

New Trend Series Vol. 3**The World of X-ray Imaging Expanded through Digital Tomosynthesis****II Clinical Report — Clinical Report on Digital Tomosynthesis****3. The Otolaryngological Field****1) Usage experience in the otolaryngological field
(cochlear implants)**

— Demonstrating the power of post-surgery checks for
cochlear implant surgery

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The characteristics of digital tomosynthesis include (1) the ability to obtain multiple slices with a single scan, (2) high spatial resolution images using FPDs (flat panel detectors), (3) minimal artifacts caused by metal implants, and (4) lower levels of radiation exposure in comparison with CT scans. Additionally, Shimadzu SONIALVISION safire X-ray R/F (Radiography/Fluoroscopy) system has tomosynthesis mode. In this paper, I report the follow up examination of post cochlear implant surgery by using tomosynthesis in Shinshu University Hospital.

Background

We launched a cochlear implant project at the otorhinolaryngology department in our hospital in 1999, and we now perform an average of 40 cases of cochlear implant surgery per year, including the clinical application of “electric acoustic stimulation,” which received approval as an advanced therapy in August 2010.

The structure of the ear and the mechanisms behind hearing

The ear consists of three sections: the outer ear (the auricle and ear canal), the middle ear (the eardrum and auditory ossicles), and the inner ear (the semicircular canals and cochlea). Sound travels down the ear canal in the form of air vibrations and makes the eardrum vibrate. The sound is then conveyed by the auditory ossicles to the cochlea. The sound signals are transmitted through vibration of the endolymph inside the cochlea, causing the hair cells inside the cochlea to move. Their waving motion produces extremely faint electrical signals, which are conveyed from the auditory nerve to the brain. The section of the brain responsible

for hearing recognizes those electrical signals as sound.

What are cochlear implants?

Hearing disorders (sound conduction disorders) due to problems with the eardrum or auditory ossicles can sometimes be improved through surgery or the use of hearing aids. For hearing disorders due to problems with the cochlea (sensorineural disorders), improvements in hearing can sometimes be obtained by implanting a cochlear implant that will convert sound to electrical signals and directly stimulate the auditory nerve through electrodes placed inside the cochlea. A cochlear implant device consists of an audio processor (the external part) and the implant itself (the internal part) (Figure 1). The audio processor is attached to the ear. It consists of a control unit that converts sound into signals and a transmitter coil that transmits the signal through the skin. The implant mainly consists of a receiver coil that receives the signal and electrodes that are inserted into the cochlea. The transmitter coil and receiver coil are on either side of the skin and held in place by a magnet.

How cochlear implants work

With a cochlear implant, sound is converted into electrical signals by the audio processor microphone. The signals encoded by the audio processor are sent wirelessly from the transmitter coil to the implant’s receiver coil, converted into stimulus pulses, and conveyed to the electrodes inside the cochlea. By stimulating the cochlea toward the entrance for high-pitched sounds and toward the back for low-pitched sounds, stimuli can be conveyed from the auditory nerve to the brain in the same way that natural hearing, and the brain recognizes it as sound.

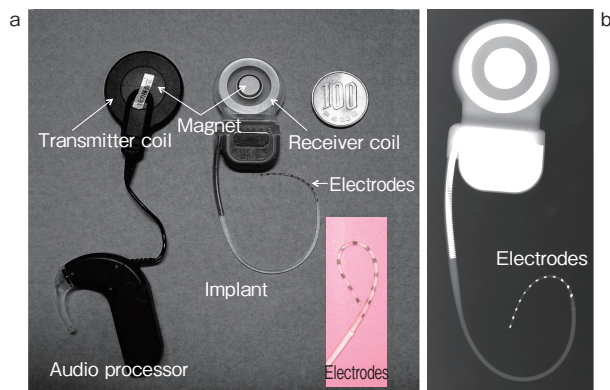


Fig. 1 Cochlear implant device (mock)
 a : External view
 b : X-ray image of the implant. The arrangement of 12 electrodes is visible.

