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# Review of Anesthesia for Middle Ear Surgery

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[Q3] [Q2] [Q6] [Q4]

**KEYWORDS**

- Anesthesia for middle ear surgery • Controlled hypotension
- Postoperative nausea and vomiting

The middle ear refers to an air-filled space between the tympanic membrane and the oval window. It is connected to the nasopharynx by the eustachian tube and is in close proximity to the temporal lobe, cerebellum, jugular bulb, and the labyrinth of the inner ear. The middle ear contains three ossicles—the malleus, incus and stapes—which are responsible for transmission of sound vibration from the eardrum to the cochlea. This air-filled cavity is traversed by the facial nerve before it exits the skull via the stylomastoid foramen.[1,2] The facial nerve provides motor innervation to the muscles of facial expression.

## COMMON MIDDLE EAR SURGERIES

Middle ear disease affects patients of all ages. Common middle ear pathologic conditions requiring surgery in adults include tympanoplasty (reconstructive surgery for the tympanic membrane, or eardrum), stapedectomy or ossiculoplasty for otosclerosis, mastoidectomy for removal of infected air cells within the mastoid bone, and removal of cholesteoma.[2] Common middle ear surgery in children includes tympanoplasty, mastoidectomy, myringotomy, grommet insertion. and cochlear implantation.[2] Some of these procedures can be performed under local anesthesia, although obviously, all surgery can be performed under general anesthesia if necessitated by patient or surgical factors (**Box 1**). [Q7]

## ANESTHETIC CONSIDERATIONS IN MIDDLE EAR SURGERY

Given the unique location, size, and delicate content of the middle ear, great care must be taken during the perioperative period. Special considerations include: provision of

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**Box 1**
**Common procedures in middle ear surgery**

*Local anesthesia*

Surgical factors

- Insertion of grommet
- Myringoplasty
- Tympanoplasty
- Stapedotomy
- Stapedectomy
- Ossiculoplasty (IOFNM)
- Mastoidectomy (IOFNM)
- Cholesteoma surgery via intact ear canal (IOFNM)

Patient factors

- Adult
- Patient must be able to understand, cooperate, hear and communicate

*General anesthesia*

Surgical factors

- Cochlear implantation
- Long operations
- Complicated surgery (eg, extensive scar tissue in middle ear)

Patient factors

- Children
- Mentally unstable, uncooperative patients
- Patients who request general anesthesia

*Abbreviation:* IOFNM, intraoperative facial nerve monitoring.

a bloodless surgical field, attention to patient's head positioning, airway management, facial nerve monitoring, the effect of nitrous oxide on the middle ear, a smooth and calm recovery, and prevention of postoperative nausea and vomiting (PONV).[2–5]

A bloodless surgical field is ideal, as even small amounts of blood will obscure the surgeon's view in microsurgery. A combination of physical and pharmacologic techniques is used to minimize bleeding. Attention to patient's head positioning is important to avoid venous obstruction and congestion. In addition, extreme hyperextension or torsion can cause injury to the brachial plexus and the cervical spine.[4] In patients with carotid atherosclerosis, carotid blood flow may be compromised or plaque emboli dislodged, and it is worth auscultating for carotid bruit before surgery. During general anesthesia, the airway can be maintained with a laryngeal mask airway (LMA) or endotracheal intubation; intubation may be more appropriate if extreme neck extension or rotation is required. LMA, however, is a suitable alternative for most middle ear surgery, and a wide range of devices are now available. A well-documented potential complication of otologic surgery is facial nerve paralysis, and a nerve stimulator is often employed for intraoperative monitoring of evoked facial nerve electromyographic activity to aid preservation of the facial nerve. Muscle relaxants should be

avoided in this circumstance or, if neuromuscular block is needed to facilitate smooth intubation, choose a dose and an agent (eg, mivacurium no longer manufactured in the United States) that ensures the return of function before the need for neuromuscular monitoring arises.[3–5] It also should be borne in mind that sudden unexpected patient movement may jeopardize the success of surgery, and depth of anesthesia monitoring may be useful. The use of nitrous oxide in middle ear surgery is controversial. A smooth recovery without coughing or straining is important, especially in patients who have undergone reconstructive middle ear surgery to prevent prosthesis displacement. PONV is a common problem after middle ear surgery that can be minimized by appropriate choice of anesthetic technique and antiemetic prophylaxis.[3–5] Most middle ear procedures can be performed as outpatient surgery; thus rapid recovery, good analgesia, and avoidance of nausea and vomiting are essential.[6] [Q8]

