



VESTIBULAR
HEALTH

Vertigo, dizziness, & vestibular rehab after posterior circulation stroke

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Central South Regional Stroke Network - November 16, 2021

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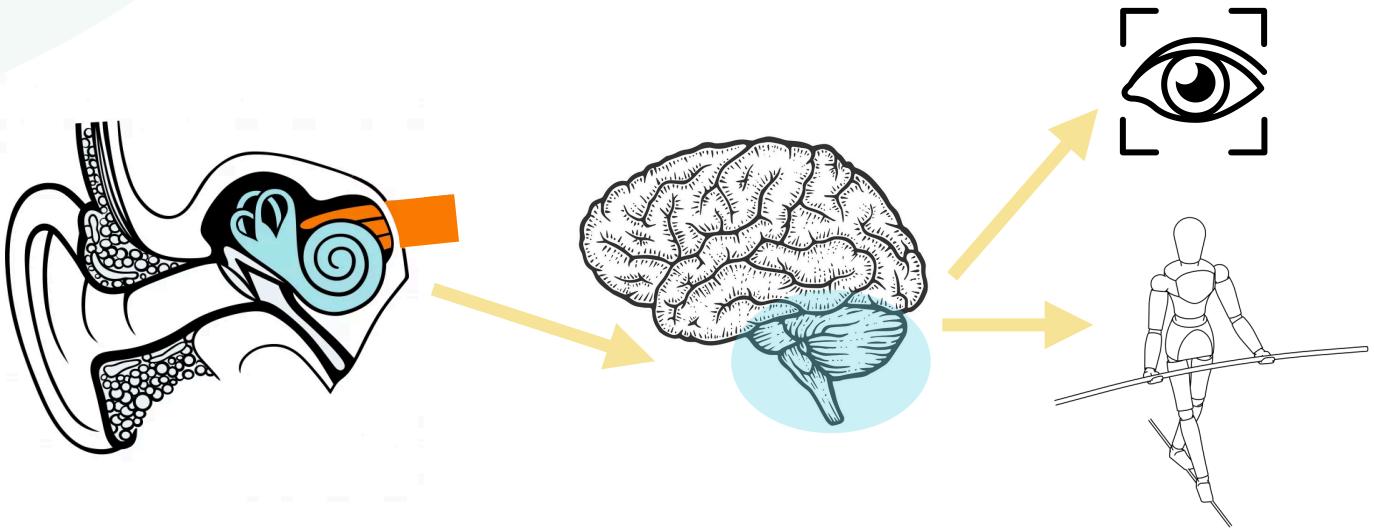
Overview

- Vestibular system (peripheral & central)
- Vestibular symptoms after posterior circulation stroke
- DDx of positional dizziness
- Role of vestibular rehabilitation in stroke rehab

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Vestibular system



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Functions of the vestibular system

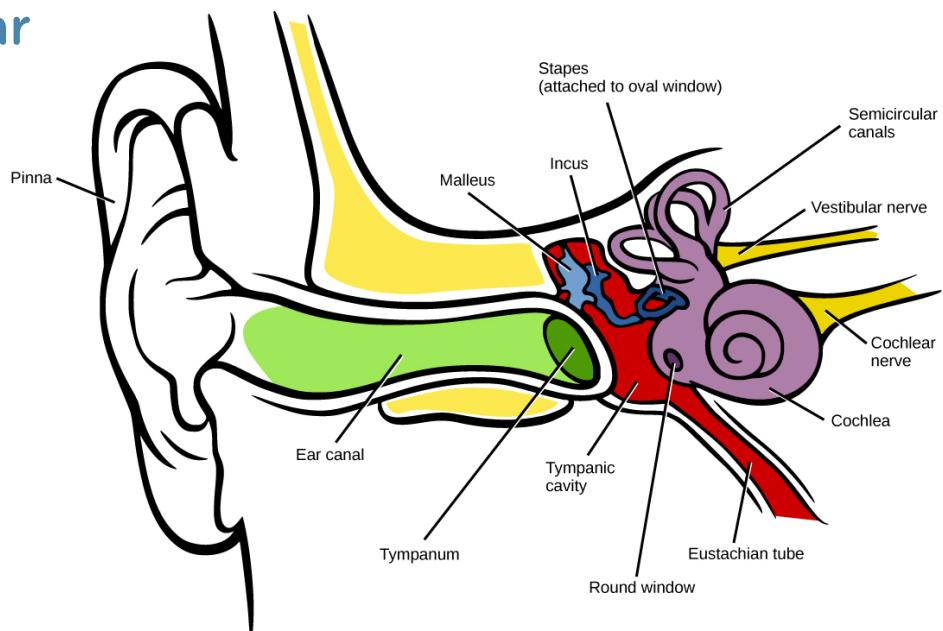
- Gaze stability
- Maintaining posture & balance
- Spatial orientation

