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LOCAL AND REGIONAL ANAESTHESIA TECHNIQUES FOR OTOLOGIC (EAR) SURGERY

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Implementing the use of local anaesthesia to perform middle ear and mastoid surgery in lower- and middle-income countries and in humanitarian outreach settings is challenging, though it has many advantages.

This article outlines the rationale for local anaesthesia in otologic surgery as well as educates the reader about local anaesthetic agents and the anatomy of the ear that allow local anaesthesia to be an effective means under which to perform otologic procedures.

Rationale for Local Anaesthesia

Performing otologic procedures under local anaesthesia - as opposed to general anaesthesia - has many advantages in a humanitarian settings. Depending on the specific setting, the main impetus for performing a procedure under local anaesthesia may be a lack of trained anaesthesia support. In the absence of trained anaesthetists or nurse anaesthetists, local anaesthesia is the safest option. Thus, ***safety of surgery under local anaesthesia is its primary advantage***.

Another reason is the potential for the lack of adequate and/or functional anaesthesia machines and monitoring equipment. Not only must there be a functioning anaesthesia machine that can deliver inhaled anaesthetic agents and assume ventilatory functions, but there must also be other equipment to ensure adequate and monitored delivery of these functions. This includes a reliable pulse-oximeter, EKG machine, blood pressure monitor, and end-tidal CO_2 monitor. Even if inhaled agents were not to be used and anaesthesia was achieved with injectable agents alone, such a propofol, most of these "ancillary" monitoring devices are still be needed for safety.

Another advantage is ***recovery time and turnover and the ability to perform more cases in a shorter time.*** Time is important in a humanitarian setting, even more so than in high income settings, as a humanitarian mission may be limited to a certain number of days or even daylight hours. The capacity to perform even *one* additional case in any given day may effectively benefit many more patients - depending on the duration of the outreach. No time needs to be allotted for reversal of anaesthesia and monitoring requirements during recovery are minimal - limited primarily to clinical observation.

Neurovascular Anatomy of the Ear

A good understanding of the complex neurovascular anatomy of the ear is crucial for successful use of local anaesthesia with otologic surgery. It also bears mention that the goal of local anaesthesia (with vasoconstrictive agents) in ear surgery, is not simply anaesthesia so that the patient feels no pain, but also *haemostasis* so the surgeon feels no pain! For this reason, a discussion of the relevant anatomy for local anaesthesia in otologic surgery must include not only the neural innervation of the ear but also its vascular supply.

Vascular supply

As evidenced by the brisk bleeding from a lacerated ear after injury, the auricle has a robust blood supply. The ***external ear*** receives its blood supply from the two terminal branches of the external carotid: the ***posterior auricular artery and small auricular rami of the superficial temporal artery*** *(Figure 1)*.

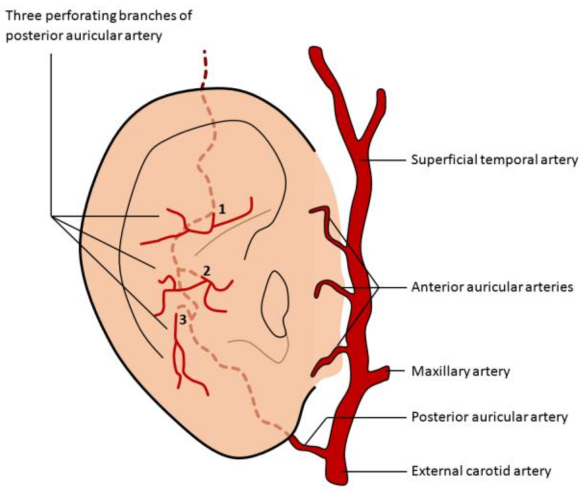


Figure 1: Arterial supply to external ear

These same two arteries supply the external ear canal with the addition of the ***deep auricular artery***. The ***deep auricular artery*** branches from the first part of the internal maxillary artery, passes through the substance of the parotid gland and behind the temporomandibular joint to penetrate and ***supply the medial portion of the external ear canal***.

The ***tympanic membrane*** receives its blood supply from vessels supplying the middle ear and external auditory canal. Working from lateral to medial, the outer surface is supplied by the ***deep auricular artery*** that also supplies the medial portion of the external ear canal. Branches of the deep auricular artery form a ***vascular ring*** around the tympanic membrane, and also includes a more prominent branch, the ***descending or manubrial artery***, that descends along the manubrium of the malleus *(Figure 2)*.

