

Spatial Orientation of the Cochlea and Relationship with Mastoid Pneumatization

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Abstract

OBJECTIVES: To describe the orientation of the basal turn of the cochlea in image-normal temporal bones, the distances of the round window and cochlear aperture from the incus and the superior semicircular canal, their bilateral symmetry and relationship with mastoid pneumatization.

STUDY DESIGN: Postmortem study of cadaveric crania.

METHODS: From 41 cranial specimens, direct axial CT images were obtained for the five crania with the largest and the five with the smallest mastoids. Landmarks were defined in xyz space: round window (RW), center of the island of the superior semicircular canal (SSCC), apex of posterior process of incus, the cochlear aperture (CA), and two cochlear basal turn points so that the plane of the cochlea could be described.

RESULTS: The median angle value (and range) between the cochlear and sagittal planes was 52° (47-61), right ear. The median distances between apex of incus and RW were 9.3 mm (8.2 to 10.4). The median distances between SSCC and RW were 8.9 mm (8.1-11.5); between SSCC and CA, 8.9 (8.4-10.1). Angle SSCC-CA-RW "watch stem position" ranged 17-18 degrees. Statistically significant bilateral symmetry was found for the relationships between plane of the cochlea and coronal plane, and distances SSCC to RW and SCC to CA. No association of any studied distance or planar relationship was found with mastoid pneumatization.

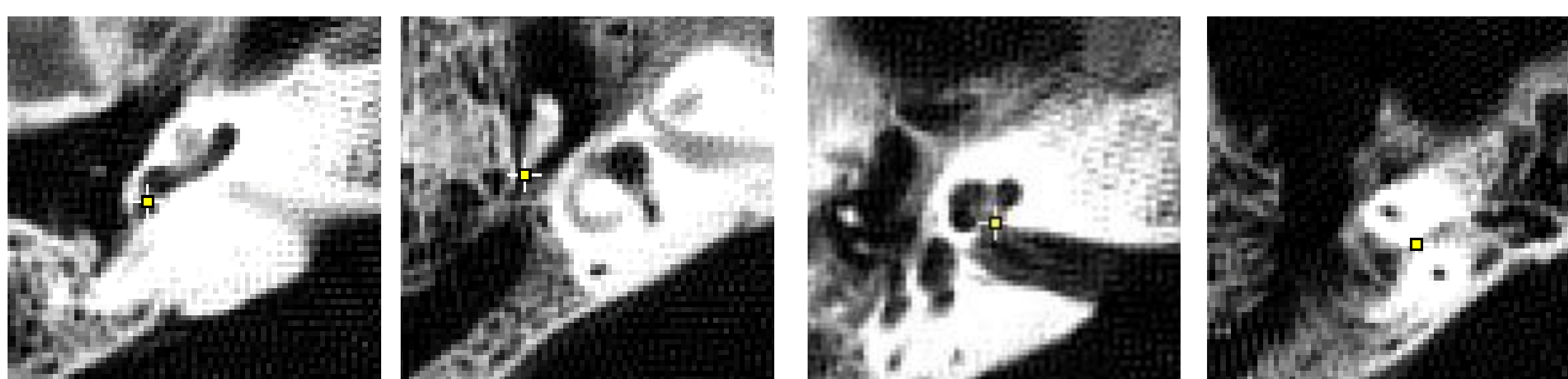
CONCLUSIONS: The variable orientation of the cochlea has no relationship with mastoid pneumatization. That bilateral symmetry was found of distances and angles, suggests that the ontogeny underlying the relationship may be of genetic origin.

Introduction

- An accurate insertion vector is crucial during cochlear implant surgery, in order to ensure placement of the electrode into the scala tympani and to avoid cochlear trauma¹
- "Mental representation of the basal turn [of] cochlea is a crucial step in cochlear implantation", and is experience-dependent²
- Several coordinate systems have been proposed, each utilizing different landmarks, to define the human cochlea in a standardized manner³
- The Cochlear View, described by Xu et al., utilizes a plane of rotation along the basal turn of the cochlea, perpendicular to the modiolar axis⁴
- Though "rotation" of the basal turn of the cochlea relative to sagittal plane, and "tilt" relative to horizontal plane have been described, the "watch stem set" of the round window has not been described

