<table>
<thead>
<tr>
<th>Title</th>
<th>The Usefulness of Reconstructed 3D Images in Surgical Planning for Cochlear Implantation in a Malformed Ear with an Abnormal Course of the Facial Nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author(s)</td>
<td>Hara, Minoru; Takahashi, Haruo; Kanda, Yukihiko</td>
</tr>
<tr>
<td>Citation</td>
<td>Clinical and Experimental Otorhinolaryngology, 5(S1), pp.S48-S52; 2012</td>
</tr>
<tr>
<td>Issue Date</td>
<td>2012-04-30</td>
</tr>
<tr>
<td>URL</td>
<td><a href="http://hdl.handle.net/10069/29404">http://hdl.handle.net/10069/29404</a></td>
</tr>
</tbody>
</table>

© 2012 by Korean Society of Otorhinolaryngology-Head and Neck Surgery.; This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (http://creativecommons.org/licenses/by-nc/3.0) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.
The Usefulness of Reconstructed 3D Images in Surgical Planning for Cochlear Implantation in a Malformed Ear with an Abnormal Course of the Facial Nerve

Minoru Hara, MD1 · Haruo Takahashi, MD1 · Yukihiro Kanda, MD2

1Department of Otorhinolaryngology Head and Neck Surgery, Nagasaki University Hospital, Nagasaki; 2Kanda ENT Clinic, Nagasaki Bell Hearing Center, Nagasaki, Japan

INTRODUCTION

A number of cochlear implantation (CI) candidates have ear malformations, in particular an abnormal course of the facial nerve (FN). The course of the FN is very important for CI surgery; the more abnormal the course of the FN, the more difficult it is to perform CI surgery. However, it is extremely difficult for surgeons to understand the three-dimensional (3D) course of the FN prior to surgery through the use of two-dimensional (2D) computed tomography (CT) images.

In this study, we attempted to reconstruct a 3D image of temporal bone structures using CT imaging and examined its usefulness in the surgical planning of CI in a malformed ear.

Objectives. It is not unusual for a cochlear implantation (CI) candidate to have some type of ear malformation, in particular an abnormal course of the facial nerve (FN). In this study, we attempted to reconstruct a 3D image of temporal bone structures using CT imaging and examine its usefulness in the surgical planning of CI in a malformed ear.

Methods. We prepared 3D images for 6 separate CI cases before surgery. First, we manually colored preoperative CT images using Photoshop CS Extended. We then converted the colored CT images to 3D images using Delta Viewer, free software for Macintosh. Before surgery, we discussed any problems anticipated based on the 3D images and plans for surgery with those who would be performing the CI.

Results. Case 1: The subject was a 3-year-old boy with malformed ossicles, semicircular canal (SC) hypoplasia, internal auditory canal stenosis, and an abnormal course of the FN. 3D image indicated that the stapes were absent, and the FN was more anteriorly displaced, so that it was difficult to perform cochleostomy. The surgical findings were similar to those depicted on the 3D image, so we could insert an electrode based on the preoperative image simulation without complications. Case 2: The subject was a 7-year-old boy with malformed stapes, atresia of the round window, cochlear and SC aplasia, and an abnormal course of the FN with bifurcation. CI was performed with no problems, in the same manner as in Case 1.

Conclusion. We were able to successfully depict the structures of the inner ear, ossicles, and FN as 3D images, which are very easy to understand visually and intuitively. These 3D images of the malformed ear are useful in preoperative image simulation and in surgical planning for those performing a CI procedure.

Key Words. Three-dimensional image, Temporal bone, Facial nerve anomaly, Cochlear implantation
MATERIALS AND METHODS

From 2010 to 2011, we prepared 3D images for 6 separate CI cases prior to surgery. These cases consisted of 5 patients (3 boys, 2 girls, ages 1-7 years), including one bilateral case. All of the patients had congenital malformations in the temporal bone structures, such as in the FN, cochlea, semicircular canal (SC), or stapes. We created 3D images using a method we developed that utilized a public personal computer.

First, we manually colored preoperative CT images, which were axial sections of the temporal bone scanned by a normal CT scanner (SOMATOM Definition; Siemens Medical, München, Germany) at a slice thickness of 0.5 mm using Photoshop CS extended. The extended version can import and edit DICOM files directly. The inner ear labyrinth, auditory ossicles, and FN were shaded in blue, red, and yellow, respectively, maintaining the shape of these structures. We had to paint every axial section of temporal bone CT images; there were about 30-40 slices. It took about two hours to accomplish the coloring process.

We then converted the colored 2D-CT images to 3D images using Delta Viewer (DV), a freeware for Macintosh available on the Internet (http://delta.math.sci.osaka-u.ac.jp/DeltaViewer/index.html). This 3D reconstruction can be done from CT images of any condition, such as the thickness of the slice of images, but the thinner the CT slices are, the more detailed and smoother the 3D images will be. This DV-3D rendering process was completed automatically within a few minutes. In this paper, we refer to the 3D images created using DV as DV-3D images.

Fig. 1 is a DV-3D image of the normal temporal bone structures. We can rotate DV-3D images freely using the DV application.

Before each CI procedure, we discussed any problems anticipated based on the DV-3D images and planned the surgery with those who would be performing the procedure. We also brought either the printed images or the notebook PC to the operating room and compared the images with the surgical findings during the CI procedure (Fig. 2).

RESULTS

Case 1. Left ear of a three-year-old boy

The patient presented with bilaterally malformed ossicles, SC hypoplasia, internal auditory canal stenosis, and an abnormal course of the FN. We had already performed CI surgery on the
patient’s right ear one year before. The outcome of his speech was not as good as that of a patient with a non-malformed ear. We then planned a second CI procedure on the patient’s left ear. We expected that it was going to be difficult to perform cochlear fenestration because of the facial nerve abnormality, so we prepared DV-3D images of this case before the CI surgery.

