Zilong Yu
Luo Zhang
Demin Han
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Editors
Zilong Yu
Otolarynology & Head and Neck Surgery
Beijing Tongren Hospital
Beijing, China

Luo Zhang
Otolaryngology Head & Neck Surgery
Beijing Tongren Hospital
Beijing, China

Demin Han
Otolaryngology Head & Neck Surgery
Beijing Tongren Hospital
Beijing, China

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Preface

The ear is mainly composed of the temporal bone, and the temporal bone houses the end organs of hearing and equilibrium, the smallest separated bones and its articulates. The brain nerves (such as the facial nerve) and the carotid artery run through the temporal bone, therefore, the temporal bone is one of the most complex bones in the body, to explore the fine anatomy and radiological feature of the temporal bone will have important clinical and scientific significances.

High resolution computed tomography (HRCT) scan was one of the most frequently used radiological methods for the ear diseases, it provided an important reference for the diagnosis, the surgical procedure, and the prognosis judgment of the ear diseases. However, the spatial resolution of clinical conventional HRCT imaging is relatively low, and the appearance of small canals is not always clear and sometimes may be confused with fractures. In addition, HRCT scan also has significant shortcomings in determining the fine structure of the temporal bone (including the stapes, the incudostapedial articulation, and the fundus of internal auditory canal) and the tiny lesions, such as the diseases of stapes, dislocation of incudostapedial articulation, the dehiscence of the facial nerve canal, etc.

Micro-computed tomography (micro-CT) scan has been used to investigate the structure and density of rodent bone since its very beginnings, due to its high spatial resolution and high contrast in imaging mineralized tissues, and high correlations and excellent agreement between conventional histomorphometry and micro-CT data have been demonstrated. What is more, the availability of micro-CT imaging has increased over the last decade and has shown its utility in many preclinical applications. By providing high-quality two-dimensional and three-dimensional reconstruction with extremely high resolution (5–80μm), micro-CT is regarded as an adequate technique for imaging surface topography of the temporal bone and evaluation of its architecture. Comparison with HRCT (maximum resolution ≈ 500 μm), micro-CT will be one of the more helpful radiological techniques to observe the fine anatomy of the temporal bone and tiny lesions in it, and the three-dimensional models from micro-CT imaging data sets for educational purposes will also be established in the medical literature.

Recently, micro-CT scan technique has been used in the study for the facial canal and its dehiscences, the anatomical characteristics of facial nerve and cochlea interaction, the complex stapes motions, the variations of the human cochlea, the quantitative analysis of the cochlea, the anatomy of the fundus of the internal acoustic meatus, the cochlear nerve implant, the human embryonic development, and so on. To the best of our knowledge, there is no book in English has been published at present to systematically explore the fine anatomy of the temporal bone and the tiny lesion in it.

In this atlas, we observed the anatomical image of the temporal bone with nearly successive slides on axial view, coronal view, and sagittal view. We believe, by doing this can help us understand the normal fine anatomy and HRCT image of the temporal bone. The three-dimensional reconstruction of the temporal bone based on data from micro-CT scan can clearly and accurately show the spatial relationship of the structures in temporal bone. In addition, man-made tiny lesions models, such as the fenestration, dislocation and fracture of the stapedial footplate, and dislocation of the incudostapedial joint, were reconstructed on two-dimensional and three-dimensional images with the micro-CT data, which were hardly recognized on HRCT images.

We wish this atlas can become one of the useful tools to understand the fine anatomy of temporal bone, re-recognize HRCT images, and provide a state-of-the-art teaching method for temporal bone.

Beijing, China
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Zilong Yu
Luo Zhang
Demin Han

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this atlas.

Acknowledgments

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Abstract

Micro-CT (micro-computed tomography) scan with 3D rendering technique was used in this atlas to reconstruct the two-dimensional, three-dimensional structures of the temporal bone and observe the models of man-made tiny lesion models in the temporal bone with extremely high resolution (≈30μm). The images were precise and accurate. We hope this atlas can become a useful tool for understanding the fine anatomy and the image of high resolution computed tomography(HRCT)of the temporal bone.

This atlas included:

I. Two-dimensional reconstructions of the temporal bone were made via micro-CT scanning on axial, coronal, and sagittal view just as HRCT showed. The detailed annotations were also made simultaneously for each image.

II. Three-dimensional reconstructions of the temporal bone were produced using the mimics and 3-matic software based on micro-CT scan data, it included the following structures: the external auditory canal, the ossicular chain, the tensor tympani muscle, the Eustachian tube, the niche of vestibular window, the cochlea, the vestibule and semicircular canals, the vestibular aqueduct, the cochlear aqueduct, the facial nerve, the internal auditory canal and their adjacent structures (such as the jugular bulb, the internal carotid artery), etc.

