AJNR

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AJNR Am J Neuroradiol 1996, 17 (1) 17-21
http://www.ajnr.org/content/17/1/17.citation

Balance and Equilibrium, I: The Vestibule and Semicircular Canals

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In this, our second temporal bone installment, we will emphasize the vestibular portion of the labyrinth, that relating to balance and equilibrium. Before proceeding, we must again remind the reader of the basic structure of the labyrinth: an inner membranous labyrinth (endolymphatic) surrounded by an outer osseous labyrinth with an interposed supportive perilymphatic labyrinth. We recommend perusal of the first installment before continuing if there are any uncertainties in this regard.

The *vestibule*, the largest labyrinthine cavity, measures 4 to 6 mm maximal diameter (1–3) (Figs 1–3). The medial wall of the vestibule is unique in that it contains two distinct depressions (Fig 4). Posterosuperiorly lies the *elliptical recess*, where the *utricle* is anchored. The smaller *spherical recess* lies anteroinferiorly and contains the *saccule*. Between these two concavities lies the *vestibular crest*, a ridge that divides posteriorly into two limbs bounding an additional small depression, the *cochlear recess*, which is the most proximal portion of the cochlear apparatus and leads to the *scala vestibuli*. This area will be discussed in greater detail in subsequent installments.

The *utricle* is firmly attached within the elliptical recess by connective tissue and filaments of the utricular branch of the superior vestibular nerve (4) (Fig 5). The saccule is ovoid and smaller than the utricle. It is adherent to the spherical recess by fibrous tissue and the saccular branch of the inferior vestibular nerve. The utricle and saccule communicate with each other via the utriculosaccular duct. The utricle also communicates with the semicircular canals and endolymphatic sinus (via the utricular duct). Additional saccular communications include the endolymphatic sinus (via the saccular duct) and *cochlea* (via the ductus reuniens). The endolymphatic *duct* arises from the endolymphatic sinus and passes through the vestibular aqueduct of the osseous labyrinth to emerge from an aperture along the posterior surface of the petrous pyramid as the endolymphatic *sac*.

The utricle and saccule are together referred to as the *static labyrinth*, because their function is to detect the position of the head relative to gravity (5–7). They each have a focal concentration of sensory receptors (*maculae*) located at right angles to each other and consisting of ciliated hair cells and tiny crystals of calcium carbonate (*otoliths*) embedded in a gelatinous mass. These otoliths respond to *gravitational pull*; therefore, changes in head position distort and stimulate the hair cells.

On the posterior wall of the utricle reside five openings for the three semicircular ducts (remember that the superior and posterior canals have a common crus). Each semicircular duct is less than one third the diameter of the bony housing from which it is separated by perilymph. The osseous superior semicircular canal is responsible for a ridge known as the *arcuate eminence* along the roof of the petrous bone (8). The lateral semicircular canal is 30° off the horizontal plane and provides much of the anatomic medial wall of the attic and aditus. Each of the semicircular canals is orthogonal with the others. The superior and lateral canals are innervated by the superior vestibular nerve, the posterior semicircular canal by the inferior vestibular nerve (Fig 6).

The semicircular canals are together referred to as the *kinetic labyrinth*, because they respond to rotational or angular acceleration (5–8). Therefore, as a unit, the utricle, saccule and semicircular canals are involved with balance and maintenance of a stable retinal image.

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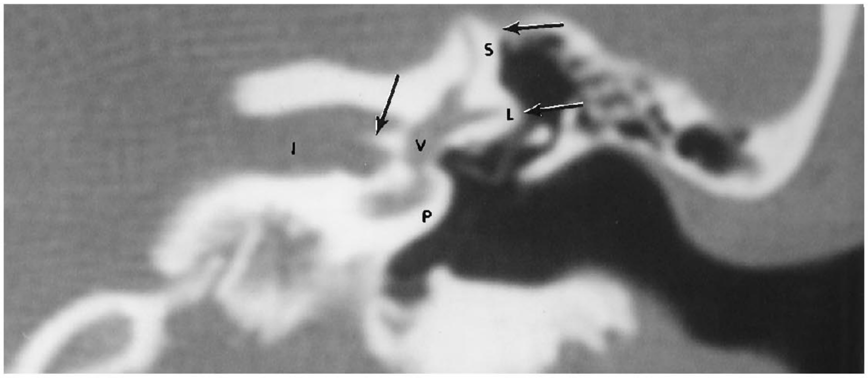
Index terms: Balance; Temporal bone, anatomy; Anatomic moments

