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Stereotactic cingulotomy

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Since its introduction in 1936, surgery for psychiatric illness has had a long and controversial history for various scientific, moral, and ethical reasons. Many different neurosurgical procedures have been performed on a variety of cortical and subcortical targets. Initially, Moniz [1] performed prefrontal leukotomies by injection of absolute alcohol into the frontal lobes and reported "worthwhile" improvement in 14 of 20 patients. Moniz [2] later described his experience with larger numbers of patients after more specific and restricted frontal lobe lesions were created using a leukotome. Freeman and Watts [3] subsequently described their prefrontal lobotomy, which was performed with a specially designed calibrated instrument that was inserted blindly to the midline and swept back and forth to interrupt surgically the white matter tracts in the frontal lobes. The authors noted that to achieve the best results, the lesion had to involve the medial frontal lobes and, by definition, the cingulate gyri.

These early operations were associated with significant mortality and morbidity. Tooth and Newton [4] reviewed 10,365 standard prefrontal lobotomy operations performed between 1943 and 1954 and confirmed that the rate of "improvement" was approximately 70% but also reported a 6% mortality, 1% epilepsy rate, and 1.5% marked disinhibition. These complications underscored the need for a less radical and more specific approach to the surgery.

Fulton [5] was the first to suggest that the anterior cingulum would be an appropriate target for psychosurgical intervention, and cingulotomy was initially carried out as an open procedure [6,7]. Foltz and White [8] reported their experience with stereotactic cingulotomy for intractable pain and noted that the best results were in those patients with concurrent anxiety-depressive states. Ballantine and Giriunas [9] subsequently demonstrated the safety and efficacy of cingulotomy in a large number of patients with psychiatric illness, and it has been the surgical procedure of choice in North America over the last 30 years.

Currently, the accepted therapeutic approach to most psychiatric disease involves a combination of well-supervised pharmacologic, behavioral, and, in some instances, electroconvulsive therapies. Not all patients respond to these modern treatment methods, however, and many remain severely disabled. Some of these patients might be considered appropriate candidates for surgical intervention if the therapeutic result and overall level of functioning could be improved.

In this article, we explore the anatomic and physiologic basis for cingulotomy and the indications for surgery. Guidelines for the appropriate selection of surgical candidates are presented along with details of the operative technique. Finally, the results and complications of cingulotomy are reviewed and compared with those of other common psychosurgical procedures.

Anatomic and physiologic rationale for cingulotomy

In 1937, the same year that Moniz [1] reported his initial experience with prefrontal lobotomy, Papez [10] postulated that a reverberating circuit in the human brain might be responsible for emotion, anxiety, and memory. The components of this rudimentary limbic system included the

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hypothalamus, septal nuclei, hippocampi, mamillary bodies, anterior thalamic nuclei, cingulate gyri, and their interconnections. It was subsequently expanded by McLean [11] in 1952 to incorporate paralimbic structures, including orbital frontal, insular, and anterior temporal cortices; the amygdala; and dorsomedial thalamic nuclei.

Although the exact mechanisms are unknown, there is mounting evidence that the limbic system, including the cingulate gyrus and its interconnections, plays a central role in the pathophysiology of major depressive disorder (MDD), obsessive-compulsive disorder (OCD), and other anxiety disorders. Electric stimulation of the anterior cingulum and subcaudate region has been shown to alter both autonomic responses and anxiety levels in human beings [12]. Stimulation of the hypothalamus in animals produces autonomic, endocrine, and complex motor effects, which suggests that the hypothalamus integrates and coordinates the behavioral expression of emotional states [13]. The limbic system, which includes the cingulate gyrus, has direct input to the hypothalamus and seems to be strategically located to mediate and interconnect somatic and visceral stimuli with higher cortical functions. Therefore, it is likely that certain psychiatric disorders (ie, MDD, OCD, other anxiety disorders) may reflect a final common pathway of limbic system dysregulation.

Data from clinical and neuroimaging studies have also converged to implicate the corticostriatothalamic circuits in the pathophysiology of OCD [14–16]. The frontal-striatal-pallidothalamic-frontal loop, which has been so well characterized for its control of motor function in Parkinson's disease, may also explain some features of OCD. From a clinical perspective, rare neurologic movement disorders like Von Economo's encephalitis and Sydenham's chorea are known to affect the basal ganglia and have been associated with obsessive and compulsive symptoms [17]. Many patients with Tourette's syndrome (TS), another disorder of the basal ganglia characterized by coprolalia and motor tics, have significant OCD symptoms throughout their lives [18]. Orbitofrontal and cingulate cortex has also been implicated in OCD, because the cognitive and behavioral features associated with lesions in this area, such as decreased response inhibition, inflexibility, and overattention to irrelevant details, are reminiscent of OCD symptoms. MRI has also demonstrated specific brain lesions in the frontal, temporal, and cingulate areas in some cases of new-onset OCD [19]. Detailed morphometric analysis of MRI scans in OCD patients has also suggested focal abnormalities in striatal areas with subtle volumetric abnormalities involving caudate nuclei [20].