## PREOPERATIVE ASSESSMENT

For adults, simple middle ear surgery can be performed under local or general anesthesia, although complicated or long procedures should be performed under general anesthesia. Patients who are able to understand the procedure, and to communicate and cooperate throughout the procedure, are suitable candidates for local anesthesia with or for foregoing sedation.[7] Patients undergoing middle ear surgery often suffer from extensive hearing loss, thus hindering their ability to cooperate, and in this situation, surgery might be better performed under general anesthesia. Leaving the hearing aid in situ in the nonsurgical ear before induction and replacement before emergence may help to minimize anxiety and ease communication. Oral anxiolysis premedication with benzodiazepines can be considered or standard sedation regimens used intraoperatively. A history of cardiovascular disease, hypovolemia, and anemia will limit the degree of hypotension possible. In pediatric patients, in addition to the usual components of preoperative assessment, it is important to check for coexisting syndromes and recent upper respiratory tract infection.[6]

## CHOICE OF ANESTHESIA

Four nerves provide innervation to the ear. The auriculotemporal nerve supplies the outer auditory meatus; the great auricular nerve supplies the medial and lower aspect of the auricle and part of the external auditory meatus. The auricular branch of the vagus nerve supplies the concha and the external auditory meatus, and the tympanic nerves supply the tympanic cavity.[1,4]

General or local anesthesia has advantages and disadvantages. Uncomplicated middle ear surgery can be performed under local anesthesia. In a study on local anesthesia in middle ear surgery by Caner and colleagues,[8] patients were premedicated with meperidine and atropine intramuscularly 30 minutes before being taken to surgery, and 5 mg to 10 mg diazepam was given intravenously if the patient was still agitated in the operating room. Two percent lidocaine with 1:10,000 epinephrine was used for infiltration and auriculotemporal/auricular nerve blocks. Seventy-three of the 100 patients said they would prefer local anesthesia for a similar operation in the future. In a similar survey, Yung[7] found the most common discomforts reported were noise during surgery and anxiety, followed by dizziness, backache, claustrophobia, and earache. Despite these discomforts, however, 89% of patients said they would prefer local anesthesia for similar operations in the future. Pain was felt mainly at the beginning of surgery when multiple injections of local anesthetic were given, and perhaps the preoperative application of lidocaine and prilocaine (EMLA) could have assisted in this. For the surgeons, the main advantage of performing [Q9]

middle ear surgery under local anesthesia is the ability to test hearing during surgery, and they also report less bleeding. The main concerns of not performing middle ear surgery under local anesthesia are that patients may not tolerate the discomfort and the possibility of sudden movement. Another drawback is potential toxicity, as near-toxic plasma levels of local anesthetic have been reported in the first 5 minutes following infiltration for tympanoplasty.[9] The head may be obscured by drapes during surgery, and extra vigilance is required for possible respiratory depression or airway obstruction. Supplementary oxygen can be provided with nasal cannulae, and it is also possible to use capnometry or a precordial stethoscope to monitor breathing. Clear plastic drapes may reduce feelings of claustrophobia, and a forced air device can be used to provide some room air ventilation.

Thus, with careful patient selection, adequate preoperative explanation, and appropriate use of sedation, middle ear surgery can be successfully performed under local anesthesia, with high patient and operator satisfaction and acceptance. Benedik and Manohin[10] compared safety and efficacy of propofol versus midazolam for conscious sedation in middle ear surgery. The study demonstrated that propofol was associated with significantly shorter recovery time and better patient and surgeon satisfaction compared with midazolam. Adverse effects of propofol and midazolam, such as respiratory depression, hypotension, and sudden intraoperative movements, are obvious drawbacks.

