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Which temporal bone anatomical structures and pathologies could be best visualized by applying reconstruction to cross-sections obtained on an axial plane?

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Abstract

Objective: In this study, we aimed to identify the position in which temporal bone anatomical structures and pathologies could be best visualized by applying reconstruction to cross-sections obtained on an axial plane in temporal bone computed tomography (CT) scans.

Methods: Sixty patients were examined with temporal bone CT between July 2008 and March 2009. We obtained multiplanar reformatted images by applying retro-reconstruction on various planes from the axial plane sections.

Results: We determined that the reconstructed images increased the anatomical and pathological details and significantly contributed to evaluating the relationship between anatomical structures and their pathologies with other normal components.

Conclusion: Obtaining multiplanar reformatted images by retro-reconstruction decreased the need for visualization of coronal sections used in standard temporal bone CT exams since the anatomical details were diversified using the new planes. In addition, the dose of radiation received by the patients and the duration of the examination could be reduced by eliminating routine coronal plane sections and obtaining new images using retro-reconstruction.

Keywords: Temporal bone, computed tomography, reconstruction, anatomy.

Özet: Aksiyel düzlemde elde edilen kesitlerin rekonstrüksiyonuyla hangi temporal kemik anatomik ve patolojik oluşumları en iyi görüntülenebilir?

Amaç: Bu çalışmada temporal kemik anatomik ve patolojik yapılarının aksiyel düzlem temporal kemik bilgisayarlı tomografi (BT) taramalarında elde edilen kesitlere rekonstrüksiyon uygulayarak bu oluşumların hangi pozisyonda en iyi görüntülenebildiğini saptamayı amaçladık.

Yöntem: Temmuz 2008 ile Mart 2009 arasında 60 hasta temporal kemik BT'si ile incelendi. Değişik aksiyel düzlem kesitlerinden retrokonstrüksiyon yöntemiyle çok düzlemli yeniden formatlanmış görüntüler elde ettik.

Bulgular: Rekonstrükte görüntülerin anatomik ve patolojik ayrıntıları daha iyi gösterdiğini ve anatomik oluşumların ve patolojilerinin diğer normal öğelerle ilişkilerinin değerlendirilmesine önemli katkı sağladığını belirledik.

Sonuç: Retrokonstrüksiyon yöntemiyle birden çok düzlemde görüntülerin yeniden formatlanması, yeni düzlemlerde farklı anatomik ayrıntılar görüntülendiğinden standart temporal kemik BT incelemelerinde kullanılan koronal kesitleri görüntüleme gerekliliğini azaltmıştır. İlaveten, rutin koronal düzlem kesitleri gereksizleştirerek ve retrokonstrüksiyon yöntemiyle yeni görüntüler elde ederek hastaların aldığı radyasyon dozu ve inceleme süresi azaltılabilir.

Anahtar sözcükler: Temporal kemik, bilgisayarlı tomografi, rekonstrüksiyon, anatomi.

Temporal bone imaging using computed tomography (CT) has recently advanced significantly. CT is an imaging modality that plays an important role in diagnosis, differential diagnosis, treatment planning, and monitoring of temporal bone anatomy and pathology. In daily practice, CT imaging of the temporal bone is obtained using standard axial and coronal sections. However, many of the anatomical details cannot be observed clearly.[1] In recent years, with advances in multidetector CT, new images can be obtained using reconstruction of the derived section in many planes.[2] The middle and inner ear anatomical structures can be observed in more detail and can be evaluated easily.[1,3]

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In our study, we generated temporal bone CT images obtained in the axial plane which were sagittal, coronal, oblique semi-oblique, parallel to the course of the vestibular aqueduct, parallel to the second part of the facial nerve, and parallel to the manubrium malleie reconstructions. In the reformatted images, we determined which reconstruction plane improved visualization of the anatomical structures and pathologies of the temporal bone. The multiplanar reconstruction method requires only axial sections during the CT examination. This approach reduced both the radiation dose received by the patient and the examination duration by eliminating the coronal sections used in daily standard temporal bone CT imaging practices.