Methods and Materials

- The Emory University Institutional Review Board determined that IRB approval was not necessary
- From 41 clinically normal crania, the 5 with the largest and the 5 with the smallest areas of mastoid pneumatization underwent direct axial CT
- Each cranium was exactly oriented relative to the Frankfort horizontal plane
- Mastoid size determined by Law lateral radiographs correlates well with pneumatization volume determined by CT⁵
- Using the publically available software program FIJI, the following landmarks were identified in xzy space: round window (RW), center of the island of the superior semicircular canal (SSCC), apex of posterior process of incus, cochlear aperture (CA), and two cochlear basal turn points to describe the plane of the cochlea



Landmarks identified in xyz space using FIJI (from left to right): round window (RW), apex of posterior process of the incus, cochlear aperture (CA), superior semicircular canal (SSCC).

Results

Calculation	Repeatability, r_s , 95%CI	Min.	1st quart.	Median	3rd quart.	Max.
Angle between cochlear and sagittal planes, right	0.11, -0.55-0.69	47.1°	50.1°	52.0°	54.2°	61.1°
Angle between cochlear and sagittal planes, left	0.91, 0.67-0.98	44.3°	47.3°	49.9°	54.8°	57.1°
Apex of incus to RW, right	0.79, 0.32-0.94	8.2 mm	9.1 mm	9.3 mm	9.5 mm	10.4 mm
Apex of incus to RW, left	0.71, 0.14-0.92	8.4 mm	9.4 mm	9.5 mm	9.8 mm	10.7 mm
Superior SCC to RW, right	0.89, 0.59-0.97	8.0 mm	8.4 mm	8.8 mm	9.0 mm	11.4 mm
Superior SCC to RW, left	0.93, 0.75-0.98	7.7 mm	8.0 mm	8.6 mm	9.0 mm	12.1 mm
SSC and cochlear aperture, right	0.62, -0.008-0.90	8.4 mm	8.6 mm	8.9 mm	9.1 mm	10.1 mm
Superior SCC and cochlear aperture, left	0.64, 0.03-0.90	8.3 mm	8.3 mm	8.6 mm	9.3 mm	11.2 mm
"Watch stem set" angle of RW, with respect to horizontal plane, right	0.66, -0.17-0.94	27.7°	31.6°	39.6°	40.7°	44.0°
"Watch stem set" angle of RW, with respect to horizontal plane, left	0.81, 0.17-0.97	24.1°	35.5°	39.2°	41.2°	46.0°

