Neurosurgery

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Systematic review

Comparison of neuropsychological side effects between contemporary radiofrequency ablative neurosurgery for psychiatric disorders and conventional neurosurgical procedures: systematic review and meta-analysis

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ABSTRACT

Background Psychiatric disorders are increasingly contributing to global disability. Despite advances in conservative management, the prevalence of treatment-resistant cases remains high. Meanwhile, neurosurgery for psychiatric disorders (NPD) remains underused, largely due to strict regulations and historical concerns, particularly those related to neuropsychological side effects (NPSE).

Objective To address this issue, we conducted a systematic review with meta-analysis to compare NPSE associated with radiofrequency ablative NPD to those observed in neuro-oncological, neurovascular and epilepsy surgeries.

Methods PubMed, Embase and LILACS databases were searched in April 2024 for articles published in English/Spanish from 1990 to 2022, following Preferred Reporting Items for Systematic Reviews and Meta-analyses guidelines.

Results A total of 48 articles with 2678 participants were included. The frequency of transient and permanent NPSE in the NPD group ranged from 0.94% to 11.50% and 0.94% to 2.03%, respectively, comparable to the other surgical groups (epilepsy: 0.31–11.70%; vascular: 0.52–22.90%; oncology: 0.94–17.60% for transient NPSE; epilepsy: 0.31–12%; vascular: 0.40–1.96% and oncology: 0.84–1.48% for permanent NPSE). Regarding permanent NPSE, arguably the most critical consideration, the NPD group showed better outcomes in memory, language and social cognition than the epilepsy group, but worse outcomes in executive and perceptual-motor functions. Compared with the vascular group, the

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Restrictions on neurosurgery for psychiatric disorders (NPD) arise from several factors. Among them, concerns about neuropsychological side effects (NPSE) are, if not the most important, certainly one of the most significant barriers to the broader use of these procedures. However, such concerns are largely based on older literature and outdated surgical techniques. To address this issue, we conducted a systematic review and meta-analysis comparing the NPSE of contemporary radiofrequency ablative NPD with those associated with three conventional neurosurgical procedures routinely performed worldwide.

WHAT THIS STUDY ADDS

⇒ Our findings suggest that the NPSE associated with NPD are comparable to, or even lower than, those observed in epilepsy, neurovascular and neuro-oncological surgeries.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Taken together, these results suggest that concerns regarding NPSE in contemporary NPD may be exaggerated and most probably should not constitute a major barrier to the use of these already underused interventions.

NPD group had better executive function but worse complex attention. Finally, the NPD group had fewer permanent deficits than the oncology group in executive function, complex attention and perceptual-motor domains, although language performance was lower.

Conclusions Contemporary NPD apparently carries a similar risk of NPSE as other conventional neurosurgical procedures, challenging misconceptions and this unjustified barrier to its broader use.

INTRODUCTION

Psychiatric disorders are increasingly contributing to disability on a global scale, ranking seventh in the most recent Global Burden of Diseases, Injuries and Risk Factors Study published in 2019.[1] Between 1990 and 2019, there was a 48% surge in the number of patients afflicted by psychiatric disorders, with 80% of cases occurring among individuals in the economically productive age range of 16–60 years. This trend resulted in a staggering global estimated cost of US$4.7 trillion in 2019.[2] Importantly, treatment continues to present significant challenges. Despite advancements in modern psychopharmacotherapy and psychotherapeutic approaches and the integration of other therapeutic modalities such as transcranial magnetic stimulation, electroconvulsive therapy and light therapy, a substantial portion of patients remains treatment-resistant. Approximately 20–60% of patients with major depression, 20–40% with obsessive-compulsive disorder and 20–60% with schizophrenia fall into this category.[3–8]

For patients who prove refractory to optimal conservative management, surgical intervention may become necessary as a last resort.[9–11] However, neurosurgery for psychiatric disorders (NPD) is presently underused. Several factors contribute to this phenomenon: the majority of psychiatrists and psychologists, who are primarily responsible for managing these patients, frequently do not engage in the surgical treatment of refractory cases; stringent criteria for surgical candidacy, which are undoubtedly essential, must be adhered to rigorously[10 11]; and the restrictions imposed on NPD.

Restrictions on NPD stem from several factors: the perceived risk of abuse, a misconceived notion regarding the appropriateness of surgical intervention for patients with a 'normal' brain and the concern over neuropsychological side effects (NPSE).

