

Irving S. Cooper and the early surgical management of movement disorders

Video history

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Irving S. Cooper was a pioneer in the field of functional neurosurgery. During his very productive and controversial career, he proposed the surgical treatment of Parkinson disease (PD) by ligating the anterior choroidal artery to control tremor and rigidity. Subsequently, he developed seminal techniques for chemopallidectomy and cryothalamectomy for PD. He also attempted to use electrical stimulation of the cerebellum or the thalamus to treat spasticity. Cooper continued his work on brain stimulation until his death in 1985. He made video recordings of nearly all of his patients during his tenure (1977–1985) at New York Medical College.

Cooper's clinical video recordings were reviewed, and selected footage was compiled into a video history of Cooper's surgical management of various movement disorders. Included are pre-, post-, and some intraoperative recordings that Cooper made to document his treatment of patients with PD, tremor, Wilson disease, cerebral palsy, chorea, dystonia musculorum deformans, and some rarer entities.

KEY WORDS • Irving S. Cooper • movement disorder • functional neurosurgery • video

Irving S. Cooper was born in Atlantic City, New Jersey, in 1922. He and his middle-class family had to overcome the hardships of the Great Depression. Instilled with an austere work ethic, Cooper worked through high school and also paid his undergraduate tuition at George Washington University, where he received his B.A. in 1942 and M.D. in 1945. He then completed a 1-year internship at the United States Naval Hospital, followed by neurosurgical training at the Mayo Clinic in Rochester, Minnesota. During his years at the Mayo Clinic (1948–1951), he also received a doctorate in neurophysiology, the basis for his later work.

Cooper was appointed to the faculty of New York University. He performed his initial clinical work at Bellevue Hospital in New York City until he organized the Department of Neurosurgery at St. Barnabas Hospital in New York City in 1954. At St. Barnabas Hospital, Cooper performed thousands of operations and developed several techniques for the treatment of movement disorders. In

1977, he was appointed Director of the Westchester County Medical Center for Physiologic Neurosurgery as well as Research Professor of Neuroanatomy at New York Medical College in Valhalla, New York. During his tenure at both St. Barnabas Hospital and Westchester County Medical Center, Cooper created a large video library of recordings of his patients. He documented the preoperative condition and postoperative outcome of hundreds of cases and also recorded his operative technique for several procedures. Cooper took great pride in his ability to improve his patients' lives, but his use of video recordings to document his results was often seen as showmanship rather than science by his contemporaries.³⁴

Cooper remained active in the field of functional neurosurgery at Westchester County Medical Center until his death in 1985.

IRVING S. COOPER

Video Materials

The video clips that accompany this text were compiled from the archived, clinical video library of Dr. Irving S.

Abbreviations used in this paper: AChA = anterior choroidal artery; DBS = deep brain stimulation; PD = Parkinson disease.

Cooper. These videos are currently in the holdings of New York Medical College and Westchester Medical Center in Valhalla. Selected segments were chosen for presentation after review of Cooper's collection.

The following text is accompanied by video-clip history of some of Cooper's pioneering contributions to the surgical management of involuntary movement disorders.

Anterior Choroidal Artery Ligation

As Cooper began his career, the operative treatment of movement disorders focused on alleviating the symptoms of PD. Early strategies for surgical intervention targeted the corticospinal tract from the motor cortex to the radicular level. In 1952, the procedure of choice was the pedunculotomy, introduced by Walker,⁴² which entailed lesioning the pyramidal tract at the level of the midbrain. While performing this procedure in 1952, Cooper inadvertently interrupted the patient's AChA and was forced to ligate the artery and abort the pedunculotomy. When the patient awoke from anesthesia, his tremor and rigidity had disappeared, and his motor and sensory functions were preserved. Cooper then began to ligate the AChA purposely to reduce tremor in patients with PD (Video Clip 1). In 1953, Cooper published his procedure and favorable results.^{1,11}

Video Clip 1. Preoperative and postoperative video footage of a patient with striatonigral degeneration who underwent AChA ligation. The patient's bradykinesia and left tremor were alleviated almost completely without major side effects.

