Presbycusis, or age-related sensorineural hearing loss, is a common disorder that affects approximately 40% to 50% of people over the age of 75. The causes generally include accumulated noise exposure; medical conditions such as heart disease, vascular disease, and diabetes; some medications; otological disorders; and genetic susceptibility. Hearing loss is typically bilateral and symmetrical and affects the higher range of frequencies first. An individual with presbycusis will have decreased hearing sensitivity and speech understanding, in addition to poor sound localization.

Quality of life is profoundly affected in those who experience hearing loss, in particular, in the elderly population. A strong correlation between hearing loss and poor physical and mental health has been found. The prevalence and severity of hearing loss is expected to increase with time due to the common use of personal stereo systems and other recreational noises. Fortunately, treatment options exist for most patients. Depending on the degree of hearing loss, these options include training in environmental adaptation, hearing aids, middle-ear implants, and cochlear implants. Although hearing aids and middle-ear devices are beneficial for many, those with severe hearing loss gain very little from their use. For these patients, cochlear implantation may be offered as another alternative.

A cochlear implant (CI) (Figure 1) is an electrical device that is surgically implanted to provide sound for patients with profound hearing loss. Its goal is to improve hearing, but unlike a hearing aid, which amplifies sound, the CI bypasses the damaged portion of the ear and directly stimulates the auditory nerve by way of an electrical impulse (Figure 2). Normal hearing is not fully restored by a CI, but the representation of sound that it provides is adequate for the patient to understand speech and environmental sounds. Studies have shown significant improvements in quality of life for postlingual deafness CI recipients.

As of December 2010, approximately 219,000 people have received cochlear implants throughout the world according to the US Food and Drug Administration (FDA). In the United States, approximately 42,600 adults and 28,400 children have received the device.

History of the Cochlear Implant
In November 1984, the FDA formally approved the first commercial cochlear implant; however, research on the device had been going on since the 1950s. Despite the recent advent of the CI, the concept of electrical stimulation to the auditory nerve to produce sound began in...
1790 with an Italian physicist by the name of Alessandro Volta. During one of his experiments, he placed a metal rod in each of his own ears and then exposed the rods to 50 V of electricity. He reported the sense of a blow to the head followed by the sound of thick soup boiling. Despite sporadic attempts to further understand the relationship between sound and electricity over the next 150 years, enthusiasm for developing a cure for the deaf waned.  

The 1930s saw a resurgence of interest when it was discovered that the middle ear could act as a transducer, and that direct auditory nerve stimulation could produce crude sound. In 1957, André Djourno and Charles Eyriès performed what many consider the first cochlear implant on a 57-year-old man with bilateral cholesteatoma and deafness. Afterward, the patient reported being able to hear simple words and sounds.  

Over the next 20 years, various researchers worked on refining the electronic components of the CI. In the 1960s, the auditory components were proving successful but issues with biocompatibility of the implants were causing problems of rejection. In the early 1970s, Dr. William House collaborated with engineer Jack Urban of 3M to make the cochlear implant a reality. Between 1972 and the mid-1980s, 1,000 patients received CIs. By the late 1980s CIs were perfected to the point of offering great benefit to the patient with minimal risk.  

Advances in the electrodes and speech processors in the CI have continued to improve.  

Until recently, CIs were considered exotic, niche medical devices. They were typically implanted in large academic medical centers. Now, otologic surgeons in private practice are turning to ambulatory surgery centers (ASC) as venues for implantation. Their reasons mirror those of other surgical fields: cost and convenience. 

**Figure 2. Surgically Implanted Cochlear Implant**

Sound is picked up by an external auditory processor (a) that processes the signal to a signal that is sent to a coil (b) that transmits a radiofrequency through the skin to the implant (c) that sends electrical pulses to an electrode array (d) in the cochlea where the auditory nerve (e) picks up these signals and delivers them to the auditory centers of the brain.  

