

# Electrical stimulation of the anterior limbs of the internal capsules in patients with severe obsessive-compulsive disorder: anecdotal reports

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Electric stimulation of the anterior limbs of the internal capsule was introduced as a treatment for patients with severe incapacitating and treatment-resistant obsessive-compulsive disorder (OCD) by two groups that collaborated closely: the Belgian group, which consisted of a psychiatric branch at the University of Antwerp and a neurosurgical branch at the Katholieke Universiteit Leuven, and the Swedish group at the Karolinska Institute in Stockholm [1,2]. Although it was clearly shown that anterior capsular stimulation induces beneficial effects in patients with severe OCD, some unpublished psychiatric and neurosurgical clinical observations may enlighten and document certain effects of this kind of brain modulation.

## Materials and methods

In six patients with severe incapacitating and treatment-resistant OCD, two quadripolar electrodes (Model 3887 [4-mm contact spacing, 3-mm contact length], Pisces Quad Compact; Medtronic) (Medtronic Inc., Minneapolis, MN) were implanted into the anterior limbs of the internal capsules by one of the authors (B.N.). Using strict selection criteria, the patients were screened by a committee for neurosurgery for psychiatric disorders, an ethical review board, and an expert committee [3]. The investigational treatment was approved by the Leuven and Antwerp local hospital ethical standards committees on human experimentation and was in accordance with the declaration of Helsinki of 1975 (1983 revision and subsequent revisions). Patients gave written and witnessed informed consent. The stimulation targets were similar to those aimed for in the anterior capsulotomy [1,3]. The electrodes were placed 3 mm anterior to the anterior border of the anterior commissure and entered the brain via precoronal burr holes. The three most ventral stimulating contacts were placed in the internal capsule, and the fourth one was sited dorsal to the internal capsule. Although psychiatrists and psychologists blindly evaluated obsessions, compulsions, anxiety, depression, and several other relevant parameters using validated psychiatric and neuropsychologic scales, we only report here on some observations that interested the authors

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The authors (B.N., L.G., and P.C.) have been previously involved in research and/or education that was in part sponsored by Medtronic. One author (B.N.) is also filing a patent together with Medtronic.

and on responses to stimulation subjectively reported by the patients. Unless otherwise defined in the text, one author (B.N.) changed the stimulation parameters (amplitude varying between 0 and 10.5 V, frequency varying between 5 and 130 Hz, and pulse width varying between 60 and 450 microseconds) and the stimulation contacts of the quadripolar electrodes. Two other authors (L.G. and P.C.) evaluated the patients. During all evaluation sessions, these authors as well as the patients and their families were blinded for stimulation condition. In some conditions, the patients may have guessed that the stimulator was on because of the stimulation-induced effects. If the patients received a programming device, they were not blinded. In that condition, however, the patients still did not know when the stimulator was automatically switched on or off.

## Subjects

The first patient (Patient 1) was a 35-year-old man who suffered from many different obsessions and compulsions, including washing, counting, and rereading-rewriting-recalculating rituals as well as concerns with dirt, germs, and household items (white-spirit). His “major” current obsession was “the sound of silence.” He avoided being in a quiet environment and listened to loud beat music whenever he could. He had an excessive fear of hair growth and detested aging. A comorbid undifferentiated somatoform disorder was present with persistent complaints of vertigo, hypersomnolence, and loss of energy.

Patient 2, a 52-year-old woman, suffered from excessive concerns with urine and feces and obsessive thoughts about harming others after having touched herbs and plants. Compulsive hand washing, checking, and a compelling urge to ask questions were omnipresent.

Patient 3 was a 38-year-old woman who had excessive toilet, washing, and counting rituals; buying compulsions; and the compelling urge to touch. The thought that persons, objects, and things might not be real preoccupied her, and she developed a whole range of compulsions to prove their existence and reality. Her parents always had to stay within eyesight or, when this was not possible, had to talk to her continuously to reassure her.

Patient 4 was a 35-year-old man who had strong fears of harming others by not being careful enough and obsessions about poisoning others by contamination with nicotine, tar, or any

harmful household product. He had strong ideas that a road accident or drowning could have happened to someone and that he would not have given the necessary assistance or would not have alerted the emergency services. He contacted his sister (or the police) several times a day to check that no accidents had taken place where he had passed. He could not take a bus, and when in a car, he laid on the back seat with his eyes closed and a towel covering his face.