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Inner ear

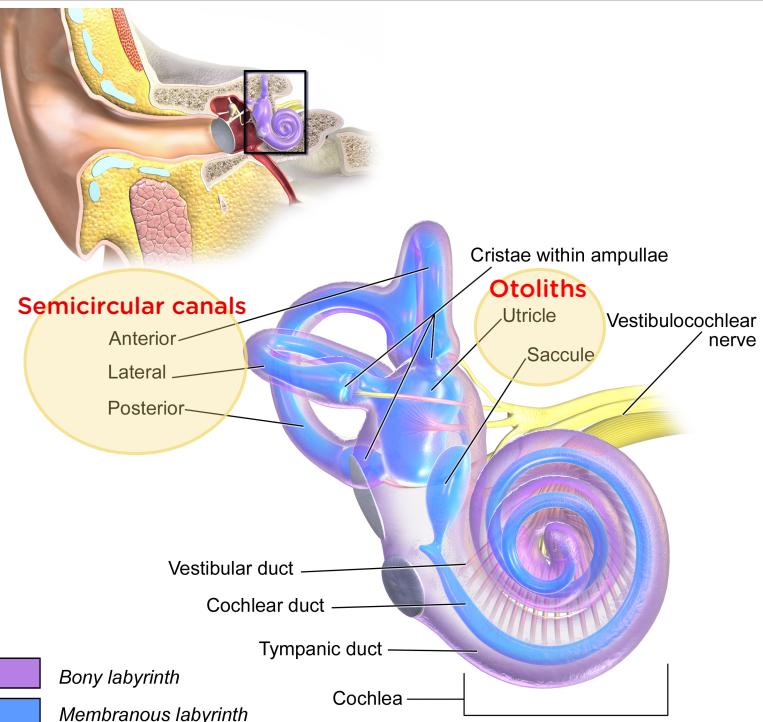


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Inner ear



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Vestibulo-ocular reflex (VOR)

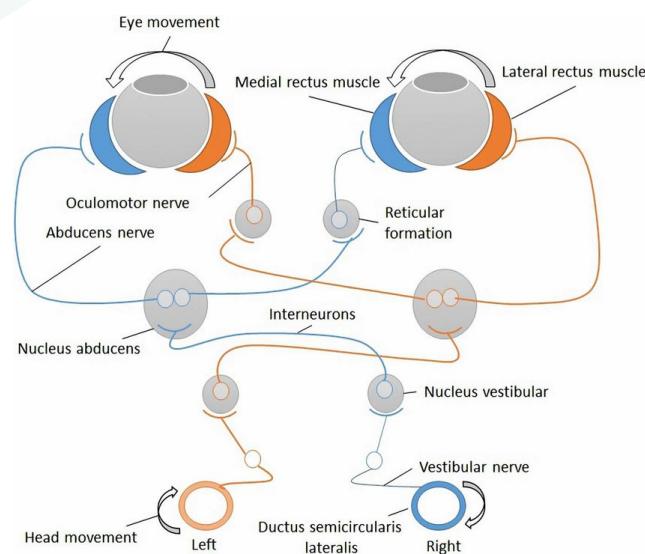
- Gaze stability
- Allows clear & stable vision during head movement
- Requires intact peripheral vestibular system, CN XIII, & central vestibular system
- Modulated by the cerebellum

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VOR



Semicircular canals sense head rotation → vestibular nerve → vestibular nuclei → coordinated motor response of extraocular muscles

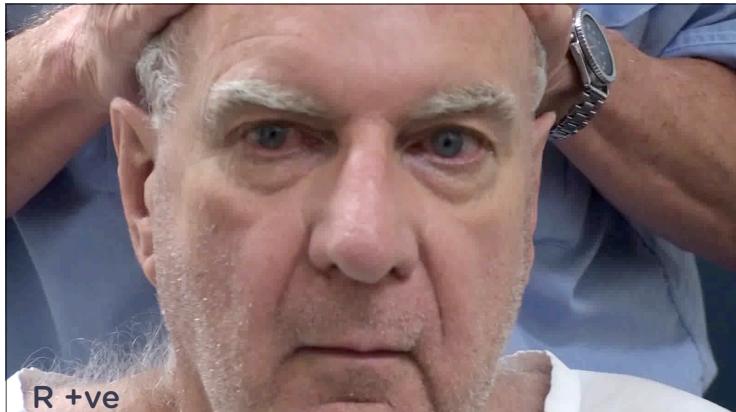
Eye movement equal & opposite to head movement

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VOR



Evaluated using head impulse
(Halmagyi-Curthoys test)

- Patient is asked to maintain visual fixation on a target
- Passive rapid head rotation in small range of motion
- Abnormal = corrective saccade

(video from Chen et al., 2014)

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Vestibulospinal reflex (VSR)

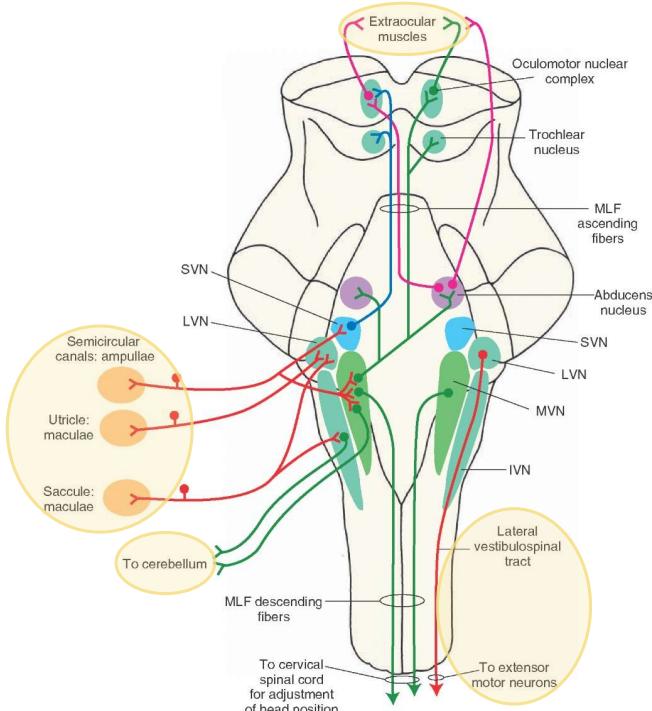
- Maintenance of balance and postural stability
- Semicircular canals and otoliths sense head tilt → vestibular nerve → vestibular nuclei → vestibulospinal tracts to spinal cord → extensor activity on side to which head is inclined, flexor activity on opposite side
- Cervical reflexes: vestibulocolic reflex, cervicoocular reflex

