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ORIGINAL ARTICLE

Comparison of Scalar Location and Insertion Depth of Cochlear Implant Electrode Implanted Through The Round Window Versus Cochleostomy Approach

Seddik Abdel Salam, Shawky Tayel, Ahmed Mehanna, Mohamed Eid, Walid Farouk

Department of Otorhinolaryngology, Head and Neck Surgery, Faculty of Medicine, Alexandria University, Egypt (SA, AM)
Department of Human Anatomy and Embryology, Faculty of Medicine, Alexandria University, Egypt (ST)
Department of Diagnostic Imaging, Faculty of Medicine, Alexandria University, Egypt (ME)
Department of Otorhinolaryngology, Head and Neck Surgery, Alexandria University Hospital, Egypt (WF)

Objective: Compare the insertion depth and scalar location of cochlear implant (CI) electrode implanted through round window membrane (RWM) versus cochleostomy approach, using multislice computed tomography (CT).

Materials and Methods: The study was conducted on twenty fresh human temporal bones. Ten were implanted through RWM approach and the other ten through cochleostomy using standard dummy CI electrode (MED-EL, Innsbruck, Austria). The CI electrodes were advanced till the point of first resistance then assessed using multislice CT.

Results: The study showed no significant differences in insertion depths whether angular or linear in the two study groups. However the RWM approach was associated with statistically significant higher incidence of scala tympani (ST) placement compared to scala vestibuli (SV) placement. Also ST placements were associated with statistically significant lower insertion depth compared to SV placement.

Conclusion: The present study suggests that, for hearing preservation cochlear implantation, advancing the CI electrode through the RWM till the point of first resistance is the recommend first choice whenever the anatomical orientation of the RWM allows.

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Introduction

Recent advances in cochlear implant technology have resulted in the relaxation of the selection criteria for their use.[1] As the benefits of implantation have been more widely demonstrated, there has been increasing emphasis not only on implanting individuals who are totally deaf, but also those with residual hearing at low frequencies.[2] Moreover, recent studies have shown that residual hearing can be preserved after cochlear implantation.[3] They suggested that the use of a hearing aid and a cochlear implant in the same ear can result in better hearing and speech perception than when using either device alone. This concept, known as electric-acoustic stimulation (EAS), was later successfully realized in practice.[4-7]

EAS is based on the concept that electric stimulation of the basal cochlear regions generates high-frequency percepts while the residual low-frequency regions of the cochlea are acoustically amplified by way of a conventional hearing aid.[8] The combination of electrical and acoustic information plays a critical role in speech recognition in the presence of noise for some cochlear implant (CI) users.[9]

The aim of surgery for EAS is to preserve residual low-frequency hearing after cochlear implantation which can be used for acoustic amplification, while a

Corresponding address:
Walid Farouk
E.N.T. Department, Alexandria University Hospital, ALEX. , EGYPT
Mobile: +201287008701
E-Mail: Dr.Walid_Farouk@Yahoo.com

CI provides electric stimulation to the auditory system in the high-frequency range to compensate for the hearing loss in the high frequencies.[10]

"Soft surgery" is a term used to describe surgical implantation of the electrode array that results in the least amount of disruption and damage to cochlear structures such as the basilar membrane, osseous spiral lamina, and the modiolar wall. Atraumatic insertions decrease sequelae secondary to fibrosis and ossification after placement of the array.[11]

In 2010 Adunka et al.[12] discussed the possible mechanisms for loss of residual hearing during CI surgery in their study about minimizing intracochlear trauma during cochlear implantation. They concluded that the etiology and mechanisms responsible for cochlear implant-related hearing loss remain mostly unknown.

Linear and angular insertion depths of the electrode array insertion have been suggested as variables that may correlate with hearing preservation and word recognition using a CI.[4, 13-14] According to general guidelines,

1) Advancing the array past the point of first resistance, which generally occurs between 17- 20 mm, may cause rupture of the basilar membrane, fracture of the osseous spiral lamina and/or ligament, and buckling of the array.[6, 15-16]

2) Insertion depth angles exceeding 400° resulted in poorer preservation of residual hearing.[9, 17]

Scala Tympani (ST) Placement has been proved to be a major factor for preservation of cochlear structures and residual hearing. The ST is bounded by both the basilar membrane and osseous spiral lamina so offering a natural protective mechanism during insertion. The scala vestibuli (SV) and the scala media (SM) are separated only by Reissner's membrane which is a fragile two-celled layered structure. The significance of this is appreciated when considering that even minor intracochlear trauma to the osseous spiral lamina during insertion has been correlated with increased thresholds and a decrease in response selectivity. Also the lumen of the ST has a slightly larger diameter than that of the SV for increased accommodation of the array.[18]

The aim of the present work was to compare the insertion depth (linear and angular) and the scalar location of cochlear implant electrode array implanted through round window membrane (RWM) versus cochleostomy approach, using high-resolution multislice computed tomography (CT).