(Reprinted with permission from Med El Corporation.)
According to the Ambulatory Surgery Center Association, patients can expect to save up to 61% by having surgery in an ASC vs in a hospital. This article reviews a case that was performed in a rural ASC with specific considerations relevant to anesthetists.

**Case Summary**

Mr E is a 76-year-old who had been followed in the hearing and balance clinic for gradual onset of hearing loss over the past few years. He had been fitted with hearing aids but did not believe he gained much benefit from them. He had a history of industrial noise exposure as a farmer and had served in the US Army artillery in the 1950s. Mr E was experiencing increasingly reduced speech discrimination. After a thorough discussion with his otologist, both the surgeon and the patient decided to perform a left CI in the ASC.

On the morning of surgery, Mr E arrived at the ASC in good spirits. A history and physical findings revealed a healthy, well-nourished appearing man with a body mass index of 25. He reported a history of mild gastroesophageal reflux disease, which was controlled with medication and diet. Back pain and hypothyroidism were also reported. He denied any other medical conditions. Surgical history consisted of 2 separate back surgeries and cystoscopy for kidney stones. Previous anesthetic complications were denied. Current medications and supplements included sertraline, levothyroxine, omeprazole, simvastatin, vitamin D, and fish oil. There was no history of drug allergies. A recent electrocardiogram and chest radiograph, which were obtained during a routine physical by the patient's primary care physician, were normal. A complete blood cell count and chemistry values were also normal. His vital signs were blood pressure, 145/71 mm Hg; heart rate, 64/min; respiratory rate, 16/min; 

Mr E held all routine medications on the morning of surgery and reported that he had nothing by mouth for more than 8 hours. On arrival to the ASC, the patient was administered, by mouth, famotidine (20 mg), acetaminophen (1000 mg), diphenhydramine (25 mg), and ondansetron (4 mg). A 20-gauge intravenous catheter was placed, and the patient emerged from anesthesia. Blood pressure of approximately 20%. Atropine (0.5 mg) was given with a subsequent return of vital signs to baseline. Immediately after skin incision, neuromuscular blockade recovery from rocuronium was confirmed by use of a peripheral nerve stimulator. The patient demonstrated >75% reversal (4/4 train-of-four) and sustained tetany of the adductor pollicis muscle. An anticholinesterase agent was not administered because of the clinical findings of the peripheral nerve stimulation. The patient's arms were tucked, all lines and monitors were oriented toward the anesthetist for access, and the patient's pressure points carefully checked. Electrophysiologic facial nerve monitoring was initiated, tested, and used throughout the operation. For hemostasis, the surgeon injected 5 mL of lidocaine with 2% epinephrine to the postauricular surgical site, well away from the facial nerve. The patient was then prepped and draped.

At one point during the preparations for incision, and after intubation, the patient had a decrease in heart rate and blood pressure of approximately 20%. Atropine (0.5 mg) was given with a subsequent return of vital signs to baseline. Immediately after skin incision, neuromuscular blockade recovery from rocuronium was confirmed by use of a peripheral nerve stimulator. The patient demonstrated >75% reversal (4/4 train-of-four) and sustained tetany of the adductor pollicis muscle. An anticholinesterase agent was not administered because of the clinical findings of the peripheral nerve stimulation. The patient's arms were tucked, all lines and monitors were oriented toward the anesthetist for access, and the patient's pressure points carefully checked. Electrophysiologic facial nerve monitoring was initiated, tested, and used throughout the operation. For hemostasis, the surgeon injected 5 mL of lidocaine with 2% epinephrine to the postauricular surgical site, well away from the facial nerve. The patient was then prepped and draped.

At one point during the preparations for incision, and after intubation, the patient had a decrease in heart rate and blood pressure of approximately 20%. Atropine (0.5 mg) was given with a subsequent return of vital signs to baseline. Immediately after skin incision, neuromuscular blockade recovery from rocuronium was confirmed by use of a peripheral nerve stimulator. The patient demonstrated >75% reversal (4/4 train-of-four) and sustained tetany of the adductor pollicis muscle. An anticholinesterase agent was not administered because of the clinical findings of the peripheral nerve stimulation. The patient's arms were tucked, all lines and monitors were oriented toward the anesthetist for access, and the patient's pressure points carefully checked. Electrophysiologic facial nerve monitoring was initiated, tested, and used throughout the operation. For hemostasis, the surgeon injected 5 mL of lidocaine with 2% epinephrine to the postauricular surgical site, well away from the facial nerve. The patient was then prepped and draped.

