Complications of Surgery for Chronic Ear Conditions

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Facial Nerve Injury

Prevention: injury to facial nerve (FN) potentially devastating complication of elective surgery; copious irrigation important (increases visibility of structures and removes bone dust); largest bur that can be accommodated should be used and awareness of full 360° of bur critical (never safe to drill under shelf); important landmarks — stapes or footplate if arch eroded (speaker uses FN monitor); Jacobson nerve; tensor tympani tendon (FN typically just above it and few millimeters anterior); cochleariform process; horizontal semicircular canal (FN inferior to this at second genu); stapes and pseudostapedial joint important location to use largest bur and most irrigation; small burs more likely to cause perforation (>2 mm diamond bur to begin opening facial recess); irrigation — helps visualize FN sooner through bone and avoid heat injuries

FN bifurcation: critical rule — “nothing is the facial nerve until you know it is the facial nerve”; rare anomaly can be misleading and lead to devastating results

FN palsy: in acute otitis media (OM), can result from venous congestion or mastoiditis; recovery usually occurs with antibiotics, sometimes with decompression; involvement of nerve by cholesteatoma complicates chronic ear surgery

Most common sites of iatrogenic injury: distal to first genu (if surgeon less experienced or tougher case), horizontal segment (most common site), second genu in descending segment, stylo-mastoid foramen (less common)

FN monitor: essential in acoustic tumor surgery but not completely reliable; instints and knowledge critical; intraoperative recognition key

Exposure of sheath: not unusual in cochlear implantation surgery; not likely to result in injury if large bur used, but should be avoided if possible

Landmark study (McCabe): injury to FN associated with nausea; if injury estimated <25% of nerve, decompression sufficient (fibers intact, regeneration likely); if injury >25% of nerve, repair recommended (interposition graft); 1 cm of length gained by revisiting FN (although not feasible during chronic ear surgery); good outcomes with decompression in less severe injuries; for primary anastomosis, optimal improvement to grade-3 to -4 injury (although grade 3 rare); recent literature supports efficacy of cable graft vs primary anastomosis

Management: end-to-end repair — mobilize up to 1 cm (with translabyrinthine, acoustic neuroma, or other skull base tumor resection or nerve graft); great auricular nerve harvested (near Erb point, between angle of mandible and mastoid tip); sural nerve can also be used; sharply cut edges of graft and trim edges of FN; insert cable graft in reverse direction to force nerve down through epineurium of graft into distal FN for healing; lay graft in fallopian canal (may secure with, eg, 2 or 3 sutures, microfibrillar collagen hemostat [Avitene], absorbable gelatin sponge [Gelfoam]); collagen tubules (NeuraGen) work well for FN anastomosis by providing epineurium and allowing more room to join bifurcated nerve; important to visualize FN in temporal bone (less likely to inadvertently injure it); immediate postoperative weakness — due to local anesthesia, tight packing, or intraoperative injury; if injury suspected, important to discuss with family immediately and take responsibility; preoperative counseling (about potential for injury) and honesty significantly decrease likelihood of litigation; reexplanation recommended if function does not return in 24 hr; delayed postoperative palsy — observation recommended; most patients recover without difficulty; packing removed if tight

Other Surgical Complications

Labyrinthine injury: inadvertent exposure of fistula; 10% of cholesteatomas have fistula of horizontal canal; important to be cognizant of this when lifting matrix off horizontal canal (elevate gently, identify, and cover)

Traumatic fenestration with drill: often results from surgeon’s unawareness of anatomic location; generally horizontal canal involved (results in injury to cochlear nerve and FN) but can also occur in semicircular canal, oval window, or cochlea; cover immediately with fascia or bone wax and do not suction; hearing loss unlikely if perilymph not suctioned during surgery for superior semicircular canal dehiscence

Vascular injury: can occur in sigmoid sinus, jugular bulb, or internal carotid artery (all within ear and temporal bone); carotid can be dehiscent in middle ear; sigmoid sinus injury — field should be flooded with saline while patient in Trendelenburg position with left side down (to prevent air embolism); place finger on sinus; wound packed with fibrillar absorbable hemostat (Surgicel) or thrombin-soaked Gelfoam or hemostatic matrix (FloSeal) placed over hole, covered with cottonoid, and suctioned to promote hemostasis

