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ORIGINAL RESEARCH

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A novel view of computed tomography images similar to the visual field of otologic surgeons

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Abstract

Objectives: In preparation for endoscopic sinus surgery (ESS), the most important computed tomography (CT) image for otolaryngologists is the coronal plane image because it has a viewpoint similar to that of the surgical visual field. Contrastingly, otologic surgeons refer to axial and coronal plane images before ear surgery and must imagine the anatomical structure of the temporal bone by reconstructing three-dimensional (3D) images in their minds. We propose a "surgical position view (SPV) image," a novel viewpoint of CT images that enables otologic surgeons to see a perspective similar to the surgical visual field.

Method: Sagittal plane CT images of the temporal bone were created from axial plane images with multi-planar reconstruction (MPR). Then, the SPV image was obtained by rotating it 90° to the supine position. The entire process can be performed anywhere in the hospital within 1 minute using the electronic medical record computer's image viewer.

Results: SPV images show anatomical structures of the temporal bone, external ear canal, mastoid cavity, sigmoid vein, facial nerve, ossicles, and cochlea, in a similar view to the actual ear surgery. Soft tissue such as cholesteatoma is depicted in the same concentration as the normal CT image.

Conclusion: The SPV image enables an otologic surgeon to see the temporal bone CT image from the actual ear surgery viewpoint simply and quickly. It helps to visualize the 3D anatomical structure of the temporal bone and can be useful for ear surgery planning.

Level of evidence: 5

KEYWORDS
computed tomography, ear surgery, multi-planar reconstruction, surgical position view

1 | INTRODUCTION

As part of preoperative planning before endoscopic sinus surgery (ESS), otolaryngologists generally refer to the axial, coronal, and sagittal planes of sino-nasal computed tomography (CT) images. Of these, the coronal plane image is the most important because it has a viewpoint similar to that of the surgical visual field of ESS. In contrast, only the axial and coronal planes of the temporal bone

CT images have been referred to as a preoperative preparation in microscopic ear surgery. In addition, otologic surgeons need to reconstruct three-dimensional (3D) images in their minds prior to the ear surgery. However, this reconstruction is difficult for inexperienced otolaryngologists. We considered it easier to imagine the anatomical structure of the temporal bone by referring to the CT images in a similar viewpoint to the surgical visual field, as in the coronal images in the ESS. Consequently, we proposed a novel viewpoint of the temporal bone CT images, enabling otologic surgeons to see from a similar viewpoint of the surgical visual field and named it "surgical position view (SPV)." We present the efficacy and reliability of SPV images for preoperative preparation for ear surgery.

2 | MATERIALS AND METHODS

Patients planned for ear surgery underwent temporal bone CT imaging in our hospital using a 320-detector row CT scanner (Aquilion One, Canon Medical Systems, Tochigi, Japan). The scanning parameters were: 120 kV, 250 mA, 0.5 mm slice thickness, 512 × 512 matrix, and 221 × 89.6 mm^2 field of view. In the image viewer of the electronic medical record, sagittal view CT images of the temporal bone were created using multi-planar reconstruction (MPR) based on axial plane CT images with a general-purpose digital imaging and communications in medicine (DICOM) viewer. The aspect of this sagittal view image was the standing posture at first; then, it was rotated 90° to the supine position. Sometimes, this image was set up on the opposite side, and it was necessary to reverse the image horizontally to complete the SPV image in such a case. In total, this procedure required only 30 seconds and only a few clicks. This study was approved by the institutional review board (IRB) in Oita University Faculty of Medicine (Permission number: 2049).

