Historical vignette

Historical evolution of stereotactic amygdalotomy for the management of severe aggression

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Friedrich Goltz first reported in the 1890s that temporal lobe removal had a taming effect in animals. The results of studies by Klüver and Bucy, and later Terzian and Ore, demonstrated that an amygdalectomy combined with a temporal lobectomy had a significant taming effect in both animals and humans. Based on these observations, Narabayashi and colleagues reported the first clinical series of patients with temporal lobe epilepsy and/or severe behavioral disturbances in which stereotactic amygdalotomy was performed to address aggressive disorders, using a frame-based stereotactic device designed by Narabayashi. Use of pneumoencephalography, combined with physiological localization by means of olfactory stimulation and field potential recordings, enabled these investigators to define the lateral part of the amygdala, while simultaneously using wax injections to create lesions. Chitanondh used a similar localization technique to produce medial amygdala lesions by injecting a mixture of olive oil, wax, and iodized oil.

In 1966, Heimburger and coworkers reported results from a series of 25 patients with epilepsy and aggressive behavior who underwent stereotactic amygdalotomy. Their technique was slightly different and their target localization was solely anatomical, based on pneumoencephalography or contrast ventriculography, and they utilized a cryoprobe to make lesions. In 1970, Balasubramaniam and Kumamurthi reported the largest clinical series to date on this technique; pneumoencephalography or contrast ventriculography was used for anatomical localization, and depth electrode recordings were used to obtain physiological confirmation of their targets, whereas either diathermy or a Bertrand loop was used for making lesions. The development of magnetic resonance imaging technology in late 1980 allowed for a more accurate anatomical localization of the amygdala, and the improvement of radiofrequency generators also made lesioning more precise. Despite these and subsequent technological advances, the number of amygdalotomies performed has geometrically decreased during the last 20 years.

KEY WORDS • aggressive behavioral disorder • pneumoencephalography • ventriculography • amygdalotomy

THE World Health Organization defines the field of psychosurgery as “the selective surgical removal or destruction of nerve pathways for the purposes of influencing behavior.”15 The birth of psychosurgery can be attributed to Egas Moniz, a Nobel laureate, who introduced the idea of operating on the brain for severe anxiety, depression, psychosis, and other psychiatric indications.15 His ideas were inspired by the work and previous observations of John F. Fulton and Carlyle Jacobsen, who documented predictable behavioral changes in lobotomized chimpanzees.15

Since then, numerous procedures have been proposed and performed for managing severe psychiatric disorders in patients. The shift in receptivity to stereotactic amygdalotomy, a procedure used in the treatment of patients with aggressive behavior disorders, reflects the same course and fate of psychosurgery more generally. The procedure was initially received with enthusiasm during the “miracle era,” but has since experienced an almost complete worldwide ban as we have transitioned to the “anathema era.”15

In this paper, we present a brief history of the birth, flourish, and ultimate demise of stereotactic amygdalotomy. Special emphasis is given to the target localization, surgical technique, and stereotactic devices commonly utilized.

Historical Evolution

In the 1890s Friedrich Goltz6 experimented with dogs to demonstrate that temporal lobe removal has a taming effect
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in animals. He observed that animals undergoing temporal lobe removal became tamer and calmer than those that did not receive an operation. Nearly 50 years later, the data of classic studies by Klüver and Bucy11–14 in the late 1930s performed on rhesus monkeys demonstrated that bilateral destruction of the temporal lobes (including the uncus, hippocampus, hippocampal gyrus, and amygdala nuclei) resulted in the development of a characteristic syndrome (later named after them), which consisted of psychic blindness, loss of normal anger and fear responses, oral exploration of objects, hypermetamorphosis (excessive tendency to attend and react to every visual stimulus), hypersexuality, and considerable changes in dietary habits. In 1955, Terzian and Ore15 observed the human counterpart of this syndrome when they performed this same surgery in a series of humans.