The 'old' psychosurgical procedures, encompassing different techniques of prefrontal leucotomy and conducted predominantly prior to the clinical introduction of stereotactic techniques, were associated with significant mortality and morbidity.[10] Regrettably, the legacy of these outdated techniques continues to shape both societal perceptions and the views of many psychiatrists and psychologists. Concerns about severe NPSE, though largely associated with these antique techniques, remain a key barrier to the wider acceptance of contemporary NPD. Numerous reviews and empirical studies have shown that the current underutilisation of NPD is not solely due to a lack of evidence or logistical challenges, but is also strongly influenced by persistent stigma associated with historical practices such as prefrontal lobotomy.[12 13] This concern is fuelled by well-known historical cases, such as that of Rosemary Kennedy, who suffered severe side effects following a prefrontal leucotomy; by iconic films like *Suddenly, Last Summer* and *One Flew Over the Cuckoo's Nest*[10]; and, more recently, by the Netflix series *Ratched* and Robin Cook's medical thriller *Bellevue* (2024).

Understanding the factors responsible for the underutilisation of NPD is crucial. Systematically addressing these factors is essential for advancing this field of functional neurosurgery. Given the above-mentioned context, in this study, we specifically investigated one such factor: the exaggerated concern regarding NPSE, which is, if not the most important, at least one of the most relevant factors hampering the utilisation of NPD. We conducted a systematic review and meta-analysis to compare the NPSE of NPD with those associated with established 'conventional' neurosurgical interventions, which are routinely performed in neurosurgical services worldwide.

This study is supported by the Task Force of Neurosurgery for Psychiatric Disorders of the World Society for Stereotactic and Functional Neurosurgery, composed of functional neurosurgeons, psychiatrists, neurologists, psychologists and neuroethicists, and by the Stereotactic and Functional Neurosurgery Committee of the World Federation of Neurological Surgeons.

METHODS

Search strategy and data extraction

A systematic review was conducted on PubMed, Embase and LILACS databases on 8 April 2024, in accordance with the Cochrane Collaboration's Recommendations and the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA). The timeframe was limited to 1990–2022 to ensure the exclusion of outdated psychosurgery studies and to capture recent and precise data coinciding with the widespread adoption of MRI for neurosurgical planning in psychiatric disorders. The search strategy employed the following terms: (neuropsychology OR neuropsychological profile OR psychological symptoms) AND neurosurgery. The review protocol was registered in the International Prospective Register of Systematic Reviews—PROSPERO (registration number CRD42024517130) on 23 Feb 2024.

The results from each database search were exported to Zotero 6.0 (George Mason University, 2020) for deduplication and initial categorisation into four main groups: NPD, vascular neurosurgery, oncology neurosurgery and epilepsy surgery. Initial screening of these categories was conducted by the authors based on title and abstract, followed by a full-text review of selected articles meeting inclusion criteria. Additionally, reference lists of selected articles were manually searched to include relevant studies not captured in the initial search. Data extraction was performed independently by five investigators (MAB, ALF, SS and AJZ) using predefined search criteria and quality assessment.

To avoid double-counting, all studies were examined for potential cohort overlap by comparing recruitment periods, participating centres, authorship patterns, sample characteristics and surgical indications.

Data extraction (10 April 2024) included article title, publication year, study type, sample size, demographics, diagnosis, brain lesion localisation, surgical procedure type, preoperative and postoperative neuropsychological assessments, and follow-up duration. All data were recorded in an Excel table and exported to Jamovi and SPSS V.22.0 software for meta-analysis.

Eligibility criteria

Studies included in this review met the following criteria: (1) articles published in English or Spanish; (2) studies examining cognitive, behavioural and emotional outcomes of NPD, brain tumours, neurovascular diseases and epilepsy; (3) neuropsychological assessments conducted using validated tests before and after surgery; (4) for epilepsy studies, only resective or ablative techniques were considered; (5) stereotactic surgery using radiofrequency (RF) ablation; (6) utilisation of MRI for surgical planning in NPD and (7) full-text availability.

Exclusion criteria were as follows: (1) neurovascular diseases presenting with subarachnoid or intracerebral haemorrhage; (2) extra-axial intracranial tumours; (3) surgical treatments involving deep brain stimulation (DBS) or other neuromodulatory techniques; (4) stereotactic surgery using radiosurgery, focused ultrasound or laser for ablation; (5) case series with fewer than 10 patients; (6) incomplete data; (7) articles focusing on ethics, letters, animal studies, book chapters, case reports and conference abstracts; and (8) unavailable articles.

For the four neurosurgical groups (NPD, vascular neurosurgery, oncology neurosurgery and epilepsy surgery), case series, case–control studies, cohort studies and randomised controlled trials were included.