Materials & Methods

The study was conducted on twenty fresh human temporal bones obtained from the Human Anatomy & Embryology Department. After approval from the Alexandria Faculty of Medicine Ethics Committee, The cochlear implantation was conducted in the temporal bone laboratory, Alexandria Faculty of Medicine by Dr A.M. using standard dummy electrode (MED-EL, Innsbruck, Austria).

I) The implantation was conducted through the following steps:

1. Twenty fresh human temporal bones were thawed and prepared for cochlear implantation using a standard transmastoid facial recess surgical technique.

2. The round window niche was identified and the lateral bony overhang of sinus tympani was removed anterior to the facial nerve and inferior to the pyramid to allow clear visualization of the round window niche.

3. The bony lip of the niche was drilled using a 1-mm diamond burr to fully expose the RWM. The mucosal fold or false membrane present is removed from the niche to expose the true membrane.

4. In ten specimens, the dummy electrode was inserted through a cochleostomy measuring approximately 1 mm created immediately antero-inferior to the RWM (Figure 1), while in the other ten the dummy electrode was inserted through the RWM through a vertical incision done in the inferior aspect of the membrane using a 21 needle (Figure 2).

5. In all specimens, the electrode insertion was stopped at the point of first resistance.

II) Radiologic assessment of the temporal bones:

The temporal bone specimens were evaluated using a high-resolution CT to assess:

1. The scalar location of the array.

2. Linear and angular insertion depths of the electrode array.

The CT was performed with a sensation 6 scanner (Siemens, Erlangen, Germany) with parameters of 104 mA, 130 kVp, matrix of 512 X 512 and section thickness of 0.63 mm. Scans were acquired in the axial plane with the cadaver head held in the supine position. All the images were transferred to a DICOM post-processing workstation using the OSIRIX software where the multiplanar reformats were done.

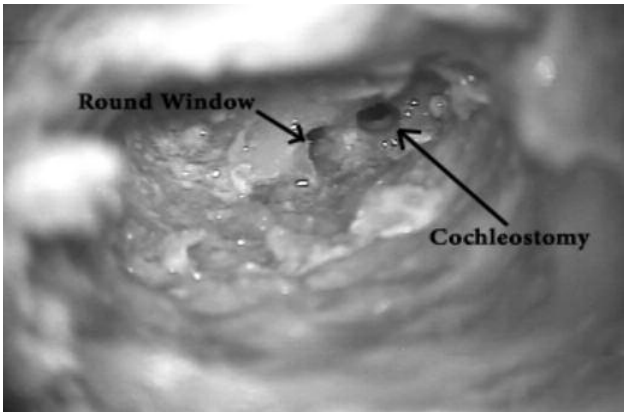

Figure 1. Photograph showing a cochleostomy made anteroinferior to the round window.

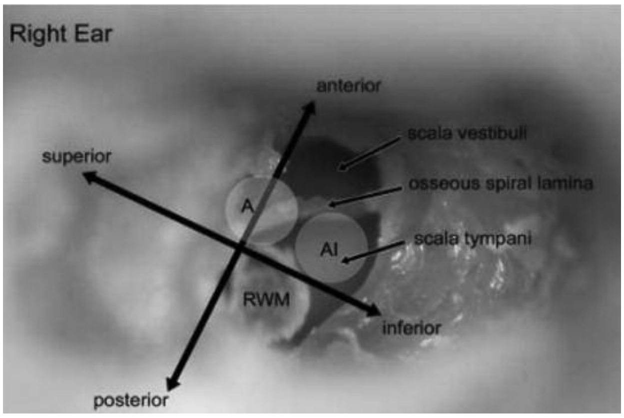

Figure 2. Photograph of right temporal bone with the basal cochlear turn drilled out. The RWM has been rotated inferiorly and outward for visualization but it normally lies beneath and in the plane of the anterior-posterior direction.[19]

1) The linear insertion depth was measured by unfolding the electrode array using curvilinear reformatting method followed by direct linear measurement on the reformatted image.

