Lesson S34: PreAnesthetic Assessment of the Patient for Deep Brain Stimulation

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Professional Gaps

Deep brain stimulation (DBS) was introduced 3 decades ago for relief of tremor associated with Parkinson’s disease and other movement disorders. More recently, the technique has been shown to be effective for a wide range of problems including depression, chronic pain and eating disorders. Many anesthesiologists may not be aware of these expanded uses and the importance of selecting appropriate anesthetic agents based on the needs of the neurosurgeon, the electrophysiologist and the patient’s condition.

Learning Objectives

At the end of this activity, the participant should be able to:

1. List indications for deep brain stimulation.
2. Describe the salient features of Parkinson disease and other movement disorders.
3. Outline the preanesthetic assessment for a patient presenting for DBS.
4. Identify targets for DBS.
5. List complications of the DBS procedure.
6. Discuss appropriate anesthetic care for each stage of the DBS procedure.
7. Describe the signs, symptoms and treatment of air embolism
8. List the electrophysiological effects of anesthetic agents as they pertain to DBS monitoring.
9. Explain what is required of patients during DBS.
10. List the concerns of drug interactions in patients with chronic pain syndromes.

Case History

A 32 year old male, a returning veteran from Afghanistan, presented with intractable phantom limb pain following traumatic amputation of both lower legs. During 6 months of therapy he had been seen and treated by multiple neurologists, pain specialists and psychiatrists with little relief. He was
scheduled for insertion of electrodes for deep brain stimulation. He was right handed, English speaking and apart from severe depression, cognitively intact. Current medications included oxycodone, fentanyl patches, sertraline, selegiline and medical marijuana as well as several herbal remedies such as St John’s Wort. He also admitted to drinking about 5-10 beers/day. Laboratory values were all within normal limits as were his vital signs.

Introduction

Deep brain stimulation involves the implantation of a pacemaker, which sends electrical impulses to specific parts of the brain. In select brain regions, it has provided therapeutic benefits for otherwise treatment-resistant movement and affective disorders such as Parkinson's disease, essential tremor, dystonia, and chronic pain. Despite the long history of DBS, its underlying principles and mechanisms remain unclear. DBS changes brain activity in a controlled manner and the effects are reversible (unlike those of “lesioning” techniques that are used in similar circumstances).

Deep Brain Stimulation

Thalamic DBS was developed initially as therapy for Parkinson’s disease and was shown to be an effective treatment for movement disorders and dystonias. Other brain targets were investigated and the process involved the subthalamic nucleus (STN) and the internal globus pallidus. DBS has been shown to improve intractable epilepsy, cephalgias, restless legs syndrome, multiple sclerosis, pantothenate kinase-associated neurodegeneration, Tourette syndrome, major depressive disorders, obsessive compulsive derangements and other movement disorders, including essential tremor, and post traumatic tremor. Although DBS has been slow to gain approval in the United States for treatment of refractory pain, several studies in Europe and Canada have reported successful outcomes, especially for failed back surgery. For patients who fail conventional pharmaceutical treatments to these many disorders, DBS may prove beneficial and, as such, will likely be performed more frequently, necessitating increased awareness of the procedure by anesthesiologists.

DBS is also used in research studies to treat chronic pain and has been used to explore various affective disorders, including major depression. These applications of DBS, while under review by the National Institutes of Health, have not yet been FDA-approved. Although DBS has proven helpful for some patients, there is potential for serious complications and side effects as the mapping of the brain is far from complete.

Recognizing that DBS may be useful for many types of disorders that do not respond to current and conventional therapies, the Federal Defense Advanced Research Projects Agency (DARPA) committed to spending more than 70 million dollars over 5 years to achieve a new level of brain implants to improve the neurological health of veterans and soldiers.