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Vestibular pathways

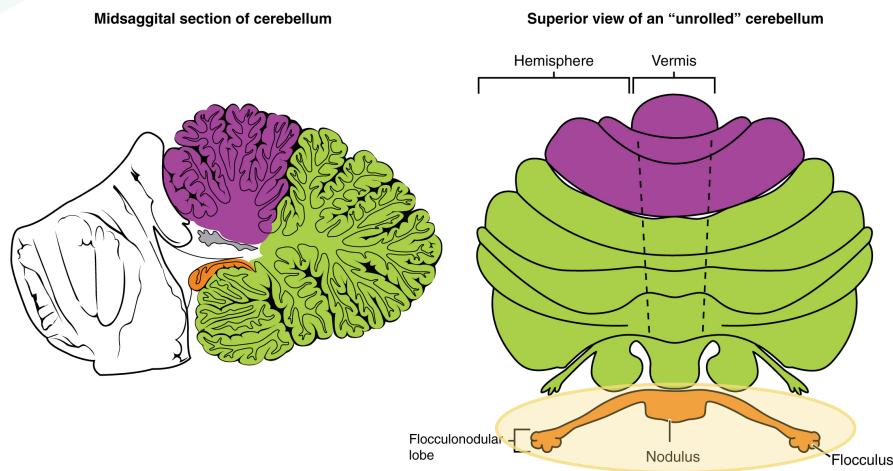


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Vestibulocerebellum



Flocculonodular lobe
& adjacent vermis

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Vestibulocerebellum

Receives input from the vestibular nuclei

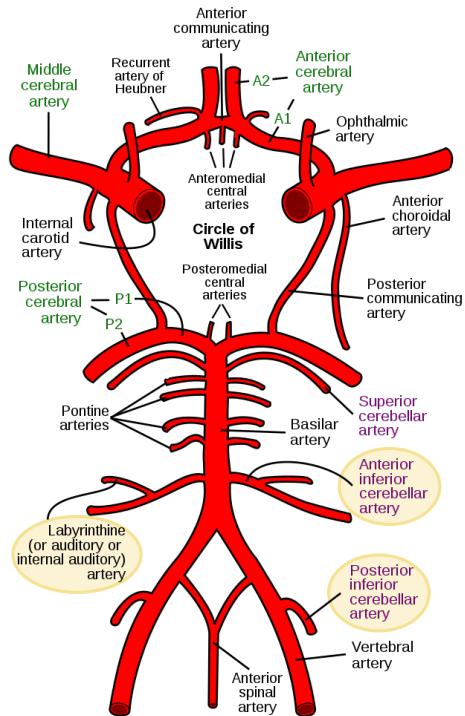
Functions:

- Gaze holding
- Smooth pursuit
- VOR cancellation
- Mediates adaptation of VOR

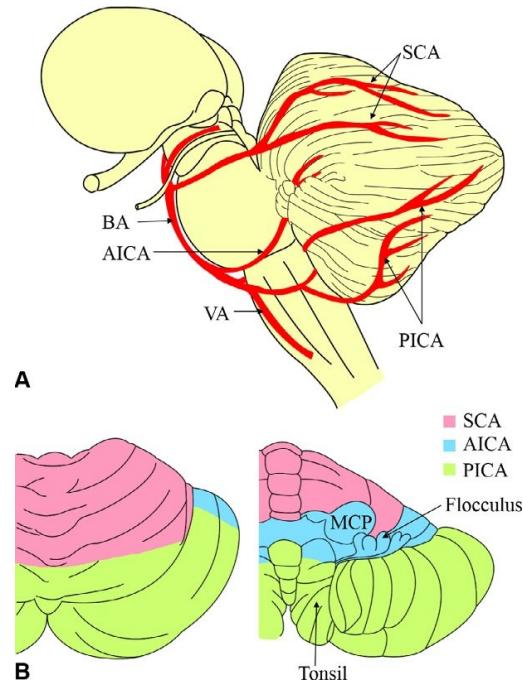
Dysfunction leads to:

- Gaze evoked nystagmus
- Saccadic smooth pursuit
- Inability to suppress VOR

Posterior circulation



Cerebellar Blood Supply



(figure from Choi et al., 2016)

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AICA

- Supplies peripheral & central vestibular structures
- Internal auditory artery is a branch of AICA - supplies CN VIII, cochlea, vestibular labyrinth
- Infarct leads to combined peripheral & central signs and symptoms
- Vertigo, hearing loss, gait ataxia, cerebellar dysmetria
- Central oculomotor signs - impaired smooth pursuit, bidirectional gaze evoked nystagmus
- Partial ocular tilt reaction (OTR) & deviation of subjective vertical - infarct of inner ear or root entry zone of CN VIII