AJNR 17:17–21, Jan 1996 0195-6108/96/1701–0017



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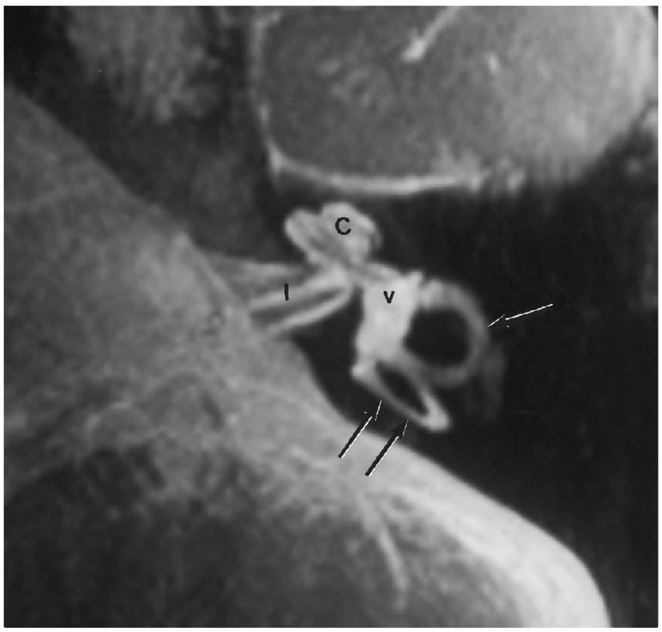

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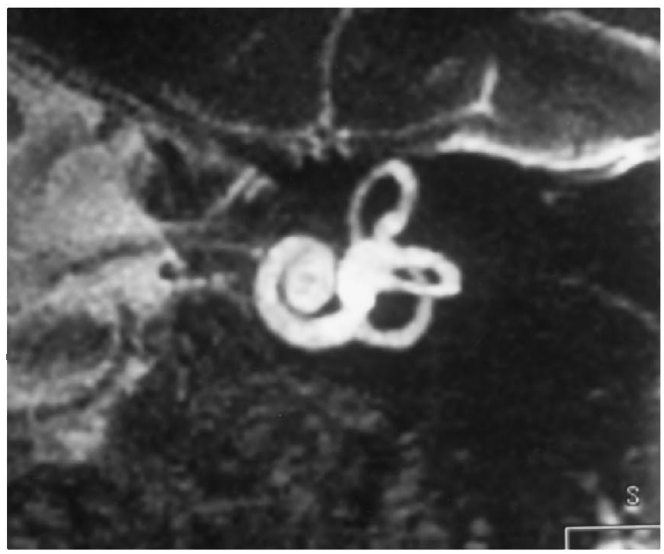

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Fig 1. Coronal CT image at level of vestibule (*V*). *L* indicates lateral semicircular canal; *S*, superior semicircular canal; *P*, promontory (basilar turn of cochlea); *I*, internal auditory canal; and *arrows*, crista falciformis.

Fig 2. Axial T2-weighted high-resolution fast spin-echo MR image of left temporal bone using phased-array coils. *I* indicates internal auditory canal; *C*, cochlea; *V*, vestibule; *single arrow*, lateral semicircular canal; and *double arrows*, posterior semicircular canal.

Fig 3. T2-weighted fast spin-echo MR pulse sequence using phased-array coils and maximum intensity projection technique. Image demonstrates all three semicircular canals emanating from the vestibule as well as the apical, middle, and basilar turns of the cochlea. (Compare with Figure 4.)

Each semicircular canal subtends two thirds of a circle and contains an ampulla for transmission of vestibular nerve fibers. These ampullae are analogous to the maculae of the utricle and saccule in that they contain hair cells. Endolymph flow in response to angular head movement stimulates these hair cells. Each semicircular canal responds to a different rotational axis.

The arterial supply to the vestibule and semicircular canals arises from the labyrinthine branch of the anterior inferior cerebellar artery (4). The posterior, superior, and lateral semicircular canals are supplied via the *anterior vestibular artery*; the capsule and posterior semicircular canal receive their nutrients via the *posterior vestibular artery*.