The ***medial, or mucosal, surface of the tympanic membrane*** is supplied by branches of the ***anterior tympanic branch of the internal maxillary artery*** and of the ***stylomastoid branch of the posterior auricular artery*** [1].

Figure 2: Arterial supply of the tympanic membrane from both the small peripheral arterioles and the larger manubrial artery, both branches of the deep auricular artery (Adapted from Hollinshead, 1982)

The blood supply of the ***middle ear and mastoid*** also arises primarily from the external carotid system. Four arterial contributions arise from the external carotid artery. Two of these contributors are the ***anterior tympanic artery*** that arises from the internal maxillary artery and the ***inferior tympanic artery*** that arises from the ascending pharyngeal artery. The other two are the ***stylomastoid artery*** that arises either from the posterior auricular or occipital artery, and the ***middle meningeal artery*** that arises from the internal maxillary artery *(Figure 3)*. After entering through the stylomastoid foramen, the ***stylomastoid artery*** gives off the ***posterior tympanic artery*** that enters the middle ear, as well as giving off branches to the mastoid air cells. The middle ***meningeal artery*** supplies two arteries to the middle ear: the ***petrosal*** and ***superior tympanic arteries***. Finally, there can be several branches from the internal carotid artery that enter through the caroticotympanic canal to supply the middle ear.

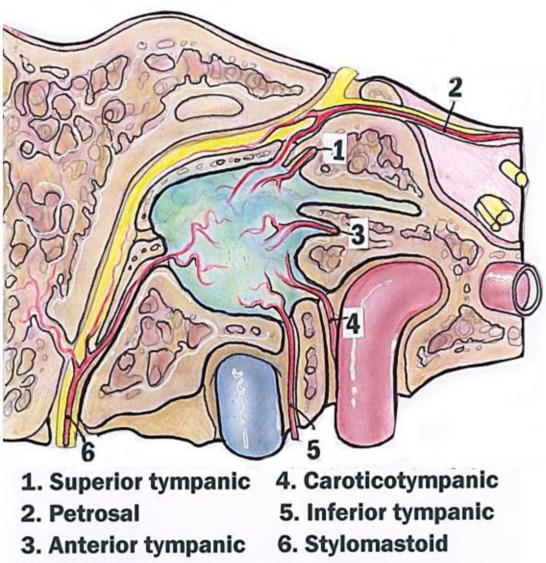


Figure 3: Contributions to the arterial supply of the middle ear (Adapted from Hollinshead, 1982)

Venous drainage of the external ear is via the ***superficial temporal*** and ***posterior auricular veins*** into the retromandibular and the external jugular veins respectively *(Figure 4)*. The retromandibular vein splits to drain into the internal and external jugular veins; on occasion, the posterior auricular vein drains directly into the sigmoid sinus via the mastoid emissary vein[1].

