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LITERATURE REVIEW

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Deep brain stimulation versus anterior capsulotomy for obsessive-compulsive disorder: a review of the literature

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Obsessive-compulsive disorder (OCD) is a chronic and debilitating psychiatric condition. Traditionally, anterior capsulotomy (AC) was an established procedure for treatment of patients with refractory OCD. Over recent decades, deep brain stimulation (DBS) has gained popularity. In this paper the authors review the published literature and compare the outcome of AC and DBS targeting of the area of the ventral capsule/ventral striatum (VC/VS) and nucleus accumbens (NAcc).

Patients in published cases were grouped according to whether they received AC or DBS and according to their preoperative scores on the Yale-Brown Obsessive-Compulsive Scale (YBOCS), and then separated according to outcome measures: remission (YBOCS score < 8); response (≥ 35% improvement in YBOCS score); nonresponse (< 35% improvement in YBOCS score); and unfavorable (i.e., worsening of the baseline YBOCS score).

Twenty studies were identified reporting on 170 patients; 62 patients underwent DBS of the VC/VS or the NAcc (mean age 38 years, follow-up 19 months, baseline YBOCS score of 33), and 108 patients underwent AC (mean age 36 years, follow-up 61 months, baseline YBOCS score of 30). In patients treated with DBS there was a 40% decrease in YBOCS score, compared with a 51% decrease for those who underwent AC ($p = 0.004$). Patients who underwent AC were 9% more likely to go into remission than patients treated with DBS ($p = 0.02$). No difference in complication rates was noted.

Anterior capsulotomy is an efficient procedure for refractory OCD. Deep brain stimulation in the VC/VS and NAcc area is an emerging and promising therapy. The current popularity of DBS over ablative surgery for OCD is not due to noneficacy of AC, but possibly because DBS is perceived as more acceptable by clinicians and patients.

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Obsessive-compulsive disorder (OCD) affects approximately 2% of the global population and represents one of the highest global burdens of psychiatric disability.[48] In the majority of cases OCD is managed successfully with psychiatric treatment. However, a significant minority of patients fail to improve or worsen.[10,41] Severe refractory OCD carries a vast morbidity[27] and in a few of the most severe cases neurosurgery has been performed.

Talairach in France first reported anterior capsulotomy (AC) in 1949.[46] Leksell in Sweden introduced a more refined stereotactic AC for surgical treatment of various psychiatric disorders in the early 1950s.[25] Obsessive-compulsive disorder was found to respond favorably.[20] In parallel, anterior cingulotomy for OCD was introduced in the US and popularized by Ballantine,[2] whereas AC remained relatively more prevalent in Europe and elsewhere.

However, the use of untargeted operations in nonselect psychiatric patients during the 1930s–1960s generated public and professional aversion to any ablative neuro-

ABBREVIATIONS AC = anterior capsulotomy; CBT = cognitive behavioral therapy; DBS = deep brain stimulation; ICH = intracranial hemorrhage; NAcc = nucleus accumbens; OCD = obsessive-compulsive disorder; VC/VS = ventral capsule/ventral striatum; YBOCS = Yale-Brown Obsessive-Compulsive Scale.

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surgery for psychiatric disorders. The emergence of deep brain stimulation (DBS) in the treatment of refractory motor disorders in the late 1980s paved the way to its eventual use in psychiatric illness.

Modern DBS for OCD was pioneered in 1999.[30] The initial target was the anterior limb of the internal capsule—the very target used for AC. Since then, the target for DBS in this area of the brain has evolved to encompass the ventral capsule/ventral striatum (VC/VS), including the area of the nucleus accumbens (NAcc).[9,18]

On its inception in movement disorder surgery, the chief benefit of DBS over ablative neurosurgery was that bilateral procedures in motor areas of the basal ganglia and thalamus could be performed with less risk of side effects on speech, swallowing, cognition, and balance. However, the rationale for DBS of nonmotor subcortical areas in psychiatric disorders is less clear, other than it is perceived as nonablative and assumed to be reversible and more forgiving than lesions, and therefore more acceptable. Unlike the case of DBS versus ablative surgery in movement disorders, there has been no previous comparison between outcomes of patients with OCD who received DBS in the anterior capsule area and patients who received AC treatment.

Here, the published literature on surgery of the anterior capsule for OCD is evaluated and the outcomes of patients treated with AC are compared with those of patients who underwent DBS in the areas of VC/VS and NAcc.