Patient 5, a 40-year-old woman, had severe contamination obsessions and was overly concerned with bodily waste and secretions. Going to the toilet took an hour (two or three times per day) and required assistance from her mother both day and night. Washing herself had become impossible, and a nurse came daily to help her with this routine. She had excessive and intrusive sexual thoughts about masturbating. She had an urgent need to ask for reassurance and to repeat sentences and statements for herself. She also hoarded old magazines and empty cigarette packs.

Patient 6 was a 37-year-old man who suffered from mostly aggressive obsessions. He had continuous intrusive thoughts and flashing images of harming others by poisoning, strangling, stabbing, or drowning. He also had a fear of writing compromising things. He avoided having pens and paper in the same room and could only read the newspaper when no ballpoint pen was near. He had excessive checking compulsions and cognitive escapes (rationalizing) to counter these aggressive thoughts. He could not drive a car anymore, because his habit of always checking in the back mirror made driving dangerous.

## Observations and subjective reports

### *Acute changes with stimulation in the early postoperative period*

Bilateral square wave pulse stimulation was started immediately after surgery. Effects that appeared immediately after starting anterior capsular stimulation are presented in the following list. We never started chronic stimulation if these effects were interpreted as side effects and if they persisted longer than 1 minute.

### Subjective feelings reported by the patient

- Anxiety: the patient may be tense or may be so anxious that he/she experiences an impression of death

- Relief of anxiety
- Feeling of happiness
- Sadness
- Nausea
- General unpleasant feeling
- Strange feeling
- Feeling of fainting
- Feels something in the head
- Sensation of warmth (in the face, chest, throat, feet, and/or legs)
- Tingling sensation (in the face or chest)
- Feels something in the throat
- Difficulty in swallowing
- Headache
- Sleepiness
- Peculiar thoughts (eg, patient wants french fries, patient feels that the stimulator is working like a compact disk that is turning, patient thinks about tennis)
- Visual symptoms and visual hallucinations (eg, patient sees black pieces of dust everywhere, patient has a black visual field on the left side and a white one on the right side, everything becomes darker, the wall seems to come closer, everything becomes smaller, patient has an impression that the room moves, patient sees fog, patient sees a certain person he/she has heard about but has never seen sitting beside her/him, patient has an impression of being in a tunnel, patient has an impression that the ceiling is dirty)
- Feels difficulty in breathing
- Becomes nervous and has the impression that time passes quickly
- Feeling of heavy legs
- Frontal pain
- One patient reported vaginal contractions on three occasions

#### Objective signs noted by the observer

- Patient makes a deep sigh
- Skin of the face turns red
- Sweating in the face and hands
- Patient says meaningless words during 20 seconds
- Patient repeats words or sentences continuously
- Repetitive movements with the hands
- Laughing or crying
- Yawning
- Patient speaks louder
- Orofacial or total body dyskinesias
- Dysarthria

The list includes subjective feelings and objective signs that appeared immediately after starting anterior capsular stimulation and may have disappeared within 10 to 30 seconds, although some of these effects remained during continuous stimulation. These effects were sometimes reproducible with similar amplitudes and sometimes not reproducible. Apart from the feelings and signs mentioned here, there were also occasions when the patient did not report anything when being stimulated at 10.5 V, 200 microseconds, and 100 Hz or that the reaction was unclear.

Patient 1 reported paresthesias in his face. At higher amplitudes, he felt uncomfortable, as if he was going to pass out. An improvement in mood was induced by using the three most ventral contacts as cathodes and the uppermost contact as an anode with an amplitude of 3 V and with the pulse lasting for 210 microseconds at a frequency of 100 Hz. The patient himself did not feel any improvements in his obsessive thoughts during this first stimulation episode, but a friend and his mother both remarked that he seemed less tense. When the stimulator was switched off for 3 days, Patient 1 started to comment on his noise obsession and felt worse.