Postoperative neuropsychological impairments

Neuropsychological evaluations assessed various functions, with results standardised according to the six main cognitive domains defined by the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-V): executive function, complex attention, memory, language, perceptual-motor control and social cognition (online supplemental table 1).[14] Two experts, a neurologist (BPD) and a neuropsychologist (NOT), independently categorised reported impairments into these domains, reaching consensus in each case (online supplemental table 2).

Postoperative impairments were classified as transient or permanent. In cases where studies did not explicitly classify changes, criteria were applied based on the timing and persistence of impairments: (1) in studies providing a single postoperative evaluation, the impairments observed were reported as permanent or transient if the assessment was performed ≥6 months or <6 months after surgery, respectively [15]; (2) in studies with multiple postoperative assessments, if an impairment was present exclusively in the last follow-up evaluation, it was operationally categorised as permanent; (3) similarly, if an impairment presented with the same frequency in the first and last postoperative assessments (≥6 months), it was classified exclusively as permanent.

Endpoints

The primary endpoints of this study were the impairment of neuropsychological functions that were previously normal or the exacerbation of pre-existing neuropsychological deficits after surgery. Due to the utilisation of diverse assessment scales by various authors to measure the presence and severity of these deficits, cross-study quantitative comparisons were not feasible. Consequently, we chose to categorise the outcomes qualitatively as either impaired or unimpaired. The categorisation of impaired was based on the presence of a statistically significant change from the preoperative to the postoperative score, regardless of the absolute test score.

Secondary endpoints included psychiatric, neurological and general complications.

Quality assessment of selected articles

Methodological quality assessment used the Newcastle-Ottawa Scale (NOS) assessment tool (online supplemental table 3).[16] Disagreements were resolved through discussion or consultation with the principal investigator (OV-F).

Statistical analysis

All statistical analyses were performed using Jamovi (V.2.6.45) and SPSS for Windows (V.22.0; IBM Corp). Each patient contributed a single data point, with no overlapping populations counted across studies. Follow-up assessments were conducted at three time points: preoperative baseline, 6 months postsurgery and the last available follow-up.

Pooled event rates of postoperative neuropsychological impairments were estimated using a random-effects model, without applying additional data transformations. CIs for proportions were those generated by Jamovi. Between-study heterogeneity was assessed using the I^2 statistic, with substantial heterogeneity defined as $I^2 > 50\%$. Detailed parameters of the meta-analysis are described in online supplemental files 5–9.

Group-level comparisons were conducted using a two-sided χ^2 test across all four surgical categories, followed by pairwise comparisons of the NPD group with each comparator group. Statistical significance was defined as $p<0.05$ (two-sided), and p values are reported as exact values where applicable.

Descriptive statistics are presented as means±SD for continuous variables, and as absolute numbers with corresponding percentages for categorical variables. For studies that reported only medians and ranges, means and SDs were estimated using the method proposed by Hozo *et al*.[17] The quantitative analysis was conducted separately for the six domains of the DSM-V and psychiatric symptoms, each classified as either transient or permanent.

Subgroup sensitivity analysis

Because two epilepsy studies included exclusively paediatric patients, whose neuropsychological development and normative expectations differ substantially from those of adults, we performed a subgroup and sensitivity analysis.

RESULTS

Our search strategy yielded 10 061 results, as illustrated in figure 1. Following title and abstract screening and removal of unrelated and duplicate studies, 116 articles underwent full review. Among these, 68 articles were excluded for not meeting the inclusion criteria (online supplemental material 1). The remaining 48 articles, listed in table 1, were included in our study for pooled analysis.[18–65] Careful scrutiny of these articles, considering recruitment periods, participating centres, authorship patterns, sample characteristics and surgical indications, revealed no evidence of cohort overlap among the studies.

The collective population across these studies comprised 2678 individuals. Among them, 941 patients underwent epilepsy surgery (35.4%), 742 were operated on for brain tumours (27.71%), 701 for vascular brain diseases (26.17%) and 294 for refractory psychiatric disorders (10.98%) (online supplemental tables 9–11). Predominantly, brain tumours were situated in the frontal and temporal lobes (exclusively frontal lobe=37%; exclusively temporal lobe=17%), paralleling the locations of most epilepsy surgeries (exclusively frontal lobe=19%; exclusively temporal lobe=62.9%), performed predominantly in the same brain lobes (online supplemental tables 10 and 11). Additionally, 84.3% of neurovascular diseases constituted brain aneurysms, suggesting the need for manipulation of frontal and temporal lobes during surgical intervention (online supplemental tables 12 and 13). Considering the data available (not present in all studies), age distribution ranged from 4 years to over 90 years (mean±SD: 42.69±8.59), with 51.72% of patients being male. Transient and permanent neuropsychological changes were grouped into six main domains, as previously outlined. The pooled proportions of postoperative transient and permanent neuropsychological impairments across surgical groups are presented in table 2. Notably, frequencies of transient and permanent impairments ranged from 0.94% to 11.50% and from 0.94% to 2.03%, respectively, in the NPD group, showing comparable trends to the other surgical groups (table 2: transient impairments: epilepsy=0.31−11.70%, vascular=0.52−22.90% and oncology=0.94−17.60%; permanent impairments: epilepsy=0.31−12%, vascular=0.40−1.96% and oncology=0.84−1.48%).