DARPA funds, promotes and manages the development of new technologies for use by the U.S. military. Since its founding in 1958, it has formed and executed research and development projects that have expanded the frontiers of technology and science and reach far beyond immediate military requirements including computer networking and the NLS hypertext system, and an important precursor to the contemporary ubiquitous graphical user interface. This recent initiative strongly indicates that there will undoubtedly be considerable exploration and expansion of the uses for DBS.
Components and placement

The DBS system consists of three components: the implanted pulse generator (IPG), the lead, and the extension. The IPG is a battery-powered neurostimulator encased in titanium which generates electrical pulses to interfere with neural activity at the target site. The lead is placed in one of three areas of the brain and consists of a coiled wire insulated in polyurethane with four platinum iridium electrodes. The lead is connected to the IPG by the extension, an insulated wire that runs from the head, down the side of the neck, behind the ear to the IPG, which is placed subcutaneously below the clavicle or, in some cases, the abdomen. The IPG can be calibrated by a neurologist, nurse, electrophysiologist or trained technician to optimize symptom suppression and control side-effects.14

Figure 1: Schematic of DBS 44

DBS leads are placed in the brain according to the type of symptoms to be addressed. For non-Parkinsonian essential tremor, the lead is placed in the ventrointermediate nucleus (VIM) of the thalamus. For dystonia and symptoms associated with Parkinson’s disease (rigidity, bradykinesia, akinesia, and tremor), the lead may be placed in either the globus pallidus or the subthalamic nucleus (Figure 1).

All three components are surgically implanted inside the body, usually under local anesthesia with sedation. A burr hole about 14 mm in diameter is drilled in the skull and the electrode inserted. During the awake procedure with local anesthesia, feedback from the patient is used to determine optimal placement. If general anesthesia is necessary, intraoperative MRI guidance may be used for direct visualization of brain tissue and the device.15 The installation of the IPG and leads are accomplished usually at a later date under general anesthesia. The right side of the brain is stimulated to address symptoms on the left side of the body and vice versa.

Physiology of DBS

The mechanism of action is not well understood in humans. Thalamic slices from studies performed on mice show that DBS causes nearby astrocytes to release adenosine triphosphate (ATP), a precursor to adenosine (through a catabolic process).16 Adenosine A1 receptor activation then depresses excitatory transmission in the thalamus causing an inhibitory effect that mimics ablation or "lesioning". Observations from other studies contradict this hypothesis. For example, lesioning of the globus pallidus externus (GPe) can produce Parkinsonism while DBS of the GPe can reverse Parkinsonian symptoms.17
Amenable conditions

Parkinson’s Disease

Parkinson’s disease (PD) is a neurodegenerative condition resulting from neuronal loss in the dopaminergic substantia nigra pars compacta (SNc). Projections from the SNc to the striatum normally control fine movements. At first, the dopamine receptors in the striatum of PD patients are upregulated in response to a reduction in dopaminergic input. As increasing populations of somata are lost in the SNc, clinical symptoms appear. Dysfunction initially occurs unilaterally in the form of micrographia, hand tremor, decreased arm swing, and foot dragging. Eventually, bilateral symptoms appear as bradykinesia, resting tremor and postural instability. A therapeutic response to levodopa (L-dopa) can be documented. Almost 90% of patients with PD have significant vocal fold bowing and adduction and pharyngeal residues of solids can be found on evaluation of swallowing.

PD is a clinical diagnosis, confirmed at postmortem analysis by demonstration of Lewy bodies and the loss of dopaminergic neurons in the SNc. The degeneration of SNc dopaminergic neurons, which project to the striatum as the nigrostriatal pathway, leads to a reduction in striatal dopamine content and eventually to the clinical phenotype. An early hypothesis that stimulation inhibited neuronal activity at the site of stimulation mimicked the outcome of ablative surgeries has been challenged. Although somatic activity near the DBS electrode may exhibit substantial inhibition or complex modulation patterns, the output from the stimulated nucleus follows the DBS pulse train by direct axonal excitation. The intrinsic activity is replaced by high frequency activity that is time locked to the stimulus and exhibits a more regular pattern. Changes in firing pattern may prevent transmission of pathologic firing and oscillatory activity, reducing adverse symptoms by compensatory processing of sensorimotor information.18

