Surgical Treatment of Parkinson's Disease

Past, Present, and Future

William C. Koller, Alireza Minagar, Kelly E. Lyons, and Rajesh Pahwa

1. PAST

Neurosurgical procedures for the management of movement disorders began prior to the introduction of stereotactic surgery. Lessons learned from these pioneering procedures established the basis for the use of stereotactic techniques in the treatment of movement disorders.

The first destructive surgical procedure on the brain to control hyperkinetic movement disorders was performed by Horsely and colleagues at the end of 19th century (1,2). They excised all or part of the motor cortex for treatment of athetosis and their work became a milestone in our understanding of scientific concepts of motor neuroanatomy and physiology. This procedure was emulated by Nazaroff, who in 1927 reported on the injection of alcohol into the same area of the cortex with variable results (3). The first surgical treatment of Parkinson's disease (PD) was performed in 1912 by the French physician Leriche, who did posterior cervical rhizotomy for control of parkinsonian tremor (4).

A few decades passed before there was a resurgence of interest in scientific neurosurgical approaches in the management of movement disorders. Bucy and Buchanan (5) extirpated the motor cortex for the treatment of athetosis in 1931, for tremor control in PD in 1932, and for cerebellar tremor in 1937 (6). Bucy and Case in 1939 and Kleme in 1940, excised parts of the cerebral cortex as a treatment for parkinsonian tremor and dystonia. Although the patients' symptoms improved, this type of ablative surgery caused significant motor disability such as spastic hemiparesis.

Putnam performed the first ablative surgical procedures directed to the spinal cord. In 1933, he reported successful relief of choreoathetosis by incising the spinal cord at C4-5 below the exit of the respiratory fibers in the anterolateral quadrant just anterior to the pyramidal tract and in 1938, his method of incising the corticospinal tract in the upper cervical cord, produced relief of dyskinesia at the cost of ipsilateral hemiplegia (7–9). This procedure was ineffective in controlling parkinsonian tremor.

1.1. Basal Ganglia Surgery for Movement Disorders

Basal ganglia surgery for the treatment of movement disorders was pioneered by the American neurosurgeon Russell Meyers during the 1940s (10,11). Earlier, it was generally conceived that such a surgical approach would be impossible because it might result in disorders of consciousness; a conclusion based on observations made following anterior cerebral artery strokes. In addition, Dandy had hypothesized that vegetative centers and the center for consciousness were located in the basal ganglia (12). In 1939, through an open craniotomy, transventricular approach, Meyers extirpated two-thirds
of the caudate nucleus in a patient with postencephalitic parkinsonism. Meyers’ procedure improved the patient’s tremor; however, his result was not reproducible in subsequent surgeries. His further investigations revealed that sectioning of pallidofugal fibers was the most successful procedure. Meyers further refined his technique and focused on the putamen, the ansa lenticularis, the pallidum, and in a few cases, the internal capsule. By 1949, he had operated on 58 patients with parkinsonian syndromes, choreoathetosis, hemiballism, and cervical dystonia. Postoperative improvement was observed in 60% of his patients, but the operative mortality was as high as 12%.

1.2. Stereotactic Surgery

In 1908, Horsely and Clark described the first animal stereotactic apparatus (13). However, several decades passed until Spiegel and his colleagues performed the first stereotactic pallidotomy in a patient with Huntington’s disease (HD) to obtain a reduction of choreic movements. Their new technique employed intracerebral ventricular landmarks rather than bony landmarks to position the target. The operative procedure was safe and practical and they called it “stereoencephalotomy,” meaning a three-dimensional technique using landmarks inside the brain (14,15). Lesions were originally induced with an electrolytic direct current, the same that Horsely and Clark had used 40 years before. Later, other techniques such as injection of oil-procaine or alcohol were applied to coagulate the globus pallidus and its efferent fibers for the relief of tremor and rigidity in PD.

1.3. Thalamotomy

Hassler, based on his anatomic and physiological research, considered the ventrolateral (VL) thalamus a target for the treatment of movement disorders. In 1952, Mundinger performed the first VL thalamotomy on a patient with PD. These results were published two years later by Hassler and Reichert (16).

In 1963, Albe-Fessard (17) performed microelectrode recordings in the cerebral hemispheres and later others such as Narabayashi in Tokyo employed this semi-microelectrode recording to localize the target area before performing an ablation (18). Through this line of research, the ventral intermediate (Vim) nucleus of the thalamus was identified as the most specific target for controlling various tremors including parkinsonian, essential, cerebellar, and post-stroke (19).

2. PRESENT

2.1. Thalamotomy

Basal ganglia stereotactic surgery initially targeted the globus pallidus and the ansa lenticularis until Hassler and Reichert selected the ventral lateral nucleus of the thalamus and its surrounding area as the favored site for tremor reduction (16). Improvement in tremor and rigidity of the limbs contralateral to the side of the lesion occurs in greater than 90% of PD patients (20–22). Although the assessments in the earlier studies were often qualitative rather than quantitative, these reported studies and the clinical anecdotal experience indicate that unilateral thalamotomies are an effective treatment for parkinsonian tremor.

Similarly, long-term follow-up studies have shown that thalamotomy has a lasting beneficial effect. After a mean follow-up of 33 mo, Kelly et al. (23) reported continued improvement of tremor in 86% of the patients. Linhares and Tasker (24) reported outcomes in 40 thalamotomy patients after 35.8 mo. They found that 75% of the patients had no upper extremity tremor; however, the procedure had to be repeated approx 30% of the time for tremor improvement. In another series, Nagaseki et al. (25) found minimal recurrence of tremor in 27 parkinsonian patients who received thalamotomies after a mean of 6.6 yr of follow-up. Jankovic et al. (26) reported complete abolition of tremor in 72% of patients with thalamotomies and significant improvement in tremor and functional ability in six patients after a mean follow-up of 52 mo. Kelly and Gillingham (21) reported that 57% of the PD patients had tremor control after 10 yr. Diedereich et al. (27) examined 17 PD patients with a mean follow-up of