Paired comparisons between the NPD group and the other surgical groups regarding transient and permanent neuropsychological impairments in each domain are detailed in tables 3 and 4, respectively.

Transient impairments in memory, language and social cognition domains were significantly lower in the NPD group[18–27] compared to the epilepsy group[28–39] (table 3). Similarly, compared with the vascular group, [40–49] the NPD group exhibited superior outcomes in all domains except language. Lastly, in comparison to the oncology group,[50–65] the NPD group demonstrated fewer transient impairments in executive function, memory, language and perceptual-motor control.

Regarding permanent impairments (table 4), the NPD group[18–27] showed favourable outcomes in memory, language and social cognition domains compared with the epilepsy group,[28–39] but unfavourable outcomes in executive and perceptual-motor functions. Compared to the vascular group,[40–49] the NPD group displayed better executive function but worse complex attention. Similarly, the NPD group had fewer permanent deficits in executive function, complex attention and perceptual-motor

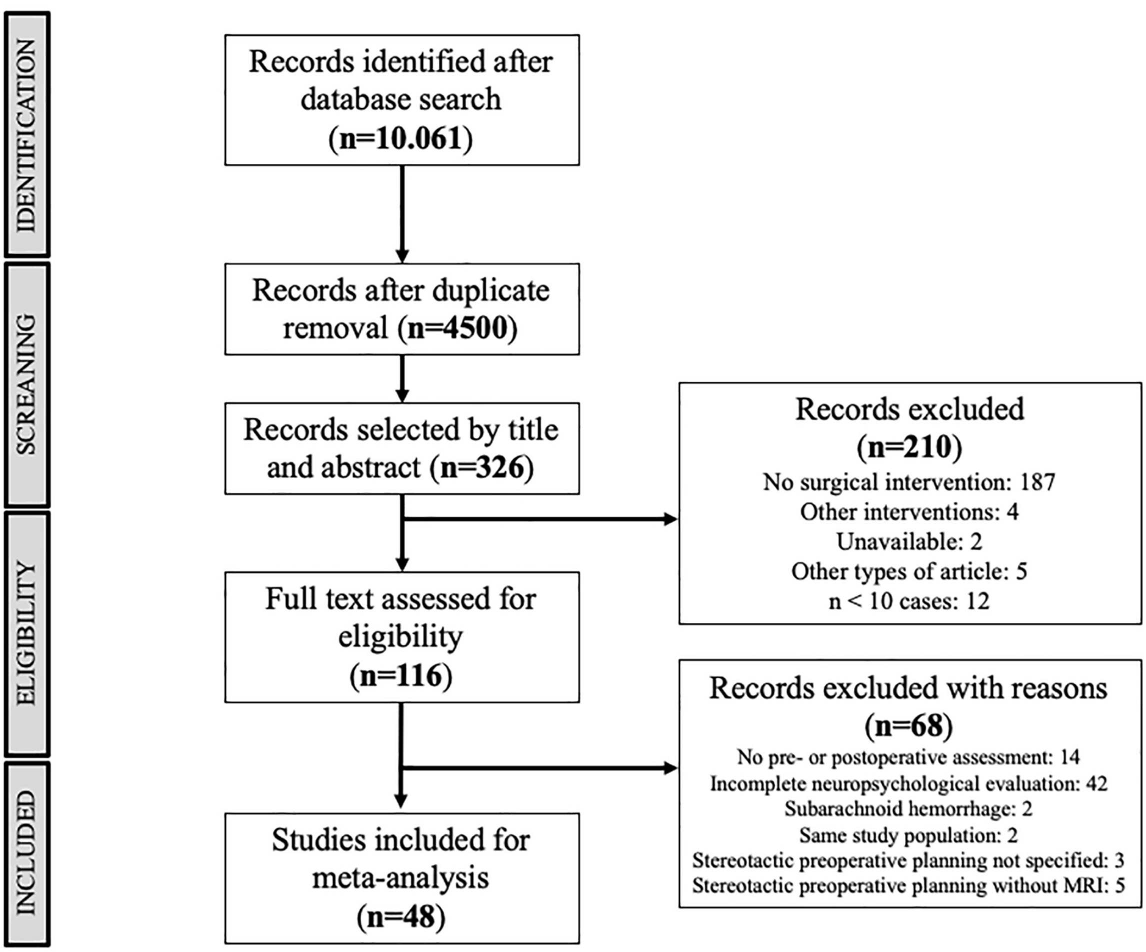

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-analyses flow diagram of study screening and selection. The search strategy in PubMed, Embase and LILACS yielded 10 061 studies, of which 116 were fully reviewed for inclusion and exclusion criteria. 48 of these studies were included in the meta-analysis.