Anesthetic concerns for PD patients include an increased sensitivity to anesthetic agents, increased risk of laryngospasm and diaphragmatic spasm, increased risk of aspiration, hallucinations (visual and tactile), decreased vital capacity which may lead to pulmonary complications, post-operative delirium, muscle tremors that produce ECG changes mimicking ventricular fibrillation, and extrapyramidal symptoms (EPS). Side effects of L-dopa consist of depletion of myocardial norepinephrine stores, peripheral vasoconstriction, hypovolemia, and orthostatic hypotension. Hypertensive patients may experience wide swings in blood pressure. Glycopyrrolate offers protection against neostigmine induced bronchoconstriction in normal subjects. However, in patients with PD, obstruction is probably caused by parasympathetic hyperactivity and susceptibility to the muscarinic effects of neostigmine and bronchospasm is increased. Thus, glycopyrrolate in usual doses may be inadequate. Use of neostigmine is best avoided.

Tourette syndrome and other psychiatric disorders

Tourette syndrome is a childhood neuropsychiatric disorder characterized by many involuntary motor and vocal tics. It may also be associated with attention deficit and hyperactivity problems, obsessive-compulsive disorders and self-injurious behavior.19 Since the first use of DBS for this condition in 1999, multiple targets have been identified including the medial thalamus, globus pallidus internus and externus the anterior limb of the internal capsule and the subthalamic nucleus. As these patients are often children general anesthesia is usually required.20

DBS has also been used for major depressive disorders. Similar areas of the brain have been targeted.
**Dystonia**

Dystonia is a movement disorder characterized by involuntary sustained or intermittent muscle contractions that cause twisting and repetitive movements. DBS of the globus pallidus interna has been shown effective in improving the quality of life, especially in primary dystonia. Secondary dystonia may be caused by exposure to certain medications, trauma, toxins, infections, stroke or central nervous system injury. These patients may also benefit from DBS, but to a lesser extent. Patients are usually young and general anesthesia is necessary, especially if the movement disorder is severe.\(^\text{21}\)

**Anorexia nervosa**

Anorexia nervosa is a severe psychiatric disorder with high rates of morbidity, comorbidities and mortality. In 21% of cases it is a chronic condition.\(^\text{22}\) Several areas have been identified as possible targets for DBS in these patients including the anterior cingulated cortex and the ventral limb of the capsula interna and the ventral striatum.\(^\text{22}\) Many of these patients are severely malnourished with electrolyte and chemical imbalances and may be anemic.

**Pain**

Several reports of successful use of DBS in selected patients such as those with phantom limb pain, cephalgia, brachial plexus injury, stroke, multiple sclerosis and spinal cord injury have been reported.\(^\text{23}\) Cingulate DBS appears useful for total body pain. These patients may be addicted to opioids and antidepressant drugs which is a significant consideration that will impact decisions about anesthetic choices and dosages.

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**Figure 2: Positioning of the DBS electrode using a stereotactic frame**

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**The DBS Procedure**

The procedure of DBS usually involves transporting the patient to several locations including the radiology suite and the operating room or neurophysiology laboratory. The process is often long and usually done with minimal sedation but considerable monitoring. Moreover, after the electrodes have been placed, the patient must return about 2 weeks later for insertion of the generator usually in the upper chest. As this part of the procedure involves tunneling and a bigger incision in the operating room, it is performed under general anesthesia.

In the first stage, a frame must be affixed to the patient’s head. This requires infiltration with local anesthesia or regional block, and is followed by imaging performed in the radiology suite. Thereafter, the patient is moved to the neurophysiology laboratory or operating room. A burr hole is made under local anesthesia and sedation, if necessary. The optimal positions for the electrodes are identified, usually with little or no sedation. Following placement
of the stimulators and testing, the patient returns to radiology for an MRI or CT scan to confirm placement and to rule out hematoma formation. In most centers the patient is observed overnight and discharged the next day.