3 | RESULTS

3.1 | Case examples

3.1.1 | Case 1

We showed SPV images of a 50-year-old man who was scheduled to undergo cochlear implantation without abnormalities in his right temporal bone (Figure 1). These images are in the same orientation as the surgical position of the right ear; the left side indicates the superior portion of the body, and the right side indicates the inferior; the upper side direction indicates the facial side, and the lower indicates the direction of the occipital side. SPV images can help measure the approximate distance from the external ear canal wall to the tegmen, or the sigmoid vein and imagine the labyrinthine structure's direction. The facial nerve canal and the iter chordae posterious, including the chorda tympani, were drawn in the same orientation as the mastoidectomy. Soft tissue was described at the same concentration as the normal CT image.

3.1.2 | Case 2

A 22-year-old man diagnosed with right middle ear cholesteatoma underwent temporal bone CT for preoperative examination. The

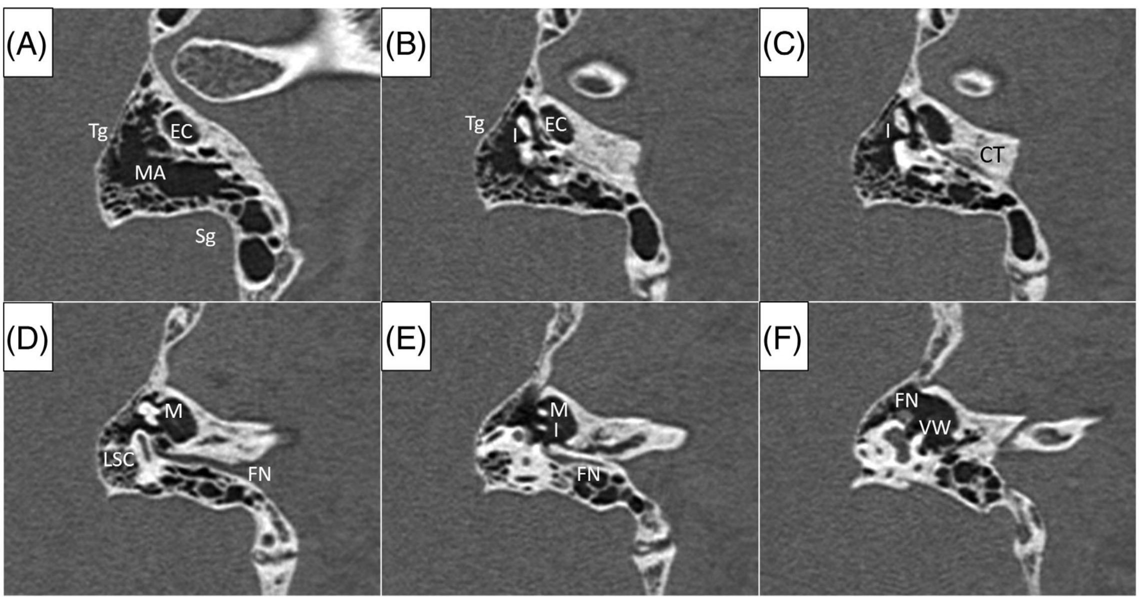

FIGURE 1 Surgical position view images of the right ear without any lesion (direction: from the outside towards the inside of the temporal bone). EC, external ear canal; Sg, sigmoid vein; MA, mastoid antrum; Tg, tegmen; I, incus; CT, chorda tympani; M, malleus; FN, facial nerve; LSC, lateral semicircular canal; VW, vestibular window. A, The external ear canal is surrounded by the mastoid antrum and the mastoid cell in three directions. This image shows the position of the tegmen and the sigmoid vein. B, The short process of incus is detected in the attic. C, The iter chordae posterious, including the chorda tympani, is drawn. D, The vertical portion of the facial nerve and the lateral semicircular canal are shown. E, Malleus body and the long process of incus line up. F, The horizontal portion of the facial nerve runs in front of the vestibular window

tympanic cavity, attic, and mastoid cavity were filled with soft tissue. SPV images showed bone defects at the 8 and 10 o'clock positions of the tegmen (Figure 2A,C). In the actual surgery, these bone defects were confirmed at the same site, as shown in the SPV images (Figure 2B,D).

