed to improve the precision of ablative procedures and reduce the risk of neurological complications. Early stereotactic systems enabled accurate localization of deep brain structures, allowing surgeons to minimize unintended tissue damage. During intraoperative use, it was observed that electrical stimulation of specific brain regions could produce varying physiological effects depending on stimulation parameters. High-frequency stimulation was found to reduce tremor, whereas lower frequencies could exacerbate motor symptoms.

These observations marked a turning point, shifting the focus from irreversible lesioning toward reversible neuromodulation. Chronic high-frequency stimulation was subsequently introduced as a therapeutic approach for Parkinson's disease, demonstrating significant clinical benefits. Over time, DBS became established as an effective treatment not only for Parkinson's disease but also for essential tremor and dystonia, and later for epilepsy.

The expanding understanding of neural circuitry further encouraged investigation into the psychiatric applications of DBS. Early exploratory attempts examined its potential in conditions such as schizophrenia and chronic pain. In recent decades, research has increasingly focused on treatment resistant psychiatric disorders, including major depressive disorder and obsessive-compulsive disorder. These developments reflect a broader evolution of DBS from a movement disorder therapy toward a neuromodulatory intervention targeting complex neuropsychiatric networks [2].

Earlier clinical experience with ablative psychiatric procedures paved the way for DBS as a potential treatment for drug-resistant depression. However, the contemporary rationale is primarily based on neuroimaging findings and clinical observations. The application of DBS in depression is closely linked to the concept that major depressive disorder (MDD) results from dysregulation within cortico-limbic networks, leading to a broad spectrum of affective and cognitive symptoms. Consequently, multiple stimulation targets have been proposed, each aiming to modulate distinct but interconnected neural circuits [3].

The fundamental component of DBS procedure is stereotactic implantation of an electrode into a specific deep brain region, which varies depending on the disorder being treated. This electrode is subsequently linked via a subcutaneous lead to a chest-mounted pulse generator, which delivers electrical impulses at patient-specific frequencies and amplitudes, tailored through individual computer-programming [4].

The first extensively studied target was the ventral capsule/ventral striatum (VC/VS), a region involved in reward processing. Its stimulation has been associated with improvement in depressive symptoms, particularly in domains related to motivation and anhedonia. Another major target is the subcallosal cingulate (SCC), which demonstrates hyperactivity in severe depression. Electrical stimulation of the SCC is thought to regulate negative affect and reduce pathological mood states. Additional investigated targets include the lateral habenula, involved in modulation of monoaminergic systems; the medial forebrain bundle (MFB), enabling direct modulation of the reward circuitry; and the inferior thalamic peduncle (ITP), which connects thalamic and frontal regions. The diversity of neural circuits implicated in MDD underscores the complexity of depressive neurobiology and highlights the importance of individualized targeting strategies [3,5].

Current clinical evidence suggests promising results in patients with treatment-resistant depression. DBS is increasingly considered a potentially safe and effective therapeutic option for selected individuals with MDD. However, this field remains under active development and requires further refinement in patient selection, targeting strategies, and long-term outcome evaluation [5].

Another severe psychiatric disorder that may benefit from the application of DBS is obsessive-compulsive disorder (OCD). Earlier clinical experience with anterior capsulotomy demonstrated that neurosurgical interventions could be effective in pharmacotherapy-resistant OCD. These findings provided the conceptual foundation for investigating DBS as a less destructive and adjustable alternative. The anterior limb of the internal capsule (ALIC) was among the first DBS targets, selected to reproduce the therapeutic effects observed after anterior capsulotomy. Stimulation of this region resulted in significant symptom improvement in patients with treatment-resistant OCD [3].

The pathophysiological hallmark of OCD is dysfunction within cortico-striato-thalamo-cortical (CSTC) circuits. Consequently, modulation of different nodes within this network may lead to distinct clinical effects. The most targeted regions include ALIC/VC-VS and the nucleus accumbens (NAc), which are often associated with faster improvement in mood and anxiety symptoms, as well as the subthalamic nucleus (STN), which appears to exert a greater influence on cognitive flexibility and behavioural control [6].

The therapeutic efficacy of DBS is increasingly attributed to modulation of pathological CSTC circuitry. Current evidence suggests that DBS represents a promising intervention for drug-resistant OCD, although ongoing research is needed to further optimize targeting strategies and clarify long-term outcomes.