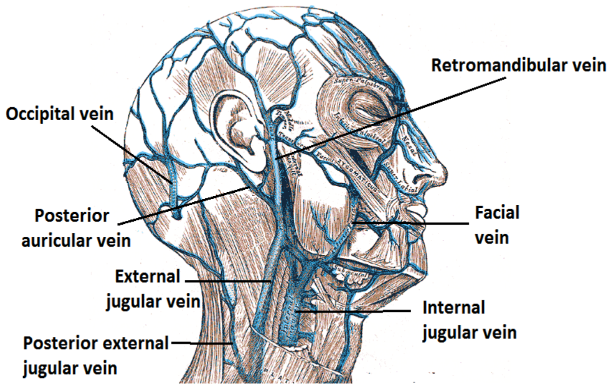


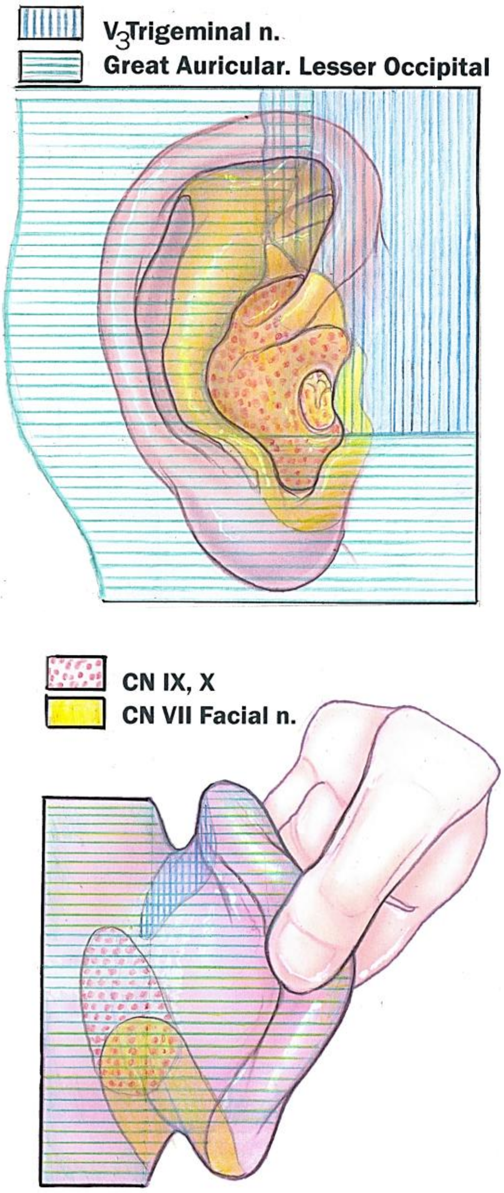
Figure 4: Venous drainage of external ear

Nerve supply

Innervation of the auricle has been explained in exquisite detail elsewhere [2], but an overview of the main contributing nerves will be presented here. Sensation to the external ear is provided by several cutaneous branches of cranial nerves as well as by cutaneous branches of the cervical plexus. This is reflective of the origin of auricular skin from both branchial and post-branchial components [1]. There is invariably some overlap in the innervation from person-to-person, but the contributions are relatively constant *(Figures 5a, b)*.

The ***auriculotemporal nerve*** is a branch of the mandibular division of the trigeminal nerve (V_3), and supplies the anterior portion of the external ear, the crus of the helix, and the tragus. It also supplies the anterior and superior walls of the external auditory canal [1, 3]. Most of the remaining lateral, posterior, and medial portions of the external ear - excluding the concha - is supplied by cutaneous branches of C2 and C3 via the greater auricular nerve. C2 and C3 roots of the cervical plexus also supply the skin overlying the mastoid via the ***lesser occipital nerve*** [1].

The concha of the external ear has similarly complex and overlapping sensory innervation. Branches of the ***7th (facial), 9th (glossopharyngeal), and 10th (vagus) cranial nerves*** supply this area. At least two of these nerves (7th and 10th), and possibly the 9th, also supply the posterior external auditory canal. All three these nerves reach their points of innervation via the ***auricular branch (Arnold's nerve) of the vagus nerve***. ***Arnold's nerve*** arises from the superior jugular ganglion and eventually emerges through the tympanomastoid fissure. Along its course, it picks up the ***auricular branch*** (not the *tympanic* branch) of the 9th cranial nerve along with a branch of the ***posterior auricular branch of the facial nerve*** [1, 3]. The ***tympanic membrane*** is also innervated by ***several different nerves*** *(Figures 6, 7)*.



Figures 5a, b: Cutaneous innervation of the lateral and posterior aspects of the auricle by the trigeminal nerve, cervical plexus, 7th cranial nerve, and 9th and 10th cranial nerves (Adapted from Hollinshead, 1982)

Just as the ***auriculotemporal branch of V_3*** supplies the anterior and superior aspects of the external ear canal, so too does it supply the anterior and superior aspects of the external tympanic membrane. The ***7th, 9th, and 10th cranial nerves*** innervate the posterior part of the external auditory canal as well as the posterior part of the tympanic membrane via the ***auricular branch of the vagus nerve***[1]. The medial portion of the tympanic membrane and middle ear are similarly innervated primarily by the ***tympanic plexus of the glossopharyngeal nerve*** *(Figure 6)*.