At first, the therapeutic effects were not at all pronounced in either Patient 1 or Patient 2. It was only in Patient 3 that the authors saw marked acute changes as have been described elsewhere [1]. She was stimulated with either the three most ventral contacts programmed as cathodes and the uppermost contact as an anode or with all four contacts programmed as cathodes and the stimulator as an anode at 4 V using pulses of 210 microseconds at a frequency of 100 Hz. Clear improvements in obsession, compulsion, depression, and anxiety were noted. Gradually, the amplitude necessary to induce those beneficial effects rose to 6.5 V. Similar high voltages applied in Patient 1 and Patient 2 also induced more pronounced beneficial effects in those patients. The same stimulation parameters were used in Patient 4, Patient 5, and Patient 6 with similar beneficial effects as in Patient 2 and Patient 3.

Immediately after stimulation with these parameters, Patient 4 and Patient 6 uttered verbal perseverations for about 10 to 15 seconds (perhaps the equivalent of recurrent obsessive thoughts and repetitive compulsive acts). Patient 4 reported feeling happy and inclined to laugh, although he could state no reason for this cheerfulness. He once reported seeing a beautiful woman exactly at the moment the stimulator was switched on.

When prompted to elaborate on this, he said it was only a brief flash in his mind that had immediately disappeared.

Patient 5's sister kept a diary during the patient's postsurgical hospitalization. "No change" was noted during visits when stimulators were turned off. On days with stimulation, she noted that Patient 5 was in the best of spirits, had more energy, talked, and laughed a lot. She demanded much less reassurance than usual.

When stimulation was first turned on, Patient 6 heaved several deep sighs before starting his perseverative sentences. He felt more light-hearted and stated that he did not see a reason why he would make his life so difficult. He felt casual but not indifferent. He talked a lot more and faster than before. With higher amplitudes, he felt restless and worked up, he felt his heart beating, and he had difficulty in falling asleep.

#### *Manipulation of stimulation parameters*

The amplitudes necessary to induce symptom reduction rose to between 6.5 and 10.5 V in all six patients 3 to 5 months after the intervention. To reduce battery consumption, a programming device was given to Patient 2 and Patient 3 as one of the strategies. The patients themselves were given the capacity to use high amplitudes and pulse widths only when they felt they needed it. They were allowed to change amplitude and pulse width, whereas frequency was kept constant at 100 Hz. The upper amplitude and pulse width thresholds were determined by one of the authors (B.N.) after ensuring that these parameters did not cause side effects in an acute setting. Patient 3 used 6.5 V when she was at home, 7.5 V when she visited someone, and 8.5 V when she was in a crowd. She told us that if she programmed the amplitude to 9 V, she would start dancing on the table. This higher amplitude immediately induced palpitations and an excessive need for sleep, a condition that she disliked. Decreasing the amplitude to 6.5 V for the sake of saving battery time made her a bit more anxious and worried, a feeling she described "as if she loses something." She chose 330 microseconds as the optimal pulse width and has been using this pulse width for more than 3 years now. Patient 2 never wanted to use the programming device.

To decrease battery consumption even more, the stimulator was programmed so that it was automatically switched off at night and switched on at 6:00 AM in Patient 2 and Patient 3, again

without the patient knowing. Both patients awoke at night about 1 minute after the stimulator was switched off; could not continue sleeping; were anxious, tense and depressed; and were trapped in obsessional thoughts and mental compulsions (constructing and repeating sentences or counting to decrease restlessness) as severe as before surgery. They could only continue sleeping after 6:00 AM, when battery power resumed. During the day, they felt better, as with the continuous stimulation regimen, but were tired as a result of the loss of sleep at night. They both asked to get another stimulation paradigm after some days.

Programming the stimulators for 1 minute on and for 1 minute off induced a happy face for 1 minute with a smile and a sad face during the following minute, and this was tested for 30 minutes in two patients. The patients did not like this kind of stimulation algorithm because they never felt continued relief of anxiety and the sudden mood switches made them feel completely unnatural. Unilateral right-sided stimulation for 2 weeks with the stimulator on during 1 minute and off during the following minute did not improve symptoms as compared to the preoperative condition.

Many contact combinations were tried out. As an example, using the three most ventral contacts as cathodes and the uppermost contact as an anode, the symptoms were reduced in Patient 1 and Patient 3. Conversely, doing the opposite in the same patients, programming the three most caudal contacts as anodes and the uppermost contact as a cathode, symptoms were comparable to the prestimulation level.