2) The angular insertion depth was directly measured on the oblique coronal reformat.

3) The scalar location of the electrode array, oblique axial and oblique sagittal (Pöschl) views were used to assess the position of the array in relation to the interscalar (spiral) lamina.[20]

III) Statistical analysis of the data:

Data were fed to the computer using the Predictive Analytics Software (PASW Statistics 18). Qualitative data were described using number and percent. Association between categorical variables was tested using Chi-square test. Quantitative data were described using median, minimum and maximum as well as mean and standard deviation.

Results

The study was conducted on twenty human temporal bones , ten of which were implanted through the RWM and the other ten were implanted through cochleostomy approach. The following radiological data were obtained as regards scalar location and insertion depth.

Comparing the two studied groups according to insertion depth and scalar location. (Table 1)

Table 1. Comparing the two studied groups according to insertion depth and scalar location.

Specimen	R.W.M Approach			Cochleostomy Approach		
	Linear Insertion Depth (mm.)	Angular Insertion Depth (degree)	Scalar Location Depth (mm.)	Linear Insertion Depth (degree)	Angular Insertion	Scalar Location
1	17	320^0	T	21	500^0	V
2	24	540^0	T	18	320^0	T
3	22	460^0	T	17	300^0	T
4	20	360^0	T	24	680^0	V
5	17	360^0	T	27	550^0	V
6	20	360^0	T	24	600^0	V
7	21	360^0	T	24	540^0	V
8	20	270^0	T	23	400^0	T
9	23	400^0	T	23	540^0	V
10	31	630^0	V	21	450^0	V

T: Scala Tympani Placenent

V: Scala Vestibuli Placement

A) Assessment of angular and linear insertion depths among both groups:

There was **no statistically significant difference** between the two study groups as regards **angular insertion** depth (p: 0.665)or **linear depths** (p: 0.148). (Table 2, Figure 3):

1. For the RWM group the linear insertion depths ranged from 17.0 – 31.0 mm (Mean ± SD, 21.50 ± 4.03 mm.) compared to linear insertion depth ranging from 17.0 – 27.0 mm (Mean ± SD, 22.20 ± 3.01mm.) in the cochleostomy approach group.

2. Angular insertion depths in degrees around the modiolus ranged from 270.0 – 630.0 degrees (Mean ± SD, 406.0° ± 108.24 degrees) in the RWM group compared to angular insertion depth ranging from 300.0 – 680.0 degrees (Mean ± SD, 488.0 ± 120.90 degrees) in the cochleostomy approach group.

B) Assessment of the scalar location among both groups:

Scala vestibuli placement was observed in one out of ten insertions in the RWM approach group compared to seven scala vestibuli insertions out of ten in the cochleostomy approach group. The study results showed a statistically significant difference between the two study groups as regards scalar location (p: 0.020, Table 3, Figure 4).

Figure 3. Oblique coronal reconstruction of two temporal bones: **A** (left) implanted through cochleostomy approach (specimen 9) showing angular insertion depth 540° (Left ear). **B** (Right) Specimen 3 implanted through RWM, Showing angular insertion depth 460° (Right. ear).

Table 2. Comparison between the two studied groups according to linear insertion and angular insertion depths:

	Cochleostomy	Round window	Sig.
Linear insertion depth (mm)			
Range	17.0 – 27.0	17.0 – 31.0	p = 0.665
Mean ± SD	22.20 ± 3.01	21.50 ± 4.03	
Median	23.0	20.50	
Angular insertion depth(mm)			
Range	300.0° – 680.0°	270.0° – 630.0°	MWp = 0.148
Mean ± SD	488.0° ± 120.90°	406.0° ± 108.24°	
Median	520.0°	360.0°	

P: p value for Student t-test
MWp: p value for Mann Whitney test

Table 3. Comparison between the two studied groups according to scalar location:

	Cochleostomy		Round window		FEp
	No	%	No	%	
Scalar location					
Tympani	3	30.0	9	90.0	0.020*
Vestibuli	7	70.0	1	10.0	

FEp: p value for Fisher Exact test
**: Statistically significant at p ≤0.05*

C) The relation between scalar location and angular insertion depth in each studied group:

In the cochleostomy approach group, ST insertions were associated with statistically significant lower angular insertion depths compared to SV insertions (p: 0.016). However in the RWM approach group, there was no significant difference (p: 0.106). This finding is most probably due to small sample size of the SV insertions in the RWM group which was only one insertion compared to nine ST insertions (Table 4).