Aberrant structures or tumors: important to recognize (eg, paraganglioma indicating glomus tumor; aberrant carotid artery); generally, carotid not visible through tympanic membrane; computed tomography (CT) recommended to visualize aberrant vessels in middle ear and huge inferior tympanic canalulus; absence of foramen spinosum on CT indicative of persistent stapidial artery

Educational Objectives

The goals of this program are to improve outcomes from complications of ear surgery, perfusion treatment of the inner ear, and biofilm formation on tympanostomy tubes (T-tubes). After hearing and assimilating this program, the clinician will be better able to:

1. Mitigate or prevent facial nerve (FN) injuries during chronic ear surgery.
2. Detect FN injuries intraoperatively and repair them.
3. Treat sudden hearing loss with intratympanic (IT) corticosteroid injection.
4. Manage refractory benign paroxysmal vertigo with IT instillation of streptomycin.
5. Discuss prevention of biofilm formation on T-tubes coated with N,N-dodecyl,methyl-polyethyleneimine.

Faculty Disclosure

In adherence to ACCME Standards for Commercial Support, Audio-Digest requires all faculty and members of the planning committee to disclose relevant financial relationships within the past 12 months that might create any personal conflicts of interest. Any identified conflicts were resolved to ensure that this educational activity promotes quality in health care and not a proprietary business or commercial interest. For this program, the faculty and planning committee reported nothing to disclose.
Internal carotid artery injury: life threatening and requires immediate action; Surgicel critical to control bleeding; eustachian tube orifice should be blocked to prevent repeat bleeding; pack ear canal gently to prevent hypotension, and consult with neurosurgery, vascular surgery, or interventional radiology

Cerebrospinal fluid (CSF) leak: important to recognize intraoperatively (although exposed dura should not cause panic); small defects can be buttonholed using temporals muscle and annulus elevator; approach of fascia from below generally not recommended (can enlarge defect); small rent in dura with bone around it can be treated with bone wax or bone cement; hospitalize patient and elevate head of bed 30°; leak onto cotton ball after tympanoplasty indicates need for further management, extensive defect — incision extended and mini-middle fossa craniotomy performed to expose temporal bone from above; use fascia, bone flap, then fascia again to repair defect; even if injury repaired but leak not stopped, lumbar drain usually effective

Perfusion of the Inner Ear

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Streptomycin: first antibiotic effective against tuberculosis but toxic to inner ear; later used for ablation of vestibular system in treatment of vestibular disorders (eg, Meniere disease [MD])

Data from Schuchnecht: criteria for ablation therapy for MD — diagnosis firmly established by history, vestibular tests and audiometric evaluation; symptoms must be at least moderately incapacitating; must have adequate auditory function in opposite ear; transystympanic labyrinthotomy — stapes removed, small barbed instrument introduced through round and oval windows, contents of vestibule aspirated, Gelofix placed into vestibule; first presentation of streptomycin perfusion — small knife wound created through annulus, plastic tubing inserted for application of streptomycin; hoped to destroy vestibular function but save hearing by varying frequency and concentration of application; successful treatment indicated by abolishment of caloric reaction to ice water; however, hearing loss total at this point

Survey about intratympanic (IT) corticosteroid injections: 101 neurologists surveyed; reported use — 84% used only dexamethasone (DM) and 13% used methylprednisolone (MP) for sudden hearing loss in MD; concentration used — 4 to 40 mg of IT DM, with median of 16 mg; 60 to 80 mg of MP with median of 40 mg; administration — 1 to 30 instillations performed in middle ear with median of 4 (over 1-20 wk) with average of 2 wk in between; anesthetic — 72% used phenol, 13% did not use anesthesia, 11% injected canal wall, 3% used lidocaine/prilocaine (EMLA); more clinical trials needed with true choice of agents and concentration, to study dose schedule and method of administration

