

Anesthesia for Functional Neurosurgery

Review of Complications

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Abstract: The use of functional stereotactic neurosurgery is increasing for treatment of patients with movement disorders and other chronic illnesses. The anesthetic considerations include the influence of the anesthetic agents on the microelectrode recordings and stimulation testing of an awake patient. The purpose of this study was to review the anesthetic management and incidences of intraoperative complications during functional neurosurgery in our institution. One hundred seventy-eight patients underwent an ablative procedure (n = 6) or the insertion of deep brain stimulator (n = 172) under monitored anesthesia care for movement disorders (n = 124), chronic pain (n = 20), and other procedures (n = 34). Local anesthetic was used for head frame pin sites and burr holes. No sedation/analgesia was administered to 57 (32%) patients. One patient required conscious sedation and another general anesthesia for the entire procedure. The remainder received small increments (mean \pm SD) of propofol (113 \pm 73 mg), midazolam (1.6 \pm 0.8 mg), and/or fentanyl (93 \pm 55 μ g). Intraoperative complications that occurred in 16% of the patients included seizures (n = 8), change in neurologic status (n = 5), airway obstruction (n = 2), and hypertension (n = 7). Functional neurosurgery can be performed with minimal anesthesia in many patients. Awareness and vigilance can improve the identification and early treatment of intraoperative complications such as seizures, loss of airway, and changes in the neurologic status.

Key Words: functional neurosurgery, movement disorders, deep brain stimulator, monitored anesthesia care

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Functional stereotactic neurosurgery involves the surgical treatment of disorders that have an alteration of function that is not usually accompanied by gross structural or anatomic changes.^{1–3} From its initial success in patients with movement disorders such as Parkinson disease, the indications and applications of functional neurosurgery have been expanded to a variety of other disorders including chronic pain and

psychiatric disorders.^{4–7} The areas of the brain that are targeted during surgery are deep and small in size. A number of different techniques are used to increase the accuracy of locating these specific areas. This includes the use of frame-based imaging to visualize brain structures and to establish coordinates, and intraoperative clinical testing of an awake patient. These procedures present a challenge to the anesthesiologist as they are demanding and the patients frequently have complex medical problems.^{8,9} There is limited information on the anesthetic management and on the incidence of intraoperative anesthesia-related complications during functional stereotactic neurosurgery.^{10–12} The purpose of this study was to review our experience of the anesthetic management of patients undergoing functional neurosurgery with monitored anesthesia care with specific interest in the incidence of intraoperative complications.

METHODS

Institutional ethics committee approval was obtained to maintain a prospectively collected database on all patients undergoing functional neurosurgery under monitored anesthesia care. Pediatric patients scheduled under general anesthesia were excluded. Data collected include general demographics, patient's medical condition, type and duration of surgery, anesthetic management, and intraoperative and postoperative complications.

Both the neurosurgical and the neurophysiology teams performed the preoperative selection and the preparation of the patient. The patients were assessed by an anesthesiologist in the preoperative anesthesia consult clinic. Preoperatively, for most patients, the medications for their disease were withheld to have them in an "off" drug state. On the day of surgery, in the magnetic resonance imaging (MRI) suite, a stereotactic head frame (Leksell) was placed on the patient's head after injection of local anesthesia (bupivacaine 0.25% with 1:100,000 epinephrine) into the pin sites by the neurosurgeon. No sedation was routinely given to the patient at this time. This was followed by the MRI scanning for the visualization of brain structures and calculation of coordinates for targeting of the specific areas of the brain. Patients were then transferred to operating room, where the care of the patient was taken over by the anesthesiologist. The head frame was attached to the operating room table, and patients were positioned in a sitting or semisitting position with protective padding to all pressure areas. After establishing intravenous access, monitors