Based on these observations, Hirotar Narabayashi and his partners16 in 1963 reported the results of the first series of 60 patients with severe behavior disturbances and hyper excitability who underwent bilateral stereotactic amygdalotomy as an attempt to improve the patients’ emotional state and behavior. All of their procedures were performed in patients after general anesthesia was induced, and a stereotactic instrument devised by Professor Narabayashi was utilized. The study relied on pneumoencephalography for localization of the anatomical target (the lateral group of amygdala nuclei). Intraoperative depth EEG and field potential recordings using olfactory stimulation with ether provided physiological confirmation of the anatomical target. A specially designed needle with concentric bipolar electrodes was inserted through small bur holes in the frontoparietal region bilaterally, 3 cm laterally from the midline. The lateral groups of amygdaloid nuclei were successfully destroyed by injection of a 0.6- to 0.8-ml mixture of oil, wax, and lipidol. This mixture usually produced a lesion of 8 to 10 mm at its largest diameter. As a result of this procedure, Narabayashi and colleagues achieved a marked reduction in the patient’s emotional excitability and a normalization of social behavior and adaptation in 85% of the cases. This clinical series’ data also demonstrated significant improvement of preoperative electroencephalographic abnormalities in cases in which preoperative abnormalities existed.18

During this same period, Hatai Chitanondh1 reported on a slightly different technique of stereotactic amygdalotomy in 1966. The procedure was performed in seven patients after induction of local anesthesia. Three patients had olfactory seizures, two had schizophrenia and olfactory hallucinations, one had posttraumatic personality disorder with olfactory hallucinations, and one had an obsessive-compulsive habit of smelling things. A bur hole was placed 3 cm lateral to the midline of the lobe and 1 cm anterior to the interaural line. Target localization was performed using contrast ventriculography. The target was placed in the medial half of the amygdaloid nuclear complex. Verification of the anatomical target was solely anatomical. The use of pneumoencephalography or ventriculography with positive contrast medium allowed for target localization, whereas a cryoprobe was used for creating lesions. The cryoprobe was stereotactically introduced through a 3-mm twist-drill skull opening into the amygdaloid nuclear complex. The anatomical target in this study averaged 2.0 cm lateral to the midline, 1.0 cm below the intercommissural line, and 45% posterior to the anterior commissure along the intercommissural line. The center of the lesion in their technique was placed in the anteromedial part of the amygdala. The tip of the cryoprobe was gradually cooled over a period of 5 minutes to −120°C and this temperature was maintained for 3 minutes. A second lesion was usually produced with the same technique. This technique was later abandoned, however, and the cryoprobe lesions were replaced by mechanical lesions, which were more precise from an anatomical standpoint and had a smaller volume.22 Heimburger et al.7 reported that 35% of the patients became free of any behavioral abnormalities and that 45% showed significant improvement.

In the late 1960s and 1970, Balasubramaniam and Ramamurthi13,14 reported on the largest clinical patient series to undergo stereotactic amygdalotomy. These investigators performed all of their procedures in patients after general anesthesia was induced; a Leksell stereotactic frame was used, and iophendylate ventriculography was performed for anatomical target localization. Physiological confirmation of the target was obtained by intraoperative EEG and electrical stimulation study via a stereotactically inserted depth electrode. Stimulation was performed with a current of 0.5 to 2 V at 50 cycles per second for 1 minute. Lesions in the amygdala were made with diathermy coagulation or a Bertrand loop and, on rare occasions, using a combination of these two methods. Diathermy coagulation lesioning was performed with an 8-mm electrode. The volume of each lesion was calculated as approximately 200 mm³. A total of nine such lesions were usually placed on each side of the lobe, increasing the total lesion volume to 1800 mm³, a size greater than the actual amygdala volume. The Bertrand loop was alternatively used in a few cases as a means of mechanical lesioning. The lesion volume in these cases was calculated as 500 mm³. Several years later, Ramamurthi19 reported on the long-term outcome of 481 patients undergoing stereotactic amygdalotomy. In this case series, 39% of the patients showed good to excellent outcomes, whereas moderate improvement was observed in 37%.

Hitchcock and Cairns20 in 1973 described a series of 18 patients with hyperactive, destructive, and rebellious behavioral disorders. The vast majority of these patients also had a history of epilepsy. Hitchcock and Cairns performed bilateral stereotactic amygdalotomies using either local or general anesthesia depending on the willingness of the patient to cooperate during the procedure. These researchers preferred a transtemporal approach instead of the previous-
ly described transfrontal method, because they believed that a direct transtemporal route might be both shorter and safer. Physiological confirmation of the anatomical target was obtained using electrical stimulation in the procedures performed after induction of local anesthesia. A 3 × 1.8–mm depth electrode was stereotactically introduced and electrical stimulation was performed for verification of the target; the electrical stimulation parameters used were 1 to 10 V, frequencies of 5 to 100 Hz, and a 1-msec pulse width. The anatomical target was centered on the medial group of the amygdaloid nuclear complex, although their intention was to destroy the entire amygdala. Postoperative improvement of violent and destructive behavior was reported in 27.7% of their patients.8