Positron emission tomography (PET) studies have provided perhaps the most compelling evidence for implicating orbitofrontal cortex, cingulate cortex, and basal ganglia dysfunction in OCD. PET ^{18}F-fluorodeoxyglucose studies in children and adults have consistently reported significant elevation of absolute glucose metabolic rates for the cerebral hemispheres and orbital gyri and somewhat less consistent elevation for the caudate nucleus in OCD patients as compared to normal controls [21–23]. In one study of clomipramine treatment in childhood-onset OCD, 6 patients who failed to respond had significantly higher right anterior cingulate and right orbital metabolism than did 11 drug-responsive patients [24]. Two reports have found regional decreases in metabolic activity correlating with a decrease in severity of OCD symptoms as measured by the Yale-Brown Obsessive-Compulsive Scale (YBOCS) after successful pharmacologic or behavioral treatment; one reported decreased caudate activity, and the other reported decreased right orbitofrontal metabolism [21,25]. In a small series of patients with chronic anxiety disorder and severe phobias, activation PET studies performed as the patients were presented with stimuli to recreate their fears demonstrated consistently increased regional cerebral blood flow (rCBF) in the anterior cingulate cortices, orbitofrontal cortex, left thalamus, and right caudate nucleus [26].

Currently, one can only speculate how disruption of different pathways in the limbic system or cingulate gyri might normalize activity, leading to symptom improvement. Recently, Rauch et al [27] reported atrophy in the caudate body in subjects who had undergone one or more cingulotomies approximately 6 months before morphometric MRI studies. Such investigations are beginning to demonstrate the functional connectivity of the cingulate gyri with subcortical nuclei. This may explain how lesions in one anatomic area might affect the integrity and function of other brain regions. Clinical observations suggest that OCD and MDD patients do not improve immediately after psychosurgery but that several weeks to months are required for positive clinical effects to be fully manifest. Thus, it is likely that secondary

neural degeneration or metabolic alterations in brain areas other than the region where the lesions are actually made may be involved in the therapeutic effect.

Neurochemical models suggest that the affective and anxiety disorders may be mediated via monoaminergic systems. In particular, the serotonergic system has received emphasis with respect to OCD. Because of the diffuse nature of the monoaminergic projections and their role as neuromodulators, however, these models are not particularly instructive in terms of the functional neuroanatomy relevant to different neurosurgical treatments as they are currently employed. Nevertheless, lesions in the cingulate cortex or other targets in the limbic system may ultimately modify these diffuse monoaminergic systems to exert a beneficial effect.

Although the exact neuroanatomic and neurochemical mechanisms underlying depression, OCD, and other anxiety states remain unclear, it is clear that the basal ganglia, limbic system, and cingulate cortex in particular play a principal role in the pathophysiology of these diseases. Similarly, lesions that affect these target areas might be expected to modulate neuropsychiatric dysfunction (the reader is referred to the article by Rauch et al in this issue for a more comprehensive presentation of these issues).

Patient selection

Only patients with severe, chronic, disabling, and treatment-refractory psychiatric illness should be considered for cingulotomy. Chronicity in this context refers to the enduring nature of the illness without extended periods of symptomatic relief and may be less important than the severity of the illness. The severity of the patient's illness must be manifest both in terms of subjective distress and a decrement in psychosocial functioning. The illness must prove to be refractory to systematic trials of pharmacologic, psychologic, and, when appropriate, electroconvulsive therapy before considering neurosurgical intervention. As in all medical decisions, the potential benefit from such an intervention must be balanced against the risks imposed by surgery.

Thoughtful assessment of psychosurgical candidacy requires that criteria for severity, chronicity, disability, and treatment refractoriness be operationalized to form guidelines. In this regard, chronicity would require at least 1 year of enduring symptoms without significant remission, although practically speaking, confirmation of treatment refractoriness usually requires more than 5 years of illness before surgery. Severity is usually measured using validated clinical research instruments corresponding to specific indicators, such as a YBOCS score of greater than 20 for OCD or a Beck Depression Inventory (BDI) score greater than 30. Disability may be reflected, for instance, by a Global Assessment of Function (GAF) score of less than 50.