Pallidotomy and Thalamotomy

Although Cooper reported postoperative improvement of symptoms in 65% of his patients,¹⁶ the results of AChA ligation were inconsistent. Experience with this procedure led Cooper to believe that direct lesioning of the basal ganglia could relieve movement disorders. In 1953, Cooper conceived of lesioning the medial globus pallidus by stereotactic injection of absolute alcohol. He reported good results in treating rigidity but inconsistent results in treating tremor.^{2-4,12,13,25-27} When it was discovered that the main outflow of the medial globus pallidus was into the ventrolateral thalamus,³⁶ the procedure of choice became the thalamotomy, which alleviated tremor.^{2,4,5,21,22} Cooper performed many of these operations and achieved impressive results.¹⁵

Despite obtaining these favorable results after the chemical lesioning of the basal ganglia, Cooper wanted to improve the safety of lesioning the brain. He searched for a technique that would produce a destructive lesion of sufficient size, was initially reversible, could be applied gradually in a controlled fashion, and would produce favorable and consistent results.²¹ Experimental production of freezing-induced brain lesions in animals showed promise for the creation of therapeutic lesions in humans.³⁵ Cooper, with help from an engineer and a cryobiologist, designed the first cryosurgical probe for use in the human brain,^{6,8,23,24} which was first used in 1962.

For cryosurgery, Cooper's patients first underwent intraoperative pneumoencephalography for localization of the target. Then, with the aid of a stereotactic guide³⁸ and Cooper's microdrive system, the cryosurgical probe was

inserted through a small craniectomy, with the tip of the cannula placed in the ventrolateral thalamus. A reversible test lesion was made by cooling the probe to 10°C. The awake patient was then examined; if tremor and rigidity were abolished without side effect, a permanent lesion was created by incrementally cooling the probe tip to temperatures as low as -196°C with liquid nitrogen (Video Clip 2).

Video Clip 2. Cooper performing a cryothalamotomy. After preparation, a small burr-hole craniectomy is made. Pneumoencephalography is performed to localize the site to be ablated; the injection of air into the ventricle can be seen. Cooper then adjusts his mechanical microdrive, which he designed and used to place the cryoprobe tip at the surgical target. The cryoprobe is inserted, and the patient is examined. The probe is then incrementally cooled (witnessed as leftward movement of the thermograph), and the patient's tremor is stopped. The patient is examined for rigidity, and the probe is removed.

Using cryosurgery,^{7,14,28,40,41} Cooper successfully treated many patients with various movement disorders, including PD (Video Clips 3 and 4), essential tremor (Video Clip 5), Wilson disease (Video Clips 6 and 7), chorea (Video Clip 8), and other uncommon entities such as Tourette syndrome (Video Clip 9) and stroke (Video Clip 10).

Video Clip 3. Preoperative and postoperative footage of a patient with PD in whom 5-year follow up was obtained. This patient was one of hundreds of patients afflicted with this disease whom Cooper treated with cryothalamotomy before the advent of levodopa. The patient's preoperative tremor is not apparent after surgery.

Video Clip 4. Preoperative and postoperative footage of a patient with a severe PD-induced tremor, in whom a 5-year follow up was obtained. This patient was treated with cryothalamotomy, which alleviated his symptoms, allowing him to use his right hand to write.

Video Clip 5. Preoperative and postoperative footage of a patient with severe idiopathic bilateral tremor treated with cryothalamotomy. Before surgery, her tremor prevented her from walking independently and from using a cup; after surgery, the patient has become more functional.

Video Clip 6. Preoperative, intra-, and postoperative footage of a patient with Wilson disease who underwent a unilateral cryothalamotomy, after which she experienced no disabling tremor and was able to live independently.

Video Clip 7. Preoperative and postoperative footage of a patient with Wilson disease in whom 5-year follow up was obtained. After unilateral cryothalamotomy, the patient experienced bilateral resolution of her symptoms. Preoperatively, she suffered notable retrocollis, tremor, and gait difficulties; postoperatively, she has a relatively normal posture and gait.

Video Clip 8. Preoperative and postoperative footage of a patient with chorea who underwent cryothalamotomy and experienced resolution of his symptoms. The preoperative right choreiform movements, visible both at rest and while ambulating, are well controlled after surgery, and the patient has better function.

Video Clip 9. Preoperative and postoperative footage of a patient with Tourette syndrome. Preoperatively, he suffered from a paroxysmal spasm of his axial muscles, which caused him severe social impairment, as well as a significant gait disturbance. This patient underwent a cryopulvinotomy, resulting in resolution of his tic and gait disturbance.