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(noninvasive blood pressure, electrocardiogram, pulse oximetry, and capnography via nasal prongs) were attached. Oxygen at 4 L/min was administered via the nasal prongs. Intravenous fluid administration consisted of normal saline at 50–75 mL/h. The anesthetic technique was monitored anesthesia care. As requested by the surgeon, sedation and/or analgesia was administered only when patients complained of excessive pain or anxiety or if they were very restless. The choice of the sedative and analgesic drugs was at the discretion of the anesthesiologist. The surgical procedure included the creation of a burr hole(s) under local anesthesia (bupivacaine 0.25% with 1:100,000 epinephrine), followed by the insertion and then the recordings from microelectrodes and stimulation testing of the patient. Once these were completed, radiologic confirmation of the position of the inserted stimulator electrodes was performed and then closure of burr hole(s). All the patients were monitored for at least 1 hour in the postanesthetic care unit and then transferred to the ward. The second stage of the procedure, the internalization of the electrodes and insertion of a generator, was usually, but not always, performed under general anesthesia at a later date.

RESULTS

One hundred seventy-eight consecutive patients scheduled for stereotactic functional surgery with monitored anesthesia care were reviewed (July 1998 to July 2004). Patient age (mean ± SD) was 51 ± 15 years, weight 75 ± 17 kg, sex ratio (F:M) 109:69, and duration of surgery 353 ± 131 minutes (range 110–720 minutes). Indications for surgery are shown in Table 1.

The surgical procedure consisted of ablative (n = 6) or deep brain stimulation (DBS) techniques (n = 172). The ablative procedures included cingulotomy (four), capsulotomy (one), and pallidotomy (one). DBSs were performed either unilaterally (n = 34) or bilaterally (n = 138).

The anesthetic management consisted of monitored anesthesia care with or without sedation and/or analgesia (Table 2). No sedation and/or analgesia was given was at any time to 57 (32%) patients. One patient required continuous sedation

TABLE 1. Indications for Surgery

Indication for Surgery	n
Movement disorders	
Parkinson disease	87
Essential tremor	16
Dystonia	16
Myoclonus	5
Others (chorea, torticollis, spasticity)	4
Chronic pain	20
Psychiatric disorders	
Chronic depression	7
Obsessive compulsive	6
Seizure disorders	9
Multiple sclerosis	8

n, number of patients.

TABLE 2. Anesthetic Management

Drug	No. of Patients	Dose (Mean ± SD)
No drugs	57	
Propofol (mg)	63	113 ± 73
Midazolam (mg)	52	1.6 ± 0.8
Fentanyl (µg)	85	93 ± 55
Remifentanyl (mg)	1	1.2
Granisetron (mg)	3	1.3 ± 0.6
Labetalol (mg)	7	21 ± 14
Esmolol (mg)	1	30
Hydralazine (mg)	1	15

throughout the entire procedure including the placement of head pins and MRI scan because of severe dystonia and spasticity. Another patient developed repetitive seizures in the MRI suite and required a general anesthesia (propofol, fentanyl, rocuronium, sevoflurane) with endotracheal intubation for the entire procedure. Two other patients required midazolam and propofol for the insertion of head pins and MRI scanning because of anxiety and restlessness. The remainder (66%) of the patients received either a single agent or a combination of agents for the initial incision and/or for closure of the burr holes. Patients did not receive any sedation during the times of microelectrode recordings and stimulation testing.

Intraoperative adverse events occurred in 28 (16%) patients (Table 3). Two patients had two different types of complications: One with a severe headache also vomited; the other patient developed bronchospasm and later became very drowsy with hemiparesis. Seizures during the intraoperative stimulation testing were the most common problem, occurring in eight (4.5%) patients. Five patients developed seizures that were focal in nature and did not require treatment; three patients had tonic clonic seizures that responded to midazolam (1–2 mg) and/or propofol (10–40 mg). After control of the seizures, the remainder of the procedure was successfully completed in all patients except one who was kept asleep for the remainder of the procedure. Respiratory complications occurred in four patients (2.2%); two patients experienced dyspnea and bronchospasm, possibly related to anxiety. Two other patients