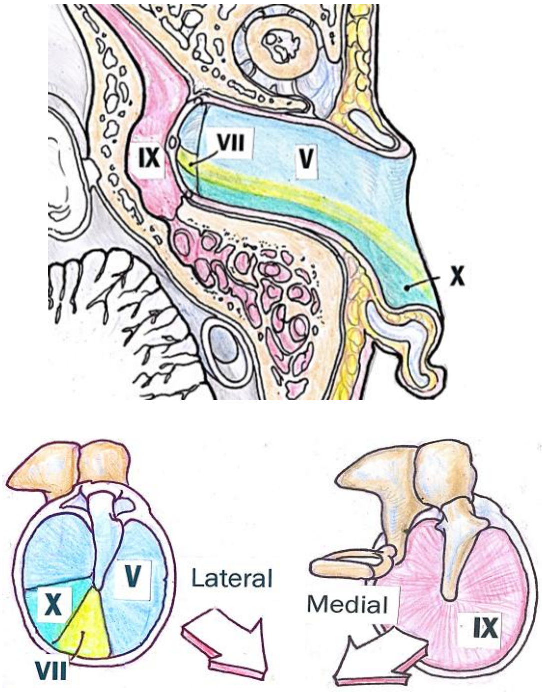


Figure 6: Innervation of external auditory canal, tympanic membrane, and middle ear (Adapted from Hollinshead, 1982)

The topography of nerves on the external surface of the tympanic membrane closely follows that of its vascularity *(Figures 4 & 7).*

Figure 7: Pattern of neural innervation of the external tympanic membrane. Notice its similarity to the vascular topography of the external tympanic membrane (Figure 3) (Adapted from Hollinshead, 1982)

As previously mentioned, the middle ear is innervated mainly by the ***tympanic branch (Jacobson's nerve) of the glossopharynxgeal nerve***. On entering the middle ear during surgery, it is often clearly seen coursing over the promontory. Jacobson's nerve combines with caroticotympanic nerves from the carotid plexus to form the ***tympanic plexus*** *(Figure 8).*

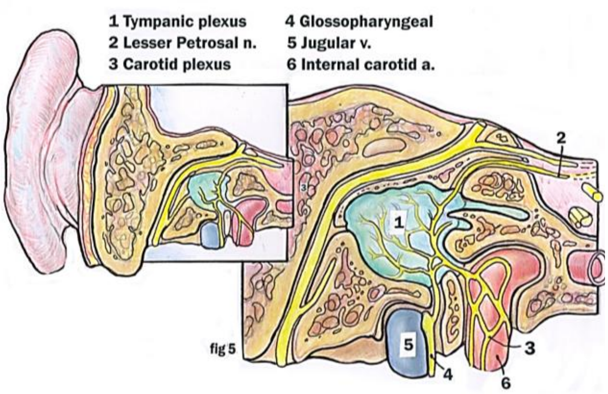


Figure 8: Contributions to tympanic plexus (Adapted from Hollinshead, 1982)

In addition to providing sensory fibers to the mucosa of the middle ear, the ***tympanic plexus*** also gives off branches to the entire tympanic cavity, mastoid air cells, and Eustachian tube.

Local Anaesthetic Agents

The primary action of local anaesthetics is to inhibit propagation of nerve impulses. This occurs by inhibition of influx of Na^+ ions, thus preventing action potentials and nerve depolarisation. The mechanism that prevents sodium influx is thought to involve specific binding sites within sodium channels located in the cell membrane of the nerve, but the exact mechanism by which this occurs is less clear [4, 5].

Two Main Classes

There are ***two main classes*** of local anaesthetics based on their chemical structure and the way in which they are metabolised: ***amino esters and amino amides***. Technically there is a newer, 3rd class of local anaesthetic, where an agent in one of the other classes is transformed into a novel agent by creating a chiral form. This is done by creating one of two stereoisomers of one of the more traditional local anaesthetics that possesses novel properties [5].

Ester-type local anaesthetics possess a C-O-O, or ester linkage, while amide local anaesthetics possess an N-H, or amide linkage. Ester-type local anaesthetics are metabolised by the plasma enzyme pseudocholinesterase to paraaminobenzoic acid (PABA). Three of the most used ester-type local anaesthetics are ***procaine, tetracaine,*** and ***cocaine***.

The second class of local anaesthetic is an ***amide-type local anaesthetics***. This class is metabolised by microsomal enzymes in the liver. A few of the most used amide-type local anaesthetics are ***lidocaine, bupivacaine,*** and ***mepivacaine*** [4]. A stereoisomer of bupivacaine, called ***ropivacaine***, is a member of the third ***chiral-form class*** of local anaesthetic.

Durations of action

Most otologic procedures do not exceed 3 hours, so any of the more commonly used agents *e.g.* lidocaine or mepivacaine, should suffice. The duration of action of lidocaine with epinephrine is about 4 hours - more than enough time to complete most otologic procedures. The duration of mepivacaine with epinephrine is even longer - around 6 hours. Both lidocaine and mepivacaine have rapid onsets of action. On the other hand, the commonly used ester-type agent, procaine, has a relatively short duration of action - 45 minutes without, and about 90 minutes with epinephrine [6].