Discussion

The value of scalar location and insertion depth of CI electrode as important factors for preservation of residual hearing during cochlear implantation and application of EAS can be summarized as follow: First: Linear and angular insertion depths of the electrode array insertion have been suggested as variables that may correlate with hearing preservation and word recognition using a CI.[21-23] Also, the risk of mechanical trauma increases with depth of insertion due to the anatomy of the cochlea and its limited ability to accommodate force as the radius of curvature increases and canal cross sectional area decreases when the apex is approached.[24]

Second: Skinner, et al.[25] concluded that "when electrodes are not in their intended position in the ST, their stimulation of surviving nerve fibers is associated with poorer word recognition than might have been possible if they had been in ST".

There are three studies in the current literature using temporal bones for hearing preservation cochlear implantation research. The first was done by Radeloff et al. [26] in 2008, who studied the variance of angular insertion depths in free-fitting and perimodiolar cochlear implant electrodes. The

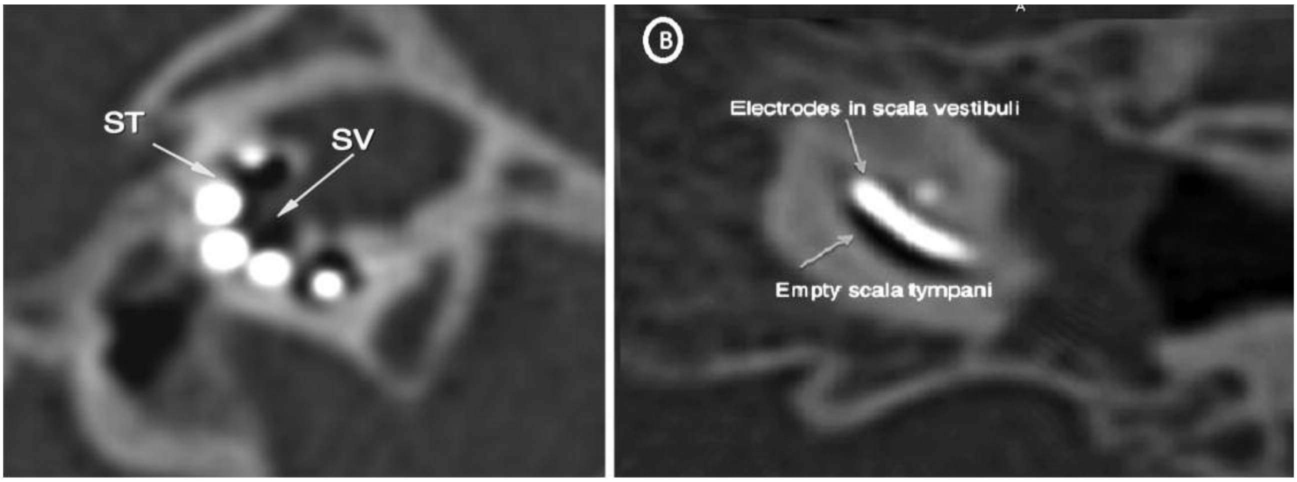

Figure 4. (Photograph A; Left side): Oblique sagittal reconstruction of temporal bone implanted through RWM approach showing CI electrode in ST. (Left ear). Photograph B: Oblique sagittal reconstruction of temporal bone implanted through cochleostomy approach showing CI electrode in SV (Left ear).

Table 4. Comparison between angular insertion depth and scalar location in each studied group.

		Tympani	Vestibuli	P
Cochleostomy	Angular insertion depth	(n = 3)	(n = 7)	
	Range	300.0 – 400.0°	450.0 – 680.0°	0.016*
	Mean ± SD	340.0 ± 52.92°	551.43 ±73.13°	
	Median	320.0°	540.0°	
Round window	Angular insertion depth	(n = 9)	(n = 1)	
	Range	270.0 – 540.0°	630.0 – 630.0°	0.106
	Mean ± SD	381.11 ± 78.81	630.0 ± -	
	Median	360.0°	630.0°	

P: p value for Mann Whitney test
**: Statistically significant at p ≤0.05*

Second study, was in 2006 by Briggs et al.[27] for comparison of RWM and cochleostomy approaches with a prototype hearing preservation electrode. The third study, by Adunka et al in 2004, which was a histologically controlled insertion for assessment of cochlear trauma from cochlear Implantation via the RWM.

