ORIGINAL ARTICLE

# The Cochlear-Carotid Interval: Preoperative Assessment for Cochlear Implant

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OBJECTIVE: To establish reference measurements in a sample of Egyptian population for the region between the basal turn of choclea and petrous internal carotid artery, which is termed the “cochlear-carotid interval” in order to investigate the range of safe normal variation before cochlear implant surgery.

PATIENTS AND METHODS: We examined 42 patients by high resolution CT of temporal bone. Two readers independently measured the bony interval between the cochlea and the petrous internal carotid artery canal.

RESULTS: Two patients were eliminated from study due to motion artifact. In total, we examined 40 patients. Cochlear-carotid interval on right side ranged from 1.0 to 3.4mm (Mean, 2.3 ± SD 0.6) and from 1.0 to 3.0 mm (Mean, 2.1 ± SD 0.5) on left side. Patients were grouped into five groups according to the measurement of their cochlear-carotid interval.

CONCLUSION: Cochlear-carotid interval varies widely between patients; it may be very thin or absent. Preoperative knowledge of patients’ group is important to determine the potential risk of carotid canal injury in cochlear implant surgery.

The petrous temporal bone contains a wide variety of neuronal, vascular, and labyrinthine structures in a relatively small area [1]. The carotid canal conveys a large artery and lies in close topographic relationship to the basal turn of cochlea. The bony wall between them consists in some cases only of the petrous bone of the otic capsule [2]. The close anatomic relationship between the cochlea and the carotid artery represents both a potential surgical hazard during cochlear implantation and a possible source of auditory and vestibular symptoms such as tinnitus and hearing loss [1].

The cochlear-carotid interval (CCI) generally extends from the basal turn of the cochlea to the genu of the vertical and horizontal portions of the petrous carotid artery canal [1].

Cochlear implantation is a common surgical procedure that is increasing rapidly in popularity [1] as it has revolutionized the options afforded to the deaf population [3]. The selection criteria have broadened to include patients with milder degrees of hearing loss as well as unilateral hearing loss [4]. Although the implantation is generally considered to be quite safe, a number of complications have been reported [5], including inadvertent penetration of the electrode array into the petrous carotid canal [3] in a patient with an intact CCI.

Gastman et al [3] investigated the possible cause of electrode wrongly penetrating into carotid canal during cochlear implant surgery, they stated that the carotid canal is a potential space that may give the tactile sensation similar to the cochlea and may mislead the surgeon. Even in experienced hands in which the surgeon thinks radiographs and brain stem testing are not routinely necessary, one must remember that there is the possibility of electrode placement into a hypotympanic air cell, the eustachian tube or the carotid canal. A relatively easy insertion may provide the surgeon with a false sense of confidence that the electrode was advanced in the basal turn of the cochlea [3].

The aim of our study was to establish reference measurements in a sample of Egyptian population for the minimal distance between the cochlea and carotid canal, which is termed cochlear-carotid interval (CCI) in order to investigate the range of safe normal variation before cochlear implant surgery.

## Patients and Methods

Forty-two patients coming for various otological problems referred from ENT Department at Ain-Shams University Hospital (ASUH) after full ENT examination underwent high resolution CT (HRCT) of temporal bone from September, 2006 to August, 2007.

The Study group consisted of 29 (69%) females and 13 (31%) males. Their age ranged from 17 to 60 years (Mean 35.5 ± 12.5 years)]. CT examination were acquired by using a spiral CT HiSpeed Advantage scanner (General Electric Corp., Milwaukee, WI, USA)

Transverse and coronal images were obtained. Scanning parameters were 120 kV, 180 mAs, 1-second rotation time, 1-mm section thickness, 1-mm collimation, 0.5 reconstruction increment, and 1-mm table feed per rotation, 512 x 512 matrixes, and 9-cm field of view. Transverse scans were acquired parallel to the hard palate and inferior to the orbit. Therefore, the cornea was not in the primary x-ray beam of the CT scanner. The coronal scans were acquired perpendicular to the transverse images. All images were displayed at a window center of 800 HU and a window width of 4000 HU.

We follow Young et al (1) method of using direct coronal images displayed in bone window, because they were orthogonal to the dimension to be measured and thus more reliably showed the cochlea and carotid canal on the same section. Digital images were transferred to General Electric (GE) Advantage work-station 4.0. Coronal images were independently reviewed by 2 readers and the bony thickness between the cochlea and the carotid canal were determined (in mm) using electronic calipers, with separate measurements for right and left side. 6 sides were eliminated due to associated inner ear pathology. Mixed model analysis of variance was used to evaluate differences between readers and sides with respect to the mean CCI.

## RESULTS

Forty-two patients underwent HRCT examination of temporal bone. Diagnostic studies were obtained in 40 patients, with two CT examinations excluded because of motion artifact. We examined 34 paired CT temporal bone and 6 unpaired (as 6 sides were eliminated due to contralateral inner ear pathology), total of 40 patients (74 sides).

