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Revisiting bilateral thalamotomy for tremor

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ABSTRACT

MRI guided focused ultrasound surgery (MRgFUS) has been FDA approved for unilateral treatment of essential tremor (ET). Before this non-incisional lesioning method can be applied to the treatment of both hemispheres the previous experience with bilateral thalamic ablation must be addressed. In particular, the high incidence of worsening of speech and balance associated with bilateral surgical thalamotomy, a rationale for the development of deep brain stimulation. The highest incidence of these complication occurred in the early years of surgery for movement disorders, when neither MRI nor current stereotactic methods were available. The vast majority of these initial patients suffering these complications had Parkinson's disease where approximately 30% developed worsening dysarthria and ataxia after bilateral thalamotomy. Patients suffering these complications commonly had baseline abnormalities in speech and balance or worsening symptoms after a first unilateral procedure. The more contemporary experience with bilateral thalamotomy in the ET population is both much more limited in patient numbers (includes patients after Gamma Knife radiosurgery), and shows a much lower rate of these complications (approximately 5%). This more recent experience suggests that bilateral thalamotomy using closed incisionless methods such as MRgFUS has the potential to safely improve ET patients with axial or bilateral limb involvement, if done in a staged manner excluding patients with baseline dysarthria or ataxia or transient worsening of these symptoms following a unilateral procedure.

1. Introduction

Deep brain stimulation (DBS) has been the predominant surgical procedure for movement disorders in the 21st century. Numerous studies document its capacity to improve motor symptoms of patients with essential tremor, Parkinson's disease (PD) and dystonia over best medical management [1–5]. Although creation of surgical lesions was widely performed for similar indications prior to the introduction of DBS, the adjustable nature of stimulation is felt to allow for a more optimal balance between relief of motor symptoms and negative impact on neighboring brain function [6]. This is true particularly for bilateral procedures such as thalamotomy where worsening of speech was commonly reported [7–12]. However DBS implantation is also known to have significant complications. These include *peri*-operative events such as bleeding, infection and unintended neurological deficits, and later events such as device malfunction and lead fracture [13–17].

Closed incisionless brain lesioning methods have been proposed as a less invasive alternative to DBS in the treatment of medication refractory movement disorders. They include use of radiosurgery (Gamma Knife) and MRI guided high intensity focused ultrasound (MRgFUS) recently FDA approved for ET [18–24]. These closed lesioning methods have potential for greatly reducing the risk of infection or bleeding, and do not require device implantation, adjustment or maintenance. Both of these less invasive methods share a similar approach with an array of multiple emitters that converge energy only on the brain target region, while a DBS electrode must be physically passed through centimeters of non-target brain tissue with a risk of unintended brain injury along its path.

While DBS is commonly employed to treat patients with bilateral symptoms, permanent lesioning methods have recently been restricted to unilateral procedures. This situation reflects a prevailing view of an unacceptable rate of complications from bilateral brain lesions (most commonly dysarthria or ataxia) that is based on studies that span several decades and are heterogeneous in surgical technique, imaging methods and patient characteristics (Tables 1 and 2).

Because of growing interest in these incisionless closed lesioning methods, we have reviewed the literature with a focus on the complication rate of bilateral lesioning of the thalamus for the treatment of patients with tremor due to PD or ET. This review is not intended as a formal meta-analysis. Several of the studies we cite were published over 50 years ago, where data was not presented using standardized methods or validated scales. A Medline search from 1965 to 2017 of tremor AND thalamotomy gave 455 citations of which 84 represented clinical reports or studies of surgical thalamotomy that

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Table 1
Bilateral thalamotomy in Parkinson's disease.