III. Man-made tiny lesions (the model of diseases) in the temporal bone were reconstructed via micro-CT scan, such as the dislocation of incudomalleolar and incudostapedial joints, the fenestration or dislocation of stapedial footplate, the fenestration of facial canal and lateral semicircular canal, the fenestration and fracture of cochlea, etc.

IV. The ability was compared between micro-CT and HRCT to display the normal structure and tiny lesion models of the temporal bone.

This atlas is available for all levels of otolaryngology and head and neck surgeons, radiologists, related research and teaching personnel.

Keywords

Micro-CT; Temporal bone; Anatomy; Three-dimensional reconstruction; Tiny lesion

Contents

About the Editors

Zilong Yu Department of Otolaryngology and Head and Neck Surgery, Beijing Tongren Hospital, Affiliated Capital Medical University, Beijing, China

Educations

Doctor degree: Shanghai Medical University (Shanghai, China, 1996–1999)

Master degree: Tongji Medical University (Wuhan, China, 1993–1996)

Bachelor degree: Binzhou Medical College (Shandong, China, 1984–1989)

Experiences

Professor: Department of ENT, Beijing Tongren Hospital, Capital Medical University (2011–)

Research fellow: Department of ENT, Innsbruck Medical University (Austria, Jan–Dec, 2004)

Associated professor: Department of ENT, Beijing Tongren Hospital, Capital Medical University (2001–2011)

Postdoctor: Beijing Tongren Hospital, Capital Medical University, Beijing Institute of Otolaryngology (1999–2001)

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Luo Zhang Department of Otolaryngology and Head and Neck Surgery, Beijing Tongren Hospital, Affiliated Capital Medical University, Beijing, China

Demin Han Department of Otolaryngology and Head and Neck Surgery, Beijing Tongren Hospital, Affiliated Capital Medical University, Beijing, China
Chinese Academy of Engineering, Beijing, China

1 Principles and Conditions of Micro-CT Scan

Zilong Yu, Luo Zhang, and Demin Han

1.1 Temporal Bone Preparation and High Resolution CT Scan

1.1.1 Location of the Temporal Bone

The temporal bone is formed by the fusion of five distinct osseous portions, including the tympanic, squamous, mastoid, petrous, and the styloid process. It houses the hearing and vestibular organs, numerous nerves and vessels, and fits into the base of the skull between the sphenoid and the occipital bones, and separates the middle cranial fossa from the posterior cranial fossa.

1.1.2 Temporal Bone Preparation

Twelve temporal bones from six corpses were provided by the Beijing Institute of Otolaryngology. In order to reduce the liquid artifact when micro-CT scanning, the corpses were ventilated for some time to let the fixation liquid (the condition of the corpse can be examined by HRCT scan) discharge via the eustachian tube. After taken out from the corpse, only the primary part of the temporal bone including the external auditory canal, middle ear, inner ear, and internal auditory canal was remained so that the block of the temporal bone could be accommodated by the micro-CT scanner. The block is dissected as following:

Superiorly: arcuate eminence of the anterior semicircular canal.
Inferiorly: stylomastoid foramen.
Laterally: bony opening of external auditory canal.
Medially: petrous apex.
Anteriorly: posterior wall of temporomandibular articulation and the foramen lacerum
Posteriorly: sigmoid sinus.

The block of temporal bone is approximately 5 cm × 4 cm × 3 cm (Fig. 1.1).

1.1.3 High Resolution CT Scan

High resolution computed tomography (HRCT) examinations were performed on the above-mentioned corpses with 1 mm contiguous sections before dissection. The equipment utilized was a Philips Brilliance 64 CT scanner (Philips, the Netherlands). The imaging parameters were as follows: voltage 120 Kv, current 200 mA, matrix 512 × 512, reconstructing section thickness 1 mm. The images were reconstructed using a high resolution bone algorithm. A window width of 4000 Hounsfield Units (HU) and a window center of 700 HU were preferred for reading these high resolution images. The final resolution is 0.65 mm.

The protocol was approved by the Institutional Committee of the Beijing Institute of Otolaryngology.

1.2 The Principles and Conditions of Micro-CT Scan

The basic principle of the micro-CT scan is using the microfocus X-ray tube to scan and project the specimen (such as the small animals): the hard tissues and the related soft tissues on different planes with cone beam, the detector accepts the X-ray which transmits these planes, the X-ray is first converted to the visible light, then converted to electric signal by light-electric converter, this signal is converted to digital signal via Analog to Digital Converter later, the projections are captured along the long axis of the specimen and reconstructed using a software (Inveon Research Workstation).