The major psychiatric diagnostic groups as defined by the *Diagnostic and Statistical Manual of Mental Disorders*, 3rd edition, revised (DSM-III-R) that might benefit from surgical intervention include OCD and major affective disorder (ie, unipolar major depression or bipolar disorder) [28]. In many instances, patients present with mixed disorders combining symptoms of anxiety, depression, and OCD, and these patients remain candidates for surgery. Schizophrenia is not currently considered an indication for surgery. A history of personality disorder, substance abuse, or other significant axis II symptomatology is often a relative contraindication to surgery.

To determine that their psychiatric illness is refractory to treatment despite appropriate care, all patients must be referred for surgical intervention by their treating psychiatrist. The referring psychiatrist must demonstrate an ongoing commitment to the patient and the evaluation process and must also agree to be responsible for postoperative management. Detailed questionnaires that document the extent and severity of the illness as well as a thorough account of the diagnostic and therapeutic history must be provided by the psychiatrist. The specifics of pharmacologic trials should include the agents used, dose, duration, response, and reason for discontinuation for any suboptimal trial. Adequate trials of electroconvulsive therapy or behavioral therapy when clinically appropriate must also be demonstrated.

The patient and family must also agree to participate completely in the evaluation process as well as in the postoperative psychiatric treatment program. In general, only adult patients (older than 18 years) who are able to render informed consent and who express a genuine desire and commitment to proceed with surgery are accepted.

If the patient meets these criteria, at our institution, he or she would undergo a more detailed presurgical screening evaluation by an experienced multidisciplinary group of psychiatrists,

neurosurgeons, and neurologists (Cingulotomy Assessment Committee). A thorough review of the medical record is carried out to ensure that the illness is indeed refractory to an exhaustive array of conventional therapies. The Massachusetts General Hospital (MGH) evaluation also includes an electroencephalogram (EEG), brain MRI, neuropsychologic testing, and independently conducted clinical examinations by a psychiatrist, neurologist, and neurosurgeon in the outpatient setting. An electrocardiogram and appropriate blood tests are obtained to assess medical risks and to exclude organic etiologies for mental status abnormalities. Validated clinical research instruments (eg, YBOCS, BDI, GAF, Minnesota Mutiphasic Personality Inventory [MMPI]) are employed to quantify psychiatric symptom severity and outcomes. There must be unanimous agreement that the patient satisfies selection criteria, that the surgery is indicated, and that the requirements for informed consent are fulfilled. A family member or close relative must also understand the evaluation process and the indications for, risks of, and alternatives to surgery and must agree to be available to provide emotional support for the patient during the hospitalization.

Surgical technique

Cingulotomy was initially performed using ventriculography for surgical guidance, but over the past decade, this has been replaced by MRI–guided stereotactic techniques. This allows for more accurate placement of the lesions and direct visualization of individual differences in cingulate and ventricular anatomy.

The procedure is carried out under mild sedation and local anesthesia. A T1-weighted stereotactic MRI scan is obtained (echo time [TE] = 10 milliseconds, repetition time [TR] = 600 milliseconds), and using the midsagittal scan as a reference, oblique coronal sections (4-mm thick, 1-mm interval) are selected in a plane parallel to the proposed trajectory of the thermocoagulation probe and spanning the entire anterior cingulum and frontal horns of the lateral ventricles. Target coordinates are calculated for a point 2 to 5 mm above the roof of the lateral ventricle, 7 mm from the midline, and 20 to 25 mm posterior to the tip of the frontal horns [29]. After calculation of the stereotactic target coordinates, a limited bicoronal scalp incision is made, and burr holes are placed bilaterally just anterior to the coronal suture and 1.5 to 2.0 cm from the midline. After dural opening and cauterization of the pia, a standard thermistor-equipped thermocoagulation electrode (Radionics, Burlington, MA) with a 10-mm noninsulated tip is introduced to the target and heated to 85°C for 90 seconds. If necessary, the electrode can be withdrawn 5 to 10 mm, and an additional lesion is made superiorly using the same parameters to ensure complete destruction of the cingulum. The resulting lesion is approximately 15 to 20 mm in height and 10 mm in diameter and should encompass the cingulum from the roof of the ventricle to the cingulate sulcus. The procedure is then carried out in an identical fashion on the opposite side. Intraoperative stimulation is not performed routinely, but neurologic testing is carried out during lesioning to ensure that no impairment of motor or sensory function, especially in the lower extremities, is incurred. On the day after surgery, a postoperative MRI scan is obtained to document the placement and extent of the lesions (Fig. 1).