TABLE 3. Intraoperative Complications

Complication	No. (%) of Incidences
Neurologic	
Seizures	8 (4.5)
Decrease level of consciousness	4 (2.2)
Neurologic deficit	1 (0.6)
Respiratory	
Airway obstruction	2 (1.1)
Respiratory distress	2 (1.1)
Cardiovascular	
Hypertension	7 (3.9)
Other	
Excessive pain	2 (1.1)
Nausea/vomiting	3 (1.7)
Blood loss	1 (0.6)

developed airway obstruction. One patient developed a sudden onset of complete airway obstruction when his head and neck became rigidly flexed owing to shifting of his body down the operating room table. He was unable to speak or breathe and became very agitated. By releasing the Leksell frame from the table and then repositioning the patient, the airway obstruction was corrected. The other patient received 1.5 mg of midazolam for the treatment of an intraoperative seizure, which resulted in oversedation and oxygen desaturation. A laryngeal mask airway was inserted to relieve airway obstruction, and the patient was kept asleep for the remainder of the procedure. Changes in neurologic status occurred in five patients (2.8%) after the insertion of DBS. One patient developed a persistent speech deficit. Three patients developed fluctuating decreases in level of consciousness and hemiplegia. A computed tomography (CT) scan performed at the end of the procedure showed hemorrhage at site of the electrodes. The fourth patient had a deteriorating loss of consciousness requiring an immediate CT scan, which showed a large intracranial hemorrhage. This patient had a poor outcome. Prior to the insertion of the DBS, seven patients had hypertension, which was defined as a blood pressure reading of 160/90 mm Hg or higher for two consecutive recordings, 5 minutes apart. The patients were treated with esmolol, hydralazine, and/or labetalol until the blood pressure was recorded at below 160/90 mm Hg, and then the DBS was inserted. Five of these patients did have a history of treated preoperative hypertension. There were no further intra- or postoperative complications in any of these patients.

Early postoperative complications included decreased level of consciousness associated with an intracranial bleed (four patients), confusion (two), seizures (one), neurologic deficits (three), and cerebrospinal fluid leak (one). An immediate postoperative CT scan was required in 11 patients who had developed a change in their neurologic status ($n = 8$) or had repetitive seizures ($n = 3$).

DISCUSSION

In our review of the anesthetic management of patients undergoing stereotactic functional neurosurgery, we found that monitored anesthesia care was successful in all but two patients. Thirty-two percent of the patients received no sedation or analgesia at any time. The remainder of the patients received some sedation and/or analgesia during some part of the procedure, but not during the microelectrode recordings and stimulation testing. Intraoperative adverse events occurred in 16% of the patients, including seizures, change in neurologic status, and loss of airway.

Functional neurosurgery is designed to test, stimulate, and then alter the physiologic activity of the central nervous system by the generation of a lesion or by chronic electrical stimulation with a DBS. The anesthetic management of patients varies among different institutions.¹⁰⁻¹⁴ The effects of anesthetic agents on the microelectrode recordings and stimulation testing are of concern. The preferred method by some neurosurgeons and neurophysiology teams, including in our institution, is to have no anesthesia and/or sedation given to the patient. The use of sedative medication, even in small doses, has been shown to affect the quality of microelectrode

recordings.¹⁵ Temporary suppression of Parkinson disease tremor has been described with the use of propofol and remifentanyl.^{9,16,17} Other centers use sedation during the periods of nonintervention and testing with infusions of propofol, remifentanyl, and more recently dexmedetomidine.¹⁸⁻²⁰ The infusions are stopped before stimulation testing to allow the patient to be awake and cooperative. General anesthesia is also used and will be needed in some specific patients such as children and adults who do not tolerate being awake. In our study, we only reviewed the patients who were scheduled for monitored anesthesia care. However, one patient required continuous sedation with remifentanyl and propofol owing to severe spasticity and another required general anesthesia owing to continuous seizures. Maltete *et al*¹⁴ reported their results in 15 patients with Parkinson disease operated on under general anesthesia and compared with a matched control group who had local anesthesia. The results showed that general anesthesia was feasible, but improvement in motor disability was greater in the local anesthesia group, suggesting that targeting of the subthalamic nucleus was less precise during general anesthesia.