Video Clip 10. Preoperative and postoperative footage of a 43-year-old woman who was considered to have spastic hemiplegia after suffering an embolic midbrain infarction secondary to rheumatic heart disease. Lesioning of the dentate nucleus, the ventrolateral nucleus of the thalamus, and the pulvinar alleviated her tremor, dystonia, and even behavioral and aphasic symptoms. The patient died of bacterial endocarditis 18 months after her final surgery. Postmortem examination allowed Cooper to observe that her condition was caused by a circumscribed lesion that involved the red nucleus and reticular substance but spared the cerebral peduncle. This patient was one of Cooper's most challenging to treat operatively, and he considered her his most interesting case.

Cerebellar Stimulation

In the early 1970s, Cooper began his work on brain stimulation. He applied the concepts of the Italian physiologist Giuseppe Moruzzi³⁷ to his own ideas of what he called "disorders of disinhibition,"¹⁷ which included cerebral palsy, spasticity, and epilepsy. Cooper designed a stimulator (Avery Laboratories, Commack, NY) for implantation on the brain, which consisted of an array of electrodes that could be placed over the surface of the cerebellum, with wires tunneled under the skin to the anterior chest (Video Clip 11). Radiofrequency receivers were implanted in the chest and were activated by an external, battery-powered transmitter. In 1972 the first of Cooper's stimulators was placed in a patient with intractable epilepsy; and in 1973, he began implanting stimulators in the cerebellum to treat spasticity.^{9,10,19,29} Cooper reported good results in his first 200 patients in 1977 (Video Clip 12).^{20,31}

Video Clip 11. Intraoperative footage of the implantation of a stimulator into the cerebellum to control spasticity secondary to cerebral palsy in a young boy. After the patient was prepared for surgery, an occipital burr-hole craniectomy was performed. The electrode array was inserted onto the surface of the cerebellum.

Video Clip 12. Preoperative and postoperative footage of a patient treated with cerebellar stimulation for spastic cerebral palsy. Before surgery the patient could not stand or walk independently because of severe spasticity. After surgery, she ambulates without assistance, albeit with marked gait abnormality. Note the external power supply that the patient carries.

Deep Brain Stimulation

Cooper continued to expand the field of functional neurosurgery. In 1979, he implanted a deep brain stimulator in a patient suffering from chronic pain and spasticity. He believed that extrapyramidal motor symptoms reflected a net loss of excitation, which could be supplemented with DBS.^{32,33} Cooper chose the ventrolateral nucleus of the thalamus as his preferred site of stimulation for such movement disorders as tremor (Video Clips 13–15), spasticity, dystonia (Video Clips 16 and 17), dysarthria, and torticollis. The procedure involved the stereotactic placement of a quadripolar-stimulating electrode (Medtronic, Minneapolis, MN) into the target site (Video Clip 18). Radio receivers were placed in the anterior chest, as they were with the earlier cerebellar stimulators placed in the cerebellum. The stimulation could then be adjusted, or bio-calibrated, to obtain relief of symptoms (Video Clip 17). Cooper continued to investigate and publish his results on DBS until his death in 1985.³⁰

Video Clip 13. Preoperative and postoperative footage of a patient with tremor who was treated with bilateral DBS. After surgery, his tremor is markedly reduced. Note the external radio transmitters, which have been taped to his chest. These devices emitted a radiofrequency signal that was received by devices implanted in the patient's chest wall.

Video Clip 14. Preoperative and postoperative footage of a patient with intention tremor in whom DBS was performed. Poststimulation, the patient's tremor is still apparent but markedly reduced.

Video Clip 15. Preoperative and postoperative footage of a patient with intention tremor in whom DBS was performed. This patient's level of function was poor before surgery. Poststimulation, her tremor has improved, allowing her to live independently.

Video Clip 16. Preoperative and postoperative footage of a patient with dystonia in whom a right-sided deep brain stimulator was implanted. Before surgery, the dystonia of his left hand is evident. After surgery, his hand is improved, allowing him to grasp objects normally. His gait is also markedly improved.

Video Clip 17. Postoperative footage of a young patient with dystonia having her deep brain stimulator adjusted. As the voltage is increased to a specific threshold (visible on the left portion of the screen), the tonic contracture of the patient's hand is relieved, and she is able to open and close her hand voluntarily.

Video Clip 18. Cooper completes the installation of a deep brain stimulator. The previously implanted brain electrode is connected to a power source embedded in the chest wall via tunneled wires. Demonstrated here is the connection of the tunneled wires to the brain electrode wires.