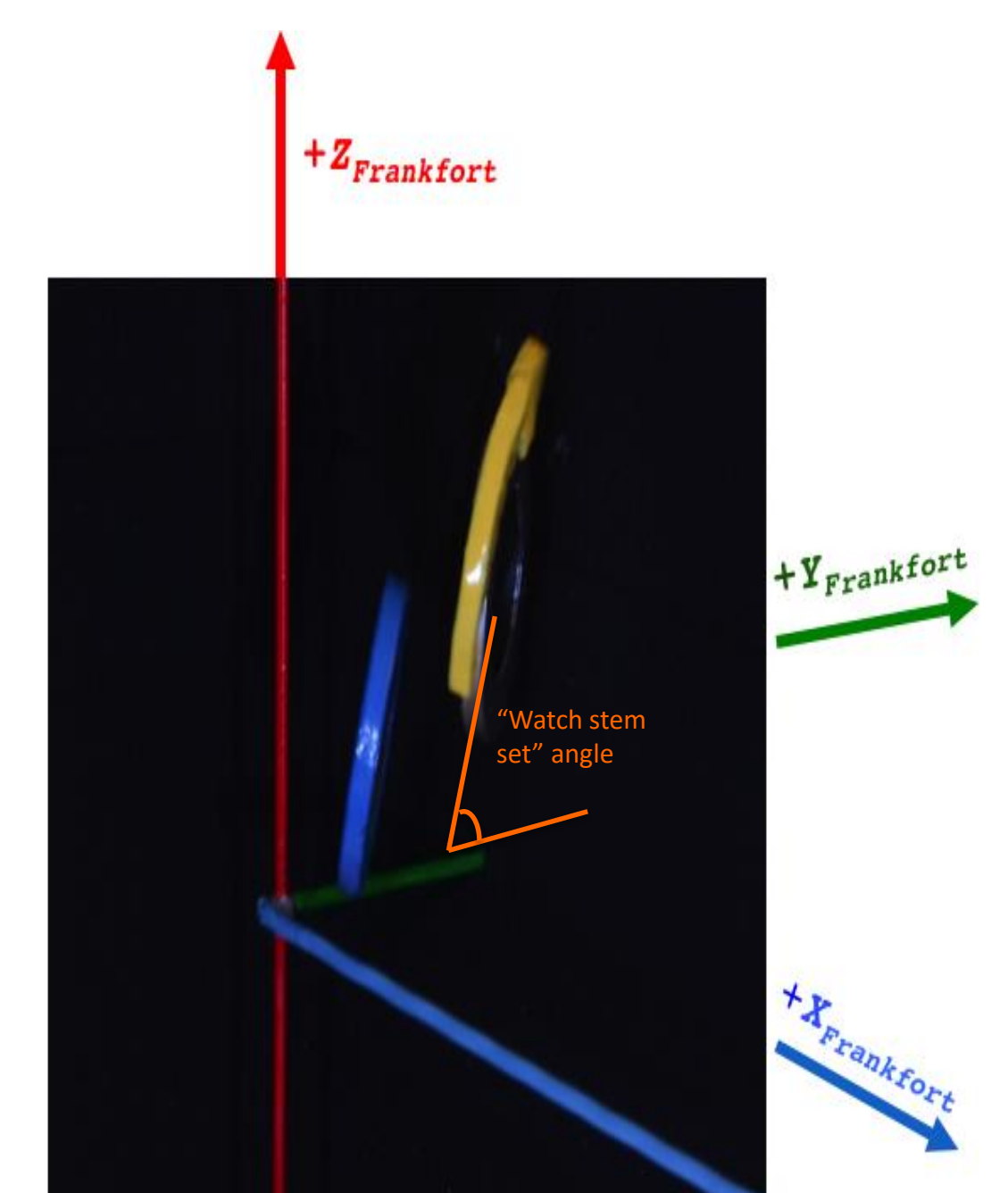
Repeatability and distribution of each determination. Each is the mean of 2 independent calculations.

Bilaterality of determinations.

Parameter	Correlation coefficient, 95% CI
Mastoid pneumatization	$r_s = 0.64$, N=10, 0.41 - 0.79
Plane of cochlea and coronal plane	$r_s = 0.63$, N=10, 0.01 - 0.90
Distance from RW to SSCC	$r_s = 0.85$, N=10, 0.48 - 0.96
Distance from SSCC to CA	$r_s = 0.95$, N=10, 0.83 - 0.98
"Watch stem set" angle	$r_s = 0.66$, N=10, -0.17 - 0.94



Depiction of the "watch stem set" angle, and ranges as calculated for right ear. Using mean data for right ear: the median is 39.6 degrees below the horizontal. At 30s degree from (below) horizontal, looking at a watch face, that would be 8:00, with each degree representing two minutes on the watch. The median is about 7:41 o'clock, with the range about 8:05 down to about 7:32.



Depiction of median orientations of studied structures in the right temporal bone, as viewed from posterior-lateral-superior. The plane of the basal turn of cochlea is depicted by silver band, the plane of the facial nerve's horizontal and vertical portions by the yellow arc, and plane of the posterior semicircular canal by dark blue band. The orange angle depicts the "watch stem set" angle.

Discussion

- For cochlear implantation, having a valid mental picture of the spatial orientation of the cochlea, especially of the basal turn's scala tympani, is challenging even in image-normal dissection-normal ears.

Conclusions

- In addition to the plane of the basal turn of the cochlea being variously positioned relative to "rotation" and "tilt", the "watch stem set" of the round window in these ear-normal adult crania is variously positioned – median 39.6° below the horizontal, range 27° to 44° for right ears
- The spatial orientation of the cochlea has no relationship with mastoid pneumatization
- Bilateral symmetry of multiple distances and angles describing cochlear spatial orientation, suggesting that the ontogeny underlying the relationships within the inner ear may be of genetic origin

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