Methods

Publications on AC or DBS for OCD were obtained from the PubMed database, from proceedings of neurosurgical meetings, and references from relevant papers. The search criteria, used were in accordance with guidelines published in the Cochrane library.[6] PubMed was searched using a combination of optimal search strategies and the following phrase(s): surg* OR neurosurg* OR psychosurg* OR radiosurg* OR cinguloto* OR capsuloto* OR tractoto* OR leucoto* OR leukoto* OR thalamoto* OR loboto* OR radio-surg* OR radiosurg* OR stereota* OR stereo-ta* OR gamma kni* OR gamma-ra* OR deep brain stimulation OR DBS OR Neurosurgical Procedures/ AND obsessive compuls* OR obsessive-compuls* OR mood disorders OR anxiety disorders.

Included studies required details of baseline characteristics (diagnosis of OCD, neurosurgical procedure conducted, patient age, and scores on the Yale-Brown Obsessive-Compulsive Scale [YBOCS]) at surgery and outcome (minimum follow-up time of 12 months, including YBOCS score at follow-up). Whenever possible, duplicate patients were identified and removed.

Moreover, included papers were screened with respect to reported adverse events. Serious adverse events were defined as those that would contribute significantly to morbidity (infection, epilepsy, intracranial hemorrhage [ICH]) or mortality, including suicide within the first 12 months after surgery. Persisting adverse events were defined as new-onset symptoms that persisted for more than 8 weeks postsurgery. These could include headache, dizziness, nausea, sleep disturbance, apathy, disinhibition, other personality changes, and others. Whenever there was uncertainty about an adverse event (i.e., the length of time it lasted, and so on) it was included in the results.

Patients were grouped according to whether they received AC (either by Gamma Knife or radiofrequency) or DBS in the VC/VS area, including the NAcc. Patients were also placed into "severity groups" according to their preoperative YBOCS score: moderate OCD, 16–23; severe OCD, 24–31; and extreme OCD, 32–40.[15,34]

These groups were separated into outcome measures based on the Christmas criteria.[6] Remission requires that YBOCS scores drop below 8. Response is defined as 35% or more improvement in YBOCS score. Nonresponder status is assigned when remission or response criteria are not met. Worse indicates a worsening of the YBOCS score. When individual data were not available, group averages were used.

Statistical Analysis

The mean values were calculated. The Student t-test was used to compare continuous data. The Fisher exact test using a 2×2 contingency table was used to compare the outcomes and complication rates in patients who underwent AC or DBS. A p value < 0.05 was considered statistically significant.

Results

In total, 20 studies reporting on 170 patients, spanning more than a decade of publications, were identified. Of these, 10 studies included 108 patients with capsulotomy[5,7,8,17,23,26,28,32,37,41] and 10 included 62 patients who underwent DBS.[1,9,13,14,18,19,21,35,36,47]

Table 1 (AC) and Table 2 (DBS) present details of the number of patients in each study, age at surgery, length of follow-up, details of the surgical procedures, and pre- and postoperative YBOCS scores. Also the level of evidence of each surveyed study is indicated: Level I, randomized controlled trials with narrow confidence interval, or systematic review of randomized controlled trials; Level II, individual cohort studies, systematic review of cohort studies, or ecological studies; Level III, case-control studies and systematic review of case-control studies; Level IV, individual case series including poor-quality cohort and case-control studies; and Level IV, expert opinion based on "first principles" or bench science. Table 3 summarizes the baseline characteristics of both patient groups across all studies with pre- and postoperative YBOCS scores. The gender divide was similar and there was no statistical age difference between the 2 groups. However, patients who underwent DBS had significantly worse preoperative YBOCS scores and longer duration of OCD. Patients who underwent AC were followed up for longer time periods and their mean improvement in YBOCS score was 51%, compared with 40% improvement in patients who underwent DBS ($p = 0.004$).

Figure 1 shows patient outcome (remission, response, nonresponder, and worse) according to surgical modality. Sixty-two percent of patients who underwent AC experienced a clinically significant response (improvement in YBOCS score ≥ 35%) compared with 52% patients who

TABLE 1. Literature review of patients with OCD who underwent AC*

Authors & Year	No. of Patients	Mean Age (yrs)	FU (mos)	Procedure	YBOCS Preop	YBOCS Postop	Level of Evidence
Sheehan et al., 2013	4	38	26	Bilat GKS, 140–160 Gy	32	17	IV
D'Astous et al., 2013†	19	40.8	84	Bilat BL, 20 × 5–6 mm	35	24	IV
Kondziolka et al., 2011	3	37, 40, 55	42	Bilat GKS, 140–150 Gy	34, 39, 39	24, 7, 18	IV
Gouvea et al., 2010	1	34	12	Bilat GKS, 180 Gy	37	0	III
Lopes et al., 2009	5	35	48	Bilat GKS, 180 Gy	32	21	IV
Rück et al., 2008	24	41	124	Bilat GKS, 160–200 Gy Unilat & bilat RF, 12–20 mm, 60°C	34	19	IV
Liu et al., 2008†	35	30	36	Bilat RF, 70–80°C	21	4	IV
Oliver et al., 2003†	10	34	12	Bilat RF, 18 mm, 75°C	30	17	IV
Christensen et al., 2002	2	18, 64	40	Bilat RF, 65–70°C	30, 31	0, 8	IV
Csigó et al., 2010†	5	32	24	Bilat RF	38	18	III