Z. Yu (✉) · L. Zhang · D. Han
Otolarynology & Head and Neck Surgery, Beijing Tongren Hospital, Beijing, China

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Fig. 1.1 Temporal bone block (right). (1) External auditory canal. (2) Mastoid. (3) Petrous apex

The bilateral temporal bones were scanned, respectively, with the micro-CT scanner (Siemens, Inveon, Germany) (Fig. 1.2). The long axis of the temporal bone parallels to the scan backplane. Scan parameters were as follows: The X-ray source voltage was set to 80 kV and current to 500 μA, image acquisition time: 20 min, auto-reconstruction time: 30 min, the diameter of X-ray: 50 μm, radioactive source: 30.6 mm × 45.9 mm, exposure time: 2000 ms, detector pixel: 3072 × 2048, image:1024 × 1024 pixel, and the resultant resolution was 29.86 μm.

1.3 The Significance and Methods of Two-Dimensional and Three-Dimensional Reconstruction for Temporal Bone

Micro-CT scan can provide the basic knowledge for scientific study and preclinical research. Because of the excellent spatial resolution, micro-CT can also show the two-dimensional and three-dimensional microstructures of the temporal bone clearly, such as the stapes, incudostapedial articulation, the fundus of internal auditory canal, and so on.

The digital data from micro-CT scan is input the computer, the intrastructures of temporal bone are oriented by rotating the image at different directions over and over again, until a certain structure (such as the lateral semicircular canal) is shown on one plane just as shown on HRCT image, then the two-dimensional images on axial, coronal, and sagittal view are built, respectively, three-dimensional reconstruction is made via software-mimics (Materialise.Mimics. Innovation.Suite.Research.v17.0.x64_p30download.com) (Fig. 1.3), and the semi-transparency is made via 3-matic Research 11.0 (x64).

Fig. 1.2 Micro-CT scanner (Siemens, Inveon, Germany)