Perioperative considerations for the anesthesiologist include the medical condition of the patient, the omission of their medications before surgery, and their anxiety about the procedure.^{10,21} These procedures are long in duration, and the positioning required may not be very comfortable for the patient. Application of the stereotactic frame and creation of the initial burr hole are painful. Local anesthesia either by regional nerve blocks or by subcutaneous infiltration can be used.²² The fixed stereotactic head frame may make the access to the patient's airway difficult and even impossible. All these factors may contribute to the occurrence of intraoperative complications. In our study, 16% of patients had an intraoperative event. Seizures were the most common event occurring in 4.5% of patients, mostly occurring during insertion of DBS and stimulation tests. They were usually focal in nature and self-limiting, but occasionally they may become generalized tonic clonic seizures requiring treatment. Initial treatment of seizures may be with a small dose of a short-acting agent such as propofol or midazolam, ensuring that patients do not injure themselves.

Respiratory complications are the most feared as the presence of the Leksell frame may make the airway difficult to access. As well, the patient's head is fixed via the frame to the operating table. With tremors, agitation, seizures, and even fatigue, the patient's body may shift, causing difficulty in talking or breathing or complete airway obstruction. One patient in our series needed to have the frame detached from the table to correct his airway obstruction. Exacerbation of the tremors may be difficult to control in patients with movement disorders, though small doses of oral levodopa have been used successfully in some patients.¹⁰

Monitoring may be technically difficult especially in patients with movement disorders and spasticity. Blood pressure control is crucial as hypertension has been associated with increased risk of intracerebral hemorrhages.²³ Blood pressure monitoring may be with an intra-arterial catheter or by noninvasive means. The use of dexmedetomidine for sedation during DBS insertion was shown to result in better control of blood pressure and less need for antihypertensive medications.²⁰

Fluid management may also be a problem with an awake patient. We restricted the intraoperative fluid administration, thus avoiding the need for urinary catheterization, though a bedpan or urinal was used, if needed. The use of a semisitting or sitting position may increase the risk of venous air embolism in spontaneously breathing patients. Two case reports have illustrated the importance of monitoring end-tidal CO₂ and precordial Doppler during functional neurosurgical procedures.^{24,25} But the continuous use of a precordial Doppler interferes with neurologic recordings and should be used only during drilling of the burr hole. We did not use a precordial Doppler.

The success of functional neurosurgery depends on careful patient selection. Bleeding disorders and refractory hypertension are contraindications for this procedure as they increase the risk of intracranial hemorrhage.¹³ Patients also need to be assessed by a neuropsychology team for their suitability to tolerate a lengthy procedure in their off-drug state, especially if they will be awake for their procedure. Surgical complications vary with the experience of the surgical teams and the type of procedure (ablative versus stimulation). This topic has been well reviewed, and it was not the intent of our study to assess the surgical outcome.^{26–28} Sudden onset of neurologic injury during or after surgery frequently requires the assistance of the anesthesiologist. If the event is severe, acute resuscitation of the patient such as securing an airway may be needed. Also, the patient may need to be urgently taken to the CT or MRI unit for scanning and back to the operating room for a craniotomy.

In summary, many patients with different neurologic and other conditions undergo stereotactic functional neurosurgical procedures requiring the care of the anesthesiologist. The procedure may seem simple to the anesthesiologist, and in reviewing of our data, these procedures can be performed with minimal or no sedation in many patients. However, intraoperative adverse events did occur in 16% of the patients. Awareness and vigilance can improve the identification and early treatment of intraoperative complications such as seizures, loss of airway, and changes in the neurologic status.

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