BL = Bertrand leukotome; FU = follow-up; GKS = Gamma Knife surgery; RF = radiofrequency ablation.
* Average data are shown for studies with > 3 patients; for studies with ≤ 3 patients the data are given individually.
† Implies that group rather than individual data were used in analysis of results.

received DBS. However, this difference was not statistically significant. Eleven percent (n = 12) of patients who underwent AC went into remission (YBOCS score < 8) compared with 2% (n = 1) of patients after DBS (p = 0.02).

Figure 2 shows patient outcome in both surgical groups according to OCD severity at baseline. There were 35 patients with moderate OCD who underwent AC; of these 63% showed a clinically significant response. There were no patients with moderate OCD who underwent DBS.

Among 35 patients with severe OCD, 11 underwent DBS and 24 underwent AC. The patients who underwent AC were 50% more likely to have a clinically relevant response (including remission) compared with patients treated with DBS (p = 0.002). Ten percent (n = 2) of patients with severe OCD who underwent AC went into remission, compared with 0% of patients who underwent DBS (not significant).

One hundred patients were classified as having extreme OCD (YBOCS score of 32–40). A similar rate of clinically significant response was achieved after AC and DBS (49% vs 52%, not significant). However, 20% (n = 10) of AC patients with extreme OCD went into remission compared with 2% (n = 1) of DBS patients with extreme OCD (p = 0.006).

Adverse Events

Table 4 shows reported adverse events according to surgical procedure. There were 2 suicides and 2 symptomatic and 5 asymptomatic ICHs. One patient developed sustained hemiplegia after intracranial bleeding. There was no difference in the rate of serious adverse events between AC and DBS. Patients who underwent AC were more than 25% more likely to have clinically significant weight gain (p = 0.0002). Wound infection was 5% more common after DBS than after AC (p = 0.02). Table 5 lists details of all adverse events reported in each surveyed study.

Discussion

This literature analysis demonstrates that patients with medically intractable OCD were helped by both stereotactic AC and DBS in the VC/VS and NAcc area. Half of

TABLE 2. Literature review of patients with OCD who underwent DBS in VC/VS and NAcc*

Authors & Year	No. of Patients	Mean Age (yrs)	FU (mos)	Side	YBOCS Preop	YBOCS Postop	Level of Evidence
Greenberg et al., 2010	21	36	29	Bilat	34	21	III
Roh et al., 2012	4	34	24	Bilat	37	15	IV
Tsai et al., 2012	4	26	15	Bilat	36	24	IV
Abelson et al., 2005	2	34, 48	18	Bilat	26, 30	25, 8	III
Goodman et al., 2010	1	27	12	Bilat	34	4	III
Huff et al., 2010	10	36	12	Rt	32	25	III
Franzini et al., 2010	2	33, 41	26	Bilat	38, 30	22, 20	IV
Denys et al., 2010	14	44	21	Bilat	34	16	III
Guehl et al., 2008†	3	45, 46, 56	12	Bilat	31, 25, 25	11†	IV
Plewnia et al., 2008	1	51	12	Rt	32	24	IV

* Average data are shown for studies with > 3 patients; for studies with ≤ 3 patients the data are given individually.
† Indicates best improvement in YBOCS score reported; improvement range in YBOCS in this paper is 35%–60%.

TABLE 3. Summary of baseline characteristics in patients who underwent DBS versus AC

Characteristic	AC	DBS	p Value
No. of patients	108	62	
% Male	54	52	NS
Mean age in yrs at op (SD)	36 (12)	38 (10)	NS
Duration of OCD in yrs (SD)	17 (9)	23 (9)	<0.0001
Mean FU in mos (SD)	61 (51)	19 (9)	<0.0001
YBOCS preop (SD)	30 (7)	33 (4)	0.002
YBOCS postop (SD)	14 (11)	20 (7)	0.0002
% Improvement (SD)	51 (27)	40 (17)	0.004

NS = not significant.

those who underwent DBS and almost two-thirds of patients treated with AC were considered to have a clinically significant improvement (Fig. 1), with patients who underwent AC more likely to go into remission when compared with those treated with DBS. The frequency and profile of adverse events between both procedures was similar.