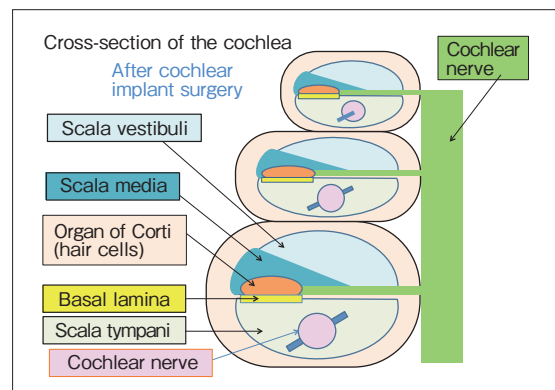


Fig. 2 Cross-section of cochlea
 The electrodes are inserted into the scala tympani.

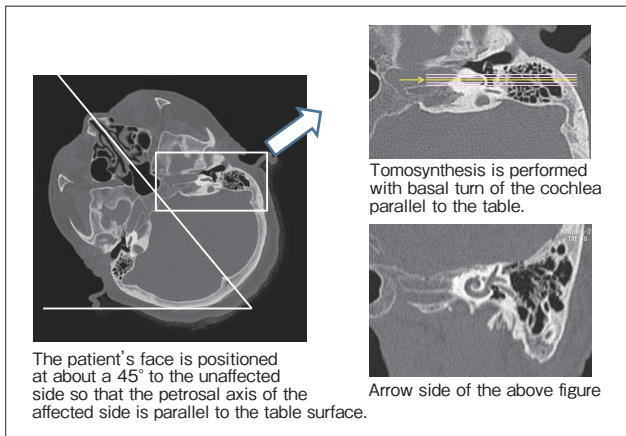


Fig. 3 Radiography posture
 The angle at which the petrosal axis of the affected side is parallel to the table surface. The face is angled to the unaffected side (at about a 45°).

The structure of the cochlea

The cochlea is a spiral tubular cavity consisting of an endolymph-filled tube wrapped several turns around the modiolus. The cross-section of the cochlea duct is partitioned into three layers: from the top, these are the scala vestibuli, the scala media, and the scala tympani. The scala vestibule and scala media are separated by Reissner's membrane, and the scala media and scala tympani are separated by the basal lamina (basal membrane), which contains the organ of Corti. Mechanical vibrations of the basal lamina are received by the spiral-shaped organ of Corti as sound stimuli and are conveyed to the cochlear nerve. The electrodes of cochlear implants are inserted into the scala tympani (Figure 2).

Radiography conditions and clinical images

(1) Radiography posture: Radiography is implemented within the space of a few days following cochlear implant surgery. The patient assumes a supine position, with his or her face

angled at about a 45° to the unaffected side, so that the petrosal axis of the affected side is parallel to the table surface (the flat panel detector surface). After making fine adjustments to the angle to obtain a broad view of the basal turn of the cochlea during radiography, tomosynthesis is performed (Figure 3).

(2) Radiography conditions: Device used: SONIALVISION safire (80 kV, 1.8 mAs, 7.1 ms, SID: 110 cm); tomography angle: 40°; tomography speed: fast; imaging frames: 67 frames; reconstruction method: FBP; reconstruction pitch: 1 mm.

Case study

High sensorineural hearing loss on both sides (age 58, female)

Because the patient suffered high sensorineural hearing loss on both sides, cochlear implant surgery on the left side was performed. Plain X-ray image (Figure 4) and tomosynthesis images (Figure 5) taken the day after surgery are shown. Due to the effect of the tomographic thickness, the electrodes are visible in multiple tomograms.

