The sensitivity and accuracy of a cone beam CT in detecting the chorda tympani

Running title: Chorda tympani on cone-beam CT

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Abstract

Background: The facial recess approach through posterior tympanotomy is the standard approach in cochlear implantation surgery. The size of the facial recess is highly variable, depending on the course of the chorda tympani. Despite their clinical importance, little is known about the sensitivity and accuracy of imaging studies in the detection of the chorda tympani. ***Material and Methods:*** A total of 13 human temporal bones were included in this study. All of the temporal bones were submitted to a cone beam CT (Accuitomo, Morita, Japan). The multi-planar reconstruction images were rotated around the mastoid portion of the facial nerve to locate the branches of the facial nerve. A branch was diagnosed as the chorda tympani when it entered the tympanic cavity near the notch of Rivinus. The distance between the bifurcation and the tip of the short crus of the incus was measured. ***Results:*** In all temporal bones, the canal of the chorda tympani or the posterior canaliculus was detected. In the CT-based evaluation, the average distance from the bifurcation to the incus short crus was 12.7 mm (8.3 – 15.8 mm). The actual distance after dissection was 12.6 mm (8.2 – 16.4 mm). The largest difference between the distances evaluated with the two procedures was 1.1 mm. ***Conclusions:*** Cone beam CT is very useful in detecting the course of the chorda tympani within the temporal bone. The measured distance is accurate.

Key Words: chorda tympani, computed tomography, posterior canaliculus, facial nerve, cochlear implant, posterior tympanotomy

Introduction

The facial recess approach is the standard approach to cochlear implantation surgery. In this approach, a window is made in a space surrounded by the chorda tympani, the mastoid portion of the facial nerve, and the fossa incudis. This procedure is called a posterior tympanotomy. The size of the window created by posterior tympanotomy depends on the course of the chorda tympani. The chorda tympani branches from the mastoid portion of the facial nerve, courses along the facial nerve, enters a bony canal called the posterior canaliculus, and exits the temporal bone to enter the tympanic cavity. As opposed to the small amount of anatomical variation in the tympanic segment of the chorda tympani [1], the origin of the posterior canaliculus from the fallopian canal is highly variable. This bifurcation can be found outside of the temporal bone or 10.9 mm proximal to the stylomastoid foramen [1]. The length of the posterior canaliculus ranges from 3 mm to 14 mm [1]. The diversity of the course of the posterior canaliculus leads to the high variability of the size of the window created by posterior tympanotomy.

Recently, the round window approach has been becoming more and more popular in cochlear implantation with hearing preservation. Wide posterior tympanotomy is necessary during the round window approach in order to control the round window membrane. If the posterior canaliculus branches from the fallopian canal proximally, only a small posterior tympanotomy is possible, and controlling the round window membrane will be difficult. In cases with a distally bifurcated posterior canaliculus, a large posterior tympanotomy can be performed, and the round window approach will be easy. Despite its clinical importance and high level of anatomical variation, only a limited number of attempts to evaluate the course of the posterior canaliculus preoperatively have been reported [2-4]. In addition, these reports studied on high resolution CT scan in early days. In this study, we explored the sensitivity and accuracy of a cone beam CT multi-planar reconstruction technique in detecting the course of the posterior canaliculus by using human temporal bones.

Material and Methods

A total of 13 human temporal bones with no middle or inner ear diseases were obtained from 13 individuals (aged from 52-97 years at death, 7 male and 6 female, 7 right ears and 6 left ears). All temporal bones were subjected to a cone beam CT (Accuitomo, Morita, Japan) with a standard condition (FOV 60 mm, 90 kV, 7.0 mA, voxel size 0.125 mm). The reconstructed images are viewed with 0.5 mm slice thickness and 0.5 mm slice intervals for reduction of the noise. The acquired image was three-dimensionally reconstructed using a One-Volume Viewer (Morita, Japan). In order to detect the posterior canaliculus, the following technique was applied. First, one slice was selected to include the whole course of the mastoid portion of the facial nerve (Fig. 1-A). Next, the multi-planar reconstruction image was rotated around the mastoid portion of the facial nerve (Fig. 1-B). Using this technique, the branches of the facial nerves were easily detected. A branch was judged as the posterior canaliculus when it branched off the facial nerve, coursed anterolateral to the facial nerve, and entered the tympanic cavity near the notch of Rivinus (Fig. 1-C). After the detection of the posterior canaliculus, the images were rotated again until a slice included the bifurcation of the posterior canaliculus and the tip of the short crus of the incus; at this point, the distance between the two structures was measured. The temporal bone was dissected afterwards, and the actual distance between the bifurcation and the tip of the short crus of the incus was measured using an image-processing program (ImageJ: National Institutes of Health, Bethesda, MD, USA).