Vagus Nerve Stimulation (VNS)

Vagus nerve stimulation (VNS) was introduced with the development of implantable pulse generators and was initially approved for the treatment of drug-resistant epilepsy. Further clinical observations of mood improvement in epilepsy patients suggested its potential utility in treatment-resistant depression (TRD). VNS is an invasive neuromodulatory procedure that involves implantation of a pulse generator in the chest wall, connected via a subcutaneous wire to an electrode wrapped around the left cervical vagus nerve [7].

The antidepressant effects of VNS are associated with widespread modulation of neuronal circuits implicated in mood regulation. Mechanistically, stimulation of vagal afferents activates projections to the nucleus tractus solitarius, which in turn influences key monoaminergic nuclei, including the locus coeruleus and the dorsal raphe nucleus. Through these pathways, VNS modulates noradrenergic and serotonergic transmission and alters the activity of limbic and prefrontal cortical regions that play central roles in the pathophysiology of depression [7].

An important direction in the evolution of this therapy is the development of non-invasive alternatives to cervical implantation, particularly transcutaneous auricular VNS (aVNS). This approach targets the auricular branch of the vagus nerve through cutaneous stimulation of the external ear. Emerging evidence suggests that aVNS may produce neuromodulatory effects comparable to conventional VNS, while significantly reducing the risk of surgical complications [8].

The therapeutic role of VNS is gaining increasing recognition in the treatment of severe depressive disorders. The strongest clinical evidence supports its efficacy in epilepsy and treatment-resistant depression, where progressive therapeutic effects and sustained improvements in quality of life have been observed. These characteristics underscore its promise as a long-term neuromodulatory strategy in refractory neuropsychiatric disorders [9]. The fundamental differences of DBS and VNS are summarized in Table 1.

Table 1. Summary of DBS and VNS characteristics.

Features	DBS	VNS
Main psychiatric indications	TRD, OCD	TRD
Electrode implantation site	Intracranial	Left cervical vagus nerve (extracranial)
Main anatomical targets	Depression: SCC, VC/VS, MFB, ITP OCD: ALIC, NAc, STN	Solitary tract nucleus (NTS), Locus coeruleus (LC), Dermal raphe nuclei (DRN)
Mechanism of action	Direct modulation of specific loops (CSTC) and reward centers.	Activation of ascending brainstem pathways and modulation of monoaminergic systems (NA, 5-HT)
Rate of the response	Often rapid modulation (functional prosthesis), dependent on the continuity of stimulation	The effect is "slow but sustained", cumulative
Invasiveness	High (requires craniotomy and stereotaxy)	Medium (neck/chest surgery)

Clinical cxamples

Obsessive-Compulsive Disorder (OCD)

Obsessive-Compulsive Disorder (OCD) is a chronic mental disorder with an early onset. It is characterized by intrusive, unwanted thoughts (obsessions) and repetitive behaviours or mental acts (compulsions). The disorder frequently follows a chronic course and is associated with substantial impairment in social, occupational, and family functioning. Patients with OCD may spend several hours per day engaged in compulsive behaviours, leading to sleep disturbances, avoidance patterns, and progressive restriction of daily activities. The burden of OCD extends beyond the patient's life, often affecting family members who may become involved in accommodating compulsive behaviours [10].

Despite available effective therapy, approximately 25% of patients remain refractory to the best pharmacological treatment, leading to significant morbidity and higher mortality. Therefore, neurosurgical procedures, such as DBS are considered in such refractory and severe cases [11].

The first study investigating deep brain stimulation for obsessive-compulsive disorder was published in 1999 by Nuttin et al. [12]. Four patients with long-standing, treatment-resistant OCD were treated with DBS targeting the anterior limbs of the internal capsules. The outcomes were promising, as in three out of four patients beneficial results could be observed. Following this, additional trials were conducted, most of which having similarly positive results.

A study by Abelson et al. [13] demonstrated great improvement in mood, anxiety, and OCD symptoms in one patient and moderate benefit in a second patient, while the remaining two participants did not show clinically meaningful improvement. Furthermore, a long-term study by Greenberg et al. [14] concluded that although the procedure carries certain risks, it may provide long-term benefits. Seven out of ten patients improved at 24–36 months, experiencing mood elevation and enhanced motivation.

Over time, multiple DBS targets have been investigated, including the anterior limb of the internal capsule, ventral capsule/ventral striatum, nucleus accumbens, bed nucleus of the stria terminalis (BNST), subthalamic nucleus, inferior thalamic peduncle, and globus pallidus internus (GPi). Striatal targets such as ALIC, VC/VS, and NAc are anatomically overlapping and likely modulate similar neural networks. Graat et al. [15] conducted a long-term study on a cohort of 50 patients with a minimum follow-up of three years. Out of the 50 patients, half of them was deemed to be responders to DBS treatment (≥35% decrease of Yale-Brown Obsessive Compulsive Scale score). Reductions in anxiety (48%) and depressive symptoms (50%) were also observed, along with a decrease in unemployment rates. The most common long-term adverse events included fatigue and cognitive complaints. One serious adverse event, a suicide attempt, was reported and was related to comorbid depression.