Both stereotactic ablation and DBS in the anterior capsule area appear to disrupt pathological activity mediated by white matter tracts between thalamus and orbitofrontal cortex, and between caudate and lenticular nucleus, which are thought to play a significant role in mediating OCD symptoms. Functional neuroimaging consistently reports hyperactive cortico-striato-thalamo-cortical circuits in patients with OCD.[24,49] Interestingly, this aberrant activity appears to be significantly reduced in patients successfully treated by medication,[3,45] cognitive behavioral therapy (CBT),[3,43] and neurosurgical intervention.[29] Thus, the anterior capsule area, especially its ventral aspect, is a sensible target for neurosurgery in patients who have severe and otherwise refractory OCD.

In this review we deliberately chose not to include publications in which DBS for OCD targeted areas other than the VC/VS and NAcc area. Similarly, publications on other stereotactic ablative procedures for OCD, such as cingulotomy, subcaudate tractotomy, and limbic leukotomy, were not included in this review. This is despite the fact that procedures such as cingulotomy are still in use, and long-term evaluation performed using established validated scales demonstrates sustained benefit for OCD.[42] However, it was thought that a fair comparison between the two surgical methods, ablation and stimulation for OCD, would benefit if the anatomical areas of the brain that were targeted were more or less homogeneous between the 2 procedures.

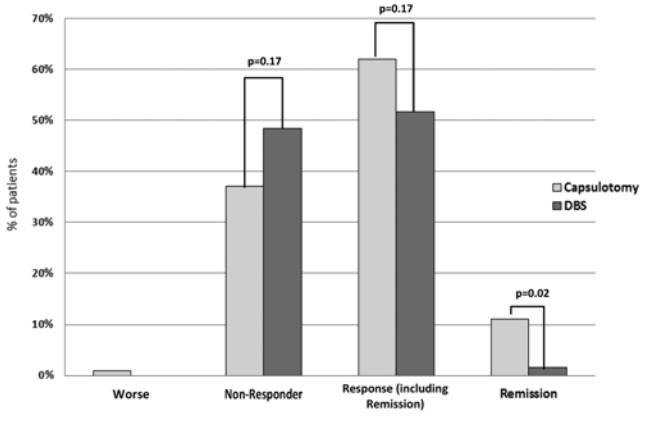


FIG. 1. Bar graph showing the outcome of patients according to surgical modality and according to the predefined 4 levels of response (remission, response, no response, and unfavorable).

Differences Between Surgical Groups

This review only considered publications with sufficiently detailed data and in which the validated YBOCS was used for patient evaluation. Therefore, the "old" literature on AC, published before the availability of modern diagnostic criteria and the availability of the YBOCS, was not taken into consideration. Nevertheless, it is not immediately apparent why AC should be more effective than DBS. In that respect there are several issues that need to be analyzed.

Patient Age at Surgery

Patients treated with DBS were on average 2 years older than those who underwent AC (Table 3), although this difference did not reach statistical significance. Whereas this disparity does not suggest vastly different age categories, it could reflect a longer duration of illness and prolonged failure of other treatments, and thus a worsening of the underlying condition. In patients with OCD treated with CBT, earlier onset of symptoms and longer duration of illness were correlated with poor long-term prognosis.[22] However, others have stated that the effect size of CBT in OCD did not alter with duration of symptoms or with age difference in adults. Interestingly, the effect size of treatment with CBT was greater in children than in adults.[31]

D'Astous and colleagues reported on 19 patients who underwent mechanical AC in Quebec.[8] The average age of patients who "responded" to treatment (defined in that study as > 25% improvement in YBOCS score) was 37.5 years (SD 12.3) compared with 44.4 years (SD 10.2) for patients who did not respond. While the so-called responder group was younger, this difference was not statistically significant. Rück et al. reported on 24 patients who underwent Gamma Knife or radiofrequency AC; 12 experienced a clinically significant response (> 35% improvement in YBOCS score) and 12 patients did not respond.[37] The mean age of responders (43 years, SD 12) was older than the nonresponders (39 years, SD 10). Once again, this difference was not statistically significant.

Extrapolating from different treatment modalities in an adult population, age does not appear to have a strong predictive value in determining outcome after treatment.

Duration of OCD

Obsessive-compulsive disorder is known to be a chronic and debilitating condition. In published cases, patients who underwent DBS had significantly longer durations of OCD presurgery than patients who underwent AC.