Although the patient may experience an immediate reduction in anxiety, there is generally a delay to the onset of beneficial effect on depression and OCD. This latency may be as long as 6 to 12 weeks and must be clearly explained to the patient and referring psychiatrist. If there has been no response to the initial cingulotomy after 3 to 6 months, reoperation and enlargement of the cingulotomy lesion are considered (Fig. 2).

Using the surgical techniques described previously, additional lesions can be placed anterior to the initial cingulotomy. The MGH experience suggests that 40% to 50% of patients require repeat surgery and that better long-term outcomes are achieved with repeat surgery and multiple lesions in the cingulate gyrus. Therefore, over the past several years, three separate lesions have been placed at the initial operation, incorporating approximately 2.0 to 2.5 cm of anterior cingulate cortex (Fig. 3). If this operation does not provide satisfactory improvement in the patient's symptoms, the cingulotomy can be converted to a limbic leukotomy at a later date by placing a lesion in the subcaudate region bilaterally.

Results

The results of bilateral cingulotomy in 198 patients suffering from a variety of psychiatric disorders were reported retrospectively by Ballantine et al [30] in 1987. With a mean follow-up of

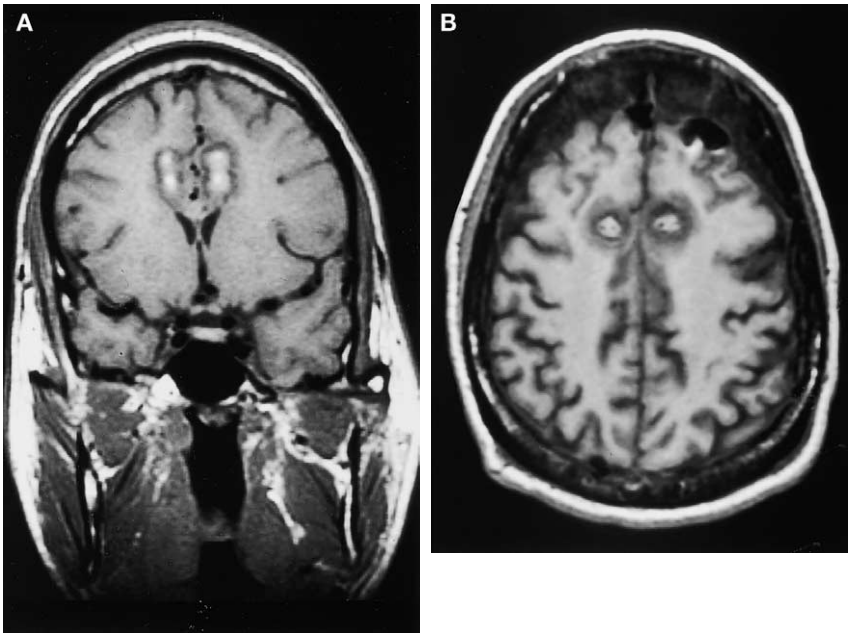

Fig. 1. Midsagittal (A) and axial (B) T1-weighted MRI scans obtained 48 hours after a single anterior cingulotomy lesion. The acute hemorrhagic lesion undergoes a dramatic reduction in size as the edema resolves.

8.6 years, 62% of patients with severe affective disorder were found to have had worthwhile improvement. Similarly, in patients with OCD, approximately 56% were found to have undergone worthwhile improvement. In 14 patients suffering from nonobsessive anxiety disorders, 50% were found to be functionally well and 29% were found to have shown marked improvement. Valid criticism of these results included the concern that many of these patients might not have met modern DSM-IV-R criteria for their psychiatric disorder and that the assessment of outcome was performed by biased observers, namely, the referring psychiatrists, using subjective rating scales.

A retrospective study was therefore devised to evaluate cingulotomy in the treatment of OCD using independent observers and strict outcome criteria. Of the 35 patients who were operated on for refractory OCD, 33 met modern DSM-IV-R criteria for OCD. In addition, at least 25% to 30% of patients demonstrated substantial benefit from the procedure as defined by a 50% improvement in their YBOCS [31]. Concerns remained about the validity of these conclusions, because many of the patients were treated before the introduction of modern psychopharmacology, specifically the selective serotonergic reuptake inhibitors (SSRIs). It was thought that many of these patients might have responded positively to the SSRIs and thus were not truly refractory to treatment.