The objective of the study by Denys et al. [16] was to determine whether bilateral DBS of the NAc is an effective and safe treatment for OCD. The authors concluded that this target may be both effective and safe; however, further studies are required. Research on BNST DBS in OCD has demonstrated promising clinical outcomes, although overall clinical experience remains limited [11,17,18].

A randomized trial comparing NAc/VC and anteromedial STN (amSTN) stimulation by Tyagi et al. [19], on six patients, showed that DBS at each site significantly reduced OCD symptoms, but almost no additional gain could be seen following combined stimulation. The two targets were associated with different effects: amSTN stimulation improved cognitive flexibility, whereas NAc/VC stimulation had a greater impact on mood.

A study targeting the ITP by Lee et al. [20] reported a favourable safety profile and positive overall outcomes. All five patients were deemed responders at one year and at the last follow-up. The study reported three adverse events in two responders; resulting in removal of the patient's device' due to the stimulator becoming patient's obsession, while the other two were not related to the device. A study of patients with Tourette's syndrome and OCD suggested that the anteromedial GPi can also be a potential surgical target for DBS [21]. The overall summary of the literature discussed is presented in Table 2.

Table 2. Summary of the mentioned studies evaluating the efficacy and safety of DBS in treatment-resistant OCD.

Authors	Results
Nuttin et al., 1999	The first study investigating DBS effect in OCD, 3 out of 4 patients experienced beneficial outcomes.
Abelson et al., 2004	One patient showed mood, anxiety, and OCD improvement; a second had moderate benefits, while two showed no significant change.
Greenberg et al., 2006	Seventy percent of patients demonstrated improvement over a 24 to 36-month period, characterized by reduced OCD severity and increased social engagement. Patients who had a DBS interruption noticed a more pronounced decline in their mood.
Denys et al., 2010	9 out of 16 patients responded to DBS. There was a significant reduction in depression and anxiety. Aside from mild forgetfulness and word-finding difficulties, no lasting adverse events were observed.
Nair et al., 2013	Two patients achieved complete resolution of their OCD symptoms, while the other two showed more than 85% reduction in their OCI scores.
Lee et al., 2018	All five patients responded to ITP DBS with a significant reduction in symptom severity. While clinical efficacy was high, one patient required device removal after the system itself became the focus of their obsessive symptoms.
Tyagi et al., 2019	While stimulating the amSTN and NAc/VC individually reduced OCD symptoms in six patients, their combined activation showed minimal additional benefit. The targets differed functionally, with amSTN promoting cognitive flexibility and NAc/VC improving mood.
Graat et al., 2021	Half of the patients were considered responders to DBS treatment. Ultimately, seven of them (14%) achieved full clinical remission at long-term follow-up. 18 of 34 patients experienced stimulation-induced hypomanic symptoms.

Overall, DBS is considered a safe and effective treatment for patients with treatment-refractory OCD. However, the optimal target selection remains uncertain. Given the complexity of OCD, further studies are needed to better define efficacy of different stimulation targets and to optimize multidisciplinary treatment approaches.

Depression

Major depressive disorder is a significant mental disorder, that affects approximately 8% of adolescents, while elevated depressive symptoms may be present in up to 34% of population globally. The prevalence of depressive symptoms among adolescents has risen substantially over the past two decades, highlighting a growing public health concern. Depression is associated with significant functional impairment, including academic difficulties, social challenges, risky behaviours, and increased risk of suicide. Moreover, early-onset depression often predicts more severe and recurrent episodes in adulthood, contributing to significant impairment of life quality [22].

Although effective behavioural and pharmacological therapies are available, approximately 30% of patients remain refractory to treatment. This resistance has prompted exploration of alternative approaches, such as DBS or VNS for managing depression [7,11].

There has been a wide range of studies investigating deep brain stimulation as a potential treatment for individuals suffering from treatment-resistant depression. The average response rate across different targets is approximately 60% in patients with longstanding, refractory depression. However, outcomes vary considerably between individuals and across studies, often requiring prolonged trial-and-error adjustment of stimulation settings. There is evidence from tractography imaging suggesting that effective antidepressant effects depend not only on targeting specific grey-matter regions but also white-matter tracts [5].