Our patients were grouped into 5 groups according to the measurements of CCI.

As represented in (Figure 1) Group 3 compromises most of our patients 51.3 % (38 out of 74 sides examined) who had CCI measuring 2 to 2.5mm with split percentage being 52% on right side (20 out of 38 examined sides), and 50% on left side (18 out of 36 examined sides).

The least number of patients lie at both ends of the statistical curve (2.7%); being at group 1 and at group 5 (each group consists of 2 out of 74 sides examined).

CCI on right side (38 sides) ranged from 1.0 to 3.4 mm (Mean, 2.3 ± SD 0.6) and CCI on left side (36 sides) ranged from 1.0 to 3.0 mm (Mean, 2.1 ± SD 0.5).

The least CCI measurement in our study was 1mm (Figure 2). None had an absent CCI

The CCI measures did not exhibit a statistically significant ($P < 0.01$) association with subject age.

We examined 34 paired CT temporal bone, out of which 16 patients (47%) had the same CCI measurement on both sides (Figure 3), another 17 patients (50%) had a difference of 0.4 to 0.6mm between CCI measurements on both sides (Figure 4), only 1 patient (3%) who had difference between both sides more than 1mm (Figure 5). Table I.

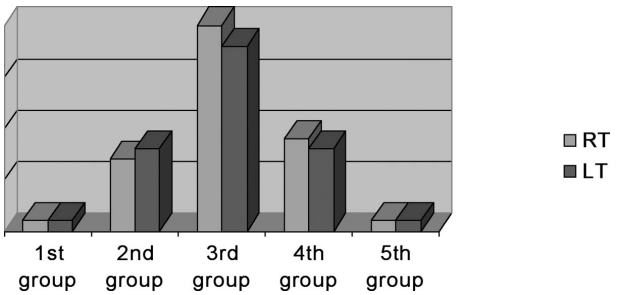


**Figure-1:** Bar graph representation of different groups in our study

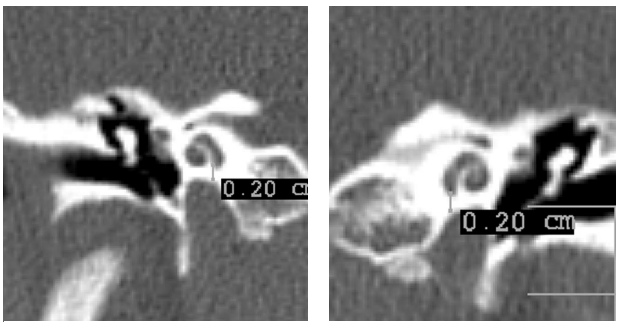


**Figure 3, a and b:** Coronal HRCT of temporal bone in a patient whose CCI measurement is the same on both sides (2mm).

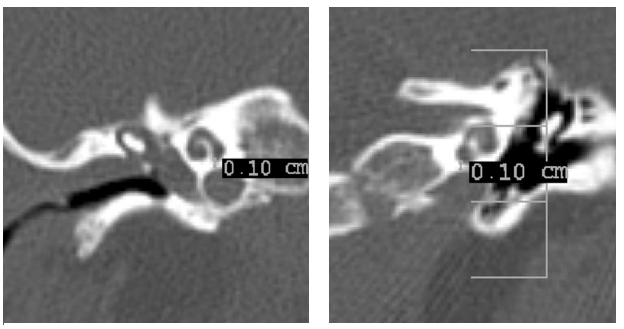


**Figure 2, a and b:** Coronal HRCT of the temporal bone. In this patient, the distance between the carotid canal and the basal turn of cochlea (CCI) is 1.0 mm on both sides

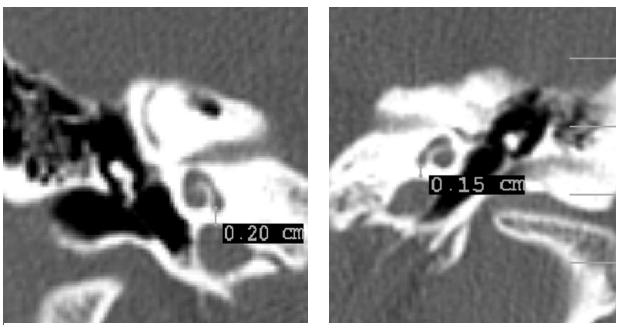


**Figure 4, a and** b: Coronal HRCT of temporal bone in a patient whose CCI measurement differ by 0.5mm between both sides [a] (RT =2.0mm), [b](LT =1.5mm)

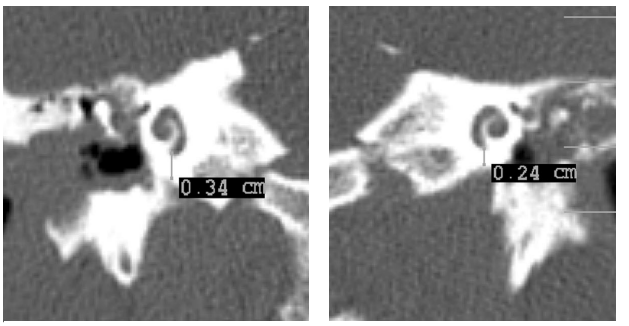


**Figure 5, a and b:** Coronal HRCT of temporal bone in a patient whose CCI measurement differ by 1mm between both sides [a] (RT =3.4mm), [b](LT =2.4mm)