Table 1 Baseline characteristics of included studies

Articles	N	Age	Sex (M/F)	Type of study
Neurosurgery for psychiatric disorders				
Kim *et al*[18]	14	36.10	10/4	Prospective cohort
Oliver *et al*[19]	15	34.20	9/6	Prospective cohort
Cho *et al*[20]	18	43.00	10/8	Prospective cohort
Liu *et al*[21]	35	29.60	22/13	Prospective cohort
Yen *et al*[22]	10	64.40	6/4	Prospective cohort
Wu *et al*[23]	12	40.00	12/0	Prospective cohort
Christmas *et al*[24]	20	40.40	5/15	Prospective cohort
Li *et al*[25]	93	36.90	90/3	Prospective cohort
Yang *et al*[26]	65	NA	62/3	Prospective cohort
Krámská *et al*[27]	12	39.70	7/5	Prospective cohort
Epilepsy surgery				
Hill *et al*[28]	47	37.25	16/31	Prospective cohort
Passamonti *et al*[29]	26	40.00	NA	Retrospective cohort
Boucher *et al*[30]	18	35.00	8/10	Retrospective cohort
Boucher *et al*[31]	29	32.65	14/15	Retrospective cohort
Ljunggren *et al*[32]	30	31.90	19/11	Prospective cohort
Thompson *et al*[33]	55	54.00	24/31	Retrospective cohort
Vermeulen *et al*[34]	199	40.00	93/106	Retrospective cohort
Bremm *et al*[35]	303	32.85	157/146	Retrospective cohort
Sveikata *et al*[36]	63	31.80	35/28	Retrospective cohort
Veersema *et al*[37]	42	4.50	24/18	Retrospective cohort
Ferguson *et al*[38]	41	10.00	25/16	Prospective cohort
Tyrlíková *et al*[39]	88	31.00	51/37	Prospective cohort
Vascular neurosurgery				
Stabell and Nornes[40]	31	33.00	15/16	Prospective cohort
Chyatte and Porterfield[41]	366	55.00	89/277	Retrospective cohort
Tuffiash *et al*[42]	25	49.80	4/21	Prospective cohort
Otawara *et al*[43]	44	56.80	17/27	Prospective cohort
Kubo *et al*[44]	28	71.60	5/23	Prospective cohort
Pereira-Filho *et al*[45]	40	53.20	7/33	Prospective cohort
Preiss *et al*[46]	33	44.20	13/20	Prospective cohort
Bründl *et al*[47]	50	53.40	14/36	Prospective cohort
Caveney *et al*[48]	74	40.40	29/45	Prospective cohort
Dammann *et al*[49]	10	57.90	4/6	Retrospective cohort
Oncological neurosurgery				
Talacchi *et al*[50]	29	NA	18/11	Prospective cohort
Wu *et al*[51]	66	38.00	40/26	Prospective cohort
Santini *et al*[52]	22	NA	10/12	Prospective cohort
Habets *et al*[53]	62	60.60	38/24	Prospective cohort
Satoer *et al*[54]	45	39.09	28/17	Case–control
Campanella *et al*[55]	66	49.90	NA	Prospective cohort
Noll *et al*[56]	64	51.16	32/32	Prospective cohort
Racine *et al*[57]	22	39.80	9/13	Prospective cohort
Campanella *et al*[58]	25	45.92	9/16	Prospective cohort
Arbula *et al*[59]	37	55.35	27/10	Prospective cohort
Campanella *et al*[60]	50	40.02	23/27	Prospective cohort
Dallabona *et al*[61]	30	59.30	19/11	Prospective cohort
Sierpowska *et al*[62]	12	44.00	9/3	Prospective cohort
Hendriks *et al*[63]	59	39.00	34/25	Prospective cohort
Bonifazi *et al*[64]	19	49.00	11/8	Prospective cohort
van Kessel *et al*[65]	134	NA	NA	Retrospective cohort

Age is expressed in years.
F, female; M, male; N, number of subjects; NA, not available.

domains than the oncology group,[50–65] although performance in the language domain was inferior.