Recent approaches to TRD have largely focused on non-serotonergic drug targets and focal brain-stimulation methods. DBS is currently offered as an experimental intervention for patients who remain unresponsive to standard treatments, including antidepressant medications and electroconvulsive therapy [5]. The key anatomical targets for DBS are the subcallosal cingulate cortex, ventral capsule/ventral striatum, nucleus accumbens, medial forebrain bundle, inferior thalamic peduncle, and lateral habenula (LHb) [5,23].

The first study of DBS for TRD, conducted by Mayberg and colleagues, was an open-label trial demonstrating that the intervention was both safe and potentially effective, reporting response rate of 66% and a remission rate of 33% at six months [24]. The cohort was later expanded by Lozano et al., who observed similar outcomes after one year, with further improvement at three-year follow-up [5,25]. Subsequent open-label studies have supported the initial findings and reported comparable response and remission rates [5,26,27].

The largest trial to date, the Abbott sponsored BROADEN study, used a double-blind, sham-controlled design. Although at six months no significant difference between active and sham groups was observed, longer follow-up revealed increased response and remission rates between 12 and 24 months. The trial was stopped due to the low likelihood of meeting its predefined endpoint. Later analyses suggested that delayed improvements may have been related to necessary adjustments in stimulation parameters that were restricted during the initial trial phase. There were also indications that treatment outcomes may depend on the duration and severity of illness in participants [5,28].

The studies show that long-term improvements following DBS are associated with enhanced quality of life, which appears to be partly independent of changes in depressive symptom severity. Improvements in mood are often accompanied by greater satisfaction with daily functioning, as demonstrated by Bergfeld et al. [29], and the results align with previous reports by Kennedy et al. [30] and Raymaekers et al. [31]. These studies indicate that DBS may contribute not only to symptom reduction but also to broader functional recovery in some patients with treatment-resistant depression.

Specifically, Bergfeld et al. reported that the clinical benefits observed during the first two years following ventral anterior limb of the internal capsule (vALIC) DBS were maintained for up to 7.5 years postoperatively [29]. Comparable long-term outcomes have been described following stimulation of the SCG (up to nine years) [29,30,32], BST (up to eight years) [29,31], and the MFB (up to five years) [29,33,34].

The important aspect of DBS, as a potential treatment for TRD, that must be taken into consideration is safety. Most common surgical complications include infection, intracranial bleeding, blurred or double vision, and dizziness, as well as postoperative pain, seizures, and dysphagia. Stimulation of limbic structures may result in transient agitation, anxiety, or hypomania. Device-related adverse events have also been reported, including electrode or extension break or dislodgement [5,35].

A meta-analysis by Hitti et al. demonstrated that active DBS has greater antidepressant effects compared with sham DBS and concluded that DBS is a safe and effective treatment for treatment-resistant depression [36]. Taken together, these findings indicate that deep brain stimulation has stable, long-lasting therapeutic benefits in patients with severe treatment- resistant depression, regardless of targeted brain structure.

Another form of invasive treatment for TRD is vagus nerve stimulation. It was initially introduced as a treatment for epilepsy [37]. However, subsequent studies demonstrated that VNS may also exert antidepressant effects [38,39].

Although the study by Rush et al. [40] did not prove short-term efficacy of VNS in patients with TRD, it yielded the procedure safe and well tolerated. A modest reduction in depressive symptoms was observed, and the authors suggested that longer treatment duration might be necessary to achieve meaningful clinical benefits. This led to a 12-month follow-up study involving the same cohort, which demonstrated results in favour of the long-term efficacy of VNS, with growing remission rates observed over consecutive months [39].

More recent studies have further supported the beneficial effects of VNS in patients with TRD. A one-year, randomized, sham-controlled trial by Conway et al. [37], which included 493 adults, found that VNS was safe and generally effective. Although the study did not meet its preliminary endpoint, based on Montgomery-Åsberg Depression Rating Scale (MADRS) response, active VNS did not significantly exceed sham stimulation, secondary outcomes demonstrated improvements in functioning and quality of life.