Stimulation at 100 Hz or 130 Hz and stimulation at higher pulse widths (210 microseconds up to 450 microseconds) induced better symptom reduction than stimulation at 5 Hz or at a pulse width of 60 microseconds.

#### *Effects of continuous stimulation*

We evaluated the six patients on a regular basis and asked peers and family about each patient's condition. Respective follow-up times are 50 months (Patient 1), 49 months (Patient 2), 47 months (Patient 3), 28 months (Patient 4), 9 months (Patient 5), and 3 months (Patient 6). Patients 2 through 6 reported spontaneously that several symptoms had improved during the period that stimulation actually took place. Patient 1 stated that he experienced only marginal or temporal benefit, but both his friend and the

authors observed a slight but definite improvement in mood. His friend also noted that he seemed more peaceful and less preoccupied by his obsessions. He certainly talked less about them and was less self-centered, as if the noise obsession was still there but had become less intrusive.

Patient 2 asked fewer questions and started to do part of the housekeeping (cleaning, laundry, ironing, and cooking) again. She still felt the urge to ask for reassurance but could control it most of the time. She could again enter rooms at home where she did not dare to go before surgery.

Patient 3 reported a 90% decrease in obsessions and compulsions, felt much happier, was much less anxious, and was not depressed. She started listening to music again and enjoyed watching television, whereas before stimulation, she complained loudly each time someone switched the television on. She could re-enter her former bedroom, which had been impossible previously because she became obsessed with thoughts of death and mortality. She used clothes she had not dared to wear for many years, and she also dared to touch a cleaning towel, which was previously impossible. She was a lot more dynamic, attended cultural events, and regained her interest in art history. She actually started to read the books she formerly collected and stored in the cellophane packing in which they came. She stopped hiding for family meetings. She accompanied her mother to the cemetery on All Souls' Day. This was unthinkable before, because she would have become trapped in ideas of nonexistence.

Patient 4 reported being more relaxed, was happier, and controlled less. He realized that he could resist the urge to control for accidents, that his obsessions and compulsions were only products of his mind, and that there was no real need to act on them. He could postpone checking the parking lot and make short walks.

Patient 5 was less anxious and less tense. Going to the toilet was less time-consuming, and she did not insist on her mother's assistance during the night anymore. After some weeks of stimulation, the nurse who came to wash her before surgery only paid short reassuring visits but did not need to assist her anymore. She experienced overall a 50% reduction in contamination fears and washing compulsions. She continued to ask many questions, but she took more initiative, read newspapers, and watched television more frequently. She was in a better mood.

Patient 6, in whom follow-up is only 3 months, felt a lot more relaxed with stimulation. He again

enjoyed going with his children to a playground or amusement park, where he had formerly dreaded the thought of having strangled or hurt one of the other children. He joined his family in a barbecue party without fear of burning others. He readily finished his "to do" list of chores that he had always postponed before surgery and felt the need for new interests.

It is clear that anterior capsular stimulation may improve some of the symptoms of OCD patients. Validated tests using strict research paradigms have been submitted for publication elsewhere. A disequilibrium in the systemic environment of the patient in reaction to the changes attributable to stimulation has to be taken into account, however. When Patient 2 became able to do some of the housekeeping again, she was expected to take up part of the responsibilities and regain some independence. She found it difficult to develop interests of her own and longed for the continuous closeness of her husband. He had been taking care of his wife and children for so long that he felt he deserved some relief and the right to engage in activities he had had to give up because of her disorder. Patient 3 became more independent and started traveling alone and abroad. She continued to live with her parents because this was comfortable, but she sometimes wondered if she wanted to care for them when they became older and in need of help. She was also sad because she realized that she had missed a large part of her young life as a result of the continuous severity of her OCD. Always being amid older people, she also had trouble in building meaningful relationships with people of her own age. Patient 5 felt much more self-confident and assertive during stimulation. She had been subdued and lived with her parents, who, together with her two sisters, had taken care of her for many years. After stimulation, she wanted to decide for herself at what time she would come home at night. She also could not stand the fact that her sisters were sharing their deepest feelings with each other and wanted to take part in this. She no longer accepted any authoritarian behavior from her father or dominance by her sisters. She started to go to school and wanted to live on her own. Conversely, she was not symptom-free and thus claimed that she could not accept full responsibility for herself and still needed help. She was living on disability benefits and controlled her own finances. She realized that living in her own apartment was financially unacceptable for the

moment. This caused numerous discussions within the family.

