DIAGNOSTIC VESTIBULAR POCKET GUIDE

Evaluation of Dizziness, Vertigo, and Imbalance

Julie A. Honaker, PhD, CCC-A

Plural Publishing Inc.

PLURAL PUBLISHING
INC.

5521 Ruffin Road
San Diego, CA 92123

e-mail: information@pluralpublishing.com
Website: https://www.pluralpublishing.com

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Preface

The goal of the *Diagnostic Vestibular Pocket Guide* is to provide hands-on, evidence-based material for students and clinicians in the trenches of vestibular evaluation. This quick reference evolved from experiences teaching vestibular assessment in both academic and clinical settings. The book is designed for patient care and complements core theories provided in comprehensive texts dedicated to balance assessment and management. The reader should be familiar with vestibular anatomy and physiology, along with a basic understanding of key concepts. The pocket guide is organized and condensed to encompass all facets of the clinical evaluation: appointment preparation, formulating the clinical question(s), vestibular screening measures, and appropriate objective testing. The work is innovative as specific chapters target common disorders and evaluation, modifications to vestibular evaluation for both ends of the lifespan, the vestibular care path, the framing of clinical impressions, and medical referral criteria. Well-known treatments are briefly discussed concerning appropriate usage and based on accurate diagnosis. Emphasis is placed on the availability of a portable reference (pocket) guide to carry throughout the clinical appointment—an invaluable resource for students and providers in the clinical setting.

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Reviewers

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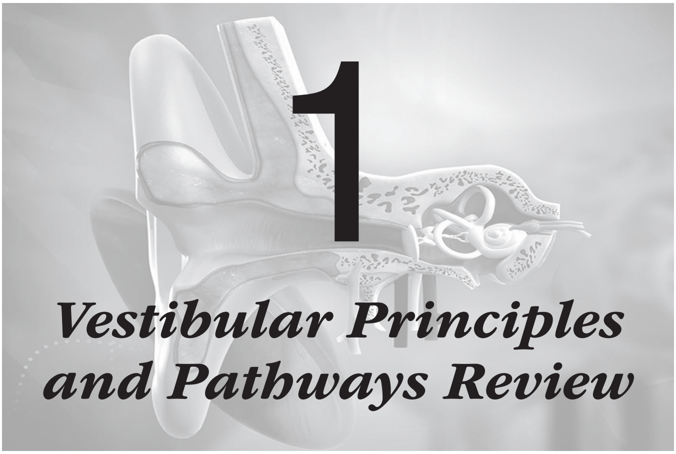

1 Vestibular Principles and Pathways Review

SENSORY MODALITIES OF BALANCE CONTROL

The balance system coordinates compensatory eye, head, and body movements allowing for clear vision with head and body activities, perception of movement and direction, and postural control. The three primary systems that contribute to balance control include vestibular, visual, and somatosensory.

- The ***vestibular system*** is an internal sensory reference that provides cues of space perception and both direction and velocity of movement. A central role of this system is to stabilize retinal images during head movements.
- The ***visual system*** is an external sensory reference that indicates environmental movement and position.
- The ***somatosensory system*** is also an external sensory reference, including both proprioception and kinesthetics that detect changes in the support surface.

ANATOMY AND PHYSIOLOGY OF THE VESTIBULAR SYSTEM

Located within the petrous portion of the temporal bone, two labyrinths (bony and membranous) comprises the vestibule, semicircular canals, and cochlea (Baloh & Honrubia, 2001). The bony labyrinth is a hollow chamber that houses the sensory organs for hearing (anterior part) and balance (posterior part). Perilymph fluid fills the space.

The membranous labyrinths (right and left) contain the cochlea and five vestibular organs: the utricle and saccule (otolith organs), and the three semicircular canals (horizontal, anterior/superior, and posterior; Figure 1–1). The vestibular organs contain receptors responsible for sensing both linear (otolith organs) and angular (semicircular canals) acceleration and deceleration. The membranous labyrinth is suspended within the bony labyrinth but is adhered to ligaments, so only the fluid within the membranous labyrinth moves with head and body movements. Endolymph fluid fills the membranous labyrinth. The membranous labyrinth also contains the endolymphatic duct and sac.