The vascular and NPD groups exhibited the highest rates of transient and permanent psychiatric complications, respectively (11.20% and 2.55%). Notably, the NPD group demonstrated significantly better outcomes than the vascular group for transient complications (p=0.000), but worse outcomes than the epilepsy (p=0.000) and oncology (p=0.019) groups. In terms of permanent complications, the NPD group presented a higher rate than the epilepsy group (p=0.025), but similar rates compared with the vascular (p=0.964) and oncology (p=0.638) surgical groups.

Several studies did not report general and neurological complications,[28 32 33 35 37 38 47 52 54 56 60–62 64] while others excluded patients with severe complications to prevent interference with neuropsychological evaluations.[31 43 44 46 53 55 58 59 65] Consequently, determining the frequency of these complications was not feasible, and further investigation was not pursued.

Subgroup sensitivity analysis

Within the epilepsy group, two studies exclusively enrolled paediatric patients (n=83), whereas the remaining 10 involved adult patients (n=868). Among adults, pooled rates of transient and permanent impairments were essentially unchanged compared with those observed in the overall epilepsy group. In contrast, the paediatric subgroup exhibited higher proportions of permanent impairments in several domains, including executive function, 12.0%; memory, 12.0%; language, 7.2%; perceptual-motor, 14.5% and social cognition, 6.0%, while no transient impairments were reported. Given the small paediatric sample size and the likely wide CIs, these findings should be interpreted with caution and suggest that the inclusion of paediatric cohorts does not materially influence the overall analysis (online supplemental table 14).

Risk of bias

Using the Newcastle-Ottawa Scale (NOS), the methodological quality of the included studies ranged from 5 to 9 points, corresponding to moderate to high quality. Most vascular, epilepsy and oncological studies scored 6/9 or higher, whereas cohorts with neuropsychiatric disorders more frequently fell within the moderate range (5–6/9), largely due to limitations in comparability and sample size. Several studies across all indications achieved the maximum score of 9/9. Detailed NOS scores for each study are provided in online supplemental table 3. These differences in methodological quality were considered in the interpretation of the pooled impairment rates.

DISCUSSION

This systematic review compares neuropsychological impairments following neurosurgery for oncological, neurovascular and epileptic disorders with those associated with NPD. Our analysis suggests that NPD generally has a significantly lower impact on neuropsychological performance compared with other surgical groups, whether considering transient or permanent impairments, although methodological differences and indirect comparisons warrant cautious interpretation (tables 3 and 4).

In this study, we excluded case reports and small case series (n<10) to reduce bias and increase generalisability. This review focused on open and lesion/resective surgeries, specifically comparing NPD with epilepsy, vascular and oncology surgeries. Epilepsy surgeries were selected due to their involvement with limbic structures, particularly the temporal and frontal lobes, and their elective nature, analogous to NPD.[28–39] Similarly, we selected vascular [40–49] and oncology [50–65] surgeries for comparable reasons: the majority of tumours were situated in the frontal

Table 2 Demographics and pooled proportions by group of surgery and domain of transient and permanent postoperative neuropsychological impairments

	Surgical groups	NPD	Epilepsy	Vascular	Oncological
Demographics	Number of studies	10	12	10	16
	Number of patients	294	941	701	742
	Age (available)	40.54±9.75	31.75±13.11	51.53±10.61	47.01±7.93
	Sex (available)	233 M/61 F	466 M/449 F	197 M/504 F	307 M/235 F
Transient impairments	Executive function	3.56%	0.31%	22.90%	15.70%
	Memory	3.56%	11.70%	21.30%	17.60%
	Complex attention	11.50%	0.31%	20.30%	4.82%
	Language	0.94%	3.32%	0.52%	14.00%
	Perceptual-motor	0.94%	0.31%	16.20%	0.95%
	Social cognition	1.78%	5.11%	13.20%	0.94%
Permanent impairments	Executive function	0.94%	0.37%	1.96%	1.21%
	Memory	2.03%	12.00%	0.57%	1.48%
	Complex attention	0.97%	0.31%	0.40%	1.46%
	Language	0.94%	7.49%	0.52%	0.89%
	Perceptual-motor	0.94%	0.33%	0.42%	1.25%
	Social cognition	1.86%	4.15%	1.11%	0.84%

and temporal lobes, and vascular surgeries often entail manipulation of the same regions. However, patients with subarachnoid or intracerebral haemorrhages were excluded from the vascular group, as haemorrhage itself could impact neuropsychological outcomes. Furthermore, considering the comprehensive preoperative neuropsychological evaluation conducted in every case, it is reasonable to assume that these surgeries were elective as well.