At approximately the same time, Sano and coworkers20,21 reported the results of the destruction of the posterior hypotalamus in patients with violent, aggressive, or restless behavior. Since 1962, they had been performing hypothalamicomies by making stereotactic lesions in the postero medial area of the hypothalamus.20,21 In this technique, a concentric bipolar needle electrode (0.8 mm at its largest diameter, with a 0.5 mm interpolar distance) was introduced into the hypothalamus under pneumoencephalographic guidance.20,21 More than one radio-frequency lesion was usually placed in the area of the posteromedial hypothalamus using a current of 1 megacycle and 2 to 3 W for 3 to 4 minutes. The size of each lesion was typically 3 to 4 mm in diameter. In the vast majority of cases, the coordinates of these lesions were from 1 mm anterior to 2 mm posterior to the midpoint of the intercommissural line, 2 to 4 mm below the intercommissural line, and 2 mm lateral to the lateral wall of the third ventricle. Lesions were usually made in both hemispheres in two separate sessions, 7 to 10 days apart from each other.20,21 In 1972, they reported on the outcome of 43 patients treated at their institution with stereotactic hypothalatomy for severe, violent, and aggressive behavior disorders; an excellent outcome occurred in 13 (30.2%) of 43 patients, and a good outcome in 28 (65.1%) patients.21 Sano et al. encountered a case of postoperative death (1 week after the procedure) from suffocation due to aspiration, whereas two of their patients had to undergo another operation because of symptom recurrence.

Modern Amygdalotomy

Lee and colleagues18 in 1998 utilized a modified Todd-Wells stereotatic apparatus in two patients undergoing bilateral amygdalotomy for medically intractable aggression. The entry point was placed 3 cm lateral to the midline and in the plane of the coronal suture. Anatomical localization was based on brain magnetic resonance imaging results and the Schaltenbrand and Wahren stereotactic brain atlas. Psychophysiological monitoring, including electromyography of facial muscles and skin conductance response measurement, was used intraoperatively. A temperature-monitoring electrode with a 2.1 × 5–mm noninsulated tip (Radionics) was used at a temperature of 80°C for 90 seconds to create a radiofrequency lesion. Three distinct lesions were placed 4 mm apart from each other on each side; the largest diameter of the total lesion was estimated to be 15 mm. Significant improvement along with a decline in the number of aggressive outbursts was reported in both patients, but both continued to have difficulties controlling occasional aggressive outbursts.16

In the past, the outcome of stereotactic amygdalotomy and posteromedial hypothalamotomy for behavioral disturbances was evaluated by using ill-defined and significantly varying criteria among different clinical series.8,10,18,19–22 Furthermore, long-term outcome data of these procedures were very limited.15,17,21 The questionable long-term benefit of these procedures, the dubious accuracy of the target localization (given the lack of appropriate instruments to anatomic ly verify the localization), and advances in psychopharmacology have all caused stereotactic amygdalotomy and hypothalamotomy for behavioral disturbances to be considered procedures of merely historical interest. Despite of recent advances in imaging guidance (such as high-resolution computed tomography and multiplanar 1.5- and 3-tesla magnetic resonance imaging), the development of highly accurate neuronavigational devices (such as primarily frame-based, but also frameless, stereotactic systems allowing image fusion and application of highly accurate and detailed stereotactic anatomical atlases), and the improvement of radiofrequency generators, stereotactic amygdalotomies or hypothalamotomies for aggressive behavior disorders have been performed rarely, and even fewer have been documented in the neurosurgical literature within the last decade.9,24

Conclusions

Since its inception, stereotactic amygdalotomy has evolved into a more accurate and precise stereotactic procedure. However, the development of psychopharmacology and the growing skepticism of the international medical community regarding psychosurgery resulted in the minimal utilization and almost total disregard for this procedure. This reality illuminates the existent tension in which surgical procedures continue to improve technically, to little avail, as utilization continues to decrease.

References

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Accepted October 20, 2006.
This paper was presented as a poster at the 74th annual meeting of the American Association of Neurological Surgeons, April 22–27, 2006, San Francisco, California.
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