A prospective study was therefore undertaken using independent observers and clinically validated outcome rating scales. Of 18 OCD patients in this study who underwent cingulotomy at the MGH after failing all modern pharmacotherapies, including the SSRIs, 5 met conservative criteria as treatment responders (>35% improvement in their YBOCS and a Clinical Global Improvement [CGI] outcome of very much improved or much improved) and 2 others were considered to be possible responders (>35% improvement in their YBOCS or a CGI outcome of very much improved or much improved), for an overall response rate of 28% to 40% [32]. Average duration of follow-up was longer than 2 years. Overall, the entire group improved significantly in terms of functional status, and no serious adverse effects were found. This was the first study to demonstrate in a prospective fashion that cingulotomy is an effective intervention in OCD patients as measured by standardized psychiatric rating scales and independent observers. Recently, another prospective study with long-term follow-up by the same group of investigators reported

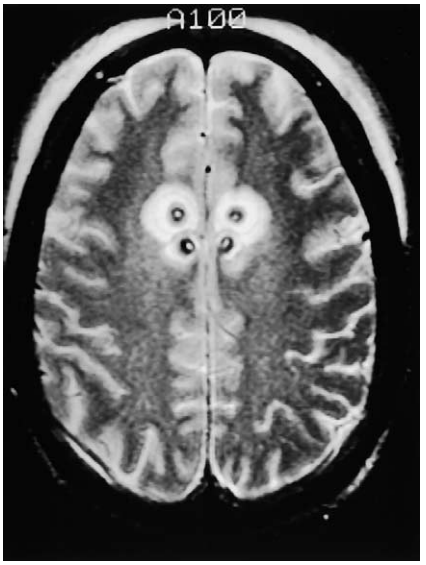

Fig. 2. Axial T1-weighted MRI scans obtained 48 hours after repeat anterior cingulotomy. Note the original lesion placed 12 months earlier and the acute lesion anteriorly.

similar findings in 44 treatment-refractory OCD patients [33]. Between 32% and 45% of patients were judged to be responders, with a mean follow-up of almost 3 years.

In more than 800 cingulotomies performed at the MGH since 1962, there have been no deaths and only two infections. Two acute subdural hematomas occurred early on in the series secondary to laceration of a cortical artery at the time of introduction of ventricular needles, but only 1 patient suffered permanent neurologic impairment. One patient suffered a delayed intracerebral hematoma after a fall 4 weeks after surgery but suffered no long-term neurologic deficits. An independent analysis of 34 patients who underwent cingulotomy demonstrated no significant behavioral or intellectual deficits as a result of the cingulate lesions themselves [34]. A subsequent evaluation of 57 patients before and after cingulotomy found no evidence of lasting neurologic or behavioral deficits after surgery. A comparison of preoperative and postoperative Weschler IQ scores demonstrated significant gains after surgery. This improvement was greatest in