The largest and longest-duration trial to date, also conducted by Conway et al., was the RECOVER study (A Prospective, Multi-center, Randomized Controlled Blinded Trial Demonstrating the Safety and Effectiveness of VNS Therapy® System as Adjunctive Therapy Versus a No Stimulation Control in Subjects with Treatment-Resistant Depression). The study aimed to follow patients for five years and evaluate whether adjunctive VNS improves patient's outcomes. In addition to antidepressant response and remission rates, the trial assessed duration of effect, quality of life, disability, psychiatric status, and safety outcomes. RECOVER results [41] demonstrated substantial clinical benefit, with more than 80% of participants achieving meaningful improvement at 12 months and maintaining it at 18 and 24 months. Notably, many of the participants who did not show meaningful benefit at 12 months achieved improvement at later time points. The study therefore suggested a durable antidepressant effect of VNS, with sustained improvements in mood and overall quality of life. Loss of benefit was infrequent, and relapse rates were low. Table 3. provides the overall summary of the literature reviewed.

Table 3. Summary of the reviewed studies evaluating the efficacy of DBS and VNS in TDR.

Authors	Results
Mayberg et al., 2005	At the 6-month endpoint, four subjects (66%) continued to respond to antidepressants. Additionally, three of these individuals reached remission or near-remission.
Rush et al., 2005	The response rate to VNS was statistically significant and notably higher than that of the sham group. The most commonly reported adverse events included voice alteration, dyspnea, and neck pain.
Kennedy et al., 2011	At the most recent follow-up visit, the overall response rate was 64.3%. There were no major adverse events reported during this period, although two patients died by suicide amid depressive relapses.
Puigdemont et al., 2012	At 1 year, DBS fully remitted 50% of patients. The surgical procedure and postoperative period were well tolerated by all patients.
Holtzheimer et al., 2017	There was no statistically significant difference in response between the active and sham stimulation groups. Furthermore, 28 patients encountered serious adverse events.
Bergfeld et al., 2022	General domain scores improved during DBS optimization and stayed stable over time. Patients scored notably higher during active DBS compared to sham.
Conway et al., 2025	Percent time in MADRS response did not distinguish between the treatment groups. However, across various measures, the duration of response and PR suggested a favorable VNS treatment effect.

VNS is an invasive procedure and is associated with adverse effects. The most commonly reported side effects include voice alteration, cough, dyspnoea, dysphagia, neck pain, and hoarseness [39,40]. Overall, however, VNS has been consistently reported as safe and generally well tolerated in patients with TRD. The clinical outcomes of DBS and VNS application in OCD and TRD are summarized in Table 4.

Table 4. Summary of clinical results of DBS and VNS in the discussed clinical entities.

Condition	Procedure	Benefits Beyond Symptoms	Adverse Events
OCD	DBS	Improvement of mood and anxiety, enhanced motivation, reduction of depressive symptoms	Fatigue, cognitive complaints, hypomania, "obsession with the device" (ITP target)
TRD	DBS	Significant functional recovery, sustained quality of life improvement (up to 9 years), enhanced motivation and anhedonia relief	Transient agitation, anxiety, hypomania, surgical risks (haemorrhage, infection), device-related events (electrode or extension break or dislodgement)
	VNS	Sustained improvement in quality of life, low relapse rates, durable long-term efficacy	Voice alteration, cough, dyspnoea, dysphagia, hoarseness

Health, well-being & public policy

Beyond its immediate health advantages, psychiatric neurosurgery facilitates patients' participation in aspects of life previously inaccessible. In addition to enhancing mental well-being, these interventions contribute to psychological health by fostering stronger relationships and elevating productivity. This impact is significant not only for the individual but also for the broader community.

Employment and professional reintegration

Individuals with mental health conditions exhibit significantly higher unemployment rates compared to the general population [42]. Comparative analyses demonstrate a strong correlation between psychological well-being and labor market participation, showing that better mental health status is a relevant predictor of stable employment and workspace productivity [43,44]. Moreover, this relationship is bidirectional: while mental stability facilitates professional activity, employment itself serves as a therapeutic agent. Financial stability fosters independence, while the cognitive and social engagement derived from job satisfaction contributes to the long-term sustainability of treatment outcomes [45]. Although direct evidence specifically linking psychiatric neurosurgery to increased employment rates remains limited, the substantial clinical improvements observed post-surgery suggest a promising trajectory. Given that psychological recovery is a well-established driver of professional reintegration, this connection warrants further empirical investigation to quantify the socioeconomic benefits of surgical intervention.