Recently, some techniques have been developed for frameless navigation targeting procedures for DBS. These approaches simplify the preoperative planning of electrode trajectories and eliminate frame placement and scanning on the day of surgery, thus shortening the process. The time that a patient is off PD medications is reduced. Access to the airway is easier. One disadvantage is that current frameless DBS equipment is cumbersome and limits the area over which deep brain mapping can be performed.24

Preanesthetic Assessment

Routine evaluation includes complete blood count, electrolyte screening panel including blood sugar level (which should be controlled at or below 120mg/dl if possible), and urinalysis to exclude urinary tract infection, coagulation profile, and assessment of renal and liver function. Most of these patients have multiple co-morbidities and baseline screening, especially as to blood count (iron deficient anemia is common) is useful. A chest X-ray will help to exclude evidence of aspiration, a common occurrence in PD patients. Depending on other co-morbidities and the clinical situation, an electrocardiogram should also be available. Antihypertensive medications should be continued and beta blocker therapy given the day of the procedure if indicated. Blood pressure should be controlled at or below 150 systolic to minimize the risk of hemorrhage. A blood specimen for type and screening of blood prior to surgery should be obtained. While blood transfusion is rarely necessary, should it be required, it will usually be an emergent situation. One of the serious complications of DBS is intracerebral hemorrhage, which has been estimated to occur in about 3-5% of patients.25 Aspirin and coumadin should be discontinued several days before DBS. Antiseizure medications such as carbamazepine or valproate may cause thrombocytopenia even though leukopenia is more common. Therefore, the type of antiseizure drugs used and any history of bleeding should be carefully evaluated preoperatively and platelet and white blood cell counts measured.

Drugs used for movement disorders often have a short half-life and effectiveness is limited with time. Associated side effects of PD drugs include dry mouth, orthostatic hypotension, nausea, vomiting, visual disturbances and urinary retention. Drug interactions also occur, especially if monoamine oxidative inhibitors are also used. To produce maximum effect during stimulation, medications are withheld on the day of surgery. Thus patients may develop increasing discomfort as the procedure continues. Also, if the indication for DBS is epilepsy, side effects of the many agents used for this disease must also be considered including hepatic enzyme induction, competitive metabolic inhibition, plasma protein level and binding, all of which may cause drug interactions and change doses and duration of effect of other agents. Ingestion of herbal preparations, such as gingko, ginger, garlic and ginseng, may interfere with clotting. If the procedure is aimed at pain reduction, narcotic patches and the doses should be identified.

The patient is usually awake during much of the procedure to allow identification of areas of the brain and accurate electrophysiologic recording. Cooperation by the patient is essential and it is important that the patient fully understands what is required. It is important to review with the patient the questions that may be asked to assess the speech center and tasks that must be performed such as “squeeze my hand or move your toes”. The patient may be asked to read and the anesthesiologist should ensure that the patient can do so with or without glasses or that the print is large enough that
enhanced vision is not necessary. Also, if the patient requires a hearing aid, that too should be considered. The language and competency of the patient should be ascertained. The anesthesiologist should be aware of any aura that the patient may experience prior to a seizure so that appropriate medications may be promptly given to avert a seizure.

Use of premedication depends on the procedure and the needs of the patient. Patients with arthritis that limits their ability to lie flat or still or those who are very anxious benefit from small doses of benzodiazepines. If the patient is to undergo a procedure in which seizure activity is not to be provoked (for example, if DBS is performed to ablate identified epileptic foci) a benzodiazepine is a suitable agent. Also, intravenous diazepam given prior to contrast injection may reduce the incidence of contrast-associated seizures. The exception is the amytal test, which is preceded by cerebral angiography (amobarbital 30mg is injected into an artery supplying eloquent cerebral areas to determine neurologic function prior to devascularization). Under these circumstances, no sedative drugs are given. For PD patients, premedication should consist of antiemetics and antacids as difficulty in swallowing and aspiration is common. Anticonvulsants are usually given preoperatively but in reduced doses at the discretion of the neurosurgeon. Some evidence suggests that hemodynamic stability may be increased during pin head holder insertion if clonidine is given orally 90 minutes before placement. Neurosurgeons and neurophysiologists often have protocols in place for sedation and hemodynamic control. The anesthesiologist should be conversant with these documents and discuss their content with the other members of the team preoperatively.