Dystonia Musculorum Deformans

Perhaps the most dramatic of Cooper's results occurred in his treatment of patients with dystonia musculorum deformans and other severe forms of dystonias. After observing the reversal of dystonic deformities of parkinsonism achieved with AChA ligation, Cooper investigated the surgical options for the treatment of other dystonias. He performed his first operation in 1955. In 1970, he published his results obtained in 164 patients treated surgically. Most patients underwent cryosurgery (Video Clip 19)—148 thalamotomies and 16 pallidotomies. Most patients (107 of 164) also required bilateral surgery, and the reoperation rate was 33%. Cooper reported a long-term success rate of 77% for patients with this disease, which before his intervention was considered untreatable and was associated with a significant rate of morbidity.³⁹ His treatment of dystonia musculorum deformans produced very visible results of which Cooper was extremely proud (Video Clips 20–25).

Video Clip 19. Intraoperative footage of a cryothalamotomy performed in a young girl with dystonia musculorum deformans. Cooper is seen examining the patient during the procedure. Also demonstrated is Cooper's mechanical microdrive, which he used to insert his cryoprobe accurately.

Video Clip 20. Preoperative footage of a 9-year-old boy with dystonia musculorum deformans and postoperative follow-up footage after three ablative surgeries. The follow-up periods presented here are at 3 years and 20 years after his last surgery. Preoperatively, the boy could not walk or drink without significant difficulty. Postoperatively, he walks and drinks easily. Twenty years after his surgery, a normal gait is demonstrated.

Video Clip 21. Preoperative footage of a 12-year-old girl with dystonia musculorum deformans causing a severe contracture of her right leg. This patient underwent a single contralateral cryothalamotomy. Postoperative footage shows the same patient 10 years and 15 years (with her young child) after her surgery, without obvious neurological deficit. This patient's outcome was so successful that Cooper was able to hire her as a clinical assistant, and she is seen in many of his videos helping other patients demonstrate their neurological deficits.

Video Clip 22. Preoperative and postoperative footage of a 24-year-old man with dystonia treated with bilateral cryothalamotomy. Before surgery, the patient's gait was morbidly ataxic. Six years after his surgery, the patient exhibits a normal gait. His symptoms were alleviated, and he was able to enlist in the United States Coast Guard after passing the required physical examination.

Video Clip 23. Preoperative and postoperative footage of a 10-year-old patient with dystonia musculorum deformans in whom bilateral cryothalamotomy was performed. Before surgery, the patient suffered from spasticity of the trunk, causing retrocollis. Three years and 10 years postoperatively, the patient exhibits a normal gait.

Video Clip 24. Preoperative and postoperative footage of a patient treated with both cryopallidotomy and cryothalamotomy for dystonia musculorum deformans. Before her surgeries, the patient was severely afflicted, with no apparent ability to function independently. Seven and 11 years later, the patient has no involuntary movements and exhibits a normal gait.

Video Clip 25. Preoperative and postoperative footage of a young boy with dystonia musculorum deformans in whom cryothalamotomy was performed. Before surgery, the patient could not ambulate independently and had difficulty returning to his wheelchair. Postoperatively he appears normal and happy.

CONCLUSIONS

Irving S. Cooper was a brilliant and charming man who dedicated his life to the treatment of crippling diseases, which had previously been considered untreatable. His own video library is testimonial to his great career and seemingly miraculous results. Despite his pioneering work in functional neurosurgery and his striking clinical successes, many colleagues found Cooper's work controversial. He published profusely in the peer-reviewed press but also often publicized his favorable results and ideas in the lay press. That a young surgeon went outside the academic community was seen as self promotion and provoked acrimony among his contemporaries. Other surgeons could not reproduce many of Cooper's results, and even the results obtained in large series of patients were negated by smaller studies or even single-animal experiments. Cooper later voiced his disdain in his autobiography *The Vital Probe: My Life as a Brain Surgeon*, which he published late in his life.¹⁸ Cooper also reflected on his controversial career in a televised interview for Cable News Network, which was recorded in 1983 (Video Clip 26). Although he may be criticized for the way in which he conveyed his surgery-related results, the importance of his contributions remains undeniable.

Video Clip 26 (with sound). Footage of a Cable News Network interview with Cooper in Valhalla. Cooper discusses his ca-

reer and comments on how the results of his operative series were not accepted by the neurosurgical community of his day. This interview was recorded in Cooper's office at New York Medical College only 2 years before his death.

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