Cost-effectiveness

While the upfront cost of a neurosurgical procedure is significantly higher than that of individual pharmacological doses or psychiatric consultations, a long-term economic perspective reveals a compelling advantage. Conventional management of treatment-resistant disorders often entails a high frequency of hospitalizations, complex pharmacotherapy, and extensive social support systems. Over time, these cumulative expenses frequently surpass the one-time investment required for surgical intervention. Although large-scale economic evaluations within the psychiatric field are still emerging, valuable insights can be drawn from the well-established use of DBS in neurology. For instance, studies on advanced Parkinson’s disease have demonstrated that DBS can be more cost-effective than Best Medical Treatment (BMT) over a lifetime horizon, primarily due to the reduction in medication dependency and nursing care requirements [46]. Applying this logic to mental health, initial evidence specifically regarding treatment-resistant depression suggests a similar trajectory. Recent findings indicate that DBS with a rechargeable device (DBS-rs) may offer superior cost-effectiveness compared to standard care. By achieving more stable clinical remission, the procedure reduces the long-term socioeconomic burden associated with chronic disability and intensive healthcare utilization. These findings suggest that for pharmacologically refractory cases, early surgical intervention may not only be a clinical necessity but also a fiscally responsible strategy for healthcare systems [47].

Social dynamics and interpersonal relationships

Patients experiencing chronic mental health conditions frequently encounter substantial difficulties in establishing and sustaining stable interpersonal relationships. This challenge is primarily attributable to impaired communication patterns, which hinder mutual understanding between the patient and others. Additionally, the widespread social stigma associated with mental illness often results in social isolation and discrimination, thereby creating barriers that obstruct patients' integration into their communities and the maintenance of robust social networks vital for recovery [48]. Enhancing the mental health of patients contributes to the development and maintenance of those social relationships, thereby facilitating the establishment of interpersonal connections [49] which are not merely a byproduct of recovery, but a primary driver of sustained mental health improvement, particularly vital for patients from lower socioeconomic backgrounds, for whom robust community and family ties often serve as the primary safety net. In such cases, surgical intervention may act as a pivotal step to break the cycle of social isolation, allowing patients to access community resources and informal support systems that are essential for long-term clinical stability [50].

Alleviating the caregiver burden

Individuals with chronic psychiatric disorders frequently suffer from a profound loss of autonomy, necessitating constant supervision and support. This caregiving role often falls upon family members, leading to what is known as caregiver burden, which is a state of chronic physical and emotional exhaustion. Research indicates that relatives of treatment-resistant patients are at a significantly higher risk of developing secondary psychiatric conditions, such as clinical depression and anxiety disorders, which exacerbates the problem of mental disorders within the family [51]. Beyond the emotional toll, there is a substantial indirect economic cost associated with caregiving. Relatives often reduce their professional hours or withdraw from the labor market entirely to provide unpaid care [52]. By restoring a patient's independence through neurosurgical intervention, the need for care is not just reduced, but often transformed. This restoration of autonomy allows caregivers to reintegrate into the workforce, thereby alleviating the financial strain on the family and reducing the long-term social welfare burden on the healthcare system. Ultimately, the success of psychiatric neurosurgery should be measured not only by the patient's clinical symptoms but also by the restoration of the entire family's quality of life.

In summary, the socioeconomic benefits of psychiatric neurosurgery predominantly derive from its capacity to disrupt the persistent cycle of chronic disability and systemic healthcare expenditures. By reallocating the clinical focus from lifelong symptom management toward the restoration of patient autonomy, these procedures offer a substantial return on investment that transcends purely medical considerations. The subsequent recovery process reduces direct financial burdens on healthcare infrastructures and enhances the social and occupational capital of patients and their families, thereby transforming a condition of ongoing dependence into one of active societal engagement.

Limits

The promising outcomes of DBS in MDD and OCD have paved the way for its potential application in other psychiatric domains, most notably treatment-resistant schizophrenia. Key anatomical targets include the nucleus accumbens (NAcc), essential for reward processing and sensory gating; its stimulation is thought to restore lateral inhibition, mitigating the 'flood of stimuli' and hallucinations characteristic of the disease. Other targets include the substantia nigra (SNpr), where stimulation aims to counteract psychosis-related hyperactivity, and the habenula (HB), which regulates dopamine release, potentially managing hyperdopaminergic states without the need for neuroleptics. Furthermore, modulating the subgenual cingulate cortex (subgenual ACC) seeks to rebalance neural networks involved in emotion processing and self-reflection, which are frequently disrupted in schizophrenic patients [53,54].

Despite reports of spectacular symptomatic remission, the procedure is associated with significant side effects. Mood-related disturbances, such as hypomania or akathisia, are frequently observed following NAcc stimulation. SNpr modulation presents a different challenge: while it may improve verbal fluency, it can simultaneously impair visuospatial memory, suggesting that the enhancement of one cognitive circuit may occur at the functional expense of another [53].