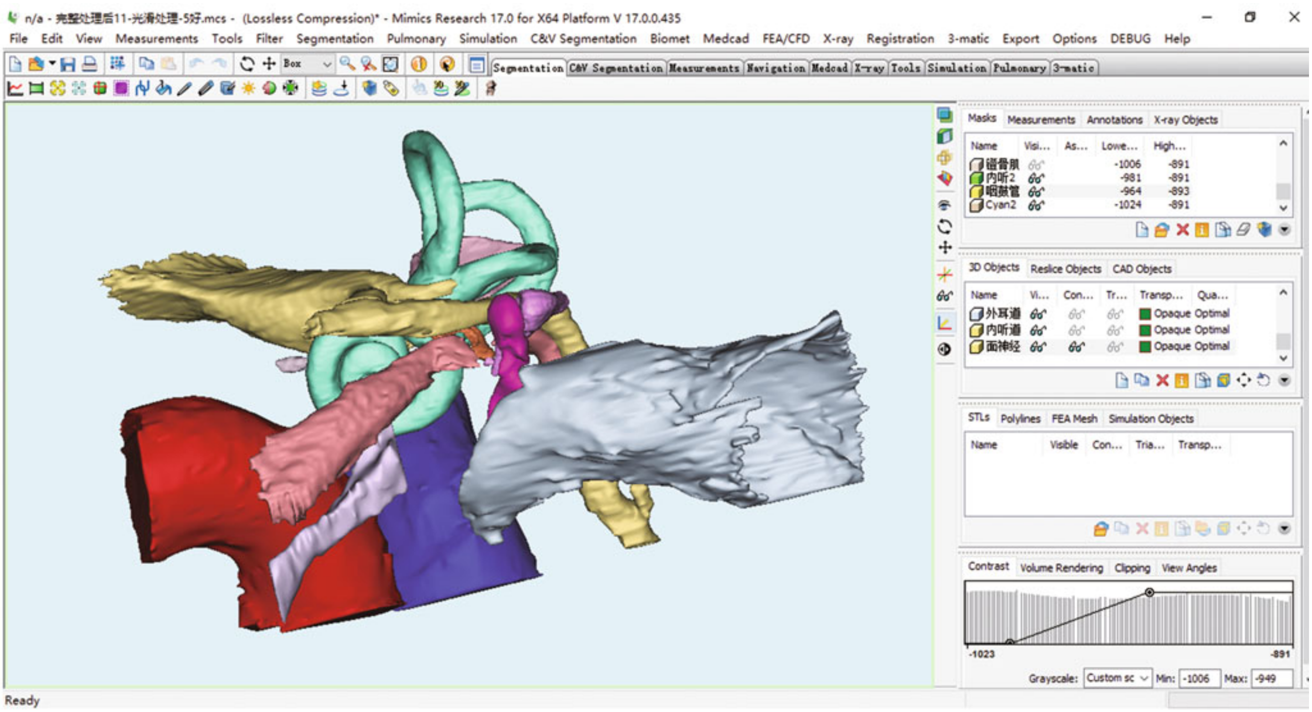

Fig. 1.3 Three-dimension reconstruction interface

1.4 Preparation and Clinical Significance of Man-Made Tiny Lesion Models in Temporal Bone

The diagnosis of the tiny lesions in temporal bone has always bewildered the radiologist and the otologist for a long time because of the insufficient resolution of clinical CT. These diseases, such as the dislocation, fenestration, and fracture of the stapedial footplates, the dislocation of incudostapedial articulation, and the atresia of the vestibular window, were usually identified during the operation at present. In this atlas, we made several tiny lesion models in the temporal bone under the surgical microscope, such as the dislocation, perforation, and fracture of the stapedial footplates et al. (the details see the Chaps. 8 and 9), and observed if these man-made disease models could be shown clearly via micro-CT scanning.

2 Two-Dimensional Reconstruction of Temporal Bone on Axial View

Zilong Yu, Luo Zhang, and Demin Han

2.1 Introduction

Two-dimensional image of the temporal bone is usually reconstructed on the axial, coronal, and sagittal planes. Those three planes own their significant advantages and disadvantages in imaging a certain structure. The structures parallel to the plane of section can be only seen partially or not at all (Valvassori and Mafee 1985). Axial plane can excellently visualize the anterior and posterior walls of the external and internal auditory canals, Eustachian tube, semicanal of tensor tympani muscle, carotid canal, molar tooth configuration formed by the malleus and incus, labyrinthine portion and first genu and tympanic portion of the facial canal, promontory, cochlea, cochlear window(niche), sinus tympani, facial recess, pyramidal eminence, stapedial superstructure, stapedial tendon, lateral semicircular canal, vestibule, fundus of internal auditory canal, vestibular and cochlear aqueducts (Virapongse et al. 1982), but the tegmen tympani, the superior and inferior walls of external and internal auditory canals, the superior and inferior walls of facial canal in tympanic portion, the mastoid portion of facial nerve due to surrounding mastoid air cells (Virapongse et al. 1982) are difficult to identify. Although micro-CT scan owns extremely high resolution, the condition above still exists to some extent.

In this chapter, all the two-dimensional images (Figs. 2.1–2.153) were reconstructed from the left temporal bone, the scanning range was from the arcuate eminence of the anterior semicircular canal to the stylomastoid foramen.

Z. Yu (✉) · L. Zhang · D. Han
Otolarynology and Head and Neck Surgery, Beijing Tongren Hospital, Beijing, China

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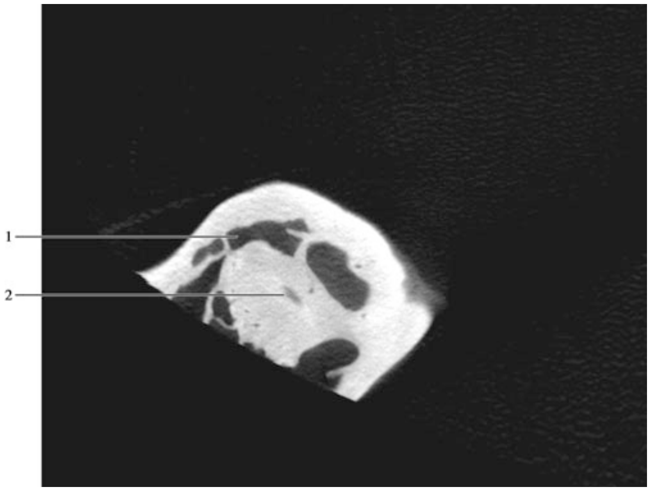


Fig. 2.1 Anterior semicircular canal on axial view. (1) Air cells around the labyrinth. (2) Anterior semicircular canal arcuate