Pharmacokinetics of drug entry into cochlear fluid: described by Salt et al in multiple papers; target tissues — sensory hair cells, afferent nerve fibers, supporting cells of cochlea, vestibular portions of inner ear; important issues — to determine which part of ear reached by drugs and at what concentration and time course; to determine how different delivery methods on application protocols influence drug levels at time points and anatomic locations; general principle — inner ear fluids do not flow appreciably and not stirred (drugs move through fluids by passive diffusion); diffusion coefficient of each substance or molecule injected into inner ear determines rate of diffusion; transfer through round window membrane (RWM) passive process; hypothetical active process not yet discovered; RWM semipermeable; 2 types of flow — radial (rapid) from RWM into scala tympani (ST) and up through same turn of cochlea into scala vestibuli (SV); longitudinal down scala tympani; routes of distribution — drug put in middle ear; travels through RWM into ST; accesses SV through vestibule; ST through endolymphatic system or extracellular spaces of spiral ligament to SV; spreads along scala by diffusion; drug clearance — important in IT treatment of inner ear disorders; clears by diffusion into adjacent compartments and lost across vascular endothelial cells into blood; accumulation occurs in intracellular compartments; drug binds to receptors and metabolized intracellularly by proteins and fluids; technical aspects — concentration and volume of drug injected; duration of time in contact with RWM; number of applications; method of application; medium in which drug dissolved (affects absorption)

Study by Norris and Shea: injected streptomycin vs gentamicin vs control into semicircular canals of cats and studied histologic evidence of hair cell loss; streptomycin caused significantly greater hair cell loss in semicircular canal (also greater in utricle); gentamicin caused greater hair cell loss in saccule and significantly greater loss in hook region of cochlea (with only minimal hair cell loss from streptomycin in that region); conclusion — streptomycin more vestibulotoxic and gentamicin more ototoxic

Perfusion of inner ear: drugs used — DM and streptomycin; procedure used by speaker — spray of lidocaine/prilocaine in ear >20 min before procedure and intravenous (IV) midazolam (Versed) if patient apprehensive; myringotomy made from anterior hypotympanum up to almost RWM; patient lies for 2 hr (3 consecutive days) to keep perfusate in contact with RWM; patient asked daily about fullness in ear, tinnitus, and hearing loss; for patients with sudden idiopathic sensorineural hearing loss, DM (24 mg in 0.6 mL of hyaluronic acid [Hyaluron]) instilled in middle ear with IV DM (if not contraindicated); hyaluronic acid creates viscosity to prevent DM from draining down eustachian tube into back of throat; positive prognostic indicators — treatment within first month of sudden hearing loss, no associated vertigo or dizziness, no severe or complete hearing loss; IT corticosteroid therapy offered to patients who have all 3 positive prognostic indicators or for active MD unresponsive to conservative medical management (eg, low-salt diet, exercise, diuretic); streptomycin (10 mg) also offered to patients with MD (with 24 mg DM in 0.6 mL hyaluronic acid) instilled in middle ear (with or without 16 mg of IV DM)

Chemical labyrinthotomy: for patients who present with incapacitating vertigo or nausea and vomiting and near total hearing loss in affected ear, streptomycin 120 mg in 0.6 mL hyaluronic acid instilled in middle ear 3 consecutive days; used only in ear with no salvageable hearing

Refractory benign paroxysmal positional vertigo (BPPV): patients completely incapacitated as BPPV progresses; preoperative treatment — canahil repositioning maneuver; balance therapy (or physical therapy); balance exercises at home; vestibular sedatives; hospitalized; preoperative testing — audiometric evaluation, videonystagmography, Dix-Hallpike, electrocochleography, bithermal caloric testing, magnetic resonance imaging (to rule out acoustic neuroma); treatment — 10 mg streptomycin and 24 mg DM suspended in 0.6 mL of hyaluronic acid; treatment technique studied on 31 patients; after 3-day treatment, no patients had any symptoms of BPPV (4 patients reported rare mild symptoms)

Prevention of Biofilm on Tympanostomy Tubes

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Study objective: to identify effectiveness of surface coating of tympanostomy tubes (T-tubes) using linear N,N-dodecylmethyl-polyethylenimine (DMPEI) in formation of bactericidal surface and prevention of biofilm in vitro

Biofilm: complex aggregate of multiple microorganisms in protective polymeric substance (polysaccharides and extracellular DNA); life cycle begins with single-cell attachment to surface, which forms early cluster. then becomes biofilm; heterogeneous
Materials and methods: used contact-active biocidal killing model (nonspecific to organism and mechanical), commercially available T-tubes (polyethylene [PE] and fluoroplastic [FP]); tubes coated with DMPEI and uncoated tubes used for controls; tubes challenged in vitro with 10,000 colony-forming units (clinical isolates of *Haemophilus influenzae*, *Moraxella catarrhalis*, and *Moraxella catarrhalis* resistant *Staphylococcus aureus* [MRSA]) and incubated for 16 hr; bacterial cell counts obtained, and scanning electron microscopy (SEM) performed for qualitative review.