Maximum dose

The maximum dose of 1% (10 mg/mL)

lidocaine should not exceed 4.5mg/kg, and if used with epinephrine, the maximum dose can be as high as 7mg/kg. For mepivacaine, the maximum dose is 5mg/kg without and 7mg/kg with epinephrine. If a large area of skin is to be anaesthetised, then a relatively low concentration of the agent should be used to avoid exceeding the maximum permitted dose; e.g., the concentration of lidocaine can be reduced from 1% or 2%, to 0.5%.

Sensitivity/allergy

A very important factor to consider when selecting a local anaesthetic agent is a patient's sensitivity to, or history of allergic reaction to, a given anaesthetic. As a class, the ***ester-type local anaesthetics carrier a much higher risk of adverse, or allergic, reactions*** compared to the amide class of local anaesthetics. One of the primary metabolites for two of the most used local anaesthetics in the ester class, procaine and tetracaine, is PABA. Therefore, neither of these agents should be used in patients who are allergic to PABA.

Sedatives and Anxiolytics

Pre- or intraoperative sedatives or anxiolytic agents can be used in combination with local anaesthesia. Agents such as benzodiazepines (Valium®) are very effecttive anxiolytic drugs and can be used as an adjuvant to local anaesthesia. Other agents such as meperidine (Demerol®), an analgesic with sedative properties, or hydroxylzine (Vistaril®), an older antihistamine, can also be used. However, if the choice is made to add these other agents to a purely local anaesthetic case, then additional monitoring and resuscitation equipment such as EKG and pulse-oximetry is advisable. Rescue drugs such as Narcan® should also be on hand. Overall, the addition of adjuvant agents adds another layer of complexity, partly detracting from the attractiveness of performing surgery strictly under local anaesthesia.

Local Anaesthesia in Ear Surgery

Advantages of Local Anaesthesia in Ear Surgery

Local anaesthesia is an accepted practice for otologic surgery, and has many advantages over general anaesthesia

- Safety is superior to general anaesthesia
- Less bleeding (although most surgeons still use injectable and topical local anaesthesia during general anaesthesia)
- Ability to assess a patient's hearing and detect any vertigo *during* surgery (especially valuable during stapedectomy)
- Avoidance of a potentially lengthy and/ or disruptive emergence from anaesthesia (advantageous in stapes surgery and ossicular reconstruction procedures)
- Less postoperative nausea/vomiting
- Less expensive [3]

Auricular Injection Techniques

Several techniques have been advocated and are generally "variations on a theme". Hence only a few methods will be described in detail.

Plester injection technique *(Figures 9-12)*

- *Step 1:* Inject the region of the postauricular fold *(Figure 9)*
- *Steps 2-4:* Without removing the needle in *Step 1*, advance the needle in 3 vectors: directly toward the posterior external ear canal, superior to the external ear canal and inferior to the external ear canal *(Figure 10)*

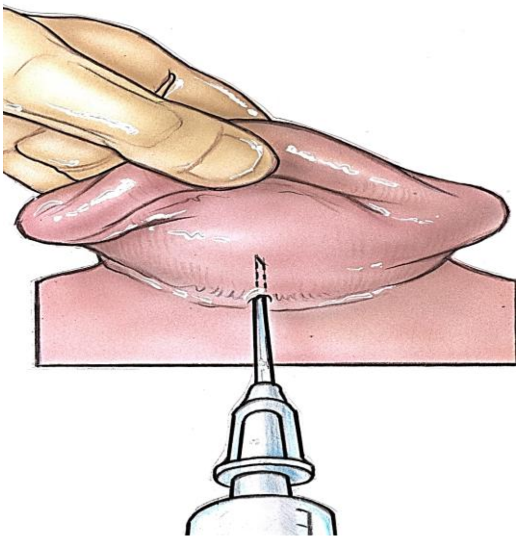


Figure 9: Postauricular injection technique (From Yung 1996)