In the NPD group, only patients treated with RF ablation were included, as magnetic resonance-guided focused ultrasound (MRgFU) and radiosurgery are incisionless procedures, and the use of MRI-guided laser interstitial thermal therapy for psychiatric disorders remains highly limited. Furthermore, radiosurgery for psychiatric disorders is restricted to a few centres, and MRgFU for this purpose is still experimental. DBS studies were excluded because this technique does not involve tissue ablation. Our study focused on RF ablation for several reasons: it is the most widely available, extensively studied and cost-effective option compared with the other techniques.

Comparing surgery for life-threatening diseases like tumours and aneurysms, where NPSE are secondary concerns, with NPD, aimed at symptom and quality of life improvement, could be seen as potentially misleading. We selected these 'conventional' neurosurgeries for comparison because they are accepted practices and widely performed globally, frequently involving brain regions related to cognition, emotion and behaviour. Additionally, the widespread use of these surgeries allows for observation of NPSE by a large number of health professionals across disciplines. Moreover, our study exclusively focused on comparing the NPSE of these surgeries, for which purpose the life-threatening aspect of the disease or surgical intent is irrelevant.

Another aspect that may be debated is the fact that we did not compare NPD with other stereotactic ablative procedures, such as those for movement disorders or pain. Although the goal of all these surgeries is to minimise symptoms and improve quality of life, the latter target primarily motor or sensory and not limbic or cognitive circuits.

Neuropsychological evaluations across studies varied in scales and domains, making a quantitative analysis impossible. Consequently, we used qualitative classifications (impaired or not impaired) to assess the frequency of impairments. The categorisation of impaired was based on the presence of a statistically significant change from the preoperative to the postoperative score, regardless of the absolute test score. This approach enabled the comparison of surgeries but limited the ability to evaluate the intensity of postoperative cognitive alterations. Nonetheless, to our knowledge, our study was the first to objectively compare the neuropsychological risk among these surgical groups.

A potential confounder in the results could be the psychotropic medications taken by patients at the time of testing. However, this information was unavailable in most studies. It is intuitive that the NPD group might require higher doses of medications with cognitive effects, which could further impact the results. If medications do introduce additional bias, it would likely be to the disadvantage of the NPD group; however, this remains speculative. Another potential confounder is the disease severity, which could influence baseline test results, but by including only studies with preoperative and postoperative evaluations, our intention was to isolate the effects of surgery itself.

Table 3 Transient neuropsychological impairments: comparison between the NPD group and the other three groups

Domains	Executive function	Memory	Complex attention	Language	Perceptual-motor	Social cognition
Psychiatric versus epilepsy	p=0.000	p=0.000*	p=0.000	p=0.000*		p=0.000*
Psychiatric versus vascular	p=0.014*	p=0.038*	p=0.004*	p=0.359	p=0.000*	p=0.000*
Psychiatric versus oncological	p=0.000*	p=0.000*	p=0.115	p=0.000*	p=0.007*	p=0.019

*Statistically better results in the NPD group.
NPD, neurosurgery for psychiatric disorders.

Table 4 Permanent neuropsychological impairments: comparison between the NPD group and the other three groups

Domains	Executive function	Memory	Complex attention	Language	Perceptual-motor	Social cognition
Psychiatric versus epilepsy	p=0.024	p=0.000*	p=0.767	p=0.000*	p=0.035	p=0.025*
Psychiatric versus vascular	p=0.003*	p=0.371	p=0.029	p=0.359	p=0.147	p=0.964
Psychiatric versus oncological	p=0.004*	p=0.134	p=0.001*	p=0.022	p=0.045*	p=0.638

*Statistically better results in the NPD group.
NPD, neurosurgery for psychiatric disorders.

Another important consideration is age-related heterogeneity, particularly within the epilepsy group. Two studies included exclusively paediatric patients, whose developmental trajectories and normative neuropsychological expectations differ substantially from those of adults. Our sensitivity analysis demonstrated that excluding paediatric studies did not meaningfully shift pooled impairment rates in the epilepsy group. In fact, the paediatric subgroup exhibited higher frequencies of permanent impairments in multiple domains. Owing to the limited sample size, findings from the paediatric sample should be considered exploratory, indicating that our conclusions may not be generalisable beyond the adult population.