At one point during the preparations for incision, and after intubation, the patient had a decrease in heart rate and blood pressure of approximately 20%. Atropine (0.5 mg) was given with a subsequent return of vital signs to baseline. Immediately after skin incision, neuromuscular blockade recovery from rocuronium was confirmed by use of a peripheral nerve stimulator. The patient demonstrated >75% reversal (4/4 train-of-four) and sustained tetany of the adductor pollicis muscle. An anticholinesterase agent was not administered because of the clinical findings of the peripheral nerve stimulation. The patient's arms were tucked, all lines and monitors were oriented toward the anesthetist for access, and the patient's pressure points carefully checked. Electrophysiologic facial nerve monitoring was initiated, tested, and used throughout the operation. For hemostasis, the surgeon injected 5 mL of lidocaine with 2% epinephrine to the postauricular surgical site, well away from the facial nerve. The patient was then prepped and draped.
Mr E’s recovery was uneventful and included some expected mild pain and dizziness that resolved in a week. He experienced a mild case of external otitis 2 weeks after surgery that was treated in the clinic with topical antibiotics. The CI was programmed 1 month after surgery. As of the last contact, Mr E reported satisfaction with the CI and his surgical course.

**Discussion**

As our population continues to age, the demand for CI surgery is expected to rise. Because of the increasing demand for improved healthcare economics, it is reasonable to expect that CIs will become a commonplace ambulatory surgical procedure. For the patient to achieve the best outcome, certain anesthetic considerations must be taken into account.

The surgical risks of CI surgery are similar to those found in middle ear and mastoid surgery. These include infection, bleeding, dural injury, and facial nerve damage. Most CI surgeons use prophylactic antibiotics that should be given intravenously before the first incision. Bleeding is usually minor unless the sigmoid sinus is injured, in which case there is a risk of air embolism and sudden right-sided heart failure. Treatment of air embolism includes immediate occlusion of the venous bleeding with pressure or saline, turning the patient on the left side, aspirating the embolus, administering 100% oxygen, discontinuing nitrous oxide, placing the patient in Trendelenburg position, and providing cardiac support as necessary. The high-speed mastoid drill can injure the dura resulting in a cerebrospinal fluid (CSF) leak. Lowering CSF pressure by hyperventilating the patient to an ETCO2 of 27 to 29 mm Hg can assist the surgeon in repairing the defect with tissue and bone wax. Administration of mannitol and placement in the reverse Trendelenburg position may be also be considered. Risk of facial nerve injury is minimized by using electromyographic neuromonitoring during surgery. Neuromuscular blockers and local anesthetics may interfere with transmission of signals and should therefore be allowed to wear off before the mastoidectomy part of the operation. Most otologists use a combination of lidocaine and epinephrine to infiltrate the surgical field to provide some initial local anesthesia and hemostasis. Although the area around the facial nerve is not intentionally blocked, sometimes there can be infiltration of the middle ear mucosa with temporary facial neurapraxia. However, the lidocaine effect has usually worn off by the time the surgeon is drilling near the facial nerve. If anesthetic technique demands that neuromuscular blockade be maintained, it is imperative that this be communicated to the surgeon.

Selection of the elderly CI patient must be consistent with that of any other ambulatory surgical procedure planned. Age alone is not useful as exclusion criteria for ambulatory surgery. A thorough history and physical examination with investigation into age-related comorbidities must be completed. In particular, cardiac and pulmonary status must be assessed. Patients who are poorly managed and at high risk of perioperative complications should have surgery in an inpatient setting. Moreover, consideration of a social support system is necessary. Many older patients live alone, and the availability of appropriate caregivers during recovery should be planned in advance.