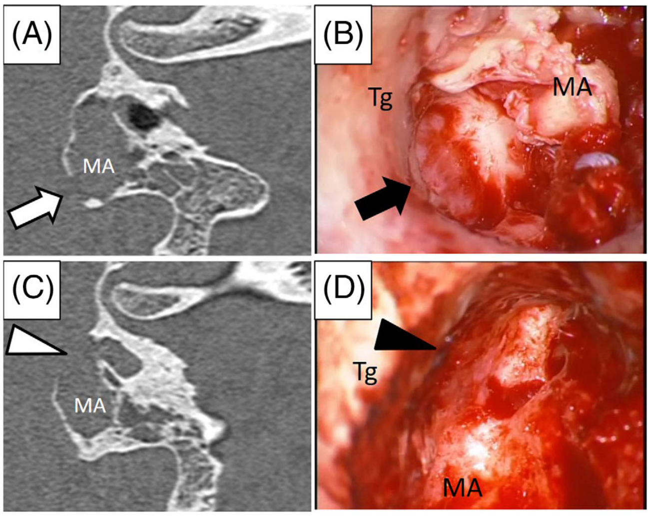

FIGURE 2 Surgical position view images of the right ear with cholesteatoma and actual surgical images. Tg, tegmen; MA, mastoid antrum. A, A bone defect is noted at the eight o'clock position (white arrow) of the tegmen. B, In actual surgery, the bone defect was found in the same direction (black arrow). C, There is a large bone defect at the 10 o'clock position (white arrowhead) of the tegmen. D, In actual surgery, the bone defect was found at the 10 o'clock position (black arrowhead)

3.1.3 | Case 3

A 66-year-old woman suffered from left facial paralysis due to Ramsay-Hunt syndrome 2 months ago. She received systemic steroid therapy, but her symptoms did not resolve. She was scheduled to undergo facial nerve decompression and underwent preoperative temporal bone CT imaging. By combining the SPV image with the axial CT image, the surgical anatomical structures could be easily recognized, as the sigmoid vein is located close to the external ear canal and the posterior cranial fossa is located close to the facial nerve (Figure 3). Based on these findings, we could perform facial nerve decompression surgery safely with the canal wall down method because of insufficient surgical space through mastoidectomy only.

4 | DISCUSSION

We propose the use of an SPV image, created by simply rotating the sagittal image reconstructed with MPR by 90°, which allows the operator to see an anatomical perspective similar to that of the ear's surgical field, much like a coronal image of an ESS. The SPV images can help to understand various aspects of ear surgery, such as the shape of the external auditory canal, the distance from the ear canal wall to the tegmen or the sigmoid vein, the pathway of the facial nerve and chorda tympani, and the form of ossicles. In addition, it can also show soft tissue, such as a cholesteatoma, and bone defects at the same window level as conventional CT images. For example, the SPV images of Case 3 revealed insufficient space around the facial nerve for performing decompression safely, and it helped to choose an adequate surgical approach.