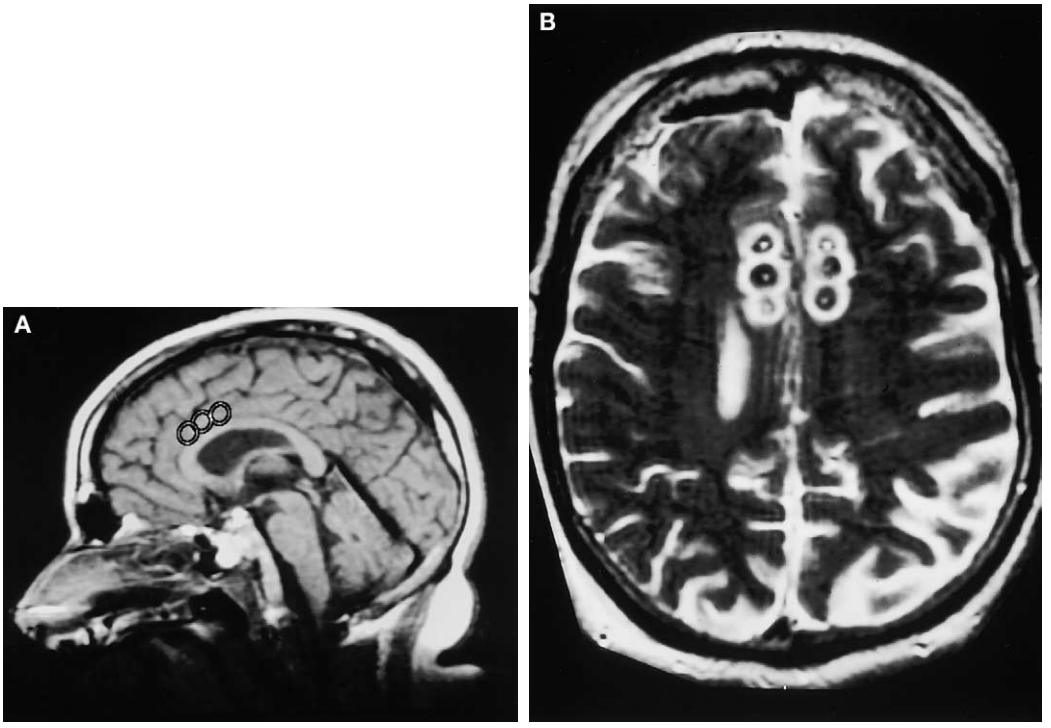

Fig. 3. Midsagittal (A) and axial (B) T1-weighted MRI scans obtained 48 hours after three anterior cingulotomy lesions ablating approximately 2.5 cm of cingulate cortex.

patients with chronic pain and depression but negligible in those with the diagnosis of schizophrenia [35].

Overall, it appears that cingulotomy is a useful intervention in many patients with severe treatment-refractory major depression or OCD. Using subjective rating scales, approximately 60% to 70% of patients show significant improvement. When more objective clinically validated rating scales are used to assess outcome, approximately 30% to 45% of patients who undergo cingulotomy are considered to be responders. Although this response rate may appear low at first glance, one must remember that all patients were completely refractory to every available treatment and that any measurable improvement might thus be considered salutary.

Discussion

Although any patient with a severe psychiatric illness was once considered a candidate for surgical intervention, it is now clear that the prudent indications for psychosurgery are more restrictive. There is general agreement among centers that patients with major affective disorder, chronic anxiety states, and OCD are the best candidates for surgery. It can be safely concluded that schizophrenia is not an indication for psychosurgery, although patients with concomitant psychotic disorders and depression might still be helped with surgery and should not be excluded. Personality disorders and psychoactive substance use disorder are also significant relative contraindications to surgery.

Appropriate selection of patients for surgery remains the major responsibility of the psychiatrist, guided by the informed and expert opinions of the other members of the psychosurgical team. Advanced neuroimaging data may ultimately aid in optimal patient selection, and preliminary PET studies of patients with OCD indicate that presurgical cerebral metabolic rates within a territory of posterior cingulate cortex predict subsequent outcome after cingulotomy [36]. If preoperative evaluation could select those patients with a better chance of responding favorably to cingulotomy, overall success rates could be greatly improved.

Much of the controversy surrounding the use of psychosurgery may be attributed to the indiscriminate application and high morbidity seen with the early surgical procedures. Stereotactic techniques have certainly minimized side effects, but the issue of case selection remains a major consideration. Cingulotomy has been the preferred surgical intervention in our experience because it provides substantial relief to a significant number of patients and is associated with a low incidence of complications or adverse events [29]. Many other centers believe that alternative surgical interventions, such as subcaudate tractotomy, limbic leukotomy, or anterior capsulotomy, can provide better results in a similar patient population.

Subcaudate tractotomy was introduced by Knight [37] in Great Britain in 1964 as one of the first attempts to restrict the size of the surgical lesion and therefore minimize the side effects seen with standard prefrontal lobotomy. The aim was to interrupt white matter tracts between orbital cortex and subcortical structures by placing a lesion in the region of the substantia innominata just below the head of the caudate nucleus. Surgical indications included major depressive illness, OCD, and anxiety states as well as a variety of other psychiatric diagnoses. The original surgical procedure was performed using stereotactically implanted radioactive yttrium 90 seeds, which yielded large lesional volumes of approximately 2000 mm^2. Currently, smaller lesions in are created by thermocoagulation with MRI stereotactic guidance.

In patients with depression and OCD, total improvement or improvement with minimal symptoms was clinically observed in two thirds of the patients. The best review of the surgical results for subcaudate tractotomy was presented by Goktepe et al [38] in 1975. Using a five-point global scale and rating scales for depression and anxiety, they reviewed 208 patients with a mean follow-up of 2.5 years. Of the 134 patients available for structured interview, good results were seen in 68% of patients suffering from depression, 62.5% of patents with anxiety states, and 50% of patients with obsessive neurosis. Patients with schizophrenia, personality disorder, drug abuse, or alcohol abuse did poorly. Some patients who had only temporary benefit from the initial lesion had second lesions created lateral to the first, with good results seen in about half of these individuals.