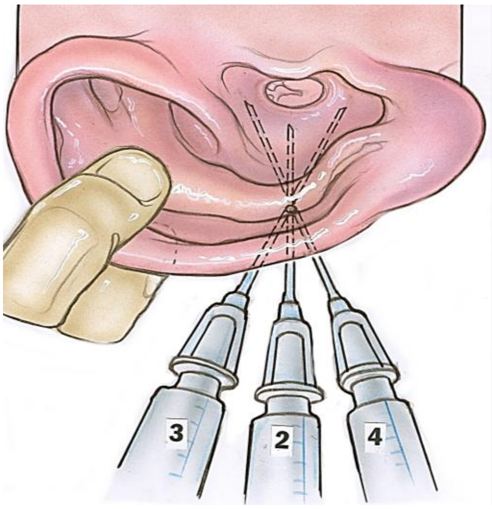


Figure 10: Postauricular injection Steps 2-4 (From Yung 1996)

- *Steps 5 - 8:* Inject the 4 quadrants of the ear canal in a stepwise fashion *(Figures 11 & 12)* [7]. This anaesthetises the external ear canal while at the same time achieving haemostasis of the skin of the ear canal and tympanic membrane. Take care during each of the canal injection steps to avoid the formation of haematomas or vesicles that could obscure the tympanic membrane during surgery or impair healing [7]

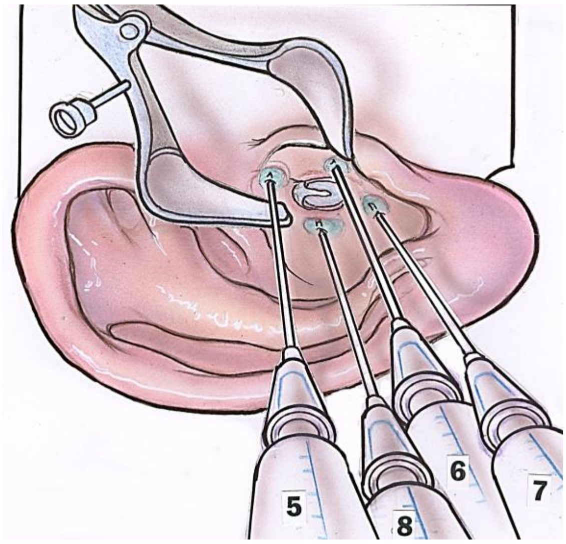


Figure 11: Canal injection steps 5-8 (From Yung 1996)

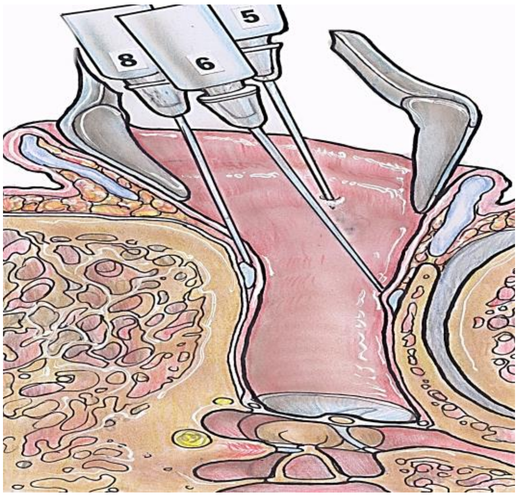


Figure 12: Axial view of canal injecttion (From Yung 1996)

Fisch injection technique

Fisch's technique uses fewer injection sites and the sites are differently placed [5].

- Insert the needle about 1cm behind the postauricular crease at a point halfway between the mastoid tip and the top of the ear
- Pass the needle anteriorly and inferiorly toward the tympanomastoid sulcus and inject local anaesthetic lateral to, but overlying the stylomastoid foramen *(Figure 13)*
- Direct a 2nd needle pass anterosuperior-

ly toward the *incisura* and inject more local anaesthetic *(Figure 13)*

- Wait 10 minutes [3] (In general, this is advisable when working under local anaesthesia also to allow more time for vasoconstriction to occur
- Inject the external ear canal; Fisch's technique differs from that of Plester in that only one canal injection is initially performed. This initial injection is placed superiorly in the region of the tympanosquamous suture line. After this initial canal injection, the other areas of the canal are tested for sensitivity and the other quadrants are injected only if needed