Of particular importance is airway evaluation. As the effects of maintenance drugs wear off, PD and dystonic patients may become rigid and mouth opening may be very difficult. Primary laryngospasm is a known complication of PD and acute withdrawal of treatment can cause airway obstruction. Dentition is often impaired. Patients who have been receiving dilantin may have gum hypertrophy and loosening of teeth that may hamper placement of an airway. The head is usually held in a frame which is attached to the table and a bar crosses in front of the mouth. Sedation may be increased if the procedure is lengthy or intraoperative complications develop. Should aspiration, vomiting or respiratory depression occur, a means to support ventilation must be immediately available. Thus, as well as careful preoperative assessment of the airway, the difficult airway cart should be available, including at a minimum different blades and tube sizes, and fiberoptic intubation. Availability of a GlideScope® is desirable. Supraglottic airways are particularly valuable as they can be placed with little or no head movement and minimal opening of the mouth. A tracheostomy kit should also be available. It is essential that the anesthesiologist be aware preoperatively of the mechanics of the frame and how to release the face piece should a problem occur.

**Anesthetic management**

The neuronal circuitry between the striatum and the globus pallidus and the subthalamic nucleus where GABA-ergic pathways are involved is complex and it is preferable, although not always possible, to use lesser anesthetic agents with GABA-ergic activity like benzodiazepines or propofol during stimulation.

Anesthetic management is divided into 3 stages:

**Stage 1:** Frame placement is done under scalp block or local anesthesia. A small amount of sedation is often beneficial. As noted above, all involved personnel should be familiar with the mechanics of the frame and how the face piece may be removed in an emergency.
Stage 2: Problems of anesthetizing in a remote location arise. Often little or no sedation is required but monitoring must continue. The head frame keeps the head stable but makes it more difficult for the patient to find a comfortable position. Propofol and dexmedetomidine have been proven useful in both CT and MRI studies in children.28,29

Stage 3: In the operating room, a burr hole is made and the electrodes implanted. Anxiety may be more predominant than pain. Essential monitors are applied. Invasive monitoring is rarely necessary. Awake responses are preferred. An awareness monitor may add information if more sedation becomes necessary. Such a monitor may also help in determining sudden deterioration if the activity decreases although no medication has been given.

Hemodynamic stability can best be achieved with small doses of narcotics. Labetalol, 5-10 mg, may be used in a patient with a history of hypertension. Hydralazine is another choice. When other agents have failed a nicardipine infusion is effective and easily titrated. Least perturbations of blood pressure on incision can be achieved by scalp infiltration with bupivacaine and a small dose of midazolam (1-1.5 mg) and/or fentanyl (25-50 ug). Communication with the surgeon and neurophysiologist is important as some prefer to withhold midazolam because of potential prolonged effects in elderly patients. If necessary, a bolus injection of propofol (20-30 mg) may be used. Thereafter, a propofol infusion of 10-20 ug/kg/min (up to 50-60 ug/kg/min in one study) allows sedation with consciousness. As the surgeon places the electrodes, communication is essential both with the operator and the patient. Movement by the latter may seriously compromise precise placement. The process is slow and delicate so it is important to have patience while fostering cooperation. In some centers, no sedation is used; or a combination of midazolam, fentanyl in small divided doses and a propofol infusion (which acts at the GABA receptors) may allow adequate sedation for many hours. Remifentanil 0.1 ug/kg/min may cause rigidity. Also, the bradycardic effect may be troubling, especially in patients who have received beta blocking medications. Dexmedetomidine is a highly specific α2-receptor agonist that offers “cooperative sedation”, anxiolysis and analgesia without respiratory depression. Patients can be awakened easily by verbal stimulation. Cerebral effects are consistent with a desirable neurophysiologic profile including neuroprotective characteristics.30,31 It is particularly valuable when eloquent areas of the brain are stimulated and an awake and cooperative patient must be capable of undergoing neurocognitive testing.32 Sympatholytic and antinociceptive properties give hemodynamic stability during periods of critical neurosurgical stimulation, as demonstrated in a study of 11 patients undergoing microelectrode recording (MER) of the STN.33 The quality of MER (that is, found acceptable) was evaluated in this study as a function of BIS® (>80), and prompt clinical arousal. An acceptable dose is 0.1-0.4 μg/kg/hr. Dose dependent hypotension and bradycardia have limited the approval of dexmedetomidine in Europe. Dexmedetomidine has anticonvulsant effects in rats34, but in a series of patients in whom the drug was used as a sedative for awake craniotomy, the anticonvulsant effect was questioned as the results were inconsistent.35 During periods when patients do not need to be awake, propofol in a moderate dose infusion (80-100 ug/kg/min) may be added to the dexmedetomidine technique.36 Successful use has been described also in adolescents31 and in 11 patients for insertion of probes for deep brain stimulation.37 Spasticity may dictate deeper sedation.