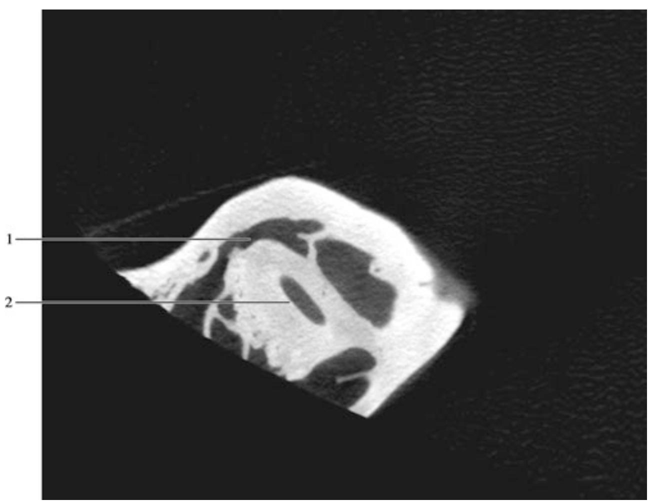


Fig. 2.2 Anterior semicircular canal on axial view. (1) Air cells around the labyrinth. (2) Anterior semicircular canal arcuate

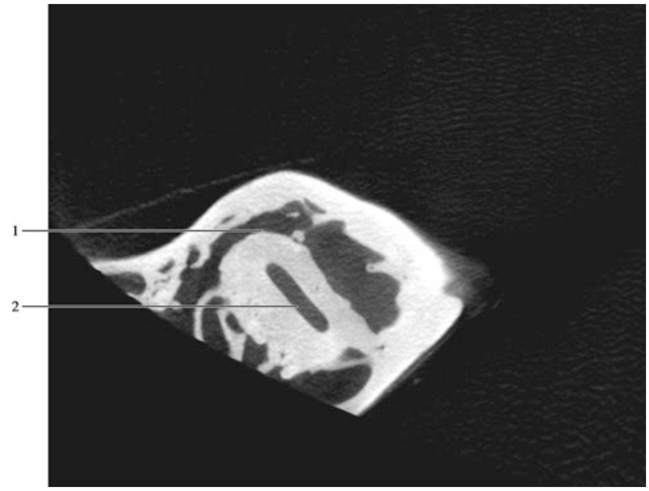


Fig. 2.3 Anterior semicircular canal on axial view. (1) Air cells around the labyrinth. (2) Anterior semicircular canal arcuate

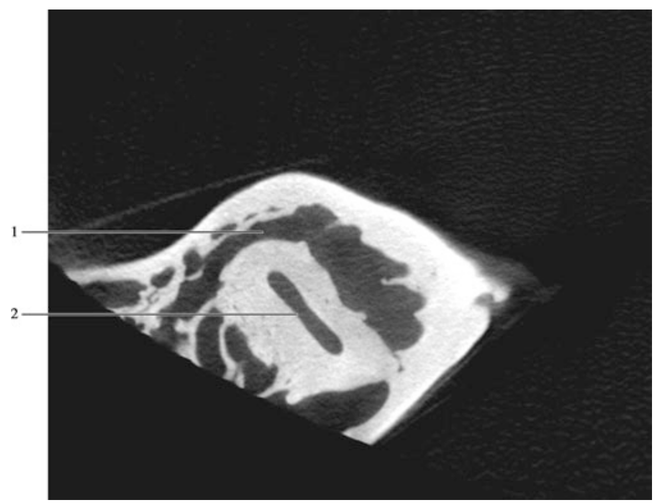


Fig. 2.4 Anterior semicircular canal on axial view. (1) Air cells around the labyrinth. (2) Anterior semicircular canal arcuate

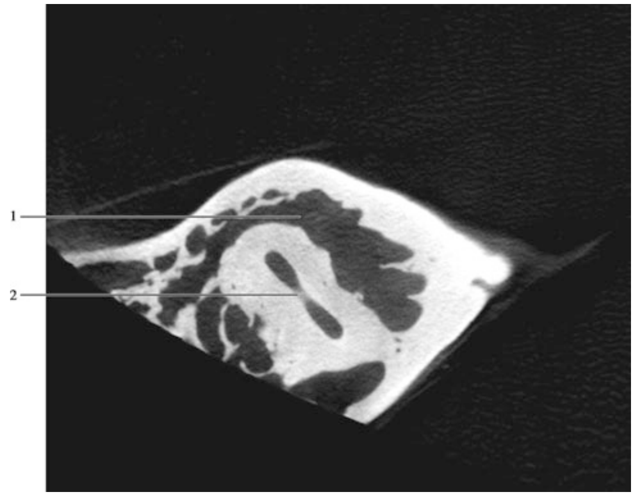


Fig. 2.5 Anterior semicircular canal on axial view. (1) Air cells around the labyrinth. (2) Anterior semicircular canal arcuate