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PICA

- Lateral Medullary or Wallenberg Syndrome
- Medial branch of PICA supplies inferior vermis including nodulus
- Nodulus is critical for modulating the VOR
- Infarct leads to vertigo, nausea, vomiting, postural instability & lateropulsion

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Vestibular symptoms

- Dizziness
- Vertigo
- Disequilibrium
- Oscillopsia
- Visual motion sensitivity

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Dizziness

Non-specific

- Lightheaded
- Rocking
- Swaying
- Floating
- Off balance
- Unsteady
- Foggy
- Woozy
- Spinning
- Pre-syncope
- Depersonalization
- Derealization

Vertigo

Illusion of movement of self or surroundings

- Rotation, spinning, dropping, shifting
- Triggered by head movement, position changes, or spontaneous
- +/- other ear symptoms (e.g. tinnitus, fullness, hearing)

Disequilibrium

Unsteadiness or imbalance

- “People must think I’m drunk”
- Instability standing or walking
- Worse with movement
- Worse with head movement

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Pulsion & alterations in subjective vertical

Feeling pushed or pulled
Altered perception of vertical

Peripheral:

- Otolith dysfunction

Central:

- PICA/Wallenberg
(ipsiversive, abN visual & postural vertical)
- Pusher syndrome
(contraversive, abN postural vertical)

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Assessing subjective visual vertical



“Bucket Test”

(Celis-Aguilar et al., 2018; figure from Luvizutto et al., 2020)

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Oscillopsia

Blurry or unstable vision with head movement

- Feeling of “lag” - eyes do not keep up with head
- Bouncing, bobbing, or blurry vision with walking
- Related to VOR impairment

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Visual motion sensitivity

Dizziness with complex visual stimulation

- Intolerance for reading, computer, TV
- Intolerance for visually busy environments
- “Grocery store syndrome”
- Visual-vestibular mismatch

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Dizziness with position changes

DDx includes:

- Orthostatic hypotension (common)
- BPPV (common)
- Central positional nystagmus (less common, can result from stroke)

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Benign Paroxysmal Positional Vertigo (BPPV)

- The most common cause of vertigo in adults
- More common with older age
- Peak incidence at age 50-80yrs
- >60yrs annual prevalence of 3.4%
- Under age 50, the most common cause is head injury
- Associated with increased falls risk & impairment in ADLs

(Bhattacharyya et al, 2017; Froehling et al., 1991; Neuhauser & Lempert, 2009; von Brevern et al., 2006)

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BPPV symptoms

Vertigo lasting ≤60 sec

Triggered by changes in head position relative to gravity

- Lying down
- Turning in bed
- Bending forward
- Looking up
- Also: getting up from lying down, head turns, rising from bent over position

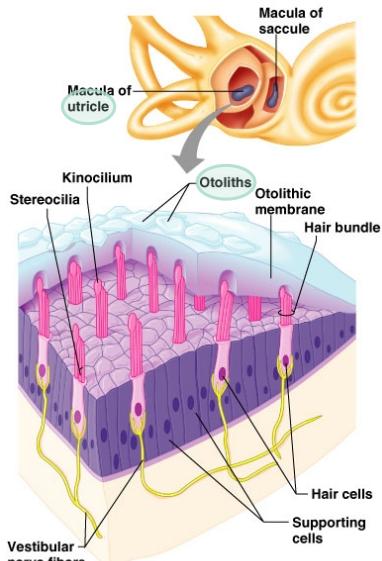
Often with nausea, vomiting, imbalance, motion sensitivity, anxiety

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BPPV etiology



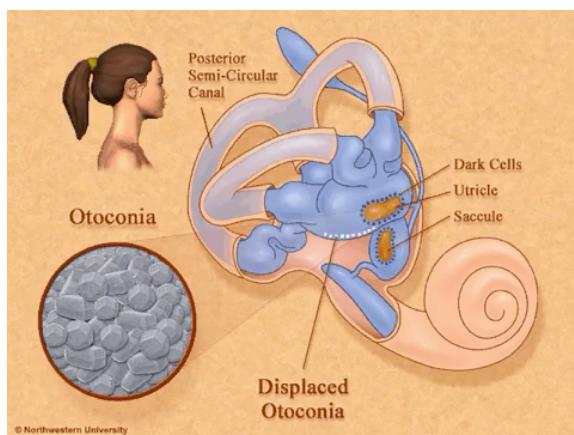
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- Calcium carbonate crystals (otoconia) embedded in the utricle
- Otoconia become dislodged from utricle
- Otoconia migrate into the semi-circular canal(s)



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BPPV etiology



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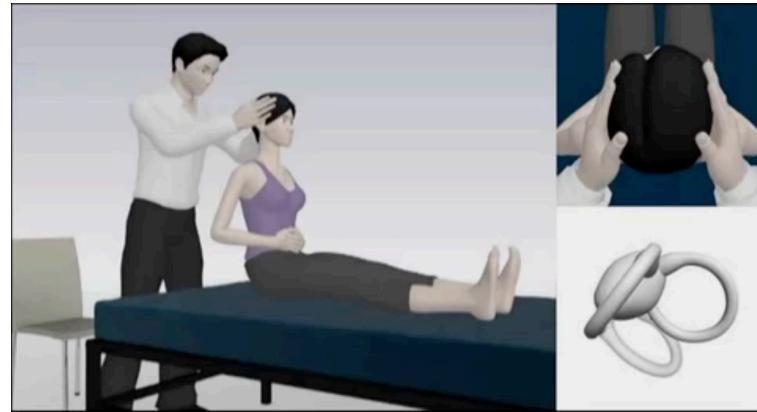
- Head movements cause the displaced otoconia to move
- Sends false signals to the brain & eye muscles
- Causes vertigo & nystagmus



