8. DISCUSSION

In cochlear implantation, the visualization of round window is important for surgeon in inserting the electrode into scala tympani of cochlea either by cochleostomy or round window membrane approach \(^{65}\). However the literature suggests that there are variations in position of round window which make it difficult for surgeon in visualizing it and may even lead to failure of surgery \(^{8,11,19,50,69,70,71}\). In our study cochleostomy was performed in all cases for inserting the electrode array into scala tympani of the cochlea.

In the present study, we assessed whether preoperative HRCT temporal bone measurements such as distance between tip of short process of incus and round window membrane, distance between oval window and round window membrane, anterior angle of basal turn of cochlea were helpful for in predicting the visualization of round window during surgery.

Pre operative HRCT scanning of temporal bone is useful in planning safe surgery in otology procedures \(^{67}\), in studying the cochlear orientation i.e. cochlear rotation \(^{59}\), morphology of human cochlea \(^{61}\) and in calculating the cochlear duct length \(^{72}\).

In our study, we provided road map for surgeon in identifying the round window using preoperative HRCT temporal bone measurements, thereby
reducing the complications of cochlear implantation and also surgical time required for performing cochlear implantation surgery.

**In our study**

**Age:** The age group ranged between 1-6 years (mean-3.6 years). Out of 68 cochlear implant candidates, 17 (25%) belonged to 1-2 years, 36 (53%) belonged to 3-4 years, 15 (22%) belonged to 5-6 years (Table 1).

**Gender:** Out of 68 cochlear implant candidates, 37 were males and 31 were females (Table 2).

**Distribution of cases in three types of visualization based on surgery:** Out of 68 cases, 24 cases belonged to Type 1 (Fully visible), 29 cases belonged to Type 2 (Partially visible) and 15 cases belonged to Type 3 (Difficult to visualize) (Table 3).

**Preoperative HRCT Measurements:**

1. **Distance between Short process of incus and Round window membrane:**

   The mean and standard deviation of distance between the tip of short process of incus and round window membrane for types 1, 2 and 3 was $7.4 \pm 0.2$ mm, $6.9 \pm 0.2$ mm, and $6.4 \pm 0.2$ mm respectively (Table 4).
The reason for measuring distance between the tip of short process and round window membrane was as tip of short process is posteriorly placed structure, if round window is posterior (closer to facial nerve); this distance would be helpful in predicting its location.

We observed that the cases with difficulty in visualization of round window showed reduced distance between the tip of short process of incus and round window membrane (Table 4).

The possible reason could be as the tip of short process of incus is posteriorly placed structure, if the round window is further posterior in position then the distance will get reduced which is illustrated in Figure 8.1 (A-B).

![Figure 8.1](image)

**Fig. 8.1** (A) Distance between the tip of short process of incus (SPI) and round window membrane (RWM); when round window is normal in position. (B) Distance between the tip of short process of incus and round window membrane is reduced; when round window is positioned posteriorly and closer to the facial nerve.
In our study, two cases showed round window which was placed anteriorly (Plate 6). In these cases the distance between the tip of short process of incus and round window was found to be increased.

The possible reason could be as the tip of short process of incus is posteriorly placed structure, if round window is placed anteriorly; then the distance will get increased which is illustrated in Figure 8.2 (A-B).

Fig. 8.2: (A) Distance between the tip of short process of incus (SPI) and round window membrane (RWM), when round window is normal in position. (B) Distance between the short process of incus and round window membrane is increased; when round window is positioned anteriorly.
2. Distance between Oval window and Round window membrane:

The mean and standard deviation of distance between oval window and round window membrane for types 1, 2 and 3 was 1.4 ± 0.2 mm, 1.9 ± 0.2 mm, and 2.5± 0.2 mm respectively (Table 5).

The reason for measuring the distance between oval window and round window membrane was as stapes covering the oval window is nearest structure to the round window; it would be very helpful for the surgeon in identifying the location of the round window.

An interesting finding in our study was that cases with difficulty in visualization of round window showed increased distance between oval window and round window membrane on preoperative HRCT scan (Table: 5) but the distance between them was found to be decreased on surgical measurement.

The possible reason could be as we obtained both the oval window and round window on single oblique coronal reformatted image; if round window is superior in position, the HRCT measurement will show increase in distance between oval window and round window membrane which is illustrated in Figure 8.3 (A-F). Due to this reason we found negative correlation between the measurement done on HRCT and surgery in difficult to visualize cases (type 3).
Fig. 8.3 (A) Schematic diagram showing distance between oval window and round window membrane, when round window is normal in position. (B) Pre-operative HRCT measurement, when round window is normal in position. (C) Schematic diagram showing round window is posterior and superior in position; and how the distance will be measured on HRCT scan, as both oval and round window were tried to obtain on single plane. (D) Pre-operative HRCT measurement showing increase in distance between oval window and round window membrane. (E) Schematic diagram showing the surgical measurement done during surgery which shows reduced distance. (F) Intra-operative measurement showing reduced distance between the head of stapes and round window membrane.
Hence, we suggest if there is increase in distance between oval window and round window membrane on Pre-operative HRCT scans, it should not be mistaken for round window to be placed inferiorly. In such cases we advise surgeon to look for the round window posterior and superior near the pyramid.

The HRCT measurement of distance between oval window and round window membrane done in our study got correlated with the measurement done on the human cadaveric temporal bones\(^{21, 62}\).