Results

In all 13 of the temporal bones, the posterior canaliculus was detected through the above-described technique. In all specimens, the posterior canaliculus branched from the fallopian canal within the temporal bone. In most temporal bones, the chorda tympani coursed parallel to the facial nerve within the fallopian canal near the bifurcation and branched off from the fallopian canal at an acute angle (Fig. 2). In some bones, the angle between the fallopian canal and the posterior canaliculus was comparatively dull (Fig. 3). In every bone, the course of the posterior canaliculus was clearly illustrated on multi-planar reconstructed CT images.

The average actual distance from the bifurcation to the short crus of the incus was 12.4 mm (8.2 – 16.4 mm). In the CT-based evaluation, the average distance was 12.6 mm (8.3 – 15.7 mm). The difference of the distances evaluated with the two procedures ranged from -0.8 to 1.1 mm (average, -0.2 mm). These results are shown in Fig. 4.

Discussion

Since the introduction of the high resolution CT, various attempts have been made to illustrate the structures embedded in the temporal bones [2]. The chorda tympani has been reported to be detectable with high resolution CT [3], but the sensitivity and accuracy have scarcely been reported. Parlier-Cuau et al. reported the sensitivity of various small structures, including the posterior canaliculus, using high resolution computed tomography [4]. The axial images were most sensitive for these detections, but the detection rate of the posterior canaliculus was as low as 71%. This low detectability can be attributed to two reasons. The first is the comparatively low resolution of a conventional CT, and the other, the limited angle of the slices.

In the study of Parlier-Cuau et al, all cases were investigated with a clinical setting (130 kV, 300 mA, spatial filter C, sections 1.2 mm thick at intervals of one mm). This spatial resolution is not high enough to visualize the posterior canaliculus whose diameter is at most 1 mm [5]. A micro-CT allows the spatial resolution of 0.9 μm to be reached and has been reported to yield an excellent definition of the posterior canaliculus [5]. However, the micro-CT is not appropriate for clinical use because of its size and high radiation dose. Recent advancement of the CT scan permits visualization of temporal bone anatomy with higher resolution. The cone beam CT has been widely used in the field of clinical otology. The cone beam CT has higher resolution than the conventional CT, a spatial resolution up to 0.08 mm, and utility in the preoperative and intraoperative evaluation of the temporal bone structures [6, 7]. This high spatial resolution seems to have contributed to the high detectability of the posterior canaliculus in our study.

The other reason for the low detection rate in the previous report is the fact that Parlier-Cuau et al. used a sequential scanner and obtained axial and coronal sections. The axial, coronal, or sagittal section often show a cut section of the posterior canaliculus, and other structures, including vessels, fissures, and air cells, can sometimes mimic it. In addition to these standard sections, Parlier-Cuau et al. reconstructed an oblique-sagittal view for the posterior canaliculus [4]; however, the detectability of the posterior canaliculus with this slice was not shown. A recent temporal bone study using micro-CT revealed that the course of the posterior canaliculus can be divided into two groups, according to the angle between the mastoid portion of the facial nerve and the posterior canaliculus. In the first, the canal originates from the lateral side of the mastoid portion of the facial nerve and courses anteriorly. In the second group, the canal originates from the posterolateral side of the mastoid portion of the facial nerve and forms a posteriorly convex curve soon after it branches [8]. This study suggests that the ideal slice to study the entire course of the posterior canaliculus is not uniform. Jeon et al. measured the size of posterior tympanotomy by creating 3D reconstructed images [9]. The 3D images illustrate the whole course of the chorda tympani, but manual reconstruction of 3D images requires considerable time and enough knowledge of the temporal bone anatomy. Automatic programs have been reported to be useful in the identification of posterior canaliculus [10]. In these programs, tubular structures are detected and their directions are calculated. The posterior canaliculus is segmented according to previously prepared models [11, 10]. These programs showed high correspondence with manual identification of the posterior canaliculus by experts, but such programs are not popular and have found little clinical usage.

In the present study, we used the multi-planar reconstruction images. By rotating the images around the mastoid portion of the facial nerve, the posterior canaliculus was easily detected and followed until it exits the temporal bone at the iter chordae. In the images acquired with a cone-beam CT, multi-planar reconstruction images show minimal distortions, contributing to the accuracy of our present study. This technique for detecting the posterior canaliculus is also applicable to the images obtained with a multi-detector helical CT, which is more popular than the cone-beam CT. The detectability of the posterior canaliculus and its accuracy should be explored in multi-detector helical CTs.