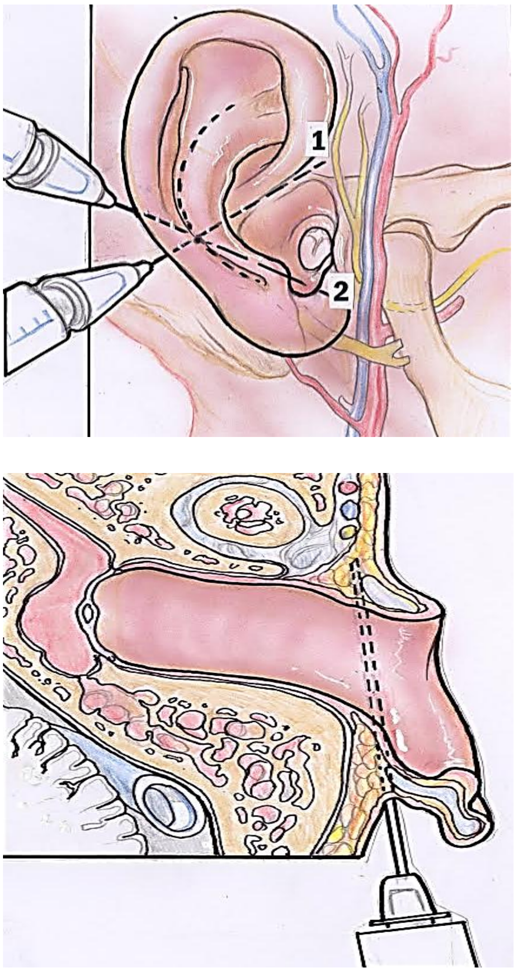


Figure 13: Fisch postauricular injecttion technique (from Lancer and Fisch 1988)

A drawback of the Fisch technique is a high risk of temporary facial nerve paresis due to injection in the region of the stylomastoid foramen; this can be very distressing for the patient and surgeon alike. Using this injecttion technique in a series of 32 patients, *Fisch* reported that 97% developed temporary postoperative facial weakness. For this reason, we recommend that injections are not administered below the level of the external auditory canal.

Additional Intraoperative Analgesia

More local anaesthetic can be administered with any of these local anaesthetic techniques should a patient experience pain during the surgery. However, the surgeon must keep a running total of the total amount of local anaesthetic agent that has been used to avoid exceeding the maximum permitted dose.

Jacobson's nerve (supplies the middle ear mucosa) can be anaesthetised if a patient experiences pain during the ***middle ear part of the procedure***, by placing a cotton ball or gelfoam soaked with 1% lidocaine or 4% tetracaine [7] on the promontory.

Field blocks

Field block is a form of regional anaesthesia that takes advantage of the subcutaneous course of somatosensory cutaneous nerve branches. A larger area can be anaesthetized with fewer injections by infiltrating the region of the course of any given nerve. Ideally, this injection is done in an area more proximal than the area in which an incision is going to be made to provide anaesthesia distal to the injection site. It requires less anaesthetic agent to be used as well as keeps the incision site undistorted [5]. Field blocks require an understanding of the anatomy of auricular innervation. ***Nerves amenable to a field block for ear surgery are the auriculotemporal, greater auricular, and the lesser occipital nerves*** *(Figure 14)*.

Figure 14: Nerves suitable for field block: greater auricular, auriculotemporal and lesser ("smaller") occipital nerves; note superficial temporal artery

Auriculotemporal nerve field block

The auriculotemporal nerve exits from the parotid gland in front of the ear *(Figure 15)*. The area to infiltrate is located by palpating the superficial temporal artery as it passes over the zygoma *(Figure 14)*. The injection is placed between this point and the *incisura* - near the root of the zygoma. About 2-3 ml of local anaesthetic is used to block the nerve [5].

V3 nerve regional block

A more complete, truly regional auriculotemporal nerve block can be achieved by performing a V_3 nerve block. This block provides excellent anaesthesia over the bulk of the cheek along with the upper pre-auricular and auriculotemporal hair covered regions. The anaesthetised area abuts the region supplied by the great auricular nerve more posteriorly [8].

- Palpate the sigmoid notch of the mandible. The notch is located inferior to the zygomatic arch about 2.5 cm anterior to the tragus
- While placing a finger over the notch, ask the patient to open the mouth; the mandibular condyle is felt sliding under the examiner's finger
- Ask the patient to close the mouth; the examining finger will stay in the notch
- Mark this point with a marking pen
- Inject a small volume of local anaesthetic in this area before proceeding to perform the block
- Insert a 5cm spinal needle perpendicular to the skin at the site where you marked the sigmoid notch *(Figure 15)*