Huff et al. reported 10 patients who underwent DBS of the NAcc for OCD. Only 1 patient had a clinically signifi-

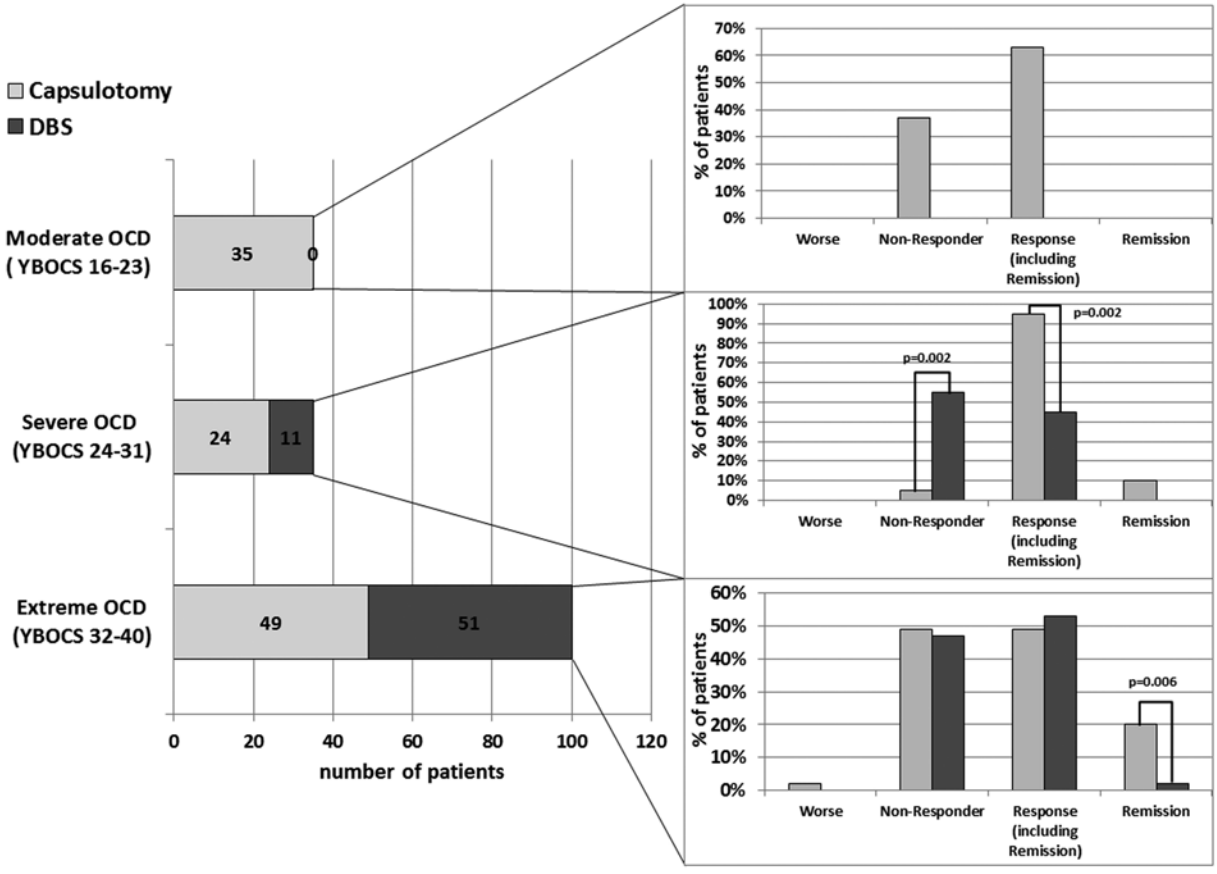


FIG. 2. Bar graphs showing the outcome of patients in both surgical arms according to severity of OCD at baseline.

TABLE 4. Adverse events by category

Adverse Events*	AC	DBS	p Value
Death (related to procedure)	0%	0%	NS
Suicide (w/in 12 mos postop)	1%	2%	NS
Symptomatic ICH	2%	0%	NS
Asymptomatic ICH	5%	3%	NS
Intracranial infection	0%	0%	NS
Residual neurological deficit at 12 mos	1%	0%	NS
Sustained endocrine change	0%	0%	NS
Epilepsy	1%	0%	NS
Persistent postop side effects	7%	5%	NS
Weight gain >10%	29%	3%	0.0002
Cognitive changes	7%	13%	NS
Personality change	6%	0%	NS
Equipment break	NA	5%	NA
Wound infection	0%	5%	0.02

NA = not applicable.