Our present study showed that the posterior canaliculus was precisely detected in all 13 temporal bones by using a cone beam CT. In the live patients, however, this high sensitivity and accuracy is not guaranteed. We used temporal bones which have smaller volume than the actual heads. The cone beam CT is susceptible for the beam hardening artifact, and this artifact gets large according to the X-ray pass length. This artifact is well corrected in recent cone beam CT, but the acquired image can be heterogeneous when the field of view is set peripherally [12]. This image uniformity may affect the detection rate of posterior canaliculus in live patients. However, the cone beam CT shows better results than the multi slice CT in detecting small structures [13]. This suggests that we can expect good detectability of the posterior canaliculus in live patients, though it should be explored actually.

Conclusion

The cone beam CT with the multi-planar reconstruction image is very useful in detecting the course of the chorda tympani within the temporal bone. The measured distance is accurate. The detectability and its accuracy should be explored in live patients to show the clinical usefulness.

Figure Legends

Figure 1

The technique used to detect the posterior canaliculus (left ear, upright position). One slice was selected to include the whole course of the mastoid portion of the facial nerve (Figure 1-A). The image was rotated around an axis set along the mastoid portion of the facial nerve at the stylomastoid foramen (Figure 1-B). The posterior canaliculus was detected around the slice, including the tip of the short crus of the incus (Figure 1-C).

Figure 2

Right ear, supine position. The chorda tympani branched off from the fallopian canal at an acute angle. The posterior canaliculus on the CT showed a similar course.

Figure 3

Left ear, supine position. The angle between the fallopian canal and the posterior canaliculus was comparatively dull. This course was illustrated on CT.

Figure 4

The distance between the bifurcation of the posterior canaliculus and the tip of the short crus of the incus was measured after the dissection and by cone-beam CT. The distances measured by the two procedures were almost identical.

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Conflict of interest

We do not have any financial relationships with the organizations that sponsored this research.

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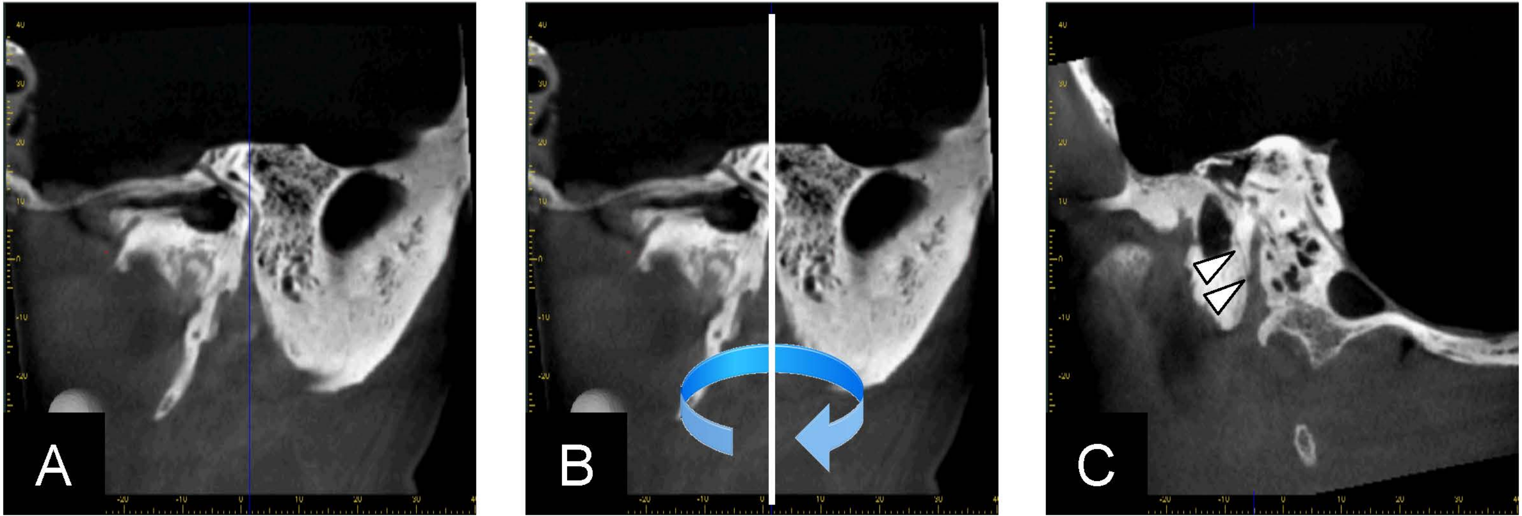
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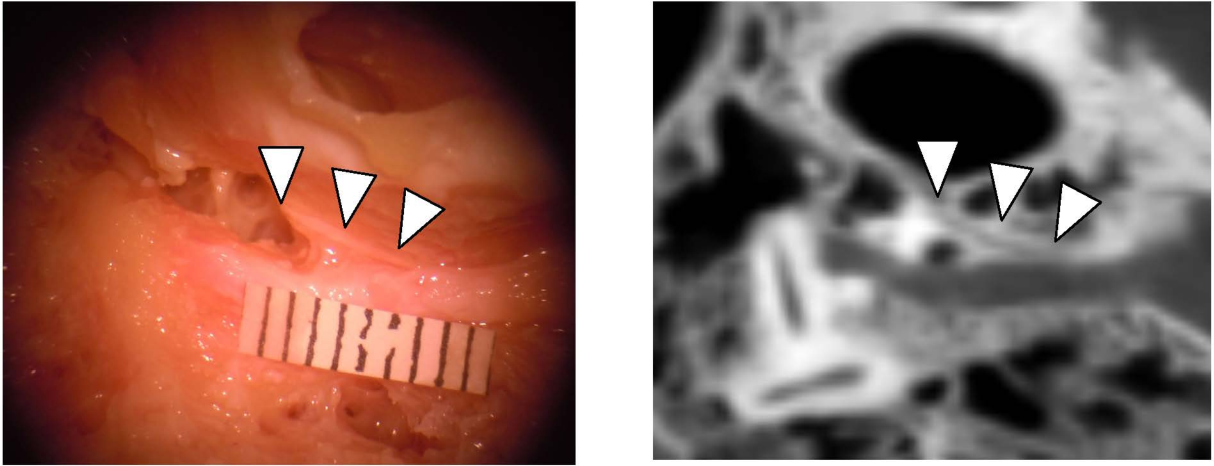