The DV-3D images (Fig. 3) indicate that the cochlear turn is intact, the lateral SC is hypoplastic, the long crus of the incus (I) and stapes (S) are absent, the labyrinthine segment of the facial nerve (FN) is more posteriorly displaced, and the tympanic and mastoid segments of the FN are antero-inferiorly displaced, running more vertically than normal control. The cochlea (Co), malleus (M), anterior semicircular canal (ASC), and posterior semicircular canal (PSC) are intact. (B) Lateral view of normal control. The green arrowhead shows the course of the FNs.

Fig. 3. (A) Lateral view of the temporal bone structures of case 1. The lateral semicircular canal (LSC) is hypoplastic, and the crus of the incus (I) and stapes (S) are absent. The labyrinthine segment of the facial nerve (FN) and the geniculate ganglion are posteriorly displaced, and the tympanic and mastoid segments of the FN are antero-inferiorly displaced, running more vertically than normal control. The cochlea (Co), malleus (M), anterior semicircular canal (ASC), and posterior semicircular canal (PSC) are intact. (B) Lateral view of normal control. The green arrowhead shows the course of the FNs.

The DV-3D images (Fig. 3) indicate that the cochlear turn is intact, the lateral SC is hypoplastic, the long crus of the incus and stapes are absent, the labyrinthine segment of the FN is more posteriorly placed, and the tympanic and mastoid segments are antero-inferiorly displaced and running more vertically than normal. Fig. 4 shows the structures pictured in the same position as we found them during surgery. These images show that the stapes are absent and that the FN runs antero-inferiorly onto the oval window.

Fig. 4. (A) The Delta Viewer 3 dimensional (DV-3D) image of case 1 in the same position during cochlear implantation surgery. (B) The DV-3D image of normal control in the same position as (A). Rectangle of dashed line shows the area of Fig. 5. Co, cochlea; ASC, anterior semicircular canal; PSC, posterior semicircular canal; LSC, lateral semicircular canal; FN, facial nerve; M, malleus; I, incus; S, stapes.

Case 2: Left ear of a seven-year-old boy
The patient presented with bilateral cochleo-vestibular malformations and abnormalities of the stapes and course of the FN. We had already performed CI surgery on the right ear one year before. We planned a second CI procedure on this patient’s left ear for the same reason we performed surgery on the first patient.

The preoperative DV-3D images (Figs. 7, 8) indicate that the shape of the cochlea and the SC are hypoplastic, the stapes seem to be fused to the FN, and the course of the FN is abnormal, as in the previous case, with bifurcation. In addition, the round window niche is closed, so there is no landmark for cochlear fenestration. We were able to successfully perform the cochlear fenestration right next to the FN, which was detected using a FN monitor and referring to a DV-3D image of the nerve course.
Fig. 7. Antero-lateral view of the temporal bone structures of case 2. The shape of the cochlea (Co) and semicircular canals are hypoplastic. The labyrinthine segment of the facial nerve (FN) and geniculate ganglion are posteriorly displaced, the tympanic and mastoid segments of the FN are antero-inferiorly displaced with bifurcation, and the stapes is fused to the facial nerve (arrow head). IAC, internal auditory canal; M, malleus; I, incus; S, stapes.

Fig. 8. The Delta Viewer 3 dimensional image of case 2 in the same position during cochlear implantation surgery. The surface of the tympanic cavity is displayed in green. The round window niche (RWN) is closed, so there was no landmark for cochlear fenestration. Co, cochlea; FN, facial nerve; ASC, anterior semicircular canal; M, malleus; I, incus.

Fig. 9. The X-ray of inserted electrode of case 2.
second branchial arch but from the otic capsule, the cause of the anomaly of this segment may not be discussed on the same basis as that of the other segments related to the second branchial arch.

**CONFLICT OF INTEREST**

No potential conflict of interest relevant to this article was reported.

**REFERENCES**


### Table 1. Summary of cases and Delta Viewer (DV) 3D image findings

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (year) (sex)</th>
<th>Day of surgery (side)</th>
<th>DV-3D image findings</th>
<th>Facial nerve</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3 (M)</td>
<td>Feb 2010 Right</td>
<td>Intact</td>
<td>Hypoplasia of LSC</td>
<td>Posteriorly displaced</td>
</tr>
<tr>
<td>2</td>
<td>7 (M)</td>
<td>Jul 2010 Left</td>
<td>Hypoplasia</td>
<td>Aplasia of LSC and PSC</td>
<td>Abnormal: fusion to FN</td>
</tr>
<tr>
<td>3</td>
<td>5 (F)</td>
<td>Mar 2010 Right</td>
<td>Intact</td>
<td>Aplasia of all SCs</td>
<td>Posteriorly displaced</td>
</tr>
<tr>
<td>4</td>
<td>3 (M)</td>
<td>Feb 2010 Right</td>
<td>Hypoplasia</td>
<td>Almost intact</td>
<td>Posteriorly displaced</td>
</tr>
<tr>
<td>5</td>
<td>6 (F), same patient as case 3</td>
<td>Feb 2011 Left</td>
<td>Intact</td>
<td>Aplasia of all SCs</td>
<td>Posteriorly displaced</td>
</tr>
<tr>
<td>6</td>
<td>1 (F)</td>
<td>Nov 2011 Left</td>
<td>Almost aplasia</td>
<td>Almost intact</td>
<td>Intact</td>
</tr>
</tbody>
</table>

CI, cochlear implantation; LSC, lateral SC; PSC, posterior SC; FN, facial nerve.