Materials and Methods

In the present study, 60 patients who were directed by clinicians to our CT unit for temporal bone CT examinations between July 2008 and March 2009 were examined. A total of 39 (65%) cases were female, and 21 (35%) were male, with a mean age of 35.8 years. The youngest patient was 12 years old, and the oldest was 76 years old. All patients were examined via axial sectional images using our CT (Siemens mark Somatom-Emotion model spiral CT; Siemens Healthcare, Erlangen, Germany). The examination was performed in a supine, neutral position, parallel to the superior orbital-meatal line without tilting of the chin. Scanning was performed from the beginning of the petrous pyramid to the mastoid. In each case, consecutive sections were obtained at 1-mm slice thickness in the axial plane. A 130 KV, 135 mAs, and 512×512 matrix was used. The rotation time was 1 second, and the average examination time was 40 seconds. To assess bone structures, the 'bone algorithm' was used. All examinations were performed without using intravenous contrast materials.

Evaluation was performed by two radiologists together. Reference angles on the left temporal bone were evaluated. A standard reconstruction algorithm was used. After the exam, we applied reconstruction on three reference planes (axial, sagittal, and coronal) to the images obtained on the axial plane, which were opened in 0.1-mm intervals. Primary and secondary reference planes were determined. In the reference plane, the left vector of the horizontal axis was defined as 0, and the right vector was defined as 180. The oblique planes were detected, in which the temporal bone anatomical structures (ossicle chain, stapes-oval window, round window, cochlea, vestibular aqueduct, semi-circular ducts, and facial nerve) and their pathologies were optimally evaluated.

Results

The coronal reconstructed images obtained from the axial 150° and sagittal 85° reference planes are required to assess the head, neck, and manibrium of the malleus.

Optimal assessment of the incus body, long process, incudostapedial joint and stapedial footplate can be performed using coronal reconstructed images obtained from the axial 150º and sagittal 60º reference planes.

'Molar tooth' formation, which also shows the incudomalleolar joint formed by the malleus and incus, can be observed using the sagittal reconstructed images obtained from the axial 60º and coronal 120º reference planes (Fig. 1).

The long axis projection of the stapes-oval window complex, which also includes stapedial anterior and posterior crosses with the stapedial footplate, can be observed based on the axial reconstructed images obtained from the coronal 30º and sagittal 150º reference planes (Fig. 2). The short axis projection could be observed based on the sagittal reconstructed images obtained from the axial 65º and coronal 120º reference planes.

The round window and adjacent anatomical structures, such as the labyrinthing segment of the facial nerve canal

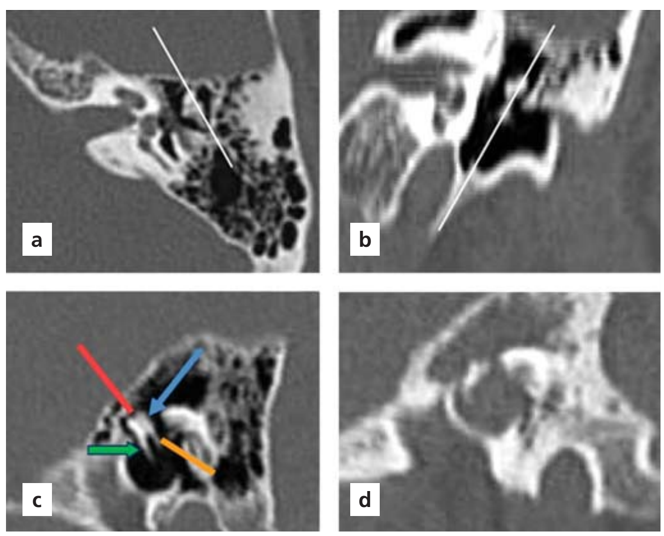

Fig. 1. (**a**–**d**) Double oblique sagittal views of the malleus and incus (**a**, **b**). Orthogonal axial 60º (**a**) and coronal 120º (**b**) reference planes (white lines). Double oblique sagittal (**c**) reconstructed view, which resembles the 'molar tooth' appearance; incus body (blue arrow), incudomalleolar joint (red line), manubrium mallei (green arrow), and incus long process (orange line). Reconstructed double oblique sagittal (**d**) view of a patient showing destruction of the partial incus body and total incus long process secondary to smooth tissue in the middle ear cavity. The clearness of the incudomalleolar joint is reduced, and there is a lateral subluxation of the manubrium mallei. [Color figure can be viewed in the online issue, which is available at www.entupdates.org]