* Definitions of events: cognitive change was defined either by self-report, clinical report, or formal neuropsychological testing; epilepsy denotes > 2 seizures within 12 months or requiring antiepileptic drug therapy for > 6 weeks after surgery; persistent postoperative side effects were side effects that lasted for > 8 weeks after surgery, including headache, nausea, vomiting, insomnia, and other symptoms that were not reported as occurring before surgery; and personality change was determined by self-report, relative's report, or formal personality testing.

cant response (56% YBOCS improvement), and the duration of OCD was 34 years. This compares to an average YBOCS improvement of 18% for the remaining 9 patients, with average disease duration of 20 years. Others noted a similar trend in an ablative series.[23] Conversely, in another ablative study the average duration of OCD was 12 years for patients who had a clinically relevant response (YBOCS improvement > 25%) versus 20 years for patients who did not respond.[8]

These conflicting results from small clinical studies make it difficult to assess whether duration of OCD is a predictor of treatment outcome after neurosurgery. Moreover, without detailed clinical vignettes, it is difficult to know if chronicity represents longer periods of treatment quiescence (and hence neurosurgery would be unnecessary earlier on) or a more medically refractory OCD course.

Severity of OCD

The mean YBOCS scores at surgery were more severe in patients treated with DBS (Table 3). However, it is not entirely clear if severity has a significant impact on treatment response. In patients with OCD who underwent non-neurosurgical treatment, OCD severity did not have an impact on treatment effect with CBT.[31,38] However, lower symptom severity was associated with greater treatment response to anxiety management.[38] For patients with OCD

TABLE 5. Details of adverse events by paper*

Paper Topic & Authors	Adverse Events
AC	
Sheehan et al., 2013	No adverse events noted.
D'Astous et al., 2013	Reoperations (2; small lesion size). Temporary: asymptomatic hemorrhage (3), frontal syndrome (5), urinary incontinence (1), pneumonia (1), UTI (1), DVT (3). Long-term: hemiplegia (1—periop hemorrhage), cognitive deficit (1).
Kondziolka et al., 2011	Patient 2 noted some impulsivity & perseveration. Neuropsychological test results were normal.
Gouvea et al., 2010	Worsening scores on tests of executive function but no negative impact on life.
Csigó et al., 2010	Temporary: incontinence (2), periorbital tumescence (2), depressive state (1), anxiety (1), somnolence (1). Long-term: increased appetite—7-kg weight gain in 12 mos (2). Improvement of scores in majority of neuropsychological tests.
Lopes et al., 2009	Multiple neurological, psychiatric, & general medical adverse effects according to the SAFTEE scale listed for patients during entire length of FU. Most events short-lived. Long-term: significant weight gain (1), tinnitus (1), facial paresthesia (1). Temporary: migraines (1), throat swelling (1). No formal neuropsychological testing noted.
Rück et al., 2008	All patients: attempted suicide (6), actual suicide (1)—first suicide attempt in 4 of 7 patients. Weight gain: preop weight 68 kg; postop weight 76 kg at 1-yr FU. Long-term mean weight was 8.1 kg (22). WCST scores ranged from 41 preop to 31 postop (7). RF: Long-term: sexual disinhibition (1), brain edema (apathy, incontinence, seizures) (1), radiation necrosis (apathy, memory problems) (1). GKS: Long-term: severe sexual dysfunction (1), urinary incontinence (1).
Liu et al., 2008	Intracerebral hematoma requiring ventricular drainage (1). Long-term: personality change—apathy/abulia (2). Temporary: urinary incontinence for 3–5 days (3), transient postop cognitive changes for up to 10 days (9).
Oliver et al., 2003	Temporary: hallucinations (1), seizures (1). Long-term: behavior change (1). No change in neuropsychological test results.
Christensen et al., 2002	Temporary: lethargy (2). No formal neuropsychological testing.
DBS	
Greenberg et al., 2010	Small intracerebral hematomas both resolved by 3 mos (2), equipment break (1 lead break, 1 extension wire break), superficial wound infection (1), depression/suicidal ideation (3), worsening of OCD (3), hypomania (1), problems at home (1). Cognitive events (verbal perseveration, brief memory flashbacks) (2). No pervasive cognitive decline.
Tsai et al., 2012	Allergy to IPG (1). Transient: hypomania (2), vertigo (1), olfactory hallucinations (1).
Roh et al., 2012	Transient: anxiety (2), hypomania (1).
Huff et al., 2010	No surgical complications noted. Paresthesia that abated (1), suicidal thoughts (1), insomnia (1), headache (1). Results on tests of cognitive function did not differ.
Goodman et al., 2010	No procedure complications or long-term adverse effects noted. No significant change in neuropsychological test performance.
Franzini et al., 2010	None noted.
Denys et al., 2010	Wound infection (1), increased libido (7), micturition problems (2), forgetfulness (5), word-finding difficulty (3). Neuropsychological test results not available.
Plewnia et al., 2008	Wound infection (1).
Guehl et al., 2008	None noted.
Abelson et al., 2005	Electrode break (1), suicide "not linked to surgery" (1). No change in results of neuropsychological testing.