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BPPV assessment

Dix-Hallpike



(video from Kim & Zee, 2014)

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BPPV assessment

Head roll



(video from Kim & Zee, 2014)

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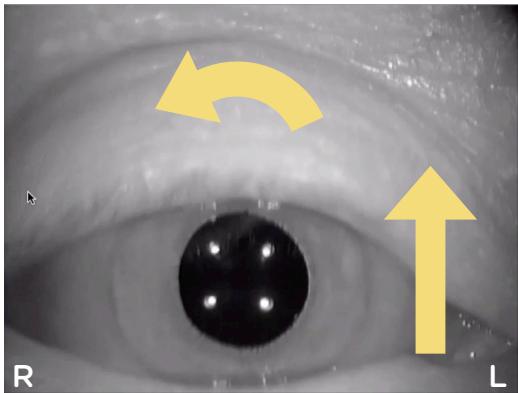


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BPPV assessment

Observe pattern of nystagmus to identify affected side & canal

- Latency
- <60 sec
- Upbeat with torsion (posterior canal)
- Horizontal (horizontal canal)

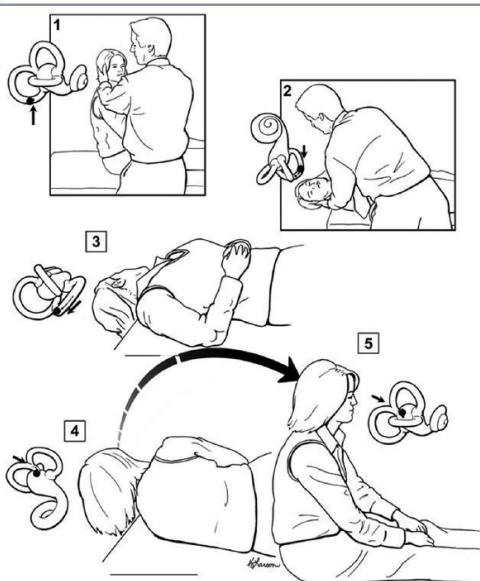


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BPPV treatment



Repositioning maneuvers specific to the affected side & canal

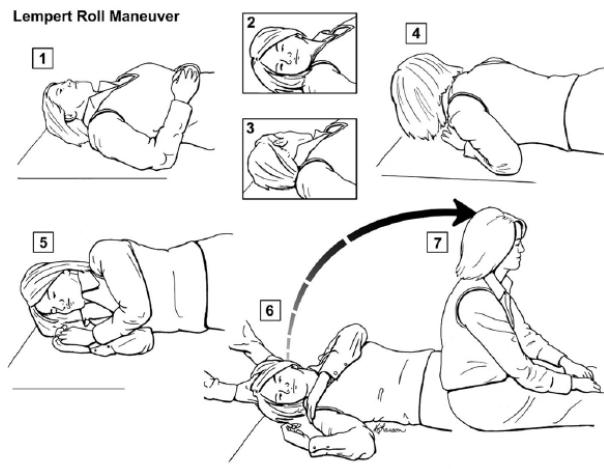
(Bhattacharyya et al, 2017)

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BPPV treatment



Repositioning maneuvers
specific to the affected
side & canal

(Bhattacharyya et al, 2017)

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BPPV treatment

Clinical Practice Guideline

Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update)

Neil Bhattacharyya, MD¹, Samuel P. Gubbels, MD²,
Seth R. Schwartz, MD, MPH³, Jonathan A. Edlow, MD⁴,
Hussam El-Kashlan, MD⁵, Terry Fife, MD⁶,
Janene M. Holmberg, PT, DPT, NCS⁷, Kathryn Mahoney⁸,
Deena B. Hollingsworth, MSN, FNP-BC⁹, Richard Roberts, PhD¹⁰,
Michael D. Seidman, MD¹¹, Robert W. Prasad Steiner, MD, PhD¹²,
Betty Tsai Do, MD¹³, Courtney C. J. Voelker, MD, PhD¹⁴,
Richard W. Waguespack, MD¹⁵, and Maureen D. Corrigan¹⁶

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SAGE

Strong evidence to
support diagnostic &
treatment maneuvers

80 to 90% success rate

(Bhattacharyya et al, 2017)

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Central positional nystagmus/vertigo

Features:

- Downbeat/upbeat without torsional component
- No latency
- Persistent
- Does not fatigue
- Sometimes asymptomatic or only mild symptoms
- Does not respond to repositioning maneuvers

Central positional nystagmus/vertigo

Possible causes:

- Lesion in cerebellar nodulus or uvula
- Stroke
- Chiari malformation
- Cerebellar degeneration
- Tumour
- Multiple sclerosis

What is vestibular rehab?