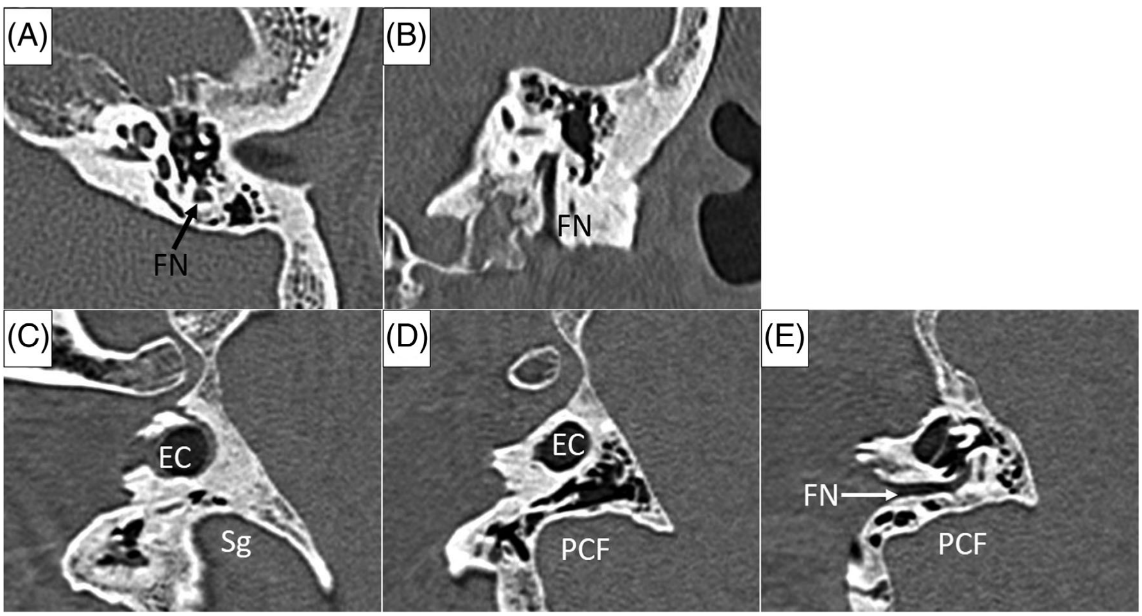

FIGURE 3 Preoperative left temporal bone computed tomography images of facial nerve decompression. FN, facial nerve; Sg, sigmoid vein; EC, external ear canal; PCF, posterior cranial fossa. Axial plane image, A, Coronal plane image, C to E, Surgical position view images: the sigmoid vein is close to the external ear canal, and the space between the facial nerve and the posterior cranial fossa appears narrow

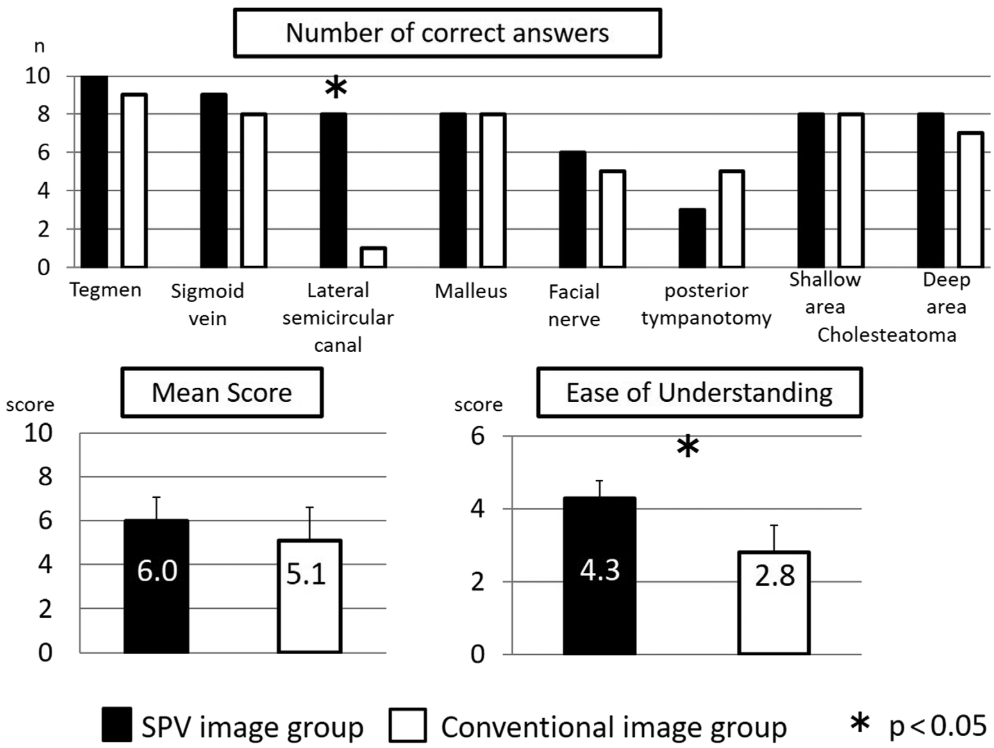

FIGURE 4 Evaluation of anatomical structure identification for medical students (Modified from Kadowaki et al.[13])