DVT = deep vein thrombosis; IPG = implantable pulse generator; SAFTEE = Systematic Assessment for Treatment Emergent Events; UTI = urinary tract infection; WCST = Wisconsin Card Sorting Test.

* Numbers in parentheses indicate number of patients.

who underwent AC, one study found no difference in the presurgery YBOCS scores between patients who responded to surgery and nonresponders.[8] In contrast, the average presurgery YBOCS scores of nonresponders (YBOCS score < 35% improvement) at the Karolinska Institute was 35 (SD 3), compared with 32 (SD 3) for patients who had a clinically significant response ($p = 0.02$), suggesting that OCD symptom severity may have a negative predictive value for treatment response.[37]

Moreover, worse OCD severity is also associated with a higher number of comorbidities, particularly generalized anxiety disorder and agoraphobia.[11] Patients with OCD who have comorbid psychiatric disorders are more likely to have impaired long-term outcome.[22] Thus, it may not be symptom severity that partly determines treatment response but other associated factors, particularly the number of comorbidities. Conversely, of the 19 patients who underwent AC for OCD in Quebec, no difference was found in the number of comorbidities between the so-called responders and nonresponders.[8]

In this review a significant number of patients who underwent AC suffered from moderate OCD (YBOCS score of 16–23); on the other hand, all patients who received DBS belonged to the severe and extreme groups (Fig. 2).

This may have contributed to the overall better effect of AC compared with DBS. Nevertheless, when patients were analyzed according to presurgery YBOCS scores, those who underwent AC were more likely to have better responses to treatment compared with patients who underwent DBS (Fig. 2).

Follow-Up Duration

Capsulotomy patients were followed up for much longer time periods than those who underwent DBS (Table 3). Deep brain stimulation modulates the neural circuitry underpinning OCD. Thus, optimizing stimulation settings may take some time, suggesting that even longer follow-up periods might be needed for DBS to ensure maximal gain.

Goodman and colleagues reported on 6 patients who underwent DBS for OCD. Of these, the majority reached maximal treatment response by 6 months, and in 1 patient maximal response was reached at 9 months.[14] A similar pattern was seen in patients who underwent capsulotomy for OCD. In those who did respond, the largest treatment response was seen within the first 6 months, and this was maintained until the last follow-up.[7,17,26,28,32] However, Kondziolka et al. recently reported on 3 patients who underwent AC who continued to experience improvements in YBOCS score up to a maximal follow-up of 55 months.[23] The published data seem to suggest that, for the most part, response to treatment is established within a relatively short time frame. Disparities in follow-up between the 2 surgical groups probably had little impact on outcome differences. Another issue that needs to be taken into account is the recommended addition of CBT in the postoperative care of patients, whether after DBS or AC. Many reports on surgery for OCD do not clarify this issue. However, 1 study suggested that the addition of CBT after DBS did improve outcome[9] and, in another study, Gamma Knife AC enabled 1 patient to undergo further psychological treatment with Exposure and Response Prevention.[44]

Surgical Learning Curve

Surgical learning curves are well documented in many surgical fields.[39,40] Stereotactic ablative neurosurgery for psychiatric disorders has been performed for more than half a century,[25] whereas experience with DBS for OCD is just over a decade old.[30] Greater experience with ablation and the more "standardized" practice of AC may account for some of the reasons why outcomes are better for that procedure. Also, the variability in modes and patterns of stimulation as well as variation in targeting the relatively wide anatomical area encompassing the anterior internal capsule-ventral striatum and NAcc area for DBS[18] may all account for the discrepancy in outcome after DBS compared with AC. There is still a learning curve in the practice of DBS for OCD, and this procedure is still considered investigational in many countries. It is interesting to note that the pioneers of DBS for OCD considered it premature for the FDA to grant a humanitarian device exemption for this procedure in 2011.[12]

The YBOCS

The YBOCS is a validated scoring scale used to determine the severity of OCD.[15,16] It is extremely useful in clinical practice as a means to determine changes over time in the global score, which represents either clinical improvement or deterioration. Moreover, it also allows a direct comparison between different treatment modalities in managing OCD, which would otherwise not be possible.