Clinical data have also highlighted the 'Functional Prosthesis' mechanism. Unlike major depression, where therapeutic effects may take weeks to manifest, schizophrenia symptoms often recur almost immediately upon cessation of stimulation. This reinforces the theory that DBS acts not as a structural cure, but as a continuous modulator that imposes a functional rhythm on dysfunctional circuits. Consequently, due to risks of apathy and personality changes, DBS remains a 'last resort' intervention, necessitating rigorous patient selection [53,54].

The necessity for such rigorous patient selection in schizophrenia highlights a major challenge within DBS therapy: the lack of a universal approach. Psychiatric disorders are characterized by immense clinical and neurobiological heterogeneity, with pathological changes often occurring simultaneously across multiple, overlapping neural networks. Consequently, the anatomical targets for stimulation must be precisely tailored to the individual, yet even such meticulous mapping cannot always preclude the occurrence of significant adverse effects.

The most often described side effects include psychiatric and behavioural side effects, such as dysarthria and ataxia, mood changes and cognitive impairment which may lead to habituation or subtle deficits in verbal fluency. The side effects also concern surgical and device-related risks. The most common complication is infection, which can affect both the head wound and the generator site in the chest. A serious, though rare event is intracranial haemorrhage, which can occur during lead insertion. Hardware problems, such as lead migration or premature battery depletion, require surgical intervention and can lead to sudden symptom recurrence [55].

Furthermore, the widespread clinical adoption of DBS is significantly hindered by a high initial economic threshold and the persistence of outdated reimbursement standards. While long-term models (15+ years) suggest that DBS is a cost-effective or even 'cost-saving' intervention, the upfront surgical and hardware costs often exceeding $40,000 remain a major deterrent. This economic barrier is particularly pronounced in OCD treatment, where high stimulation parameters lead to rapid depletion of non-rechargeable batteries (often within 1.5 years). Such frequent Implantable Pulse Generator (IPG) replacements not only increase the surgical risk for the patient but also escalate the 5-year Incremental Cost-Effectiveness Ratio (ICER) to approximately $203,202/QALY, far exceeding the traditional US willingness-to-pay threshold of $50,000/QALY. In contrast, rechargeable systems demonstrate increasing cost-effectiveness over time, yet they suffer from a lack of standardized insurance coverage. This “reimbursement gap”, often justified by the HDE (Humanitarian Device Exemption) status being erroneously equated with 'experimental' therapy, limits access to DBS primarily to high-resource settings and prevents it from becoming a first-line option for treatment-resistant populations [55,56].

The economic and accessibility barriers observed in DBS are not unique for this method. Similar systemic constraints significantly limit the clinical application of VNS. While the technical reasons for these limitations are different, ranging from hardware depletion in DBS to delayed clinical onset in VNS, both therapies face a common reimbursement issue that restricts their use.

Despite FDA approval for TRD, several critical limitations hinder the widespread clinical utility of VNS. The most prominent constraint is the latency of therapeutic response. VNS is characterized by a 'slow but sustained' antidepressant effect, with significant clinical improvement often taking months or even a year to manifest. Furthermore, optimal dosing remains a subject of debate. Earlier studies were frequently 'underdosed' with output limited to 1.0 mA, whereas recent data suggest that up to 3.0 mA is required for superior clinical outcomes. The current lack of standardized parameters for pulse width and frequency further complicates the clinical landscape, impeding the establishment of a “gold standard” for stimulation.

Finally, the invasive nature of the procedure remains a deterrent for many patients. While non-invasive transcutaneous VNS (taVNS) has emerged as an alternative, it is still in its infancy and requires further research to determine its full therapeutic potential due to modest effect sizes and a lack of large-scale RCTs. This situation is exacerbated by the Centers for Medicare & Medicaid Services (CMS) non-coverage determination from 2007, based on the statistically non-significant results of early RCTs, which creates a severe financial burden for patients further limiting the use of the therapy [9].