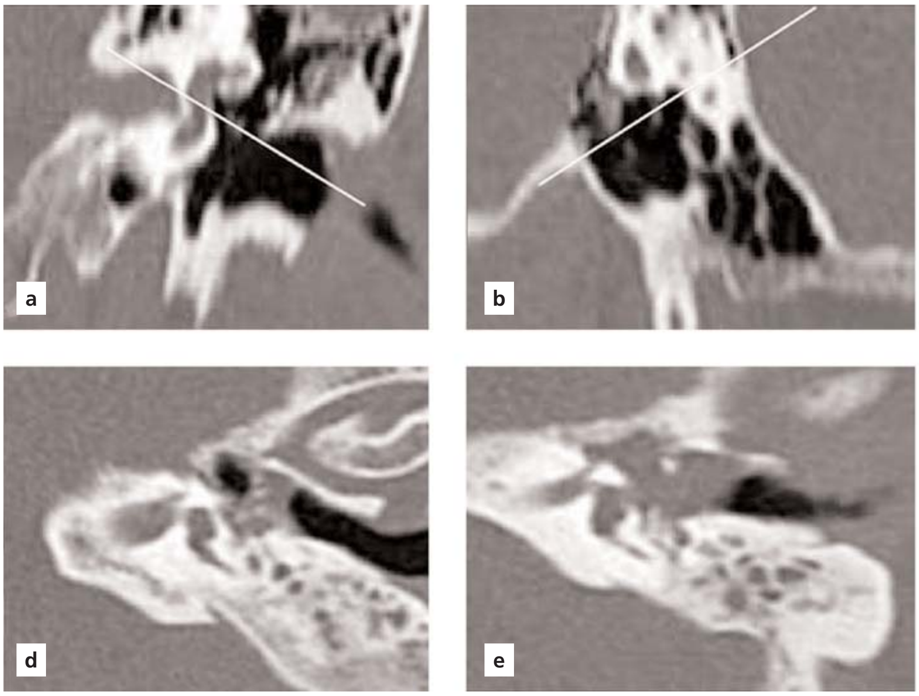

Fig. 2. (**a**–**e**) Double oblique axial views of stapes at the oval window. Orthogonal coronal 30º (**a**) and sagittal 150º (**b**) reference planes (**white lines**). Double oblique axial (**c**) reconstructed view at the oval window level; stapedial anterior crus (**orange line**), posterior crus (**blue line**), and stapedial footplate (**red arrow**). Double oblique axial reconstructed images from other patients; the obliteration of the circumference of malleus, incus, and stapes by the smooth tissue and destruction of incus and stapedial posterior crus by the cholesteatoma (**d**, **e**). [Color figure can be viewed in the online issue, which is available at www.entupdates.org]

and superior vestibular nerve canal, can be observed using the sagittal reconstructed images obtained from the axial 60º reference planes.

The short axis projection of the apical turn, middle turn, and basal turn of the cochlea can be observed based on the coronal reconstructed images obtained from the axial 30º and sagittal 75º reference planes and the long axis projection can be observed based on the sagittal reconstructed images obtained from the axial 120º reference planes.

The sagittal reconstructed images obtained from the axial 135º reference plane (Fig. 3) are required to assess the superior semi-circular canal.

Axial reconstructed images obtained from the coronal 180º reference plane are required to assess the lateral semi-circular canal.

The sagittal reconstructed images obtained from the axial 40º reference plane (Fig. 4) are required to assess the posterior semi-circular canal.