However, as with many scoring systems, it does not take into consideration aspects of everyday life and quality of life. We appreciate that these dimensions can be difficult to measure and even more cumbersome to compare across different treatment modalities. Some studies have used other scoring systems such as the global assessment of function in an attempt to measure these subjective outcomes.[13,18,23,26,28,32,37] Older, pre-YBOCS publications on AC for OCD often provided detailed clinical vignettes about whether the patients' functioning had improved; his or her return to work part- or full-time; impact on relationships; and so on.[20] These old reports provided a wealth of information that was certainly very pertinent to patients in their everyday life after surgery. We chose not to consider these publications in our review because they lacked the (then nonexistent) modern YBOCS, which would make direct comparison with modern DBS publications impossible. Even a qualitative evaluation between DBS publications and old AC papers would have been impossible because modern DBS publications lack the detailed vignettes that some of the old publications contained.

Adverse Events

The proportion of adverse events that occurred in patients who underwent AC and those treated with DBS was quite similar; however, there were a few notable differences (Table 4). Capsulotomy patients were more likely to experience clinically significant weight gain. However, because of a noted history of weight gain after AC, papers on this procedure appeared to be more fastidious in noting weight gain as a side effect. Weight was rarely mentioned in DBS publications. Moreover, AC has traditionally been associated with frontal lobe dysfunction such as apathy and disinhibition. However, the published data suggest that the rate of executive dysfunction is greater in DBS patients. It should be noted that publications on DBS often reported on formal tests of cognition and personality, whereas AC publications did so with less frequency. Therefore, it seems likely that this result may simply be a product of underreporting in publications on AC.

Of note, the rate of serious adverse effects (suicide, death, ICH, residual neurological deficit) was low, and it was similar between the 2 groups.

The advantage that DBS has over AC is that, should side effects outweigh benefits, these side effects are theoretically reversible on altering or switching off stimulation. On the other hand, reports of symptom rebound with depleted batteries, and the need for frequent battery replacements and associated high costs are starting to emerge, highlighting potential disadvantages of DBS.[48] Other drawbacks of DBS compared with AC are the additional risks of infection and equipment breakage. In the surveyed studies, the cumulative rate of infection reported was in line with other DBS publications.[4,33]

Limitations of This Review

In the absence of a head-to-head comparison, this literature review compiles the data available to inform the reader about the respective pros and cons of AC versus DBS for OCD. However, there are some inherent limitations to our findings due to the very nature and details (or absence thereof) of the reviewed publications.

Grouped Data

For some of the data analysis, grouped and average data were used as opposed to individual data.[7,8,26,32] All grouped data used in this analysis were for patients who underwent AC. This would not have an impact on the average age of patients, the gender split, the length of follow-up, the initial YBOCS score, the improvement in YBOCS score, or the number of adverse effects. This did affect the number of patients in each severity group (moderate, severe, and extreme OCD) and in each response group (remission, response, no response, and unfavorable). It was possible to decipher some of this information. However, patients were not considered to meet response or remission criteria unless clearly stated, and were considered nonresponders if in doubt. It is thus plausible that the number of patients treated with AC who responded is underrepresented.

Classification of Outcomes

For example, in the paper by Liu et al.[26] it is possible to ascertain the number of responders and nonresponders. It is not possible to ascertain the number of patients who went into remission. Because the average improvement in YBOCS score was almost 80%, it seems plausible that a number of these patients would have gone into remission. In this study they were all classified as responders. Thus, from these data, the overall number of patients treated with AC who went into remission is almost certainly underrepresented.

Even taking into consideration a stringent analysis and interpretation of the available data, this review highlights an important finding: AC is an effective treatment for refractory OCD. We may safely conclude that the reason that AC has been and still is underused is not due to its lack of efficacy. Conversely, superiority over AC cannot be the reason for contemporary enthusiasm for DBS in the surgical treatment of OCD—either in terms of efficacy or with regard to side effects and complications. However, DBS does provide more opportunities to study brain circuitry and allows the conduct of sham treatment studies that may provide a stronger evidence base for this surgical therapy. Another advantage is that different parameters (number and site of electrode contacts, frequency, polarity, and intensity) can be tested to provide bespoke optimization for individual patients. However, this can be extremely time-consuming and challenging. Moreover, at least theoretically, DBS is still considered and perceived as a "reversible" surgery.

Conclusions

The AC and DBS procedures are effective for refractory OCD. Deep brain stimulation in the ventral anterior capsule and its vicinity is an emerging and promising treatment. None of these therapies is strictly evidence based, and there are no head-to-head comparative studies between these 2 procedures. Also, none of the studies surveyed used evaluation by independent parties who were not involved in selection, surgery, or follow-up of the patients. Hence, an observer bias in reporting results cannot be excluded. However, there is a wealth of historical praxis and modern data pointing to the efficacy of AC. One may safely conclude that the current popularity of DBS over ablative surgery for OCD is not due to clinical superiority over AC, but rather that clinicians and patients find DBS to be more acceptable.

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Author Contributions

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Supplemental Information

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