Small doses of remifentanil 0.01-0.05 mcg/kg/min for 3-5 minutes combined with propofol 15 ug/kg/min have been used for sudden pain. Longer onset of action of fentanyl makes it less useful. Fentanyl is also cumulative. However, in doses of 25 mcg, the drug may be beneficial. Alfentanil offers no particular advantage. If sedation becomes excessive, naloxone or flumazenil may be given to
reverse narcotic and benzodiazepine effects. However, flumazenil involves the receptor site on the GABAAa receptor chloride channel complex and has been implicated in neuroexcitatory phenomena, especially seizures. Also, the duration of action of flumazenil is shorter than that of midazolam or diazepam. Thus, the sedative effects of these latter drugs may resurface postoperatively, especially in older patients in whom the half-life of the benzodiazepines is extended. Naloxone should be given in increments of 0.1 mg as sudden reversal of analgesia may cause the patient to move unduly and cause scalp tearing. Even if it has been necessary to place a supraglottic airway, patients can still be awakened and tolerate the airway, especially if lidocaine 50 mg has been given intravenously. Intelligible sounds can be appreciated.

Fluid replacement should be with non-glucose containing solutions. The amount should be limited as urinary catheters are usually not placed.

Some patients may not be eligible for DBS under local anesthesia for medical or psychological reasons. General anesthesia with higher doses of remifentanil and propofol have been used. The STN and the typical bursting pattern could be identified but a widening of the baseline noise could not. Bispectral analysis monitoring was used. Clinical improvement was acceptable in both studies.

**Complications**

In one analysis of 258 DBS cases, the complication rate was found to be 11.6%, including airway, respiratory, neurologic and psychological problems. Age (>64) was determined to be an independent risk factor. Intracranial hemorrhage and seizures occurred in 3.6%. Two patients requested termination of the procedure and both had evidence of a small intracranial hemorrhage. Postoperative hemiplegia may occur from spasm or clot formation. In such cases, immediate CT scan is indicated. Aspiration has been reported in 1.6%; coughing or sneezing in 1.2%.

The differential diagnosis of coughing rests between a dry mouth, “smoker’s cough” and an embolic event. The patient is semi-sitting and the negative pressure gradient between the surgical field and the right atrium allows entrainment of air into the venous circulation from epidural veins, opened either at the incision or at any of the pin head sites. Occurrence in awake and spontaneously breathing patients is increased over that seen in ventilated and paralyzed patients because of the transfer of negative intrathoracic pressure to the central venous system with the initiation of each breath.

Coughing is the first symptom of entrained air, followed by chest pain, dyspnea and tachypnea. Side stream capnography detects decreased end tidal CO2 (ETCO2) quickly and should be standard equipment, even when oxygen is supplied by nasal cannula. Continuous Doppler monitoring interferes with neural recording and may not be effective. Decreased SPO2 (4-5 points) and tachycardia are early changes. The surgeon must be informed immediately; the field flooded with saline and wax applied to the bone edges. The head should be lowered and the legs elevated. Lidocaine 50mg may help to decrease coughing. Arterial blood gas analyses confirm the diagnosis with high PaCO2 and low PaO2. If hemodynamic stability returns promptly, it may not be necessary to abandon the procedure.

