Role of Imaging in Hearing loss patients

Essay

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List of contents

Page No.

Introduction -- 1

Aim of the work -- 3

CT and MRI techniques ----------------------------------- 4

Radiological anatomy of middle ear --------------------- 17

Inner ear and sensorineural hearing loss---------------- 25

Imaging of cochlear implanation ------------------------ 67

Summary and conclusion --------------------------------- 91

References --- 93

Arabic summary -- 112

List Of Abbreviations

ABI:Auditory brainstem implant

CHL:conductive hearing loss

CPA:Cerebellopontine angle

CSF:cerebrospinal fluid

CT:Computed tomography

EAC:External auditory canal

ELD:Endolymphatic duct

ELS:Endolymphatic sac

FOV:Field of view

HRCT:High resolution computed tomography

IAC:Internal auditory canal

PLF:Perilymph fistula

MRI:Magnetic resonance imaging

SNHL:Sensorineural hearing loss

3DFT:Three Dimensional Fourier Transformer

Abstract

The essay reviewed two different parts of the temporal bone which are:the middle ear and the inner ear.In each part the normal radiological anatomy was discussed as well as the most common pathologies that cause sensorineural hearing loss ,regarding their clinical assessment and their imaging modalties.The essay pointed out the role of imaging in cochlear implant candidates preoperatively and postoperatively.

Key Words

Clinical Assessment –Sensorineural Hearing loss-CT -MRI -Cochlear Implantation..

Introduction

After arthritis and hypertension, hearing loss is the third most common chronic condition in older adults .The vast majority of hearing loss is sensorineural, particularly in the elderly, and sensorineural hearing loss (SNHL) is primarily a result of damage to the cochlea of the inner ear (Cruickshanks et al., 1998).

At present, clinicians cannot evaluate intra-cochlear anatomy,when searching for causes of SNHL. Because of small size and inaccessible location, intra-cochlear structures are difficult to image.The scala media of the cochlea, which contains the Organ of Corti, is approximately 250 microns in greatest dimension .Furthermore, the cochlea is located deep in skull, and except for the round and oval windows, is surrounded almost entirely by the dense bone of the otic capsule (Kemp,2002).

Cochlear anatomy was traditionally been studied via histolology unfortunately, histologic preparation is destructive of cochlear function and time consuming as it generally requires demineralization of the otic capsule. Furthermore, histologic imaging does not permit serial examinations of the cochlea over time, and thus, does not provide anatomic correlates of function in dynamic and progressive pathologic states, such as Meniere's disease (Casselman,2002).

In clinical audiology, several methods of non invasively imaging the cochlea are used. Computed tomography (CT) is commonly used to look for gross abnormalities in the bony anatomy of the otic capsule in the setting of SNHL, especially when considering congenital malformations. CT is also used to evaluate for other bony defects associated with inner ear pathology, such as superior canal dehiscence syndrome and large vestibular aqueduct(Minor et al.,2003).Magnetic resonance imaging (MRI) has been used to diagnose intra and retrocochlear pathology as a cause of SNHL, such as acoustic neuroma and cochlear otosclerosis (Goh et al.,2002).

Nevertheless, recent improvements in imaging technology may enable visualization of the inner ear at resolutions sufficient to assess cochlear injury. Knowledge of anatomic changes associated with different types of cochlear injury may be useful in directing therapeutic interventions and in monitoring therapeutic response. The ability to visualize intra-cochlear anatomy may also permit targeted, image-guided interventions for the treatment of inner ear disorders. These developments promise to revolutionize the diagnosis and treatment of hearing loss. Measures of cochlear function exist, such as otoacoustic emissions and auditory brainstem response testing .However,these tests do not provide information on anatomic changes associated with changes in cochlear function(Watkin,2001).

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AIM OF THE WORK

The aim of this work is to review the imaging modalities in normals and different cochlear pathologies for the diagnosis and treatment of sensorineural hearing loss with special emphasis on cochlear implantation.

CT and MRI techniques

Computed tomography in clinical practice

Since it was first introduced three decades ago, computed tomography has become an important investigative tool and has since become an integral part of clinical practice (Hounsfield, 1973).

Improvements in tube technology and computer hardware and software have shortened scan times and improved the resolution of scans. The incorporation of slip ring technology into scanners in the late 1980s resulted in the development of spiral (helical) scanners. More recently, multislice scanners with scan times of less than a second have become widely available. These important technological changes have been linked to newer and faster computers to provide the systems that are currently available (Lewis, 2001).

Spiral (helical) computed tomographic scanners :

The incorporation of slip ring technology into the design of scanners in the late 1980s removed the need for a rigid mechanical linkage between the power cables and the x ray tube (Hara et al.,2001).

Spiral scanning has several advantages. The scan time is much shorter than that of conventional computed tomography. Closely spaced scans are readily obtained, allowing good quality reconstructions in different planes. Lesions can be evaluated during different phases of contrast enhancement. Computed tomographic angiography is possible, and the likelihood that a small lesion may be overlooked is less/smaller. Spiral computed tomography is a powerful diagnostic tool. A spiral scanner is not as fast as a multislice scanner but is considerably cheaper typically one third to one half the cost of a multislice scanner (Dawson and Lees, 2001).