The incidence of complications was small but included postoperative seizures in 2.2% of patients and undesirable personality traits in 6.7%. Transient disinhibition was common. Of the 25 patients who had died at the time of review, 3 had committed suicide. One patient died from

inadvertent destruction of the hypothalamus when a yttrium seed migrated off target.

Limbic leukotomy was introduced by Kelly et al [39] in 1973 and combines subcaudate tractotomy with anterior cingulotomy. This procedure was designed to disconnect orbital-frontal-thalamic pathways with the former lesion and to interrupt an important portion of Papez's circuit with the latter. Kelly et al [39] reasoned that these two lesions might lead to a better result for the symptoms of OCD than either lesion alone. Indications for surgical intervention included obsessional neurosis, anxiety states, depression, and a variety of other psychiatric diagnoses. This stereotactic procedure placed three small (6-mm diameter) lesions in the lower medial quadrant of each frontal lobe and two lesions in each cingulate gyrus.

Using the same five-point scale described in the study of Goktepe [38], 66 patients were assessed before and after surgery (mean follow-up of 16 months). In patients with obsessional neurosis, 89% were clinically improved; in chronic anxiety, 66% were improved; in depression, 78% were improved; and in a small number of schizophrenics, more than 80% were improved [40]. Kelly et al [41] later reported in 49 patients with OCD that 84% were improved 20 months after surgery. They too noted that postoperative symptom improvement was not immediate, with a fluctuating but progressive reduction of symptoms over the first postoperative year. Although many patients complained of lethargy, confusion, and lack of sphincter control in the early postoperative period, persistent complications were rare. No patients developed seizures after surgery, 1 patient suffered severe memory loss because of improper lesion placement, and 12% of patients complained of persistent lethargy. Measurements of IQ showed slight improvement after surgery.

Recently, the results of a more modern series of MRI-guided stereotactic limbic leukotomy were reported in 21 patients [42]. Mean follow-up was longer than 2 years, and 35% to 50% of patients were considered to be treatment responders using clinically validated rating scales. Transient side effects were more common than after either cingulotomy or subcaudate tractotomy alone, with permanent minor memory loss or urinary difficulties observed in approximately 10% of patients.

Although Talairach et al [43] were the first to describe anterior capsulotomy, Leksell popularized the procedure for patients with a variety of psychiatric disorders [44]. The aim was to interrupt presumed frontothalamic connections in the anterior limb of the internal capsule, where they pass between the head of the caudate nucleus and the putamen. Clinical indications initially included schizophrenia, depression, chronic anxiety states, and obsessional neurosis but are currently almost entirely limited to OCD.

The target coordinates as described by Leksell are in the anterior one third of the anterior limb of the internal capsule 5 mm behind the tip of the frontal horns and 20 mm lateral to the midline at the level of the intercomissural plane. Lesions were created by thermocoagulation using a bipolar electrode system and were typically approximately 15 mm in height and 4 to 5 mm in diameter.

In the first 116 patients operated on by Leksell, 50% of patients with obsessional neurosis and 48% of depressed patients had a satisfactory response [44]. Only 20% of patients with anxiety neurosis and 14% of patients with schizophrenia were improved. In this classification system, only patients who were free of symptoms or markedly improved were judged as having a satisfactory response. Of the patients who were rated as worse after capsulotomy, 9 were schizophrenics, 4 were depressives, and 3 were obsessives. In another series of 35 patients with OCD who underwent capsulotomy and were followed prospectively by independent psychiatrists, 16 were rated as free of symptoms and 9 were much improved, for an overall satisfactory result of 70% [45]. In a review of all cases of capsulotomy previously reported in the literature, Mindus et al [46] found sufficient data to categorize outcome in 213 of 362 patients. Of these, 137 [64%] were deemed to have a satisfactory result.

More recently, Mindus et al [47] followed 24 patients prospectively with standardized rating scales. Complications of the surgery included transient episodes of confusion during the first week in 19 of 22 patients available for follow-up, with occasional nocturnal incontinence. One patient was noted to have an intracranial hemorrhage without neurologic sequelae, and 1 patient suffered seizures. One patient committed suicide in the postoperative phase, and 8 patients suffered from depression requiring treatment. Excessive fatigue was a complaint in 7 patients, and 4 had poor memory. Two patients showed slovenliness. Weight gain is common after capsulotomy, with an overall mean weight gain of about 10% in all patients. No evidence of cognitive dysfunction has been reported in 200 capsulotomy patients studied using a variety of psychometric tests. Reoperation

was required in 2 patients who did not achieve a satisfactory result, with only 1 improving after the second operation. Burzaco [48] subjected 17 of his 85 patients to a second procedure during which the lesions were enlarged, and half of these reoperations yielded satisfactory results.