The thrust of imaging this area is twofold: to identify bony labyrinth detail and to document demineralization, congenital deformity, fractures, and erosive lesions. This is done primarily with computed tomography (CT) (Fig 1). Detailed imaging of the membranous labyrinth is mainly via high-resolution thin-section magnetic resonance (MR) imaging (Figs 2–3). Gadolinium enhancement most often occurs with

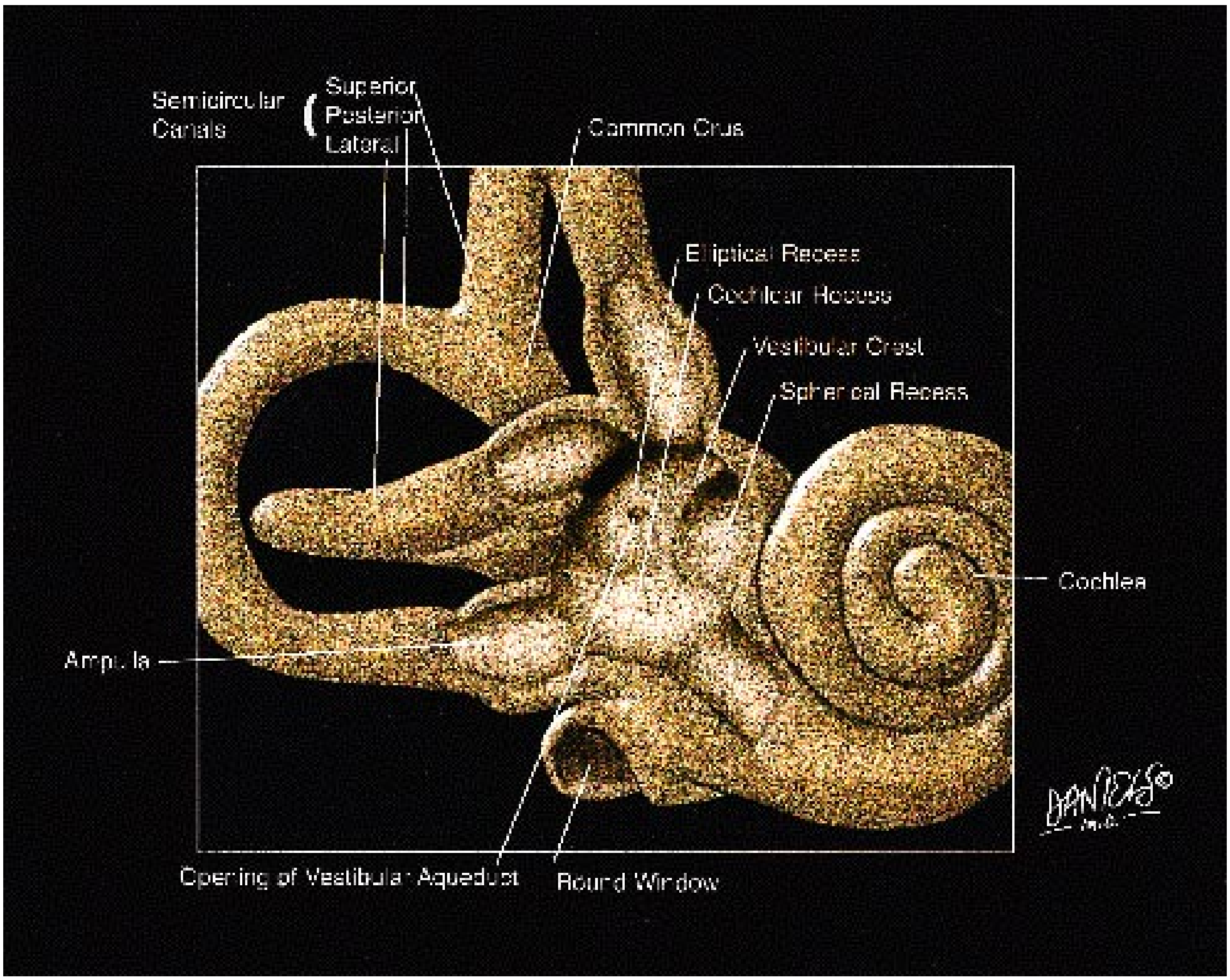

Fig 4. Cut-away lateral view of the right osseous labyrinth. In the medial wall of the vestibule are depressions representing the spherical, elliptical, and cochlear recesses, which contain the saccule, the utricle, and the posterior part of the cochlear duct, respectively. The vestibular crest separates the spherical and elliptical recesses (modified from Williams et al [9], Ferner [10], Proctor [11], and Netter and Colacino [12]).