Multislice computed tomographic scanners :

A multislice (multidetector) computed tomographic scanner can be considered as a "turbocharged" spiral scanner. Conventional and spiral scanners use a single row of detectors to pick up the x ray beam after it has passed through the patient. Multislice scanners currently have up to sixty four active rows of detectors, and scanners under development will use direct digital detectors on flat panels .The increased number of detectors and tube rotation times that take a fraction of a second combine to give faster coverage of a given volume of tissue (Hara et al.,2001).

The use of a multislice scanner will considerably increase throughput of patients compared with a conventional scanner, but the throughput will be similar to that achieved with a modern spiral scanner. Multislice scanners generate an increased amount of data compared with single slice scanners, and in practice the throughput of patients is limited by the time taken to image and reconstruct these data. The volume of data resulting from studies of multislice computed tomography can pose considerable strain on storage systems(Dawson and Lees, 2001).

Advantages of multislice scanning:(Gleuker et al.,2001)

- Faster acquisition compared with spiral scanner.
- Better for uncooperative breathless, and trauma patients.
- Less movement artefact.
- A larger area can be covered during a single acquisition.
- Lifelike multiplanar reformats.
- Improved vascular and cardiac imaging.

Disadvantages of multislice:(Gleuker et al.,2001)

- Increased costs for replacement tubes and data storage.
- More time required to analyse data .
- Increased radiological workload .
- Potential for higher radiation dose.

Radiological Anatomy Of Temporal Bone:

The most commonly used CT display of the temporal bone is the axial projection. If one will make the effort to be thoroughly familiar with the anatomy as displayed in this projection, the vast majority of temporal bone problems can be completely evaluated. Multiple projections are possible by combining patient positioning with a tilting examining couch but these unusual views are rarely needed (Llyod,1979).

When viewing the skull from above with the bony calvarium removed, one notices an X.The upper limbs of the X are formed by the lateral walls of the orbit and the lower limbs of the X are formed by the posterior surface of the temporal bones. In the center of the X is the sella turcica(fig 1) (Goodhill ,1979).

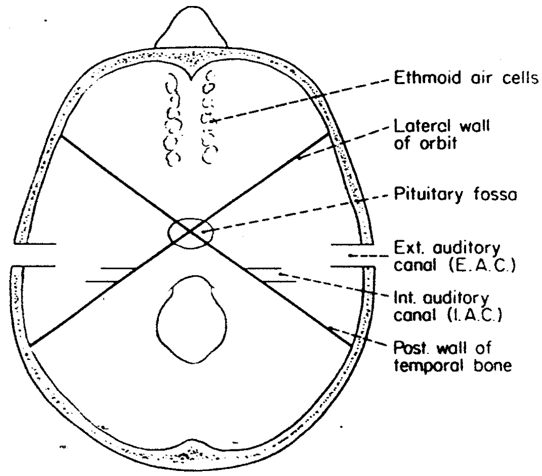

Figure 1: When viewing the base of the skull from above with the bony calvarium removed, an X is seen produced by the lateral walls of the orbit and posterior surfaces of the temporal bones. This X is very important for tensil strength of the base of the skull. All of the structures of the inner ear tend to align with the posterior surface of the temporal bone. The internal auditory canal and the external auditory canals would lie parallel to the plane of a piece of x-ray film placed behind the patient's head.(Quoted from Goodhill ,1979)

All of the structures of the inner ear orientate to the posterior wall of the temporal bone the lower limb of the X .The axis of the cochlea with its 2&3/4 turns is perpendicular to the posterior wall of the temporal bone. The three semicircular canals are so arranged that the superior semicircular canal is perpendicular to the posterior wall, the posterior semicircular canal is parallel to the posterior wall, and the horizontal semicircular canal lies in the plane of the base of the skull. If one were to place a sheet of x-ray film behind the patient's head, the internal auditory canal would have its long axis parallel to the film and the external auditory canal would be approximately parallel to the film (Bentson et al., 1980).

Continuing with this same concept, the middle ear structure and mastoid antrum all line up approximately on a 15° angle to the midsagittal plane. The combination of epitympanic recess, aditus ad antrum, and mastoid antrum also line up on this 15° angulation to the midsagittal plane (fig. 2) (Bentson et al., 1980)

Sound is transmitted from the external canal through the ossicular chain to the oval window and fluid spaces of the inner ear. The sequence of sound transmission is: tympanic membrane to long process of malleus (manubrium), head of malleus, body of incus, long process of incus, stapes superstructure, footplate and, finally, to the inner ear. The long process of the incus lies posterior to the manubrium of the malleus. In the axial projection, their course is almost parallel. The long process of the incus ends as the poorly visualized lenticuloform process which articulates with the head of the stapes. As the name implies the stapes is `stirrup shaped" with the two crura forming an arch to insert in the footplate of the stapes. The crura measure between 0.1 and 0.3 mm in diameter and are extremely delicate. The footplate of the stapes is a biconcave disk with a periphery of hyaline cartilage that sits in the oval window niche. Through the footplate, the sound is transmitted to the inner ear structures.(Donaldson et al.,1968).