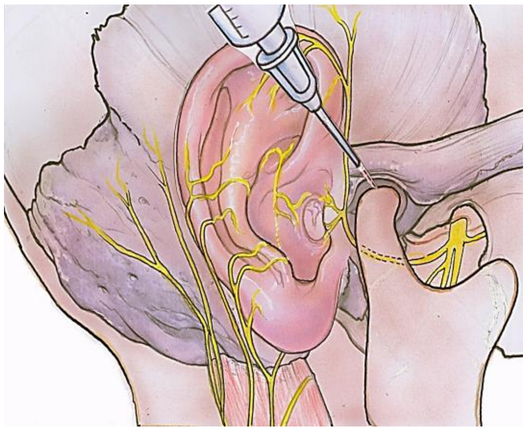


Figure 15: Auriculotemporal nerve block

- At a depth of about 4cm, the needle will hit the lateral pterygoid plate
- Withdraw the needle almost to the skin and redirect it 1cm posterior to the 1st pass, and to the same depth
- Aspirate to ensure that the tip of the needle is not in a vessel
- Slowly inject 3-4ml local anaesthetic

Greater auricular nerve field block

The greater auricular nerve block numbs the lower third of the ear and the lower post-auricular skin *(Figure 14)*. We describe two techniques below.

The ***first technique*** blocks the nerve more proximally and is therefore more of a regional block

- Identify the anterior and posterior borders of the sternocleidomastoid muscle, and draw parallel lines to delineate these borders of the muscle
- Draw a third line parallel to and in the middle of these two lines to mark the middle of the muscle
- Draw a line from the inferior edge of the external auditory canal 6.5cm inferiorly to meet the midline mark on the sternocleidomastoid
- At this point, inject a few ml of local anaesthetic [8].

The alternative technique takes advantage of the fact that the nerve exits from around the posterior border of the sternocleidomastoid muscle and then splits into anterior and posterior branches *(Figure 14)*. By locating the mastoid tip and injecting local anaesthetic both anterior and posterior to the mastoid the two branches of the nerve can be blocked [5].

Lesser occipital nerve block

A lesser occipital nerve block anaesthetises most of the skin overlying the mastoid.

- Locate the posterior border of the origin of the sternocleidomastoid muscle at the base of the skull *(Figure 14)*
- Introduce a needle at this point directly posteromedial and slightly cephalad until the bone of the calvarium is reached
- Withdraw the needle by few millimeters
- Aspirate to ensure that the tip is not in the occipital artery
- Inject a few ml of local anaesthetic

Vagus nerve field block

Although usually anaesthetised during the infiltration of other regions of the postauricular sulcus, the auricular branch of the vagus can be pinpointed and blocked by injecting local anaesthetic where the nerve exits the skull base between the mastoid process and the tympanic plate [9].

Other nerves

Even though the concha and middle ear mucosa are innervated by the 7th and 9th cranial nerves, these nerves are not amenable to a regional block. Anaesthesia in the distribution of these nerves can be achieved by local infiltration of the external ear canal and topical anaesthesia applied in the middle ear.

Effectiveness of Local Anesthesia for Middle Ear Surgery

Several authors have commented on the effectiveness of local anaesthesia for otologic surgery. *Caner* reported on 100 consecutive patients undergoing various middle ear procedures under local anaesthesia with IV sedation, including mastoidectomy [10]. In this paper, 96% of patients who underwent stapes surgery or tympanoplasty alone said that they had no pain during surgery; of all patients, 22% said that pain was distressing. The most distressing experiences were anxiety (44%) and noise created by the procedure (33%). However, 73% of patients in this study said they would have a similar operation done again under local anaesthesia. Furthermore, only one patient had transient facial weakness. In a similar paper by *Yung,* 108 patients that underwent various otologic procedures including mastoidectomy reported similarly favourable results [7]. The most frequent complaints were that of noise during the operation (30%) and anxiety (24%). Interestingly, otalgia was reported as the lowest specified discomfort (2%). As in Caner's paper, a high percentage (89%) reported that they would prefer local anaesthesia for a similar procedure. *Lancer and Fisch* also reported a high success rate with local anaesthesia and that both patients and surgeons were highly satisfied with local anaesthesia and that there had been no adverse effects [3]. One major concern of the latter paper was the 97% rate of transient (partial or total) facial nerve paralysis. Although transient, it was still unpleasant for a significant number (55%) of patients. These few studies corroborate the notion that otologic surgery done under local anaesthesia is not only an effective technique, but is acceptable to both patients and surgeons. It should be noted, however, that in all these studies adjuvant sedation was used in addition to local anaesthesia.

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