In 1977, Kullberg [49] attempted to compare cingulotomy and capsulotomy in the treatment of 26 patients in a randomized fashion. Six of 13 capsulotomy patients and 3 of 13 cingulotomy patients were better, but transient deterioration in mental status was much more marked after capsulotomy than after cingulotomy.

With currently available data, it is impossible to determine whether there is one optimal surgical technique or strategy. The obstacles that prevent a direct comparison of results across centers include diagnostic inaccuracies, nonstandardized presurgical evaluation tools, center bias, and varied outcome assessment scales. In virtually all published reports, however, some modification of the Pippard Postoperative Rating Scale, CGI scale, or equivalent has been used to determine clinical outcome [50]. The Pippard scale rates outcome in five categories as follows: A = very much improved, B = much improved, C = slightly improved, D = unchanged, and E = worse. The CGI expands the scale and rates outcome as follows: 1 = very much improved, 2 = much improved, 3 = slightly improved, 4 = unchanged, 5 = slightly worse, 6 = much worse, and 7 = very much worse.

Although comparisons are imperfect and the rating of outcome is subjective, these scales do seem to have some clinical validity. If a Pippard outcome of A and B or a CGI outcome of 1 or 2 is considered satisfactory, cingulotomy was effective in 56% of patients with OCD, subcaudate tractotomy in 50%, limbic leukotomy in 61%, and capsulotomy in 67%. In patients with major affective disorder, cingulotomy was effective in 65%, subcaudate tractotomy in 68%, limbic leukotomy in 78%, and capsulotomy in 55% [51].

The difficulty with these results is that they were obtained many years ago before the availability of modern psychopharmacologic treatments. Patients who undergo surgery today have a much wider range of drug therapies and tend to be much more resistant to treatment. Comparing current outcomes with historical results can therefore be misleading. Direct comparisons of the relative efficacy of the various modern surgical options will only be possible when centers report their experience using validated objective rating scales (eg, YBOCS, BDI). Based on current methods of comparison, the clinical superiority of any one procedure is not convincing. Although many centers claim advantages for their specific surgical intervention, we are unable to determine whether one of the four major psychosurgical procedures is superior to the others at this point. Cingulotomy is more commonly performed in the United States, whereas in Europe, capsulotomy and limbic leukotomy are more prevalent. They all seem to be roughly equivalent from a therapeutic point of view, but in terms of unwanted side effects, cingulotomy seems to be the safest of all procedures currently performed.

Regardless of the choice of procedure, surgical failures should be investigated, and if the lesion size or location is suboptimal, consideration should be given to another procedure. At least 45% of patients undergoing cingulotomy require repeat operation, with good results being salvaged in half [29]. Because of this high rate of reoperation in cingulotomy, we now recommend placement of three lesions in each cingulate gyrus at the first operation to ablate approximately 2.5 cm of the gyrus. The exact size or volume of tissue required for an effective outcome at each of the target sites has yet to be determined.

Although controversy exists regarding the exact choice of surgical procedure to be employed, there is unanimous agreement that the presurgical evaluation be performed by committed multidisciplinary teams with expertise and experience in the surgical treatment of psychiatric illness. Diagnosis based on the DSM-III-R or DSM-N-R classification scheme is encouraged, and although it is impossible to mandate uniformly across all centers, prospective trials employing standardized clinical instruments with long-term follow-up are needed. Comparisons of preoperative and postoperative functional status remain an important parameter in addition to targeting psychiatric symptoms in characterizing outcome. All centers with experience emphasize the importance of rehabilitation after surgery and the need for ongoing psychiatric follow-up. The operation is not a panacea and should be considered as only one aspect in the overall management of these patients.

Summary

Cingulotomy can be helpful in certain patients with severe, disabling, and treatment-refractory major affective disorders, OCD, and chronic

anxiety states. This form of psychosurgical treatment should only be carried out by an expert multidisciplinary team with experience in these disorders. Cingulotomy should be considered as one part of an entire treatment plan and must be followed by an appropriate psychiatric rehabilitation program. Many patients are greatly improved after cingulotomy, and the complications or side effects are few. Cingulotomy remains an important therapeutic option for disabling psychiatric disease and is probably underutilized.

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