Discussion

The clinical utility of neurosurgical interventions is significantly impeded by the widespread stigma associated with psychiatric surgery. As evidenced by recent stakeholder surveys, immediate affective responses to procedures such as DBS and Ablative Brain Interventions (ABIs) are markedly more negative relative to non-invasive alternatives like repetitive Transcranial Magnetic Stimulation (rTMS). This divergence indicates that the perceived invasiveness of a procedure constitutes not merely a medical risk factor but also a psychological barrier rooted in historical misconceptions. The stigma surrounding these interventions creates a significant knowledge gap, where patients remain unaware of the high efficacy rates and modern safety profiles of current neuromodulatory techniques. Because these misconceptions are fueled by strong emotional reactions rather than objective data, they are notoriously difficult to correct through standard clinical counseling. Consequently, this stigma-driven avoidance leads to a tragic clinical paradox: patients suffering from the most severe, treatment-resistant forms of mental illness are often the ones most likely to decline the very interventions that could offer them remission. Furthermore, the shared stigma between Electroconvulsive Therapy (ECT) and neurosurgical procedures suggests that any treatment perceived as altering the brain directly is viewed with a higher degree of suspicion than pharmacotherapy [57]. This cultural bias not only prevents patients from accessing beneficial treatments but also perpetuates poor mental health outcomes and chronic disability. To mitigate this, healthcare systems must prioritize educational transparency and address the emotional roots of stigma, ensuring that the decision for or against surgical intervention is based on clinical necessity rather than historical prejudice.

The clinical urgency to overcome these social barriers is further underscored by the limitations of the current therapeutic gold standard: pharmacotherapy. A significant proportion of patients undergoing conventional pharmacological and behavioral interventions fail to achieve sustained clinical remission or experience frequent relapses. The prevalence of treatment-resistant mental illnesses remains high, with rates reaching up to 30% across various diagnoses [58,59]. Regrettably, the prognosis for these refractory disorders is often poor, imposing a profound emotional burden on patients and their families. In many cases, prolonged pharmacotherapy is either ineffective or becomes intolerable due to a severe side-effect profile. Despite advancements in psychopharmacology, modern medications continue to be associated with debilitating adverse effects that affect medication adherence in patients [60]. Antipsychotics often lead to metabolic syndrome, significant weight gain, and permanent movement disorders such as tardive dyskinesia, while chronic antidepressant use can result in emotional blunting, sexual dysfunction, and persistent cognitive impairment [61]. For patients trapped in therapeutic impasse, where the burden of medication outweighs its benefits or fails to yield clinical improvement, neurosurgical intervention may represent the only viable path forward. In such instances, surgery may no longer be an alternative, but a critical last resort aimed at restoring a quality of life that conventional medicine cannot provide.

This therapeutic shift is fundamentally justified by the superior spatial selectivity of neurosurgical interventions compared to traditional pharmacotherapy. Unlike systemic medications, which circulate throughout the entire body and often induce a wide range of off-target side effects, surgical procedures remain strictly localized to the intended neural site. The rapid evolution of advanced neuroimaging modalities, such as functional MRI and Diffusion Tensor Imaging (DTI), has fundamentally revolutionized the planning and execution of these interventions. These tools enable clinicians to map individual functional brain regions and white matter connectivity with high fidelity [62,63]. Consequently, modern psychiatric neurosurgery can directly target dysfunctional neural circuits with pinpoint accuracy, significantly increasing the specificity of the treatment while safeguarding healthy neural tissue and preserving essential cognitive and emotional functions.

Building upon the limitations of chronic pharmacotherapy, the clinical discussion must also address the systemic and methodological landscape of neurosurgical alternatives. The legal status and accessibility of psychiatric neurosurgery differ considerably across international contexts. These procedures are often governed by stringent regulations influenced by local health policies and bioethical standards, with some jurisdictions imposing partial or complete prohibitions [64]. Beyond legal constraints, economic factors constitute a primary limitation. In nations where social insurance schemes do not cover these interventions, the out-of-pocket expenses become prohibitively high for the average patient [65]. This financial barrier is further compounded by a scarcity of specialized practitioners and a limited number of certified treatment centers, thereby contributing to the marginalization of neurosurgery as a feasible therapeutic modality. Additionally, the intricate nature of neuropsychiatric interventions necessitates not only precise surgical techniques but also sustained, intensive neuropsychological rehabilitation during the postoperative period. The absence of comprehensive systemic frameworks to support such multifaceted care critically impedes the advancement and diffusion of contemporary neuromodulation therapies. The limited availability of psychiatric neurosurgery is evident in the current clinical research landscape. Despite significant academic interest, the literature is marked by small cohort sizes and a lack of large-scale, randomized controlled trials. This scarcity of high-level evidence stems from profound ethical and practical constraints. For instance, implementing 'sham' surgeries as placebo controls raises significant bioethical dilemmas. Furthermore, the rigorous selection criteria for these invasive interventions inherently limit the patient pool, resulting in small sample sizes. These methodological hurdles impede the standardization of global clinical guidelines, unlike the more established pharmacological protocols. To overcome these barriers, future research must prioritize multicenter collaborations and long-term observational registries, which are essential for generating robust longitudinal data to solidify neurosurgery's position within the psychiatric therapeutic hierarchy.

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