In the present study twenty fresh human temporal bones were implanted. Ten of them via RWM and the other ten via cochleostomy measuring approximately 1 mm immediately anteroinferior to RWM, using standard dummy electrode from MED-EL (Innsbruck, Austria) with a total intracochlear length of 31 mm using a standard transmastoid facial recess approach. Electrode insertion in all specimens was stopped at the point of first resistance.

On the other hand, Radeloff et al.[26] used twenty-eight temporal bones that were implanted with the standard C40+ electrode carrier (MED-EL, Innsbruck, Austria) while other eighteen with the Contour Soft tip electrode (Cochlear Limited, Lane Cove, NSW, Australia) were implanted through a standard transmastoid facial recess approach through cochleostomies anterior or anterior-inferior to the RWM. Similar to the present study all insertions were stopped at the point of first resistance.

In their study in 2006, Briggs et al.[27] implanted eighteen human temporal bones using a standard transmastoid facial recess technique. Twelve temporal bones were implanted through the RWM, while the other six were implanted through a cochleostomy inferior to the RWM using a prototype 16-mm multi-channel array.

Adunka et al[28] implanted eight human temporal bones using 2 different cochlear implant (CI) arrays. the standard C40+ and the Flex EAS electrode by MED-EL (Innsbruck, Austria) with the total intracochlear length of 31.5 and 26.0 mm for the C40+ and Flex EAS carriers respectively. All insertions were done via the RWM through standard transmastoid facial recess approach. Similar to the present study all insertions were stopped at the point of first resistance to minimize cochlear trauma.

Radiological assessment of the temporal bones was done in the present study using multislice CT, compared to Radeloff et al.[26] who used fluoroscopy and Briggs et al.[27] and Adunka et al[28] who used high-resolution X-ray in their assessment.

In the present study, there was no significant difference in the angular or linear insertion depths between the two study groups, however scala tympani insertions showed statistically significant higher incidence in the RWM group compared to the other group.

As regards the insertion depth, the results of the present study coincide with that of Briggs et al.[27], in which they also concluded that there is no significant difference in angular insertion depth between RWM and cochleostomy approach. However the mean angular insertion depths in the present study where higher than those of Briggs et al.[27] with a mean of 406° in the present study compared to 240° in their study for RWM approach group and a mean insertion depth of 488° in the present study compared to 255°in their study for the cochleostomy group. This difference in angular insertion depth between the two studies is most probably due to variation in the cochleostomy site, the electrode design and the radiological assessment tools.

The results of the present study as regards the electrode insertion depth coincide with the that of Adunka et al.[28] with a mean angular insertion depth in the RWM approach group 406° in the present study compared to 393.88ºin their study. While the average linear insertion depth for the RWM group was 21.5 mm in the present study compared to 26.5 mm in that of Adunka et al.[28]

On other hand, the present study showed that ST insertions in the cochleostomy group were associated with statistically significant lower angular insertion depths compared to SV insertions. However, in the RWM group there was no significant difference. Most probably this is due to the small sample size, as SV insertion in RWM group was only one (with angular insertion depth 630.0º) compared to nine ST insertions (mean insertion depth 381.11º) in the same group. This finding coincides with the results of Radeloff et al.[26] where SV insertion has statistically significant higher angular insertion depths.

As regards the scalar location of the implant electrode, the results of the present study almost coincide with that of Adunka et al.[28] with nine ST insertions out of ten insertions in RWM group of the present study compared to ST insertion of all electrode arrays implanted via the RWM approach in Adunka et al.[28] study.

However, the data from the present study suggests that RWM approach is more ideal for hearing preservation cochlear implantation. The intraoperative decision of implantation through the RWM or cochleostomy may have an anatomical background as regards the orientation of the RWM relative to both the facial recess view and the longitudinal axis of the first segment of ST. This factor plays an important role for atraumatic electrode insertion into ST.[29]

In conclusion the present study shows that there is no significant difference in the angular or linear insertion depths between RWM and cochleostomy approach. On the contrary there was statistically significant higher incidence of ST placement in the RWM approach compared to the cochleostomy one. The study also demonstrated that ST placement is associated with statistically significant lower angular insertion depth compared to SV placement. So the present study suggests that -whenever the anatomical orientation of the RWM allows- advancing the CI electrode through the RWM till the point of first resistance is the recommend first choice for hearing preservation cochlear implantation.

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