**Anterior angle of Basal turn of Cochlea:**

The mean and standard deviation of anterior angle of basal turn of cochlea for types 1, 2 and 3 was \(58\pm 4^0, 58 \pm 5^0\), and \(59 \pm 4^0\) mm respectively (Table 6).

The cochlea reaches the adult size by 22\(^{nd}\) weeks, and then the remodeling of the otic capsule will be stopped\(^{54}\). However, the literature states that there are changes in orientation of cochlea due to growth of cranium which is termed as cochlear rotation\(^{59}\). The ENT surgeons believe that the variations in the position of round window could be caused due to cochlear rotation on horizontal and vertical axis.

Lloyd et al.\(^{59}\) and Rodrigo Martinez-Monedero et al.\(^{61}\) studies stated that basal turn angle was more in cases where round window was difficult to visualize and also in pediatric age group compared to adults.
Hence, we measured the anterior angle of basal turn of cochlea to study changes in cochlear orientation. However, the findings of our study did not correlate with the above two studies. The possible reason could be due to difference in method of measuring the basal turn angle of cochlea used in our study. Moreover the method used in our study was not able to predict the visualization of round window during surgery.

**Correlation between measurement done on HRCT scan and Surgery:**

The distance between oval window and round window membrane showed positive correlation between HRCT scan and surgery for types 1 and 2 where as it showed negative correlation for type 3 (Table 7). The reason for negative correlation for type 3 has been explained above.

**Correlation between pre-operative HRCT measurements and surgical view:**

The visibility of round window was assessed after performing the optimum posterior tympanotomy.

Of the 68 Cochlear implant cases, 24 cases showed fully visible round window; of it 23 cases got correlated with HRCT measurements identified the cases as fully visible round window. One case (65th) which was predicted
difficulty in visualization of round window on HRCT was found to be fully visible during surgery.

29 cases showed partially visible round window all the cases got correlated with HRCT measurements identified the cases as partially visible.

15 cases showed difficult to visualize; 14 cases got correlated with the HRCT measurements which identified the cases as difficult to visualize round window. One Case (67th) which was predicted as fully visible round window on HRCT was found to be difficult to visualize during surgery.

Jiang D et al. 73 classified (St. Thomas Hospital) visibility of round window in to fully visible (Type I), > than 50% of RWM visible (Type II A), < than 50 % of RWM visible (Type II B) and Difficulty in visualization of RWM (Type III). They suggested appropriate cochlear insertion route depending on the exposure of RWM. They suggested membranous cochleostomy for Type I, membranous cochleostomy / Extended RW approach for Type II A, Extended RW approach/ Conventional Bony cochleostomy for Type II B, Conventional Bony Cochleostomy for Type III.

Annabelle C. Leong et al. 65 have prospectively evaluated St. Thomas Hospital and approach route stated by them for insertion of electrode. They also studied if RWM accessibility differs from adults to children. Their study found that St. Thomas Hospital classification was useful in providing the surgical
approach required in different types of visualization of round window membrane. They stated visibility of round window membrane is difficult in pediatrics patients when compared to adults this is evident from our study also.

Akinori kashio et al. (5) have developed a simple method using preoperative axial sections of HRCT scans for predicting the visibility of round window niche during surgery. They determined the influence of external auditory canal angle with respect to basal turn and facial nerve location in visualizing the round window niche through facial recess. However in inserting the electrode either through cochleostomy or round window membrane the visualization of round window was important for the surgeon. Their study evaluated the visibility of round window niche rather than round window membrane which was a major drawback besides the angular measurements would not be helpful for the surgeon in locating the round window in difficult cases.

**Surgical management in difficult cases:**

In the first five difficult cases (Case no.’s: 9, 13, 17, 19, 36) the surgeon was not able to identify round window despite performing optimal posterior tympanotomy.

In these cases, surgeon made a separate opening into the cochlea by drilling the promontory 2-3 mm below the oval window. After that, where ever
the surgeon found the lumen of the cochlea he inserted the electrode array and confirmed the placement by performing neural response telemetry intraoperatively and by post operative X-ray.

In the next ten cases, visualization of the round window was difficult and took longer intraoperative time for the surgeon in finding the round window. Out of ten, in eight cases the round window was found near facial nerve and closer to pyramid (i.e. round window is placed posteriorly and superiorly). Theodre R McRackan et al. 74 have stated that round window was aligned more closely with facial nerve in children compared to adults which is evident our study.

Gen Murakam et al. 50, M. Hamamoto et al. 71 have stated that the fracture of posterior wall of external auditory canal would be helpful in cases where round window is positioned posteriorly. This technique was useful in our two cases (39th, 64th) where round window was visualized deep inside the round window niche with a large overhang and closer to the pyramid; Hence posterior bony wall of external auditory meatus was fractured and displaced anteriorly to visualize the round window.
Correlation of preoperative HRCT measurements with respect to age:

In our study the preoperative HRCT measurements did not show any correlation with respect to age which is similar to the findings of study done by Dahm et al. They stated that middle ear and inner ear structures attained adult size at birth and did not show any increase in distances done between the anatomical landmarks relevant for cochlear implantation.

In our study the anterior angle of basal turn of cochlea did not show any correlation with respect to age; contradictory to the findings of the studies by Lloyd et al. and Rodrigo Martinez-Monedero et al. The possible reason for this could be difference in method of measuring the basal turn angle of cochlea used in our study.