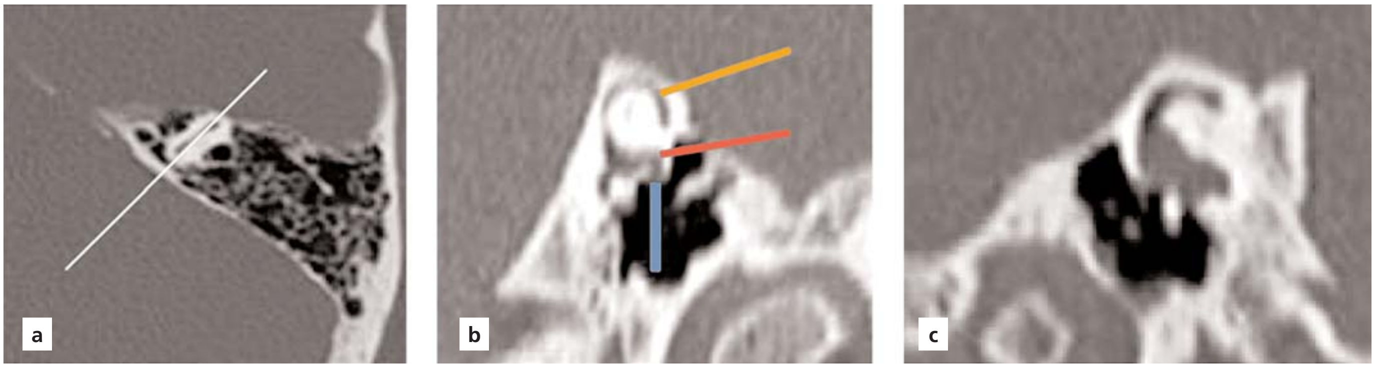

Fig. 3. (**a**–**c**) Single oblique-sagittal views of the superior semi-circular canal. Orthogonal axial 135º (**a**) reference plane (**white line**) parallel to the roof of superior semi-circular canal. Single oblique sagittal (**b**) reconstructed view; the bone continuity at the roof of superior semi-circular canal (**orange line**), facial nerve (**blue line**), and lateral semi-circular canal (**red line**). Single oblique sagittal (**c**) reconstructed images of another patient showing the deformity and the short rotation of the superior semi-circular canal. [Color figure can be viewed in the online issue, which is available at www.entupdates.org]

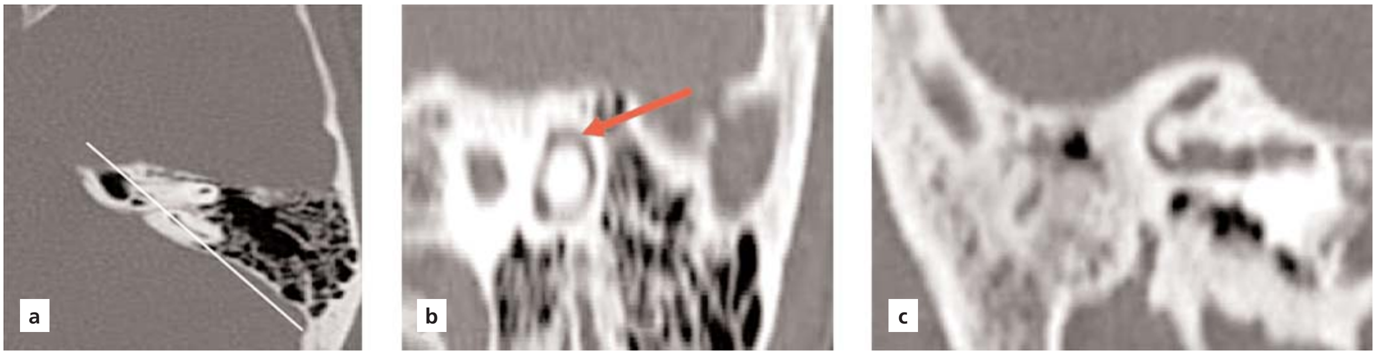

Fig. 4. (**a–c**) Single oblique-sagittal views of the posterior semi-circular canal. Orthogonal axial 40º (**a**) reference plane (white line) parallel to the roof of the posterior semi-circular canal. Single oblique sagittal (**b**) reconstructed view; posterior semi-circular canal (red arrow). Single oblique sagittal (**c**) reconstructed images of another patient with a common cavity deformity in the right ear showing the deformity and the short rotation of the posterior semi-circular canal. [Color figure can be viewed in the online issue, which is available at www.entupdates.org]

The sagittal reconstructed images obtained from the axial 90º reference plane (Fig. 5) are required to assess the vestibular aqueduct.

Visualization of the tympanic and mastoid segments of the facial nerve are provided by the sagittal reconstructed images obtained from the axial 60º and coronal 95º reference planes.