Alpha-2 agonists such as clonidine or, more recently, dexmedetomidine, may have some advantages, as they produce arousable sedation, analgesia, and a modest reduction in heart rate and blood pressure without respiratory depression, particularly important when the head is obscured by surgical drapes.[11] Dexmedetomidine has been used successfully as the primary sedative with supplementary low-dose propofol and midazolam for monitored anesthesia care during awake thyroplasty, a procedure that requires the patient to verbalize when asked and otherwise remain immobile.[12] Surgeons reported satisfactory operating conditions, and patients had no recall of the procedure and no pain.[12] It also has a role in awake craniotomy.[13] Thus, dexmedetomidine could be used in a similar way for middle ear surgery but has not been widely reported in the literature.

In summary, the advantages of performing middle ear surgery under local anesthesia and conscious sedation include less bleeding, reduced pain in the immediate postoperative period, early mobilization, cost-effectiveness, and the ability to test hearing restoration during surgery.[8]

Despite these advantages, however, and the special concerns of general anesthesia for middle ear surgery outlined earlier, most middle ear surgery is still performed under general anesthesia.

Total intravenous anesthesia (TIVA) versus volatile-based anesthesia for middle ear surgery long has been a subject of debate. Mukherjee and colleagues[14] compared PONV, pain, and conditions for surgery in patients who had undergone middle ear surgery under TIVA using remifentanil and propofol, with technique using fentanyl, propofol, and isoflurane maintenance. More patients in the inhalation group suffered from PONV (25%) versus the TIVA group (8%) in the recovery room. In the early postoperative period, the TIVA group reported higher pain scores and required more morphine in the recovery room, but there was no significant difference at 2, 4, 6, 8, 12, and 18 hours. Conditions for surgery in the TIVA group were reported to be superior. In another study comparing propofol-based anesthesia with inhalation anesthetic techniques in terms of recovery profile and incidence of PONV for middle ear surgery, TIVA was associated with more rapid emergence and less nausea and vomiting.[15,16]

The use of nitrous oxide in anesthetic practice has declined in recent years as a result of concerns over both physical and metabolic effect.[17,18] The use of nitrous oxide in middle ear surgery is particularly controversial. Nitrous oxide is more soluble than nitrogen in blood and in high concentrations enters the middle ear cavity more rapidly than nitrogen leaves, causing a raise in middle ear pressure if the eustachian tube is obstructed.[4,5] During tympanoplasty, the middle ear is open to the atmosphere; thus there is no build-up of pressure, but once a tympanic membrane graft is placed the continued use of nitrous oxide might cause displacement of graft. At the end of surgery, when it is discontinued, nitrous oxide is rapidly absorbed, which may then result in negative pressure also possibly resulting in graft dislodgement, serous otitis media, disarticulation of the stapes, or impaired hearing.[4,5] Thus, the use of nitrous oxide is not recommended in tympanoplasty. Furthermore, a well known adverse effect of nitrous oxide is PONV, and consequently, its use in middle ear surgery may further increase the incidence of PONV above that already associated with this type surgery.

Endotracheal intubation and laryngoscopy during general anesthesia is associated with many potential complications such as sore throat, cough, dental injury, difficult emergence, and use of muscle relaxants for tube insertion.[19] In comparison, the LMA is free from such complications, and a smooth recovery can be attained easily. It also offers advantages of intravenous sedation with less risk of over sedation and obstructive apnea.[20] Safety and efficacy of the LMA were compared with endotracheal intubation in patients who underwent otologic surgery in a retrospective chart review study conducted at a military tertiary care teaching hospital. No major airway complication was reported in either group; a significant decrease in the use of neuromuscular blockers was noted in the LMA group, and total anesthetic time was also shorter in this group. There was no difference in the incidence of PONV or duration of postanesthesia care unit stay.[21] The use of the LMA for head and neck procedures is reviewed by Mandel in this issue.