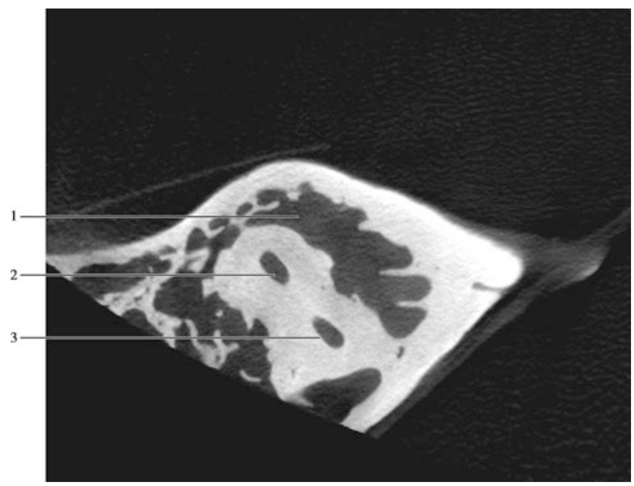


Fig. 2.6 Anterior semicircular canal on axial view. (1) Air cells around the labyrinth. (2) Anterior crus of anterior semicircular canal. (3) Posterior crus of anterior semicircular canal

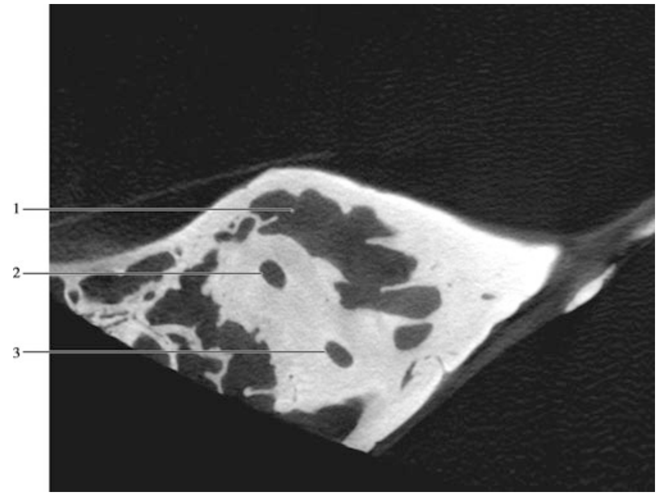


Fig. 2.7 Anterior semicircular canal on axial view. (1) Air cells around the labyrinth. (2) Anterior crus of anterior semicircular canal. (3) Posterior crus of anterior semicircular canal

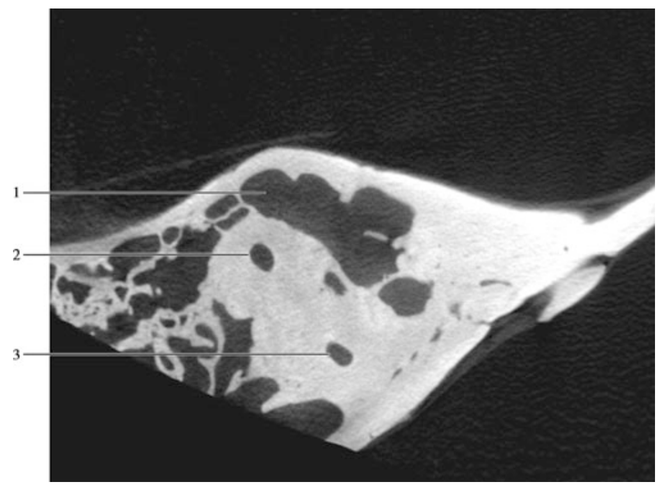


Fig. 2.8 Anterior semicircular canal on axial view. (1) Air cells around the labyrinthine. (2) Anterior crus of anterior semicircular canal. (3) Posterior crus of anterior semicircular canal

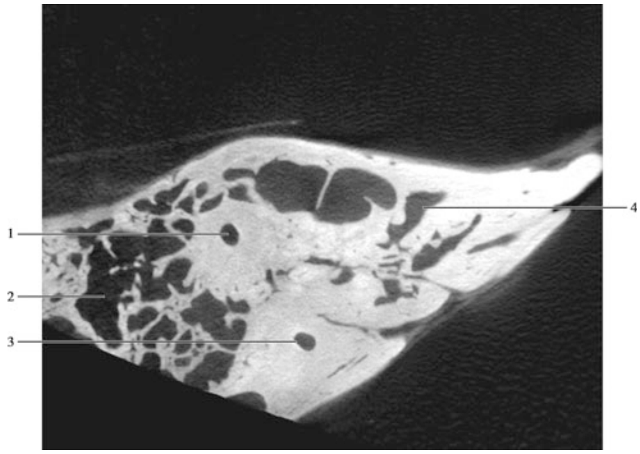


Fig. 2.9 Anterior semicircular canal on axial view. (1) Anterior crus of anterior semicircular canal. (2) Antrum. (3) Posterior crus of anterior semicircular canal. (4) Air cells in petrous apex