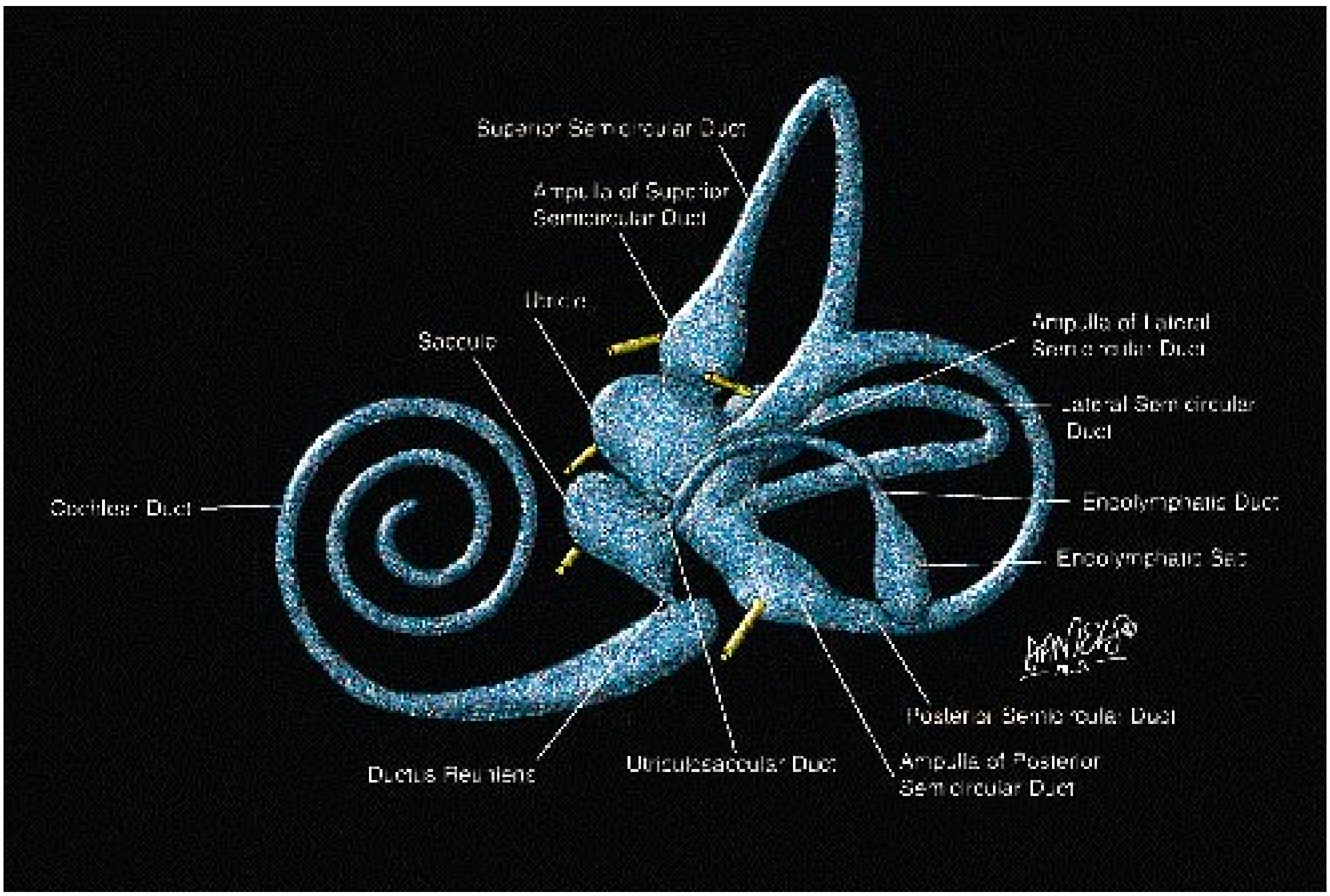

Fig 5. Medial view of the right membranous labyrinth. Demonstrated are the saccule and utricle communicating with each other and with the endolymphatic duct extending to the endolymphatic sac. Also shown are the semicircular ducts communicating with the utricle (modified from Williams et al [9], Ferner [10], Proctor [11], and Netter and Colacino [12]).