A bloodless operative field is essential, because even a few drops of blood can obscure the surgical field. Physical and pharmacologic techniques are used: a head-up tilt 15° to 20°, avoidance of venous obstruction, normocapnia, and controlled hypotension. Controlled hypotension is defined as a reduction of systolic blood pressure to 80 mm Hg90 mmHg, a reduction of mean arterial pressure to 50 mm Hg to 65 mm Hg in patients without hypertension, or a reduction of 30% of baseline mean arterial pressure in patients with hypertension.[22] A slightly elevated position of the head reduces arterial and venous pressures in areas above the heart; however, it increases the risk of air embolism. In the presence of hypotension, elevating the head will further compromise perfusion of the head and neck region. Pharmacologic agents used for controlled hypotension in ear, nose, and throat surgery include: inhalation anesthetics (eg, isoflurane and sevoflurane), vasodilators (eg, sodium nitroprusside and nitroglycerin), beta adrenoceptor antagonists (labetalol and esmolol), alpha-2 adrenergic agonists (clonidine and dexmedetomidine), opioids (remifentanil),[23] and more recently magnesium sulfate.[24] However, controlled hypotension is not without risk; in addition to the adverse effects of certain pharmacologic agents, it can cause tissue hypoxia by reducing microcirculatory autoregulation of vital organs.

In moderate concentrations, isoflurane lowers blood pressure via a vasodilating effect while preserving cerebral autoregulation. However, at higher concentrations, it causes an increase in intracranial pressure due to increased cerebral blood flow and impairment of cerebral autoregulation.[23] Sevoflurane produces its hypotensive effect by direct vasodilatation without modifying cochlear blood flow.[25,26] In addition, [Q10]

it has a low blood gas solubility and low airway irritability, making it a good agent for gas induction in pediatric patient, although its use is commonly associated with emergence agitation and negative postoperative behavioral changes in this group.[27] In high concentrations, inhalation anesthetics interfere with the measurement of evoked potentials use for facial nerve monitoring. [Q11]

The vasodilators sodium nitroprusside and nitroglycerin have become less popular because of adverse effects and the availability of better agents. Sodium nitroprusside is very potent and has a fast onset and offset, but it has several serious adverse effects including tachyphylaxis, rebound hypertension, organ ischemia, and cyanide toxicity.[23] Sodium nitroprusside employed as an adjunct to sevoflurane anesthesia in children improved surgical field visibility but provoked lactic acidosis and increased hypercapnia.[23] Nitroglycerin is a short acting nonspecific direct vasodilator of venous and arterial vessels, which does not produce toxic metabolites. Compared with sodium nitroprusside, nitroglycerin is less effective in inducing hypotension and does so more slowly.[23] Both agents require close blood pressure monitoring, preferably with an arterial line.

Labetalol is a competitive antagonist at beta and alpha receptors with a ratio of 7:1. Beta adrenoceptor blockade decreases myocardial contractility and heart rate, while alpha blockade produces vasodilatation.[23] Adverse effects include bronchospasm, prolonged hypotension, and conduction blockade. Esmolol is a short-acting beta-1 adrenoceptor antagonist, which has an onset time of about 3 minutes and duration of action of approximately 10 minutes. It decreases blood pressure by lowering heart rate and reducing renin activity and catecholamine levels.[28] Compared with sodium nitroprusside, beta adrenoceptor antagonists lower blood pressure and reduce blood flow to the middle ear and improve surgical field without metabolic complications.[22]

The alpha-2 adrenoceptor agonists, clonidine and dexmedetomidine, have been discussed earlier in relation to their sedative and analgesic properties. They also markedly reduce catecholamine secretion, are anesthetic sparing, and produce moderate bradycardia and hypotension.[27,29,30] A randomized study investigating the effectiveness of dexmedetomidine in reducing bleeding during septoplasty and tympanoplasty operations demonstrated dexmedetomidine significantly reduced bleeding and fentanyl requirement in septoplasty and reduced fentanyl requirement in tympanoplasty operations, but the decrease in bleeding was not significant.[30] Durmus and colleagues[31] used dexmedetomidine to improve the quality of surgical field in both tympanoplasty and septoplasty, and concluded that dexmedetomidine is a useful adjuvant to decrease bleeding.