**Results:** T-tubes challenged with MRSA had lower bacterial cell counts when coated with DMPEI vs uncoated controls; on SEM biofilm seen on control tubes but not DMPEI-coated tubes; similar results for *H influenzae* and *M catarrhalis*.

**Mechanism of action for DMPEI:** long chain polyethyleneimine with positive charge; synthesized by adding alkyl and methyl groups, which cause it to become long hydrophobic chain; “greasy tail” with weakly positive polyethyleneimine; lures polymer and spikes it with positively charged polyethyleneimine, disrupts cell membrane, causes osmotic imbalance and bursts cell, leading to cell death.

**Biofilm:** exists in OM (in mucosa) and in T-tubes removed for refractory otorrea; materials used for T-tubes nonporal and hydrophobic and attract bacteria; biofilm in middle ear mucosa polymicrobial, thus DMPEI affords critical advantage of being nonspecific and mechanical (avoiding potential drug resistance)

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**Estimated time to complete the educational process:**

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1. Use of smaller sized burs (<2 mm) is important to prevent facial nerve (FN) injury during surgery for chronic ear conditions.
   (A) True (B) False

2. Which of the following is the most common site of iatrogenic injury to the FN?
   (A) Distal to the first genu
   (B) The second genu in the descending segment
   (C) Horizontal segment
   (D) Stylomastoid foramen

3. Which of the following is recommended for management of delayed postoperative FN palsy?
   (A) Cable graft (C) Primary anastomosis
   (B) Decompression (D) Observation of patient and removal of tight packing

4. When sigmoid sinus injury occurs intraoperatively, the field should be flooded with saline and patient placed in ______ with ______ side down to prevent air embolism.
   (A) Trendelenburg; left (B) Reverse Trendelenburg; right

5. Absence of the foramen spinosum on computed tomography is indicative of a persistent stapedial artery.
   (A) True (B) False

6. Identify the incorrect statement about movement of drugs through the fluids of the inner ear.
   (A) Involves passive diffusion
   (B) Diffusion coefficient of each molecule determines rate at which molecules move in fluid
   (C) The round window membrane is freely permeable
   (D) There is rapid radial flow from the round window membrane into the scala tympani

7. Through their histologic studies of hair cell loss in cats, Norris and Shea concluded that streptomycin is more ______ and gentamicin is more ______.
   (A) Ototoxic; vestibulotoxic (B) Vestibulotoxic; ototoxic

8. Which of the following prognostic indicators would indicate appropriate candidacy for treatment with intratympanic corticosteroid therapy for sudden idiopathic sensorineural hearing loss?
   (A) Presence of sudden hearing loss for <1 mo (C) Mild to moderate hearing loss
   (B) Absence of vertigo or dizziness (D) All the above

9. Chemical labyrinthectomy can be performed with instillation of ______ of streptomycin in 0.6 mg of hyaluronic acid into the middle ear on 3 consecutive.
   (A) 10 mg (B) 40 mg (C) 80 mg (D) 120 mg

10. Scanning electron microscopy showed that tympanostomy tubes coated with linear N,N-dodecyl,methyl-polyethylenimine (DMPEI) and challenged with ______ had lower bacterial cell counts than uncoated control T-tubes and biofilm was not visible.
    (A) Methicillin-resistant Staphylococcus aureus (C) Moraxella catarrhalis
    (B) Haemophilus influenzae (D) All the above

Answers to Audio-Digest Otolaryngology Volume 46, Issue 14: 1-B, 2-C, 3-A, 4-C, 5-A, 6-B, 7-A, 8-D, 9-B, 10-A