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# Striking the Right Balance: A Glimpse into the History of Vestibular Testing

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*In this edition of "Striking the Right Balance," Mostafa Eldaebes, M.B.B.Ch, M.Sc, Aud(C), Reg. CASLPO, takes us on a journey through time in the evolution of vestibular testing as we know it today.*

*Michael Vekasi, AuD, R.Aud, Aud(C), FAAA and Erica Zaia, MSc, RAUD are coordinating the "Striking the Right Balance," feature which will cover the latest information on 'all things vestibular.'*

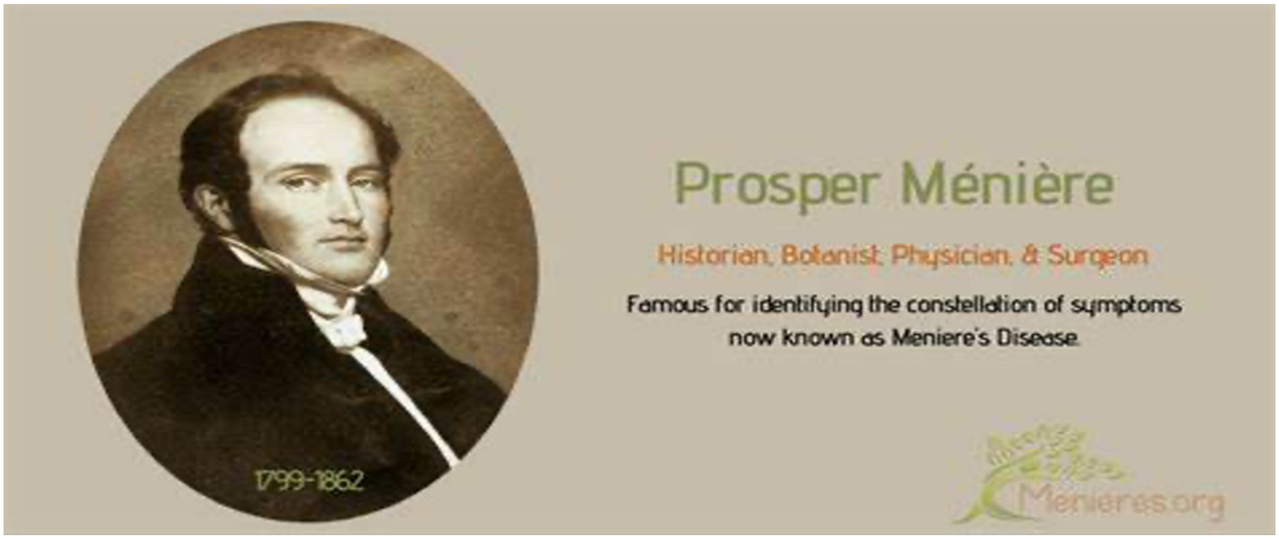
*If you would like to be more involved in all things vestibular, please check out and like our Facebook page by searching for "CAA National Vestibular Special Interest Group" within Facebook. You can also reach us by email at CAAvestibular@gmail.com.*

The vestibular system has been a mystery for centuries. Although the anatomy of the discovery of the vestibular apparatus dates to the Renaissance era (c.1400 - c.1600), its function and physiology were a mystery until the middle of the 19$^{th}$ century (Hachmeister, 2003). The close interaction of the vestibular system with other sensory systems and the shared representation of the vestibular system in the cerebral cortex with other sensory areas have made vestibular testing development a challenge for scientists. Vestibular testing that relied on the subjective feeling of movement was also found to be unreliable; therefore, vestibular testing development has been focusing mainly on vestibular reflexes, especially the vestibulo-ocular reflex or VOR (Baloh et al., 2012). This article will briefly take you into a vestibular journey through history to shed some light on some of the developmental milestones behind the vestibular testing that we use today, particularly the VOR testing. In addition, it might be helpful to understand the history behind some of the testing we perform daily in our clinical practice.

The first major milestone in solving the vestibular mystery could be attributed to the physiologist, Jean Pierre Flourens, when he found in 1825 that destroying the pigeon's lateral semicircular canal made the pigeon keep turning horizontally in a circle. Flourens experiments on pigeons were an eye-opener for other scientists that the inner ear's semicircular canals might have a function that could be critical for maintaining balance and equilibrium and that the cochlea's main role is only sound perception (Wiest, 2015).

Jan Evangelista Purkinje, another pioneer of modern experimental physiology, left the Piarist monk order "to deal more freely with science." Purkinje, besides so many other discoveries in medicine, was the first to discover that changing the head position in humans can cause vertigo (Mazurak & Kusa, 2018).

The other major milestone was in 1861 when Prosper Ménière presented a paper in front of the French Academy of Medicine reporting that an inner ear disease can cause hearing loss, vertigo, and tinnitus. Before Meniere's discovery, causes of vertigo in humans were attributed to illnesses of the brain, either caused by the motion of animal spirits in the head, vapors swirling inside the brain, or disorders of the ventricles. Unfortunately, Dr. Ménière would die one year after his presentation from influenza and pneumonia. I don't think he knew then how important his writings would become in identifying one of the most famous vestibular conditions that bears his name today (Méniére, 1861).