- Exercise-based program
- Designed by physiotherapists with post-graduate training
- Improve problems caused by vestibular disorders

Goals:

- Reduce vertigo & dizziness
- Improve gaze stability
- Improve balance
- Improve mobility
- Prevent falls

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Vestibular rehab assessment

Clinical interview to understand symptoms, priorities, & functional goals

Patient reported outcome measures

- Dizziness Inventory
- Activity Specific Balance Confidence Scale
- Dizziness Catastrophizing Scale

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Vestibular rehab assessment

Clinical tests of peripheral vestibular function

- Head impulse
- Dynamic Visual Acuity
- Post-headshake nystagmus

Clinical tests of central vestibular function

- Oculomotor assessment (with & without fixation)
- VOR cancellation
- Cerebellar coordination

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Vestibular rehab assessment

Positional testing for BPPV

- Dix-Hallpike
- Head roll

Neuromusculoskeletal exam

- ROM
- Strength
- Spasticity/tone
- Sensation

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Vestibular rehab assessment

Static balance, dynamic balance, & gait assessment

- Modified Clinical Test of Sensory Interaction in Balance with posturography
- Gait speed
- Berg Balance Scale
- Five Times Sit to Stand
- Timed Up and Go
- Dynamic Gait Index / Functional Gait Assessment
- Community Balance & Mobility Scale

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Vestibular rehab assessment

Motion Sensitivity Testing

Baseline Symptoms	Intensity	Duration	Score
1. Sitting to Supine			
2. Supine to Left side			
3. Supine to Right side			
4. Supine to sitting			
5. Left Dix-Hallpike			
6. Up from left			
7. Right Dix-Hallpike			
8. Up from right			
9. Sitting, head tipped left knee (18° apart)			
10. Head up from left knee			
11. Sitting, head tipped to right knee (18° apart)			
12. Head up from right knee			
13. Sitting head turns (5)			
14. Sitting head pitches (5)			
15. In stance, 180 degree turn to right			
16. In stance, 180 deg turn to left			
	Total		MSQ
MSQ=total score x (# pos's)/20.48			

Motion sensitivity assessment (for movement provoked symptoms)

- Motion Sensitivity Quotient
- Rate intensity & time duration of symptoms

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Vestibular rehab treatment

- BPPV treatment maneuvers
- Gaze stability / VOR adaptation exercises
- Habituation/desensitization strategies
- Balance & gait training
- General reconditioning
- Education & goal setting

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How do vestibular exercises help?

- Do not regenerate a damaged vestibular organ or nerve
- Facilitate central nervous system compensation for vestibular loss
- Reduce symptoms and improve function through neuroplasticity
- Training the brain to recalibrate how it interprets vestibular signals
- Adaptation driven by movement
- Gains are often slower with central disorders

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Is vestibular rehab effective?



Moderate to strong evidence (high quality RCTs) that vestibular rehab is safe & effective for peripheral vestibular hypofunction

BPPV - combination of treatment maneuvers & exercises for longer term functional recovery

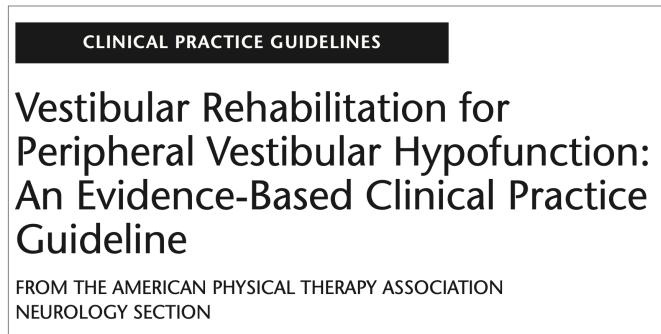
(McDonnell & Hillier, 2015)

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Peripheral vestibular hypofunction



Strong evidence for vestibular rehab in unilateral & bilateral peripheral vestibular hypofunction

Recommendations for exercise dose of gaze stability exercises

(Hall et al., 2016)

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Neurologic disorders

ACRM AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation
journal homepage: www.archives-pmr.org
Archives of Physical Medicine and Rehabilitation 2021;102:1379-89

SYSTEMATIC REVIEW

Efficacy of Vestibular Rehabilitation in Patients With Neurologic Disorders: A Systematic Review

Marco Tramontano, MSc,^{a,b} Valentina Russo, MSc,^c Grazia Fernanda Spitoni, PhD,^{a,d} Irene Ciancarelli, MD,^c Stefano Paolucci, MD,^a Leonardo Manzari, MD,^e Giovanni Morone, PhD^b

From the ^aFondazione Santa Lucia IRCCS, Rome; ^bDepartment of Movement, Human and Health Sciences, University of Rome "Foro Italico," Rome; ^cDepartment of Life, Health and Environmental Sciences, University of L'Aquila, L'Aquila; ^dDepartment of Dynamic and Clinical Psychology, Sapienza University of Rome, Rome; and ^eM.S.A. ENT Academy Center, Cassino (FR), Italy.

Abstract
Objective: The aim of this systematic review is to critically assess the effectiveness of vestibular rehabilitation (VR) administered either alone or in combination with other neurorehabilitation strategies in patients with neurologic disorders.

Lack of high quality studies & heterogeneity

Safe, beneficial, & could be implemented within standard neurological rehab

(Tramontano et al., 2021)

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Stroke & gait

The Effects of Vestibular Rehabilitation on Gait Performance in Patients with Stroke: A Systematic Review of Randomized Controlled Trials

Tsubasa Mitsutake, PhD,* Takeshi Imura, PhD,† and Ryo Tanaka, PhD,†

Background: Patients with post-stroke hemiparesis have poor postural stability; nevertheless, it is unclear whether vestibular rehabilitation affects gait performance after a stroke or not. We performed a systematic review of randomized controlled trials to investigate the effects of vestibular rehabilitation on gait performance in patients.