VESTIBULAR ORGANS

Semicircular Canals (SCCs)

Each SCC is positioned orthogonal to one another (at 90° angles) and responsible for converting angular acceleration into electrical code to interpret head and body movements. Vertical SCCs are positioned at 45° angles to the mid-sagittal plane, and

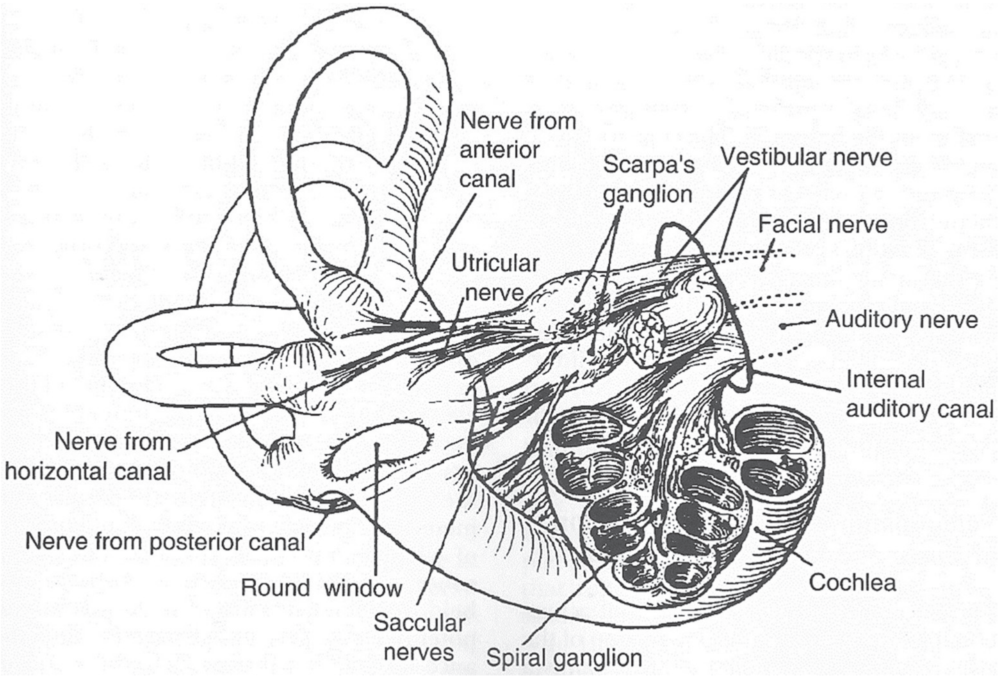

Figure 1–1. The membranous labyrinth and innervation of the labyrinth. From Baloh and Honrubia, 2001, pp. 11, Figure 1–6. Reproduced with permission of the Licensor through PLSclear.

horizontal SCCs are pitched upward approximately 30° (Schubert & Shepard, 2016). The SCCs work as functional pairs, concerning parallel planes:

- Left and right horizontal canals
- Right anterior canal and left posterior canal (RALP)
- Left anterior canal and right posterior canal (LARP)

When one SCC of the "functional pair" is excited, the other (paired) canal is inhibited. This push/pull pairing of the canals is necessary for the central nervous system (CNS) to process asymmetrical neural activity and coordinate corresponding motor output.

Each SCC contains an expanded end called the ***ampulla***. Within the ampulla is the ***crista ampullaris*** (sensory epithelium) that contains type one and type two hair cells and supporting cells. Positioned directly on top of the crista is a gelatinous structure called the ***cupula*** that extends to the top of the ampulla. The density (specific gravity) of the cupula (and the surrounding endolymph fluid) is similar in density to water; thus, the SCCs are non-gravity sensitive structures.

Stereocilia project from the sensory hair cells into the cupula. The stereocilia are bundled together and arranged in a pattern of increasing length from short to tall, with the tallest cilia called the ***kinocilium***. Changes in membrane potentials of the hair cell result from the movement of the cupula (either moving toward or away from the utricle) due to the direction of endolymph flow within the SCC (Schubert & Minor, 2004). The kinocilium is important for ***morphological polarization***. When stereocilia are moved toward the kinocilium, the neural firing activity in that hair cell is increased (opening of transduction channels). If moved away from the kinocilium, the neural firing activity is decreased (closing of transduction channels). Ewald's 2nd and 3rd laws (Ewald, 1892) describe the endolymph flow patterns responsible for changes in neural activity within the horizontal and vertical SCCs (Table 1–1).

Otolith Organ System

Each utricle and saccule are responsive for converting linear acceleration/linear deceleration and gravitational forces into an electrical code to interpret perception and orientation (Schubert & Shepard, 2016). The organs act as gravito-inertial force sensors.

- Utricles are positioned horizontally and sense horizontal linear acceleration.
- Saccules are positioned vertically and detect vertical linear acceleration.

Each otolith organ contains a ***macula*** where hair cells and supporting cells are embedded. Stereocilia extends from the hair cells into a gelatinous layer called the ***otolithic membrane***. This layer contains calcium carbonate crystals called ***otoconia***, which are dense structures with a specific gravity greater than the surrounding endolymph, allowing the otolith organs to be gravity sensors (Schubert & Shepard, 2016).

The otolith organs are divided into two sections by a central line called the ***striola,*** or "line of polarity reversal" (Curthoys et al., 2018, p. 2). Similar to the SCCs, the stereocilia within the otolith organs are also arranged in a pattern of increasing length toward the kinocilium. The otolith organs also work as functional pairs (both saccules as one pair, and