Although CI surgery has been performed under local with monitored anesthesia care, as a rule, general endotracheal anesthesia is the preferred anesthetic. The surgery is performed largely under microscope visualization. Therefore, movement of the patient adds risk of injury to middle ear structures during surgery. In addition, the preparation, draping, and surgical time can often be well over 1 hour. An elderly patient’s ability to lie still for such an extended period of time may be limited.

Preoperative preparation may include the administration of a broad-spectrum antibiotic to help reduce the chance of wound infection. A multifactorial approach to prophylaxis for postoperative nausea and vomiting should also be taken. Drugs to consider include famotidine, ondansetron, diphenhydramine, and transdermal scopolamine depending on the patient’s history. If transdermal scopolamine is used, caregivers should be instructed on signs and symptoms of overdose such as confusion, blurred vision, and dry mouth. Although Innis and Anderson found otolaryngologic surgeries to have low risk of deep vein thrombosis, use of pneumatic compression stockings and mechanical compression devices, along with early postoperative ambulation, are still recommended for the low-to-moderate risk patient.

Generally speaking, it can be expected that the patient will be turned 180° away from the anesthesia machine, although this depends on surgeon preference and room configuration. An extension circuit will be necessary and placement of patient monitors and IV lines should be preplanned to allow for access. Careful attention to positioning and protection of pressure points is vital. Although the patient is placed in a supine position, the head is turned severely to the side to allow adequate surgical exposure. This rotation of the head introduces risks to include endotracheal tube displacement, increased intracranial pressure, and potential nerve or spinal injuries. A thorough preoperative assessment of cervical range of motion can be useful in determining a safe range of positioning. Collaboration with the surgeon is especially important in preventing injury while still achieving optimal surgical exposure. Reassessment of endotracheal tube placement after positioning is recommended as well.

Challenges of CI surgery in the elderly population are presented during positioning, prepping, and draping.
During this time period the patient is not being stimulated, and therefore poses the risk of hypotension secondary to an anesthetic that is sufficient to prevent movement. Small doses of short-acting neuromuscular blockers may be given but may need to be reversed after surgical stimulation has begun. Another option is to support hemodynamics with the use of a sympathomimetic such as ephedrine or phenylephrine.

Opioid requirements are generally low during and after implantation. Small doses of fentanyl or other opioids to maintain comfort is recommended.

Emergence and extubation from anesthesia should focus on standard parameters of adequate ability to regain and maintain spontaneous breathing. The anesthetist must keep in mind that the patient is deaf and will not be able to respond to verbal commands. Even though the CI has been placed, it will not be programmed for another month.

Standard monitoring and assessment of the patient’s condition should be initiated in the postanesthesia care unit, with special attention to complaints of dizziness and nausea. Caregivers should be advised of the increased risk of falls due to dizziness, as well as the potential for postoperative delirium and cognitive dysfunction.

Conclusion

As the size of the elderly population increases and as noise pollution continues to be present, a greater number of people will be candidates for CI. Ambulatory surgery settings can be viable venues for CI surgery, thus helping to contain costs and allow greater convenience than hospital-based centers. With careful patient selection and an awareness of the unique anesthetic considerations for CI surgery, ASCs can provide a safe and convenient environment for CI patients.

REFERENCES


AUTHORS

Aimee M. Joseph, CRNA, DNAP, is an independent contractor for Tidewater Anesthesia, Incorp, which supplies CRNA anesthesia services to Lakeview Medical Center. At the time this article was written, she was a doctoral student at Virginia Commonwealth University, Department of Nurse Anesthesia, Richmond, Virginia. Email: amjoseph@vmail.com.

L. Frederick Lassen, MD, FACS, is a neurotologist and medical director of Mid-Atlantic Hearing and Balance Center in Suffolk, Virginia. He is also in private practice at Lakeview Medical Center in Suffolk, Virginia. Email: lfllassen@yahoo.com.