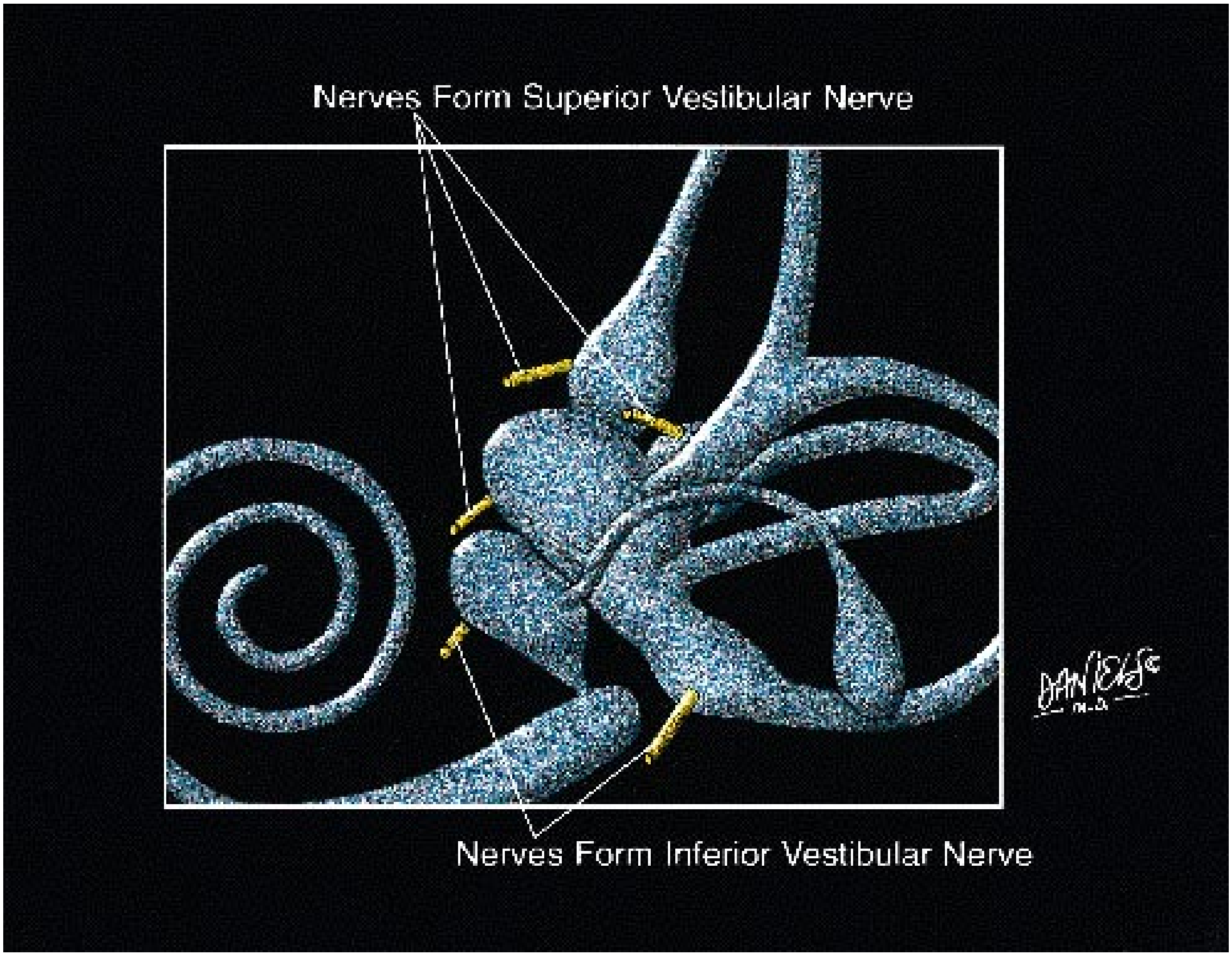

Fig 6. Insert view of the membranous labyrinth from Figure 5. Labeled are nerve branches extending from the utricle and ampullae of the superior and lateral semicircular canals, which form the superior vestibular nerve, and branches extending from the saccule and ampulla of the posterior semicircular canal, which form the inferior vestibular nerve.

labyrinthitis. Hyperintensity on nonenhanced T1-weighted images is considered the result of hemorrhage. Obliteration of the membranous labyrinth may be *ossific* (labyrinthine ossificans), best seen with CT, or *fibrous* (earlier stage), perhaps most easily appreciated with newer MR sequences that emphasize thin sections and T2 weighting. The normally uniformly hyperintense signal of the endolymph and perilymph would be altered in this circumstance.

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