3 RCTs identified

2 of 3 studies showed benefit of vestibular rehab over usual care (DGI, gait speed, Tinetti)

(Mitsutake et al., 2020)

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Stroke & dizziness

Pilot RCT

RESEARCH Open Access

Vestibular rehabilitation for persons with stroke and concomitant dizziness—a pilot study

Eva Ekwall Hansson¹ , Hélène Pessah-Rasmussen^{2,3}, Annika Bring^{4,5}, Birgit Vahlberg⁶ and Liselott Persson⁷

Abstract

Background: Dizziness is common among patients with first time stroke. It affects self-perceived health and is a risk factor for falls. Vestibular rehabilitation (VR) is effective for treating dizziness among various conditions, but the effect of dizziness with origin in the central nervous system is poorly studied.

This pilot study of a randomized controlled trial aimed at investigating a vestibular rehabilitation programme



Usual care vs.
usual care plus vestibular exercises:

- Standing on pad
- Bouncing on swiss ball
- Bouncing on trampoline
- Sit to stand
- Progressions with eye movement, head movement, eyes closed, or combination of these
- Adapted to each patient

(Ekwall Hansson et al., 2020)

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Stroke & dizziness

No difference in outcomes between groups (ABC, Berg, FGA) - possibly due to small sample size (n = 32)

Did not consider site of lesion or cause of dizziness

High adherence to intervention

RESEARCH Open Access

Vestibular rehabilitation for persons with stroke and concomitant dizziness—a pilot study

Eva Ekwall Hansson¹ , Hélène Pessah-Rasmussen^{2,3}, Annika Bring^{4,5}, Birgit Vahlberg⁶ and Liselott Persson⁷

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(Ekwall Hansson et al., 2020)



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Vestibular therapy in stroke rehab

Add vestibular exercises to usual care

- Gaze stability exercises
- Habituation
- Balance training - eyes closed, head turns, compliant surfaces

Potential barriers

- Provocation of dizziness
- Nausea in subacute/early rehab phase (anti-emetics)
- Slower gains with cerebellar dysfunction

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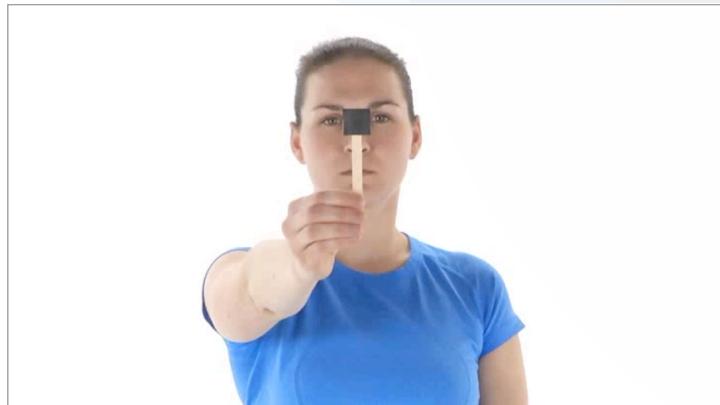
Gaze stability exercises

VOR adaptation

Desensitization to head movements

Place target on wall

Target must stay stable & in focus



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Habituation

Desensitization to head or body movements that provoke symptoms

Individualized to the patient

Graded repeated exposure

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Balance training

Compliant or unstable surfaces

Eyes closed

Head movements

+ combinations of above

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Balance training

Rating of perceived difficulty (0 to 10 scale)

Please choose from 0 to 10 corresponding to your perceived difficulty of each exercise:

0	1	2	3	4	5	6	7	8	9	10
Extremely easy	Easy	Somewhat easy	Somewhat hard	Hard	Extremely hard					

(Alsubaie et al., 2019)

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Summary

- Vestibular symptoms are common after posterior stroke
- Can see a mix of peripheral & central vestibular signs after posterior stroke
- BPPV is relatively common & very treatable
(suspect this if symptoms <60 sec with changes in head position relative to gravity)

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Summary

- Vestibular rehab as an addition to usual care
 - Gaze stability exercises for VOR deficit
 - Habituation exercises for motion provoked symptoms
 - Balance & gait training considering challenge to different sensory systems

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References

- Alsubaie SF, Whitney SL, Furman JM, et al. Reliability and Validity of Ratings of Perceived Difficulty During Performance of Static Standing Balance Exercises. *Physical Therapy*. 2019;99(10):1381-1393. doi:10.1093/ptj/pzz091
- Balci BD, Akdal G, Yaka E, Angin S. Vestibular rehabilitation in acute central vestibulopathy: A randomized controlled trial. *Journal of Vestibular Research*. 2013;23(4-5):259-267. doi:10.3233/VES-130491
- Bhattacharyya N, Gubbels SP, Schwartz SR, et al. Clinical Practice Guideline: Benign Paroxysmal Positional Vertigo (Update). *Otolaryngol Head Neck Surg*. 2017;156(3_suppl):S1-S47. doi:10.1177/0194599816689667
- Brown KE, Whitney SL, Marchetti GF, Wrisley DM, Furman JM. Physical Therapy for Central Vestibular Dysfunction. *Archives of Physical Medicine and Rehabilitation*. 2006;87(1):76-81. doi:10.1016/j.apmr.2005.08.003
- Celis-Aguilar E, Castro-Urquiza A, Mariscal-Castro J. Evaluation and interpretation of the bucket test in healthy individuals. *Acta Oto-Laryngologica*. 2018;138(5):458-462. doi:10.1080/00016489.2017.1410289
- Chen L, Todd M, Halmagyi GM, Aw S. Head impulse gain and saccade analysis in pontine-cerebellar stroke and vestibular neuritis. *Neurology*. 2014;83(17):1513-1522. doi:10.1212/WNL.0000000000000906
- Choi KD, Lee H, Kim JS. Ischemic syndromes causing dizziness and vertigo. In: *Handbook of Clinical Neurology*. Vol 137. Elsevier; 2016:317-340. doi:10.1016/B978-0-444-63437-5.00023-6
- Costa C, Arneiro G, Branco I, et al. Does vestibular rehabilitation optimize physiotherapy benefits in the early stages of PICA stroke recovery? A case series. *Annals of Medicine*. 2019;51(sup1):224-224. doi:10.1080/07853890.2018.1560738
- Ekvall Hansson E, Pessah-Rasmussen H, Bring A, Vahlberg B, Persson L. Vestibular rehabilitation for persons with stroke and concomitant dizziness—a pilot study. *Pilot Feasibility Studies*. 2020;6(1):146. doi:10.1186/s40814-020-00690-2