Study	N	Stereotactic frame	Localization technique	Ablation method	Complications
Krayenbuhl et al. [8] (1961)	23	Riechert	Roentgen-ray checks and electrical stimulation	Electrocoagulation	30.4% worsening speech 34.8% psych disturbances 17.4% worsening gait 8.7% moratlity
Speakman et al. [9] (1963)	25	Rand-Wells	Ventriculography	Wire loop cuts	8% slurring of speech 4% confusion 4% ICH resulting in death
Gillingham et al. [33] (1964)	75[a]			Electrocoagulation	36% reduced voice volume 33.3% dysarthria
Selby et al. [10] (1967)	54	Riechert	Ventriculography and electrical stimulation	Electrocoagulation	23.8% worsening speech 2.1% worsening MS
Bravo et al. [12] (1967)	515			Chemothalamotomy, hot wax injection, or cryothalamotomy	60% speech problems with chemothalamotomy 20% sleepiness and apathy 0.6% permanent confusion 0.8% mortality
Cooper[7] (1969)	250	Basal ganglia guide	Ventriculography	Chemothalamotomy or cryothalamotomy	39.6% balance problems 24% Swallowing problems 7.2% worsening MS 2% speech disturbances 2% death 0.8% hemiplegia
Matsumoto et al. [11] (1976)	27	Devised by study group	Ventriculography	Electrocoagulation	29.6% word blocking 11.1% slow speech 3.7% hypophonia 3.7% memory disturbance
Nagaseki et al. [34] (1986)	2	Leksell	Ventrigulography in early cases, CT in late cases, in addition to microelectrode recording & electrical stimulation	Thermocoagulation	Transient dysarthria in 1 patient
Duma et al. [18] (1998)	4	Leksell	MRI	Gamma knife radiosurgery	none
Moriyama et al. [39] (1999)	9	Sugita	Ventriculography	Electtocoagulation	44.4% transient speech changes 11.1% persistent speech changes

ICH, intracerebral hemorrhage; MS, mental status.
[a] These 75 patients underwent various types of bilateral procedures that include thalamotomy, pallidotomy, thalamocapsular and pallidocapsular lesions.

included patients with either ET or PD. These studies were then reviewed to see if they commented specifically regarding patients with bilateral procedures, and those papers were include in this review. A major source for some of the older literature was the monograph by Irving Cooper "Involuntary Movement Disorders" published in 1969 [7]. Additional studies were found among the citations of more contemporary reviews comparing thalamotomy and DBS [6,32].

1.1. Efficacy for tremor reduction

As with unilateral thalamotomy, bilateral surgery has a consistently high success rate in the reduction of tremor in Parkinson's disease and essential tremor over a wide range of studies [7–11,18,25–31]. Additionally, if the tremor is abolished and remains absent for more than 3 months after thalamotomy, it is unlikely that it will recur [32]. In his series of 250 patients with bilateral thalamotomy for the treatment of Parkinson's disease, Cooper reported that after the second surgery tremor abolished in 74% of patients, moderately improved in 19%, slightly improved in 6%, and unchanged in only 1% [7]. Selby reported similar rates at which tremor abolished in 81% of patients, improved in 17%, and unchanged in 2% [10].

1.2. Complications

1.2.1. PD

The greatest concern when performing bilateral thalamotomy is the

Table 2
Bilateral thalamotomy in essential tremor.

Study	N	Stereotactic frame	Localization technique	Ablation method	Complications
Nagaseki et al. [34]	2	Leksell	Ventrigulography in early cases, CT in late cases, in addition to microelectrode recording & electrical stimulation	Thermocoagulation	None
Goldman et al. [29,30]	1	COMPASS	Ventriculography & microelectrode recording & electrical stimulation	Radiofrequency	Persistent ataxic dysarthria
Akbostanci et al. [35]	1	Leksell	Electrical stimulation	Radiofrequency	None
Zirh et al. [36]	3		Microelectrode recording	Radiofrequency	66.7% persistent mild dysarthria
Young et al. [19]	68	Leksell	MRI	Gamma knife radiosurgery	2.9% delayed speech & balance problems
Gallay et al[37]	3	Leksell	MRI	FUS of cerebellar- thalamic tract*	None

* Only study to target this white matter area bordering thalamic nuclei.