In 1870 German physiologist FriedrichGoltz was the first to propose that the semicircular canals in the inner ear are stimulated by the change in the hydrostatic pressure of the fluid it contains as a response to the change in head position, a concept that is known as the "hydrostatic concept or theory." He hypothesized that if the destruction of the semicircular canals causes vertigo and dizziness, then it must be the organ responsible for equilibrioception (Goltz, 1870).

In 1874, a distinguished Austrian physician, Joseph Breuer, in collaborative work with the physicist, Ernst Mach, developed the Mach-Breuer theory of semicircular canal function. The ampullary nerve of a single semicircular canal can sense endolymph flow in both directions. Breuer's diligent dissection of the inner ear of hundreds of birds, frogs, and fish led him to be the first to explain how the inner ear vestibular receptors work. He also reported that linear head tilt could cause the otolithic membrane to slip, leading to the bending of hairs that project into it, which consequently can stimulate underlying sensory receptors, a theory known in modern vestibular textbooks as the "shear theory" of hair cell stimulation. Alexander Crum Brown, a forgotten pioneer in vestibular science and a Scottish Chemist, reached a very similar conclusion as Mach and Breuer at the same time (Wiest & Baloh, 2002).

These historical landmarks paved the way for another major leap in resolving the mystery of how humans can strike the right balance. An astounding Austrian physician who later became a Swedish citizen, Robert Bárány (1876–1936), is considered the father of Oto-neurology and Vestibular science. Bárány received his MD degree from Vienna University in 1900, after which, in 1903, he started his preceptorship with Adam Politzer, the founder of Austrian Otology. His collaboration with Dr. Politzer at the General Hospital of Vienna Ear Clinic, allowed him to pursue his interest in studying the pathophysiology of the vestibular apparatus. At the time, syringing the external auditory canal was part of the treatment for ear infections, and Bárány noticed that some of his patients experienced dizziness accompanied by nystagmus during ear syringing. The explanation of such a phenomenon came to him by a pure accident (as did many other medical discoveries), which he termed the "caloric response." Dr. Barany received a Nobel Prize for discovering new methods for functional testing of the vestibular system in 1914. If you think such a stroke of luck awarded him the Nobel Prize, he was not as lucky as you might think. The telegram notifying him of his award did not reach him until 1915, as he was captured in the same year as a prisoner in WWI and sent to a prison camp in central Asia. It was not until 1916 that he received the award after the intervention of Prince Carl of Sweden to release him from the prisoners' camp.

*A patient whose ears I was syringing said to me: ''Doctor, I only get giddy when the water is not warm enough. When I do my own ears at home and use warm enough water I never get giddy. I then called the nurse and asked her to get me warmer water for the syringe. She maintained that it was already warm enough. I replied that if the patient found it too cold we should conform to his wish. The next time she brought me very hot water in the bowl. When I syringed the patient's ear he shouted: ''But Doctor, this water is much too hot and now I am giddy again. I quickly observed his eyes and noticed that the nystagmus was in an exactly opposite direction from the previous one when cold water had been used. It came to me then in a flash that obviously the temperature of the water was responsible for the nystagmus.''* Bárány recounted during his Nobel Prize acceptance speech (Bárány, 1916).

Bárány's contributions to the vestibular world did not stop at the caloric response. From 1917 he continued his pursuit of vestibular research in Stockholm. In 1921, he described a syndrome of episodic vertigo induced by a sudden movement of the head. He attributed it to a disorder of the otoliths. The syndrome was given more detail later in 1952 by the work of Dix and Hallpike, who named it "Benign Paroxysmal Positional Vertigo" (Dix & Hallpike, 1952).

The discovery of the idea of rotational chair testing dates back to the late 1700s, when Charles Darwin's grandfather, Erasmus Darwin described an experiment in 1796 of rotating himself while looking at a point on the ceiling. Darwin noticed the feeling of rotatory vertigo that was maintained way after the rotation motion stopped. During the nineteenth century, swinging or rotation was widely used in European psychiatric wards for two main purposes. The first was a therapeutic purpose for mental illness and psychiatric disorders, as it was widely accepted back then that it increases blood circulation to the brain. However, the second purpose was not as noble, where the patients would be rotated to the point of vomiting and threatened to be repeated if they did not modify their behaviour (Desmond, 2015).

In 1820, Purkinje developed a special chair to repeat Darwin's experiment more sophisticatedly to rotate subjects and observe their eyes during and after rotation (Cox, 1804; Cohen, 1984; Grüsser, 1984).