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References

- Furman JM, Whitney SL. Central Causes of Dizziness. *Physical Therapy*. 2000;80(2):179-187. doi:10.1093/ptj/80.2.179
- Ghiossi B, Gorman S, Aguiar P. Rehabilitation Management of Dizziness after Cerebellar CVA: A Case Report. *2013;6(3):11*.
- Hall CD, Herdman SJ, Whitney SL, et al. Vestibular Rehabilitation for Peripheral Vestibular Hypofunction: An Evidence-Based Clinical Practice Guideline From the American Physical Therapy Neurology Section. *Journal of Neurologic Physical Therapy*. 2016;40(2):124-155. doi:10.1097/NPT.0000000000000120
- Herdman SJ, Clendaniel R. *Vestibular Rehabilitation*. F. A. Davis Company; 2014.
- Johns P, Rosenberg H. Just the Facts: How to assess a patient with constant significant vertigo and nystagmus in the emergency department. *CJEM*. 2020;22(4):463-467. doi:10.1017/cem.2020.34
- Kheradmand A, Zee DS. Cerebellum and Ocular Motor Control. *Front Neur*. 2011;2. doi:10.3389/fneur.2011.00053
- Kim JS, Zee DS. Benign Paroxysmal Positional Vertigo. Solomon CG, ed. *N Engl J Med*. 2014;370(12):1138-1147. doi:10.1056/NEJMcp1309481
- Lee H. Neuro-Otological Aspects of Cerebellar Stroke Syndrome. *J Clin Neurol*. 2009;5(2):65. doi:10.3988/jcn.2009.5.2.65
- Macdonald NK, Kaski D, Saman Y, Al-Shaikh Sulaiman A, Anwer A, Bamiou DE. Central Positional Nystagmus: A Systematic Literature Review. *Front Neurol*. 2017;8:141. doi:10.3389/fneur.2017.00141
- McDonnell MN, Hillier SL. Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. Cochrane ENT Group, ed. *Cochrane Database of Systematic Reviews*. Published online January 13, 2015. doi:10.1002/14651858.CD005397.pub4

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References

- Mitsutake T, Imura T, Tanaka R. The Effects of Vestibular Rehabilitation on Gait Performance in Patients with Stroke: A Systematic Review of Randomized Controlled Trials. *Journal of Stroke and Cerebrovascular Diseases*. 2020;29(11):105214. doi:10.1016/j.jstrokecerebrovasdis.2020.105214
- Mitsutake T, Sakamoto M, Ueta K, Oka S, Horikawa E. Effects of vestibular rehabilitation on gait performance in poststroke patients: a pilot randomized controlled trial. *International Journal of Rehabilitation Research*. 2017;40(3):240-245. doi:10.1097/MRR.0000000000000234
- Neuhauser HK, Lempert T. Vertigo: Epidemiologic Aspects. *Semin Neurol*. 2009;29(05):473-481. doi:10.1055/s-0029-1241043
- Saleem S, Arora B, Chauhan P. Comparative Study to Evaluate the Effectiveness of Vestibular Rehabilitation Therapy versus Dual Task Training on Balance and Gait in Posterior Cerebral Artery (PCA) Stroke. *JCDR*. Published online 2019. doi:10.7860/JCDR/2019/41828.13309
- Tramontano M, Bergamini E, Iosa M, Belluscio V, Vannozzi G, Morone G. Vestibular rehabilitation training in patients with subacute stroke: A preliminary randomized controlled trial. *NRE*. 2018;43(2):247-254. doi:10.3233/NRE-182427
- Tramontano M, Russo V, Spitoni GF, et al. Efficacy of Vestibular Rehabilitation in Patients With Neurologic Disorders: A Systematic Review. *Archives of Physical Medicine and Rehabilitation*. 2021;102(7):1379-1389. doi:10.1016/j.apmr.2020.11.017
- von Brevern M, Radtke A, Lezius F, et al. Epidemiology of benign paroxysmal positional vertigo: a population based study. *Journal of Neurology, Neurosurgery & Psychiatry*. 2006;78(7):710-715. doi:10.1136/jnnp.2006.100420
- Young AS, Nham B, Bradshaw AP, et al. Clinical, oculographic, and vestibular test characteristics of vestibular migraine. *Cephalgia*. 2021;41(10):1039-1052. doi:10.1177/03331024211006042

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