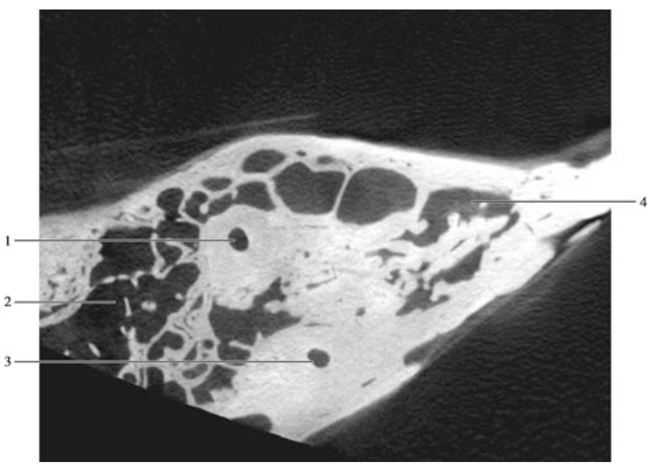


Fig. 2.10 Anterior semicircular canal on axial view. (1) Anterior crus of anterior semicircular canal. (2) Antrum. (3) Posterior crus of anterior semicircular canal. (4) Air cells in petrous apex

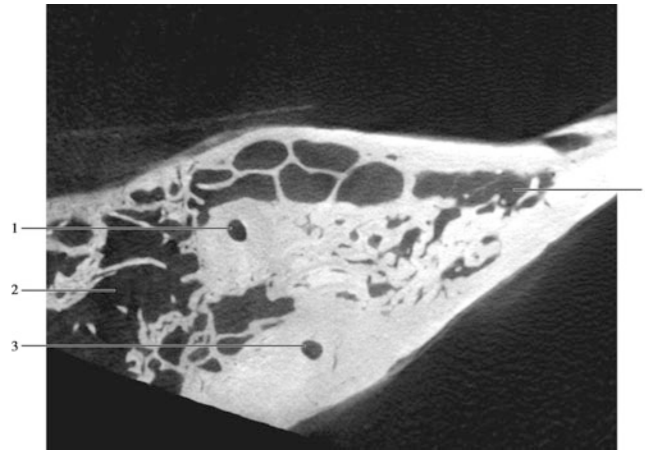


Fig. 2.11 Anterior semicircular canal on axial view. (1) Anterior crus of anterior semicircular canal. (2) Antrum. (3) Posterior crus of anterior semicircular canal. (4) Air cells in petrous apex

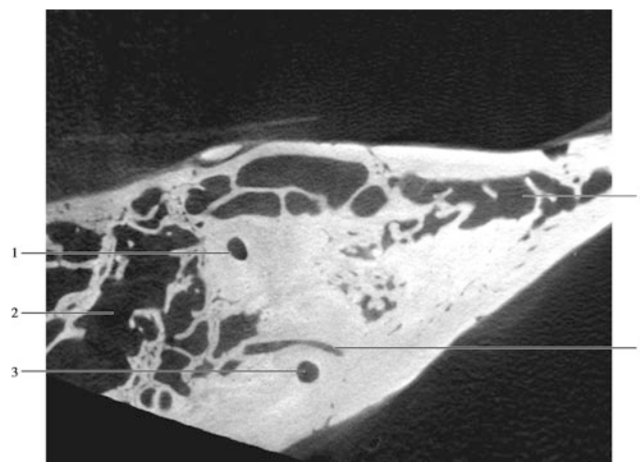


Fig. 2.12 Anterior semicircular canal on axial view. (1) Anterior crus of anterior semicircular canal. (2) Antrum. (3) Posterior crus of anterior semicircular canal. (4) Air cells in petrous apex. (5) Petromastoid canal (subarcuate artery)