In addition to these cases, we have experienced that the SPV images were helpful in planning mastoidectomy with temporal bone fractures and a lower skull base, as they could accurately indicate the correct direction for drilling. These series of MPR image-creation processes are executed using a general-purpose DICOM viewer on the image server, allowing us to create and refer to the images of the electronic medical records from anywhere in our hospital. Any hospital can easily use SPV images if they can create and refer to the MPR images by themselves, using an electronic medical record computer. There may be differences depending on the facility, but SPV images can be obtained within ∼10 seconds.

Moreover, various simulator platforms and image processing procedures have been reported that help otolaryngologists with preoperative surgical imagination, surgical training, and understanding of temporal bone anatomy.[1-6] Simulator platforms, in which virtual reality simulators and 3D printed models are widely used, are immensely helpful for surgical training.[5] These provide advantages for visualization since the line of sight can be changed freely, and because it provides easy reference to case-specific images.[1] However, special equipment and software are required to use these simulator platforms; thus, they seem to be available in a limited number of facilities.

Furthermore, the aforementioned reports described that image-processing procedures, including CT volume rendering (CTVR) and MPR, have also been used for preoperative image visualization of the temporal bone.[7] CTVR shows the CT image of the temporal bone three-dimensionally, which and allows it to be seen from various angles. However, since the soft tissue is not visualized, the target of CTVR is limited to the evaluation of ossicular morphology.[4] In addition, a workstation, and the cooperation of radiologists for image processing, are required. These reports have mentioned programs that enable 3D reconstruction of temporal CT images and the execution of surgical simulations, many of which require effort, money, and special equipment and software.

Similarly, there are several reports on the reconstruction of temporal bone CT images by MPR. Although MPR images can show soft tissue well,[8,9] these reports mainly focused on the shape of the inner ear or the condition of the ossicular chains, and their purpose was limited to some aspects of ear surgery.[4,10,11] Another report was intended only for the radiology imaging and not for preoperative planning of ear surgery.[7] Wiet et al. stated that preoperative planning was a type of "just in time" training.[12] Similarly, SPV images can assist preoperative planning in various aspects of ear surgery, which can also be considered a kind of surgical training. We showed medical students CT images of the temporal bone and then showed a surgical video of mastoidectomy to evaluate whether 10 items of anatomical structures could be correctly identified. Ten students were divided into SPV image group and conventional axial and coronal image group each, and the SPV image group tended to have a high average score and significantly better score for subjective ease of understanding.[13] Therefore, the SPV image is also useful as an educational tool for temporal bone anatomy (Figure 4).

We recognize that the SPV image has a limitation: the orientation of the image does not exactly match the line of sight of the otologic surgeon. However, the direction of the line of sight via the surgical microscope often changes during ear surgery; thus, we believe that the SPV image is not as problematic as the coronal plane CT image, which does not match the surgical field of the ESS. However, this limitation does not seem to be significant.

5 | CONCLUSION

The SPV image is a novel viewpoint for visualizing the temporal bone CT image and enables otologic surgeons to visualize temporal bone CT images as if they were actually looking at the surgical field. By combining it with conventional axial and coronal plane images, SPV imaging may be a useful tool for the preoperative planning of ear surgery and the understanding of the temporal bone's anatomy. The most significant advantages of the SPV image, compared with other imaging modalities, are its simplicity and convenience for utilization. It could be readily introduced in many medical institutions.

CONFLICT OF INTEREST

The authors declare no conflicts of interest associated with this manuscript.

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