Discussion

Temporal bones have a complex anatomy, which includes hearing and balance organs. In addition, temporal bones contain functional spaces, plurality of holes, and channels through which blood vessels and nerves pass.[1,4]

At the end of the 1950s when politomography became more common, temporal bone imaging emerged as a specialized area within radiology departments. The recommended tube angulation during assessment of the temporal bone varies depending on the region examined, but in daily use, standard techniques include axial and coronal projections.[1,5] To visualize the anatomical structures, improved additional projections were developed. These projections, which are not orthogonal, were supported by temporal bone politomography pioneers.[1,5–7]

Other planes known in classical otologic radiology were investigated for the first time by Zonneveld in 1983.[7] This report discussed observations of classical autoradiological planes using proper patient positioning techniques

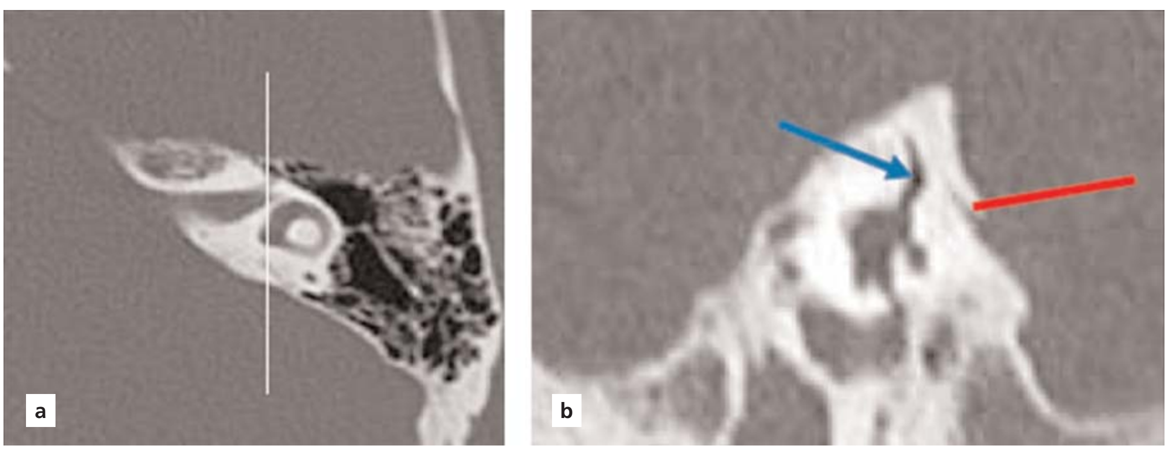

Fig. 5. (**a**, **b**) Single oblique-sagittal views of the vestibular aqueduct. Orthogonal axial 90º (**a**) reference plane (white line) including the vestibule medial wall and vestibular aqueduct. Single oblique sagittal (**b**) reconstructed view; vestibular aqueduct (red line) and common crus (blue arrow). [Color figure can be viewed in the online issue, which is available at www.entupdates.org]

in direct CT.[6,7] Autoradiological planes used with direct CT include transverse (Hirtz), coronal, sagittal, semiaxial (Guillen), semilongitudinal (Zonneveld), axiopetrosal (Pöschl), and longitudinal (Stenvers).[6–12] To achieve these planes using CT, the device was surrounded by a plate that rotates the patient through the sectional plane centre around the vertical axis.

The majority of temporal bone structures can be observed in the transverse (axial) plane.[6,7,9,10] This plane is ideal for basic assessment of temporal bones, since it provides the patient with comfort and enables comparison of the bilateral petrous bone in a single plane.[6,7,9,10] When a single-sectional plane is used, the structures parallel to the sectional plane are partially visible or absent. Therefore, temporal bone CT imaging requires at least two positions.[6,7] The choice of the second tomographic plane depends on the results of the fundamental assessment in the transverse plane, as well as the clinical information that can reveal which additional planes provide useful information.[6,7]

CT technology has developed rapidly since its introduction. Over time with evolving CT technology, it has become possible to reconstruct in different planes with slice thicknesses in millimeters. Thus, a detailed evaluation of temporal bone anatomical structures (ossicle chain, the stapes oval window complexes, round window, cochlea, vestibular aqueduct, semi-circular canal, and facial nerve canal) and pathologies, as well as the increased accuracy of CT for diagnosis, was provided.[1,4,5,12–17] With the introduction of high-resolution CT (HRCT) algorithms, studies have been performed with a spatial resolution of less than 1 millimeter; these are known as thin-section thicknesses with ‘edge enhanced’ filters. In addition, reconstruction programs can be applied to these studies.[1,4,5,7,8] In recent years, three-dimensional (3D) multiplanar reformatted imaging obtained from conventional cross-sectional CT data has been used at an increasing frequency.