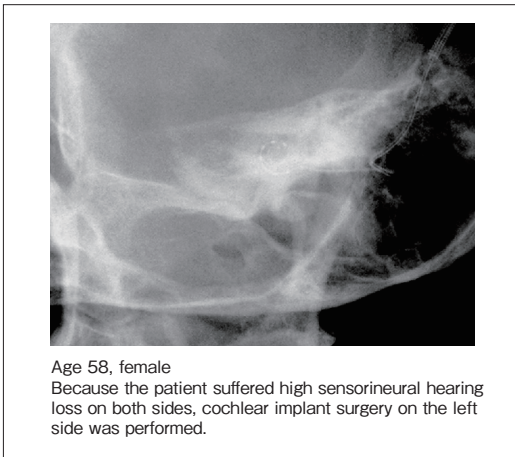


Fig. 4 Case study—plain x-ray image
 Image is indistinct due to overlapping positions of electrodes and petrosa.

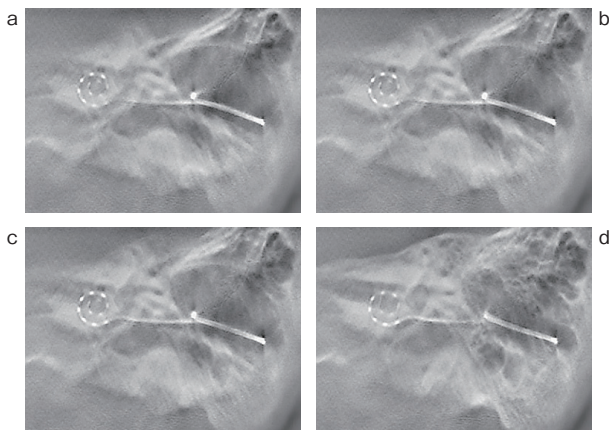


Fig. 5 Case study—tomosynthesis images
 a : Cochlear apex d : Base of cochlea
 a, b, c and d were taken at 2-mm intervals.

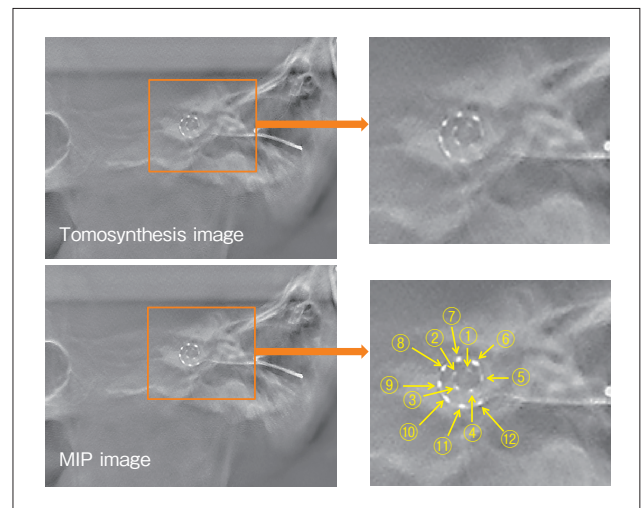


Fig. 6 Case study—tomosynthesis MIP images
 With MIP processing, electrodes can be seen with good contrast.

Due to the use of MIP processing for the tomography imaging, the arrangement of the electrodes could be seen with good contrast in one image (Figure 6). This case was diagnosed as success, as the electrodes had been correctly inserted from the cochlear base region (12) to the cochlear apex (1), and the distance from the modiolus had been properly maintained.

The utility of tomosynthesis

Because SONIALVISION safire has tomography capability built into its Radiography/Fluoroscopy system, it is possible to perform tomography by adjusting the patient head angle to make the cochlea spiral structure plane by using fluoroscopy. With plain X-ray images, the electrodes overlap the pars petrosa and cochlea spiral structure cannot be adequately

checked. However, using tomography, the positional relation between the electrodes and the locations where the cochlea senses stimuli for each frequency band can be clearly defined, which is useful for mapping sound recognition.

Acknowledgements

The author thank Prof. Shinichi Usami and Dr. Keta Tsukada of the Department of Otorhinolaryngology at Shinshu University School of Medicine for the guidance they provided in the writing of this paper.

Reference

1) Usami, S., Moteki, H., et al. : Achievement of hearing preservation in the presence of an electrode covering the residual hearing region. *Acta. Otolaryngol.*, **131**, 405 ~ 412, 2011.