Remifentanil is an ultrashort-acting mu receptor agonist. It is able to decrease systemic blood pressure, reduce blood flow to the middle ear, and produce better visibility in the operative field without impairing autoregulation of the middle ear microcirculation.[23,32] The proposed mechanism of action is via central sympathetic blockade. Degoute and colleagues[32] reported that remifentanil combined with sevoflurane in children enabled controlled hypotension, reduced middle ear blood flow, and provided a good surgical field for middle ear surgery with no additional need for other hypotensive agents. Furthermore, remifentanil reduced sevoflurane requirement and helped avoid the use of muscle relaxants. There is some evidence that intraoperative infusion of high doses of remifentanil can cause postoperative hyperalgesia, increasing the postoperative analgesic requirement but this is controversial.[33,34]

Magnesium sulfate is a noncompetitive N-methyl-D aspartate (NMDA) receptor antagonist with antinociceptive effects, and it inhibits entry of calcium ions into cells. Magnesium sulfate is used as a vasodilator for controlled hypotension. Ryu and colleagues[24] compared remifentanil and magnesium sulfate for middle ear surgery

in terms of hemodynamic effects and postoperative pain when combined with sevoflurane. They reported no significant difference over time in mean arterial pressure or heart rate between the drugs. Patients in the magnesium sulfate group had a lower sevoflurane requirement than those receiving remifentanil. Overall, magnesium sulfate was associated with more stable perioperative hemodynamics and produced better analgesia and less PONV compared with remifentanil.

Otologic surgical procedures are associated with facial nerve paralysis, and thus facial nerve protection is an important consideration. Preservation of the facial nerve can be easily confirmed if the patient is not paralyzed,[4] but use of muscle relaxants compromises the interpretation of evoked facial electromyographic activity. Since any sudden movement could jeopardize surgery, it has been suggested that partial neuromuscular blockade as determined by train-of-four peripheral nerve stimulation be used.[35]

Middle ear surgery is associated with a high incidence of PONV. In the absence of antiemetic treatment, 62% to 80% of patients will be afflicted.[36] The etiology of PONV is multifactorial and depends on various factors, including patient demographics, history of PONV, anesthetic technique, use of nitrous oxide, duration of anesthesia and operation, and even surgical experience.[37–39] TIVA reduces PONV compared with using volatile agents.[14] Use of nitrous oxide is associated with a higher incidence of PONV. Patients operated on by residents required more aggressive prophylaxis for PONV than those operated on by specialists.[39] Prophylactic administration of antiemetic medication also decreases the incidence of PONV. Usmani and colleagues[37] compared the efficacy of ondansetron (0.1 mg/kg), dexamethasone (0.15 mg/kg) and a combination of ondansetron (0.1 mg/kg) and dexamethasone (0.15 mg/kg) for prevention of PONV in a randomized double-blind study involving 90 ASA I and II [Q12] patients. They concluded that prophylactic therapy with ondansetron together with dexamethasone is superior to either drug alone. Another study comparing the efficacy of combining granisetron and dexamethasone to either drug alone yielded similar [Q13] results.[40] This also holds true in pediatric patients.[41,42] Thus, the combination of a selective 5-hydroxy tryptamine type 3 receptor antagonist together with dexamethasone is more effective in preventing PONV than either drug alone. Yeo and colleagues[43] compared the antiemetic efficacy of dexamethasone combined with midazolam and concluded that the addition of midazolam did not significantly reduce the overall incidence of PONV compared with dexamethasone alone. However, the addition of midazolam did lower the incidence of vomiting and the need for rescue antiemetic.[43]

Patients who underwent middle ear surgery under local anesthesia experienced less immediate postoperative pain than those under general anesthesia. A multimodal analgesic approach combining opioids, nonsteroidal anti-inflammatory drugs/coxibs, [Q14] and acetaminophen is generally appropriate. A recent study found blockade of the auricular branch of the vagus nerve with 0.2 mL of 0.25% bupivacaine to be more effective than intranasal fentanyl (2 μg/kg) in management of postoperative pain in infants and children undergoing myringotomy and tube placement.[44]

In conclusion, with careful patient selection, local anesthesia with sedation is a good alternative to general anesthesia for simple middle ear surgery. General anesthesia with TIVA provides a better recovery profile and less nausea and vomiting compared with inhalational anesthesia, and nitrous oxide should be avoided. Remifentanil is a good drug for controlled hypotension and for avoidance of muscle relaxants. If required, partial neuromuscular blockade can still allow facial nerve monitoring during surgery. Combination PONV prophylaxis is more effective than single drug treatment.

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