A similar form of increased independence as a result of stimulation could be noted in Patient 1. He was a successful artist. After he started being stimulated, he dared to try out new ways of painting, although he never thought about this before surgery. He painted more of his own ideas and developed a style of his own. He received critical acclaim, and art connoisseurs stated that he painted better and more balanced than before implantation of the electrodes. During stimulation, he felt lots of energy, which made him produce many paintings per day. His success placed social demands on him, and he tended to experience more fear of failure and an extreme need for endorsement.

#### *Impact of stimulation on quality of life*

Quality of life (QoL) in patients considering neurosurgery for treatment-refractory OCD is low. Severe OCD interferes with the ability to work and to do the housekeeping and with education, family relationships, and social life; beyond that, physical and psychologic well-being is low. After 1 year of stimulation, all six patients remain defective in several domains of health-related QoL. Patient 1 was more successful in his work. Patients 2 through 5 were unemployed at the time of surgery and did not start to work afterward. Patient 2 became more active in housekeeping tasks, whereas she had been hospitalized almost continuously for several years before surgery. Patient 3 was much less dependent on her parents, and her family relationships improved tremendously. Patient 4 went through a divorce at the time of surgery. He has recently started to go out again on Saturday nights and is meeting new people. He also started some volunteer work at a library (part-time). Patient 5 started adult education classes and devotes serious energy to her studies.

#### *Medication, additional treatment, and counseling*

In the opinion of the authors, the follow-up of electrically stimulated OCD patients is comparable to the follow-up of electrically stimulated parkinsonian patients. As parkinsonian patients are still followed by a neurologist, OCD patients need follow-up with their psychiatrist. Until now and for the sake of scientific methodology, medication was tapered off to a minimum before surgical intervention and kept stable throughout

the first year of stimulation. No additional psychotherapy specifically aimed at improving OCD (eg, exposure and response prevention [ERP]) was given during this period. Patients were asked to remain under the care of their treating psychiatrist for treatment “as usual” and to come to our centers only as part of the research evaluation. It seems likely, although not yet studied in detail, that the stimulated patients respond better to drug treatment and behavioral therapy than when not stimulated. Only the first four patients have completed their first year of stimulation to date. Patient 1 is still taking the same medication, but the dose of benzodiazepine (BZD) could be slightly reduced for Patient 2 and Patient 3. For Patient 4, medication was completely changed 2 years after surgery by the treating psychiatrist. None of the patients engage in ERP treatment, but they avoid less and seem to involve themselves more in everyday life.

#### *Replacement of batteries*

When batteries wore out, patients started to feel worse again and OCD symptoms resumed at their former intensity over the course of a few days. All patients immediately contacted one of the authors (B.N.) when they thought the battery was empty, although only two of them had a programmer by which they could really check whether the battery had run low. Stimulation was always performed with a symmetric voltage supply, but because impedances differed somewhat between the left and right sides, the battery of one stimulator was usually empty earlier than that of the other. Usually, only one of the stimulators (either right or left side) had run low when patients requested a check on battery status for sudden worsening, implying that unilateral stimulation is less effective than bilateral stimulation. Similarly, in observing acute reactions (minutes) when changing stimulation parameters, it was almost always clearly noticeable that the effects of bilateral stimulation were more pronounced than those of unilateral stimulation, whether it was right-sided or left-sided stimulation. The patients' urge to ask for renewal of the stimulators was comparable to that of some parkinsonian patients, who are electrically stimulated in either subthalamic nuclei or ventral intermediate nuclei, to request this when their battery runs low. Their condition changed dramatically after stimulator renewal, even on the operating table, straightaway after the stimulators