Many anatomical structures of the middle and inner ear cannot be properly assessed using standard temporal bone imaging techniques, which are performed using axial and coronal sections. Obtaining these sections simultaneously increases both the radiation dose received by the patient and the duration of the examination.[3,18–21] In addition, many patients cannot maintain the position in which the head is brought to backward flexion in the prone position, which is required to obtain coronal images.[1,3,5] Since the dental region is within the field, there will be artefacts in the direct coronal sections of patients with a dental apparatus.[3] To eliminate these restrictions, instead of direct coronal imaging, the concept of obtaining coronal reconstructions from the axial images using thin-slice thickness has been proposed.[2,20,22–29]

Venema et al. attempted to address the question, ‘Can coronal reconstructions obtained from the axial spiral CT data in 0.5-mm-slice thickness take the place of direct coronal sections?’ in a study conducted in 1999.[3] Direct coronal sections and reconstructed coronal images of axial sections were compared by five observers. They also compared the contributions of two group images for diagnosis. It was concluded that there is no significant difference in the image quality between direct coronal sections and reconstructed coronal data. Within the framework of these results, coronal reconstructions obtained from axial images can replace direct coronal sections. Similar results were obtained by Shinaver et al. in 1997.[22]

Fatterpekar et al. in 2006 indicated that three-dimensional (3D) multiplanar reformatted imaging obtained from conventional CT data and 3D volume rendered CT images were used at an increasing frequency. They also emphasized that with the ability to perform rapid reformatting in many planes and to interfere with the spatial orientation, a detailed assessment of temporal bone anatomical structures was provided.[4]

Zhen et al. in 2007 presented three adult cadaver bones scanned by generating petrous bone using multislice CT (MSCT), and a multiplanar reformatted image with a 0.6-mm thickness was obtained.[2] The temporal bone cadaveric specimens were then sliced in cross-sections 0.1 mm in thickness. A total of 50 micro-anatomical structures that could not be assessed with clarity by CT images, obtained using thicker slices, were compared with the multiplanar reformatted (MPR) images. We found that the images obtained by MPR were similar to those in anatomical specimens, and it was concluded that MPR images were adequate for diagnostic knowledge and surgical anatomy.

Lane et al. in 2006 used MSCT with a 64-slice detector to show axial images of the temporal bone acquired in 100 cases and then applied in multiplanar reconstruction. They concluded that the convenient reconstructed images could be used to assess the anatomical structures. As a result, they indicated a need for an additional series for the development of diagnostic accuracy of middle and inner ear diseases by CT.[1]

Layton et al. indicated in 2011 that with improved CT technology, excellent multiplanar reformatting from single axial acquisition data could reduce imaging times and motion artefacts. Small temporal bone structures could be identified confidently using the reformatted images in different planes.[30]

Lim et al. in 2013 evaluated the feasibility of MPR imaging with temporal bone CT for the diagnosis of temporal bone fractures. In the case of a temporal bone fracture in the middle ear cavity, MPR imaging parallel to the fracture line was recommended for further evaluation. The serial oblique images were acquired rectangularly to a fracture line with 0.5-mm intervals in the axial temporal bone scan.[31]

Zhou et al. in 2014 evaluated the oblique axial and coronal planes, on which the tympanic bone remnant was shown, and the ossicular mass appeared to be the largest in size. HRCT evaluation using MPR provided significant benefits. Preoperative measures for individual patients could provide guidance for canaloplasty and tympanoplasty procedures.[32]

In our study, we obtained axial images of temporal bones from patients who were directed to our clinic for temporal bone CT imaging. At the workstation, we opened these images using 0.1-mm intervals. We recognized the left vector of the horizontal axis to be 0º, while the right vector was 180º. We determined the reference planes and reformatted the images, which can reveal the anatomical structures and pathologies of the temporal bone. Our findings were similar to the study performed by Lane et al. in 2006 using a 64-slice detector MSCT.[1] Additionally, the reconstruction of posterior and lateral semi-circular canals was first described by us.

The limitation of our study was the low image quality of the reconstructed images which were performed by spiral CT device.

Using multiplanar reformatted imaging, it is posssible to perform reconstructions in coronal and other planes. Decreasing the radiation exposure and the examination duration allows us to examine more patients and eliminates restrictions associated with patient positioning.[27,29,33] The optimal assessment of temporal bone anatomical structures and pathologies was provided, and the contribution of CT in diagnostic accuracy of temporal bone pathologies increased. Based on the advantages of multiplanar reformatted imaging, radiologists are playing an active role in directing the medical and surgical treatment of middle ear diseases.

Conflict of Interest: No conflicts declared.

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