**Table-1:** Details of CCI measurements in each group

| | CCI (in mm) | _ of (patients) | No of sides | RT side | LT side | % |
|---|---|---|---|---|---|---|
| Group 1 | <1.5 mm | 1 | 2 | 1 | 1 | 2.7 |
| Group 2 | 1.5 - 1.9 mm | 8 | 15 | 7 | 8 | 20.3 |
| Group 3 | 2 - 2.5 mm | 20 | 38 | 20 | 18 | 51.3 |
| Group 4 | 2.6 - 3 mm | 10 | 17 | 9 | 8 | 23 |
| Group 5 | > 3 mm | 1 | 2 | 1 | 1 | 2.7 |
| Total | | 40 | 74 | 38 | 36 | 100 |

* CCI: cochlear- carotid interval

## DISCUSSION

The internal carotid artery is divided into 4 parts: cervical, petrous, cavernous and cerebral. The petrous portion has its pathway involved in one single bone canal inside the temporal bone and it has two segments; One vertical, defining a correlation posteriorly, with the jugular fossa, anteriorly, with the auditory tube, and antero-laterally with the tympanic bone. In the anterior-inferior region, the chlocleoform process, extremely close to the cochlear turns, has a change in direction, starting its horizontal segment that is directed antero-medially. It is at this site, where the artery lies closest to the cochlea (6).

Cochlear implantation is a relatively routine surgical procedure with significant benefits to patients in terms of quality of life and communication enhancement with minimal risks. Although rare, the potential for major complications exists. The procedure is performed within millimeters of the brain, the end organs of balance, the facial nerve, and major vessels, including the jugular vein and the carotid artery (3).

Preoperative high-resolution temporal bone CT can demonstrate cochlear patency and detail middle and inner ear anatomy. In particular, attention is paid to the posterior tympanum and inner ear structures to establish normal anatomy and avoid surgical pitfalls (7).

The thickness of the bone between the otic capsule and carotid canal has been described to vary from 0.5 to 10 mm, with mean distances of 1.3 -1.5 mm (2, 8- 11).

In Young et al, (1) study, a series of 30 temporal bone CT scans were retrospectively reviewed for the CCI after having a patient with absent CCI. They found it to range from 0.2 to 3.8 mm (mean 1.2 ±SD 0.8) on right side and from 0.2 to 5.0 0n left side (mean 1.1 ± 0.9).

A systematic assessment of the relationship between the cochlea and the carotid canal was performed on plastic casts of 173 human temporal bone specimens in order to investigate the range of normal variation by Muren et al .(2) They found that the distance can be as thin as 0.2 mm. In other cases the distance can be more than 6 mm. (2)

Dew et al (10) did a study to measure the cochlear carotid distance and cochlear carotid angle in 33 temporal bones in order to provide a practical, consistent and safe method to maximize carotid artery exposure when exposing its horizontal petrous part in preparation for intrapetrous carotid artery bypass surgery while minimizing cochlear injury and correlated this distance to the width of a Sheehy weapon knife which can be easily measured intraoperatively. They found that the mean cochlear -carotid distance was (4.3 mm).

In our study slightly higher values were obtained than those given by Young et al (1): CCI on right side (38) ranged from 1.0 to 3.4 mm (mean, 2.3 ± (SD 0.6)) and CCI on left side (36) ranged from 1.0 to 3.0 mm (mean, 2.1 ± (SD 0.5).

According to our grouping of patients into 5 groups regarding CCI measurements; most of our patients 51.3 % had CCI of 2 to 2.5mm (group 3), The least number of patients lie at both ends of the statistical curve (2.7%); being at groups 1 and at group 5.

Though findings as such are quite reassuring that the large number of patients fall into safe CCI range of more than 2.0 mm, yet it also highlights the crucial importance of picking up and identifying those, relatively smaller group of potentially critical cases of very small or nearly absent CCI, during the preoperative diagnostic work-up of patients.

These small distances highlight the importance of grouping the patient according to their CCI as we did in our study, the smaller the CCI, the higher the potential for injury to the carotid artery and improper placement of the electrode in cochlear implant surgeries. As suggested by Chaturvedi et al (12), a realistic and practical imaging protocol should comprise of a preoperative HRCT temporal bone in all patients prior to cochlear surgeries in order to accurately pick those small yet important patients with small CCD to avoid inadvert complications.

Cochlear-carotid interval varies widely between patients; it may be very thin or absent. Preoperative knowledge of patients' group is important to determine the potential risk of carotid canal injury in cochlear implant surgery.

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