In the hypotympanum, along the posterior and inferior wall, lie some structures that are rarely visible in conventional radiographic techniques. This is the region of the sinus tympani .It's base is hidden from view through the external auditory canal because of the overlying tendon of the stapedius muscle and the stapes superstructure. The boundaries of the sinus tympani are as follows: medially and anteriorly lie the basal turn of the cochlea, otic capsule and round window. Posteriorly, are air cells that separate the sinus tympani from the sigmoid plate of the temporal bone. Laterally, a volcano-shaped mound of bone, the pyramidal eminence, combines with the canal for the descending portion of the facial nerve to form a boundary. This prominence contains the stapedius muscle whose tendons pass directly anterior to insert into the neck of the stapes. At times, the bony separation between the facial nerve and stapedius muscle may be deficient. The inferior border of the sinus tympani is formed by a bony ridge (the subiculum) extending from, the superior lip of the round window laterally to the facial canal (Anson and Donaldson, 1973).

A 1-to 3-mm plate of bone forms the roof (tegmen)of the middle ear.Anterior, in the middle ear cavity, the eustachian tube takes it origin from approximately the midportion rather than from the lower hypotympanum. Air cells of the petrous apex are alleged to drain directly into the eustachian tube as well as into the mastoid antrum (Babin and Hanafee, 1967).

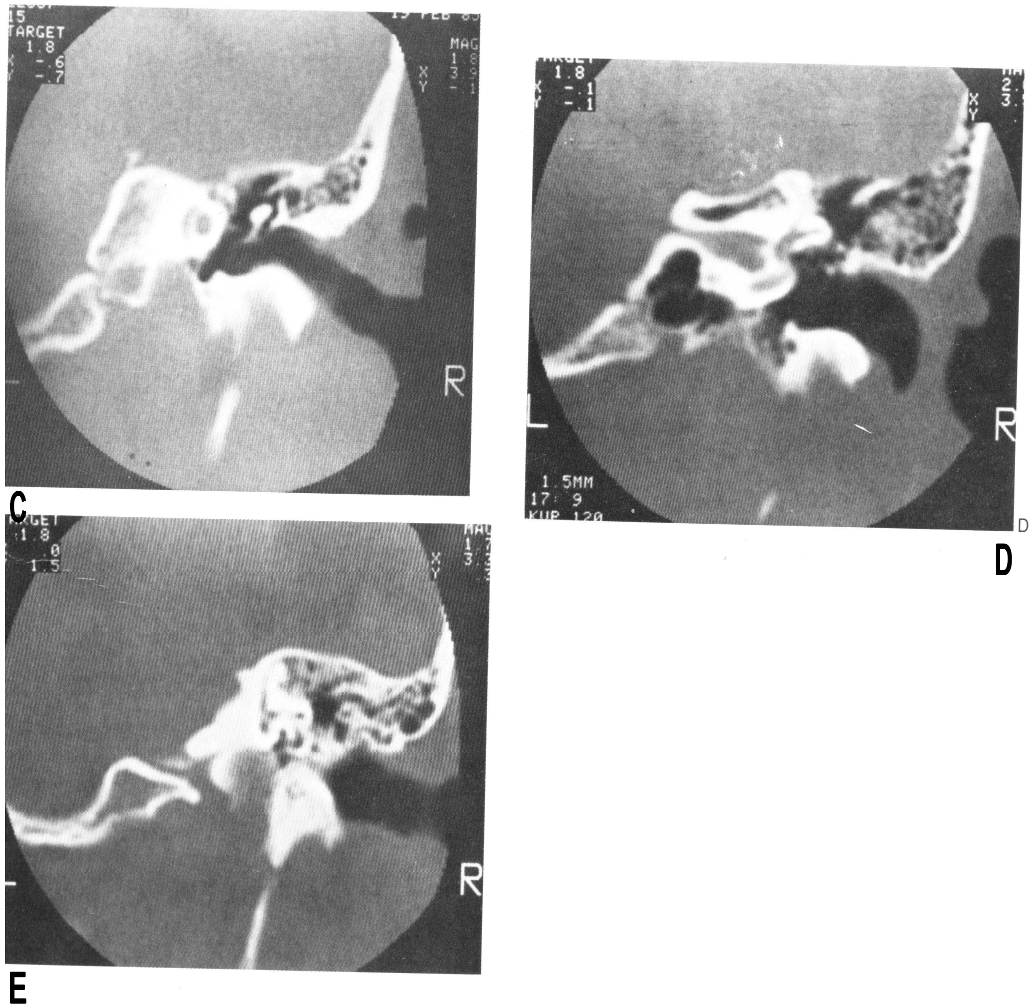

Figure 2: C-E: Representative images for middle ear CT display. C: Most anterior section usually required for middle ear study. D: Middle section. The patient is scanned approximately 4 mm on each side (anterior and posterior) of this section. v = vestibule. E: Most posterior section usually obtained. (Quoted from swartz and Harnsberger, 1998)