Notably, we found that only approximately half of the studies[18–27 29 30 34 36 39–42 45 48–51 57 63] reported general (bleeding, infection, etc) or neurological complications, including all articles on NPD,[18–27] where no permanent motor, sensory or speech impairments were reported. As a result, estimating the rate of these complications in the present study would be inaccurate. Stereotactic ablative surgery is minimally invasive, typically leading to fewer complications compared with open neurosurgical procedures.[66 67]

Psychiatric complications were observed across groups, including fatigue, depression, irritability, anxiety and hallucinations. While it was expected that the NPD group might experience more psychiatric complications, they performed significantly better than the vascular group for transient complications. Regarding permanent complications, the NPD group had rates similar to the vascular and oncology groups but higher than the epilepsy group.

Our study aimed to compare cognitive, emotional and behavioural complications following contemporary ablative surgery for psychiatric disorders with those observed after other neurosurgical procedures. Results showed that the NPD group performed better in 12 out of 17 comparisons for transient impairments (table 3) and 7 out of 18 comparisons for permanent impairments (table 4) compared with the other three groups.

The apparently comparable or even reduced impact on the neuropsychological domains of the NPD group may be attributed to several factors, including the improved accuracy of modern stereotactic apparatus; the utilisation of MRI and dedicated software for stereotactic planning; advancements in surgical technique overall; the systematic adoption of globally accepted scales to measure disease severity and its impact on disability and quality of life; judicious surgical indications; the continual refinement of functional neuroimaging studies; and a better understanding of the pathophysiology underlying psychiatric disorders, among others.

In addition to concerns about NPSE, which our study suggests may be less severe than previously believed, other factors also contribute to the underuse and restrictions of NPD. These include a lack of high-level evidence supporting NPD's effectiveness, the perceived risks of abuse reminiscent of past psychosurgical practices, misconceptions about the suitability of surgery for patients with 'normal' brains based on outdated anatomical interpretations, concerns about the increased vulnerability of psychiatric patients, leading to stringent regulatory oversight, and insufficient involvement of psychiatrists and psychologists in refractory cases. These factors will be addressed in a future study by our group.

Although functional neurosurgeons collaborate with specialists in movement disorders, epilepsy and pain, similar collaboration with psychiatrists and psychologists is limited. This is primarily due to a lack of awareness about NPD and reliance on outdated perceptions of older psychosurgical procedures. It is crucial to demystify modern NPD techniques and raise awareness among psychiatrists and psychologists about these interventions. We encourage functional neurosurgery societies to strengthen ties with psychiatric societies and incorporate NPD education into psychiatry residency programmes.

Limitations

Our study's strict selection criteria may have resulted in the exclusion of certain adverse effects, particularly due to potential under-reporting. The heterogeneity of the sample was another limitation, as it contributed to high variability in the results. Factors such as disease differences, varying assessment scales and follow-up periods made quantitative analysis challenging, and we relied on qualitative classifications (impaired vs not impaired). The baseline comparison of the different surgery groups was also a concern and was not feasible due to the heterogeneous reporting of data, as previously mentioned. While these limitations are inherent in comparing diverse neurosurgical procedures, the high heterogeneity across groups does not invalidate the fairness of our comparisons.

The study design also presents challenges for comparison, as we conducted four parallel single-arm meta-analyses using consistent methodological criteria and rigour, rather than a controlled or network meta-analysis. This approach was necessary due to the lack of controlled studies and the unavailability of individual patient data.

Study quality varied across indications and directly influences the confidence in our pooled estimates. Although many vascular, epilepsy and oncological cohorts achieved high NOS scores (8–9/9), studies across all indications more commonly fell within the moderate range (5–6/9). These methodological constraints increase susceptibility to bias and reduce the precision of impairment estimates, particularly within the NPD group, which comprised the highest proportion of studies with moderate risk of bias. Consequently, differences observed between surgical indications should be interpreted with caution, as they may reflect variations in study quality rather than true differences in neuropsychological risk.

Our study did not examine neurological and general side effects (secondary endpoints) comprehensively, as relevant data were missing from about half of the studies. Additionally, the study exclusively focused on RF. Other techniques, such as MRgFU, laser ablation, radiosurgery and DBS, may yield different outcomes.

CONCLUSIONS

This study qualitatively compared the neuropsychological complications of contemporary NPD with those from vascular, oncology and epilepsy surgeries. Our findings suggest that the risk of negative outcomes associated with NPD appears to be low and, in some domains, may be comparable to or even lower than those observed in other neurosurgical procedures. However, statistical significance is sensitive to sample size and does not necessarily equate to clinical significance. Our binary categorisation (impaired vs not impaired) reflects the presence of measurable changes, not its magnitude or functional impact. We hope this study contributes to the ongoing discussion on contemporary NPD and encourages continued, careful evaluation of these procedures as potential treatment options for patients with refractory psychiatric conditions.

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