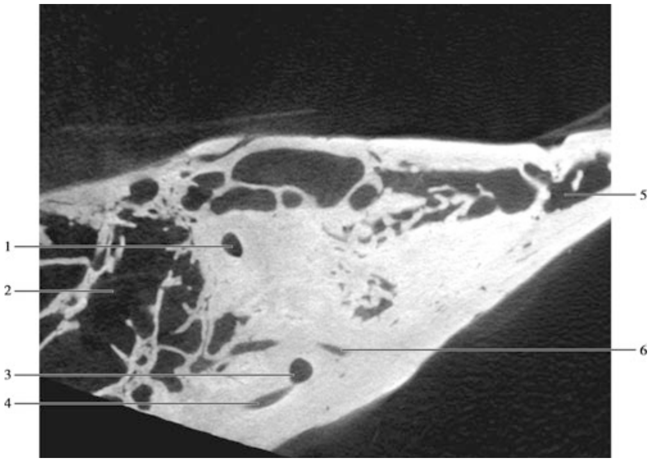


Fig. 2.13 Anterior-posterior semicircular canal and common crus on axial view. (1) Anterior crus of anterior semicircular canal. (2) Antrum. (3) Common crus. (4) Posterior semicircular canal. (5) Air cells in petrous apex. (6) Petromastoid canal

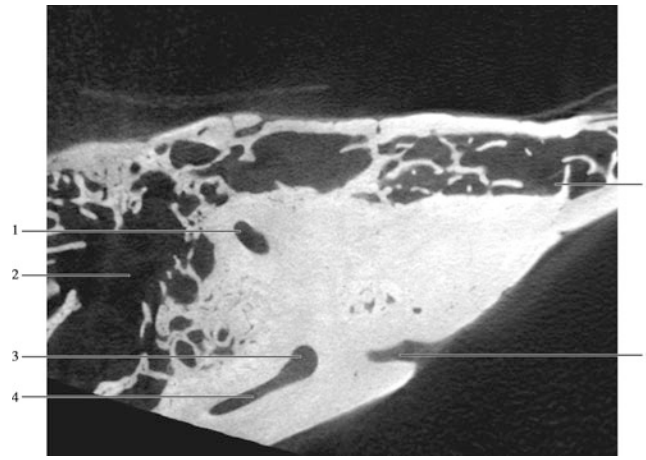


Fig. 2.15 Anterior-posterior semicircular canal and common crus on axial view. (1) Anterior crus of anterior semicircular canal. (2) Antrum. (3) Common crus. (4) Posterior semicircular canal. (5) Air cells in petrous apex. (6) Petromastoid canal

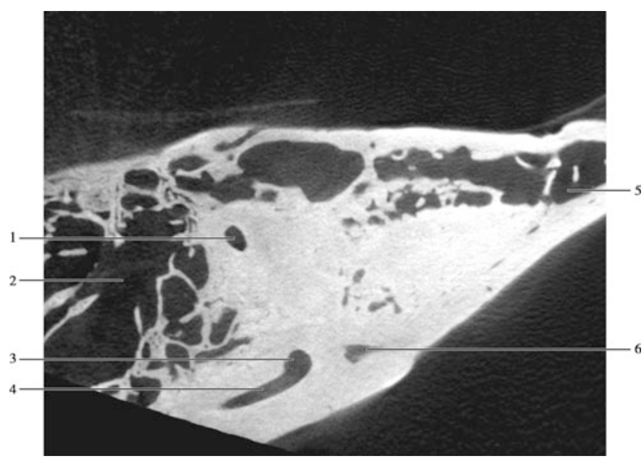
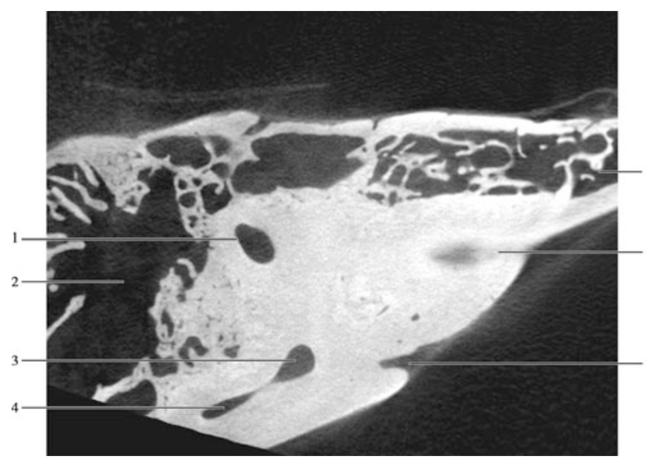


Fig. 2.14 Anterior-posterior semicircular canal and common crus on axial view. (1) Anterior crus of anterior semicircular canal. (2) Antrum. (3) Common crus. (4) Posterior semicircular canal. (5) Air cells in petrous apex. (6) Petromastoid canal



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