Dr. Bárány was the first to use this concept routinely, along with his caloric test for all his patients to determine their inner ear function. In 1907 he described in his book that he would seat a patient on a swivel chair and manually rotate the patient 10 times in 20 seconds, then suddenly stop the patient while facing him. Bárány measured the average duration of post-rotatory nystagmus, which he reported as 22 seconds in normal subjects. Bárány also found that patients with unilateral inner ear damage had a post-rotatory stronger nystagmus beating towards the good ear. This important observation would later lay the basis for the discovery of the bedside head impulse test (Baloh et al., 2012).

In 1984, after testing a patient with bilateral vestibular nerve section due to bilateral vestibular schwannomas, Professor Gabor Michael Halmagyi and Professor Ian Curthoys from the University of Sydney reported that a small, fast, unpredictable head movement in the horizontal plane (head impulses), are valid indicators for semicircular canal (SCC) function. In 1988, they described the clinical Head Impulse Test (HIT) as a clinical indicator of unilateral canal paresis (Halmagyi & Curthoys, 1988). Later, the HIT proves to be a key component in the bedside assessment of patients with acute dizziness. A normal test (absence of saccades) suggests a central localization for the dizziness, while abnormal test (presence of corrective saccades) suggests a peripheral localization (Newman-Toker et al., 2008). Almost 20 years later, in 2009, the same team from Sydney, would introduce a video method to test the horizontal SCCs. They followed this in 2013 by another method for testing the vertical SCCs, which is recognized and being used in many vestibular clinics worldwide as the Video HIT or vHIT (MacDougall et al., 2009; MacDougall et al., 2013).

Despite all the advancements that has been made in the vestibular world so far, there are still a lot of questions that need to be answered, and improvements to be made to our diagnostic tools to enhance the diagnostic and rehabilitative care of patients with vestibular disorders.

## References


1. Baloh, R. W., Halmagyi, G. M., & Zee, D. S. (2012). The history and future of neuro-otology. CONTINUUM: Lifelong Learning in Neurology, 18(5), 1001-1015.
2. Cohen, B. (1984). Erasmus Darwin's observations on rotation and vertigo. Human neurobiology, 3(3), 121-128.
3. Cox, J. M. (1811). Practical Observations on Insanity...: To which are Subjoined Remarks on Medical Jurisprudence as Connected with Diseased Intellect (No. 22632). Thomas Dobson.
4. Grüsser, O. J. (1984). JE Purkyn?'s contributions to the physiology of the visual, the vestibular and the oculomotor systems. Human neurobiology, 3(3), 129-144.
5. Desmond, A. (2015, June 2nd). The Dubious History of the Rotational Chair. Retrieved from The Dubious History of the Rotational Chair| Alan Desmond, AuD |Hearinghealthmatters.org
6. Dix, M., & Hallpike, C. S. (1952). The pathology, symptomatology and diagnosis of certain common disorders of the vestibular system.
7. Goltz, F. (1870). Ueber die physiologische Bedeutung der Bogengänge des Ohrlabyrinths. Archiv für die gesamte Physiologie des Menschen und der Tiere, 3(1), 172-192.
8. Hachmeister, J. E. (2003). An abbreviated history of the ear: from Renaissance to present. The Yale journal of biology and medicine, 76(2), 81.
9. Halmagyi, G. M., & Curthoys, I. S. (1988). A clinical sign of canal paresis. Archives of neurology, 45(7), 737-739.

10. Lecture, R. B. N. Some New Methods for Functional Testing of the Vestibular Apparatus and the Cerebellum. Nobelprize. org. Nobel Media AB 2014. Nobelprize. org.
11. MacDougall, H. G., McGarvie, L. A., Halmagyi, G. M., Curthoys, I. S., & Weber, K. P. (2013). The video Head Impulse Test (vHIT) detects vertical semicircular canal dysfunction. PloS one, 8(4), e61488.
12. MacDougall, H. G., Weber, K. P., McGarvie, L. A., Halmagyi, G. M., & Curthoys, I. (2009). The video head impulse test: diagnostic accuracy in peripheral vestibulopathy. Neurology, 73(14), 1134-1141.
13. Mazurak, M., & Kusa, J. (2018). Jan Evangelista Purkinje: a passion for discovery. Texas Heart Institute Journal, 45(1), 23.
14. Méniére, P. (1861). Memoire sur des lesions de l'oreille interne donnant lieu a des symptomes de congestion cerebral apoplectiforme, Gazmed. De Paris s3, 16, 597-601.
15. Newman-Toker, D. E., Kattah, J. C., Alvernia, J. E., & Wang, D. Z. (2008). Normal head impulse test differentiates acute cerebellar strokes from vestibular neuritis. Neurology, 70(24 Part 2), 2378-2385.
16. Pearce, J M S (2006). Robert Barany. Journal of Neurology, Neurosurgery & Psychiatry, 78(3), 302–302. doi:10.1136/jnnp.2006.0110197
17. Wiest, G. (2015). The origins of vestibular science. Annals of the New York Academy of Sciences, 1343(1), 1-9.
18. Wiest, G., & Baloh, R. W. (2002). The pioneering work of Josef Breuer on the vestibular system. Archives of neurology, 59(10), 1647-1653.