were switched on. In Patient 2, the degree of this change fluctuated. The beneficial effects were sometimes only seen after several days, but the husband once said that we had suddenly altered his wife into a lovely young flower. He was not used to this appeal, and he felt uneasy about it. These sudden changes required adaptations in their relationship that were not easy to attain. All patients reacted strongly when the batteries ran down. They felt bad again, and although after a few battery replacements, they knew that these bad feelings were caused by technical reasons, it was difficult to accept this and to put it into perspective. Patient 4 twice experienced a brief hypomanic state (2–3 days) after placement of new batteries. His family reported that he was overactive and could not sleep at all for 36 hours. He tried to impress others and even threatened violence if others did not accept him as “the man who could do it all.” He felt good about himself and regretted that his brother (who also had severe OCD and had committed suicide several years before) could not have benefited from stimulation. He also made some sexual insinuations and passes directed at some acquaintances, and he suddenly demanded a paternity test for his 8-year-old son. When questioned about these episodes in a psychiatric interview some time later, he remembered the hyperactive state but not the showing off and swaggering behavior. He explained that during an argument years earlier, his former wife had told him he could never be sure that he was his son’s father and that this had come into his mind and obsessed him for a few days. He did not persist in demanding the paternity test.

## Complications

### *Technical problems and hardware failures*

The most important inconvenience was definitely the high current amplitude needed to maintain acceptable results in the years after the surgery. Stimulators had to be replaced every 5 to 12 months in all patients. This makes the therapy difficult to use as standard therapy, but one can think of strategies either to improve battery technology (eg, rechargeable batteries) or to reduce battery consumption. The stimulators could be replaced under local anesthesia and in an ambulatory setting.

Severe weight loss as a result of severe pyelonephritis in Patient 2 caused the left stimulator, which was implanted in the left hemiabdo-

men, to migrate more caudally, which induced traction on the extension cable and thus on the electrode. This traction led to fracture of the left electrode and worsening of the OCD symptoms 44 months after surgery. The electrode was replaced, and the patient improved again.

In Patient 5, the impedance of the uppermost contact increased to more than 4000  $\Omega$  shortly after implantation, which suggests a broken contact. Therefore, we could only stimulate with three of the four contacts on the left side, but clear beneficial effects on OCD symptoms were still seen.

### *Side effects*

Possible side effects were a major concern when starting this new kind of therapy. There were no intracranial hemorrhages, epileptic fits, or infections, although there was a more than usual swelling of the face in Patient 5 during the first 4 days after surgery, which was prophylactically treated with antibiotics for 1 week even though cultures of aspirated subcutaneous fluid remained sterile.

On some days, Patient 1 felt the leads and the stimulator and wanted to take the system out. During most of the time, however, he wanted to continue the stimulation. He found the advantages of the capsular stimulation not comparable to the disadvantage of needing to have the stimulators replaced every 8 months. Apart from severe OCD, he also suffered from undifferentiated somatoform disorder. For those reasons, his electrodes were removed, and he underwent a bilateral anterior capsulotomy. Other patients complained less about the presence of the stimulators.

Fatigue lasting for several months was a major complaint of Patient 3. When she was given the option of decreasing the amplitude to get immediate relief of her fatigue, she chose to continue stimulation because she appreciated the fact that the benefits of the stimulation were so much greater than the disadvantage of the fatigue. Paradoxically, she showed more energy during the daytime and took much more initiative than before surgery. All patients reported better sleep at night.

Although Patient 3 once reported that one of the authors resembled her previous lover, no frontal signs were noted during subsequent neuropsychologic testing. Also, no permanent pathologic frontal signs were observed in the other patients. Patient 3 complained of a worsening of

memory, but neuropsychologic tests before and 1 year after surgery could not document any difference. Patient 2 was treated for pyelonephritis, which was interpreted as being unrelated to the stimulation. Patient 2 lost weight, and Patients 3 through 5 gained weight to different degrees.

### Summary

Anterior capsular stimulation induces some improvement in severe treatment-resistant OCD patients. At this stage, not all stimulation-induced effects can be explained. The effects are a valuable source for further neurophysiologic and neuroanatomic research. It was reassuring that when the group of Drs Rasmussen, Greenberg, and Friebs in Providence and the group of Drs Rezai, Montgomery, and Malone in Cleveland started to operate on OCD patients using exactly the

same technique, similar effects were seen in the patients. The authors still want to stress that anterior capsular stimulation remains investigational and needs optimization, especially to try to solve the problem of the short battery life of the stimulators.

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