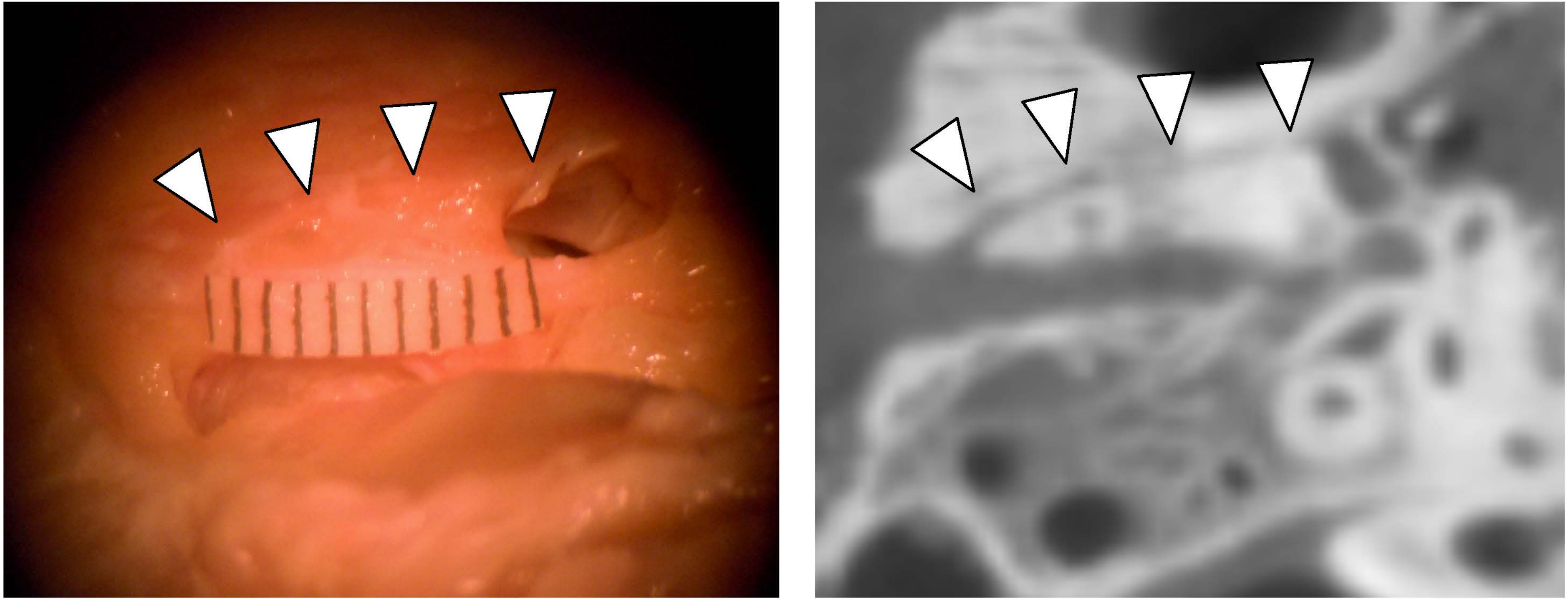

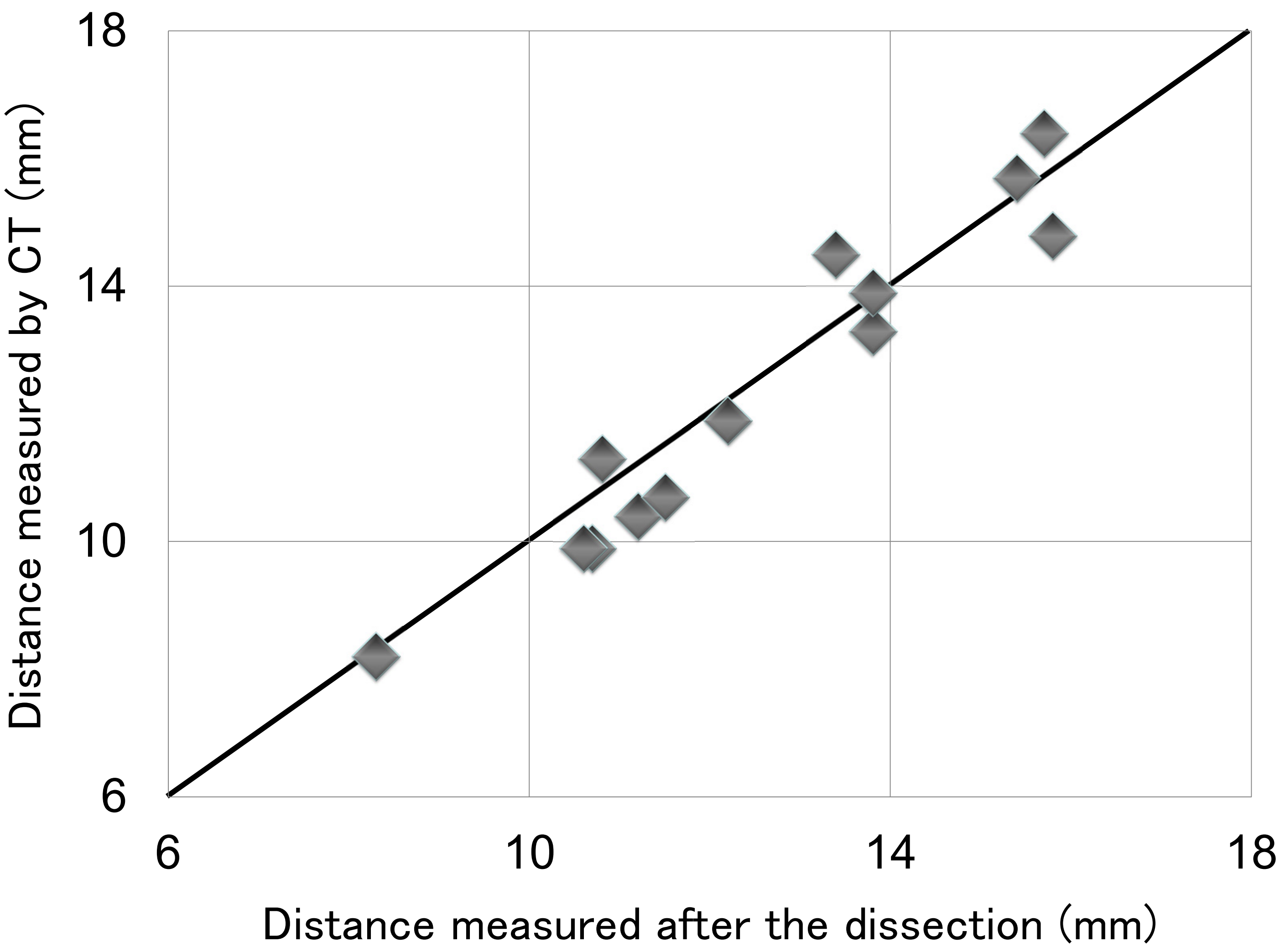
18
14
10
6
Distance measured by CT (mm)
6
10
14
18
Distance measured after the dissection (mm)