Postoperative pain is generally not severe as the brain itself has no pain endings. Acetaminophen (Tylenol®) with or without codeine may suffice. In some instances patients have been discharged on the same day following awake craniotomy where there have been no complications, sedation was minimal and operating time short. However, an overnight stay is recommended for neurologic monitoring and resumption of drug therapy.
Management of the Case

Consultation with the patient’s pain doctor was requested. The physician responded and accompanied the patient during the first part of the procedure. The coagulation profile was determined to be within normal limits. All of his medications, except for herbal preparations, were continued including some restricted alcohol consumption. Opioid patches were reviewed and updated. The patient was able to tolerate placement of the stereotactic head frame with local anesthetic infiltration at the pin sites and midazolam. He was sedated with a propofol infusion, 50 ug/kg/min during the MRI study. On returning to the operating room he was awake.

After standard monitoring was placed, the patient received 2 doses of fentanyl 50 ug, midazolam 4 mg and propofol 100 mg. A “scalp block” was placed with 0.5% bupivacaine at the supraorbital nerves and the greater occipital nerves. The patient was able to cooperate for the testing and the remainder of the procedure. Repeated doses of fentanyl were required as well as a dexmedetomidine infusion.

Conclusion

Propofol, fentanyl, midazolam and dexmedetomidine have emerged as the agents causing the fewest physiologic disturbances and most useful in providing acceptable conditions during minimally invasive neurosurgical procedures that require cooperation by the patient. Anesthetic care is required in several sites in the hospital and necessitates considerable flexibility.

Ancillary support should be provided such as administration of an H3 antagonist, often combined with dexamethasone to minimize the risk of nausea and vomiting. Lips can be moistened and even ice chips given in small quantities to improve comfort and decrease the need to cough.

Special attention should be paid to airway management and positioning. A comfortable position without pressure on vulnerable tissues is required. It is essential that there be adequate visual and verbal communication between all members of the procedure team and the patient. The patient must be able to see objects and read with or without glasses if necessary.

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REFERENCES


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Post-test

1. **Deep brain stimulation:**
   a. Usually requires general anesthesia
   b. Has been used successfully for many different disorders
   c. Is effective only for Parkinson disease
   d. Only has about 50% success rate

2. **The combination of drugs shown to most suitable for DBS is:**
   a. Remifentanil, isoflurane and dexmedetomidine
   b. Fentanyl, midazolam and dexmedetomidine
   c. Best to use none at all
   d. Propofol, morphine and glycopyrrolate

3. **Side effects of PD drugs are least likely to include:**
   a. Dry mouth
   b. Orthostatic hypotension
   c. Gum hypertrophy
   d. Urinary retention

4. **Parkinson Disease:**
   a. Is diagnosed conclusively postmortem
   b. Causes loss of dopaminergic neurons in the SNc
   c. Initially appears to be a unilateral disease
   d. All of the above

5. **Complications of DBS:**
   a. Most frequently include intracranial hemorrhage
   b. Have been reported in about 11% of patients
   c. Always require immediate open craniotomy
   d. Are extremely rare
6. **Venous air embolism:**
   a. Can be rapidly detected by side stream capnography
   b. Is more likely to occur in spontaneously breathing patients
   c. Does not necessarily require that the procedure be aborted
   d. All of the above

7. **Insertion of the generator for the electrodes:**
   a. Requires general anesthesia
   b. Is usually done on the same day as the electrodes are inserted
   c. Cannot be completed for at least 1 year
   d. Commonly is in the groin

8. **Fluid replacement during DBS:**
   a. Should be generous to avoid hypotension
   b. Is usually withheld completely
   c. Requires some dextrose as the patient has not eaten for many hours
   d. Should be restricted to maintenance replacement, especially if no urinary catheter is in place

9. **Successful placement of electrodes requires:**
   a. Communication between the patient and procedure team
   b. General anesthesia to minimize movement
   c. Intubation to reduce risk of embolus
   d. Administration of dilantin

10. **DBS has NOT been shown to be therapeutic for:**
    a. Obsessive compulsive disorders
    b. Phantom limb pain unresponsive to other therapies
    c. Anorexia nervosa
    d. Muscular dystrophy