Protheses for patients with severe bilateral vestibular loss

BY HERMAN KINGMA

Discover the innovative BalanceBelt by Herman Kingma, a revolutionary aid developed in Maastricht to assist patients with bilateral vestibular loss in regaining stability.

In February 2003, I met a patient with severe bilateral vestibular loss due to gentamicin toxicity, and I felt disheartened. Despite the fantastic diagnostic vestibular lab we had at Maastricht University Hospital, what could I truly offer her? She had the typical symptoms: severe imbalance, fear of falling, and an inability to see clearly when moving her head due to the loss of image stabilisation (no vestibulo-ocular reflex, leading to reduced dynamic visual acuity). Desperate for help, she turned to me. Diagnostic tests – calorics and head impulse tests – confirmed the extent of her condition. Fortunately, she could still hear and speak, and told me that she felt as if her life was over. She stayed home, quiet and safe, avoiding social events, shopping and busy streets where the constant motion overwhelmed her. She had become highly visually dependent. Two years of intensive rehab had improved things but not to the extent that she could enjoy life again. She was desperate and in tears. As a top referral centre for vestibular disorders, we frequently saw patients like her. Even though many colleagues insisted that severe bilateral vestibular loss was rare and that most patients adapted without issue, my experience was quite different. Perhaps it was because I saw the patients who couldn't accept their limitations. For them, this condition was a major problem – made worse by the seeming lack of any effective treatment.

I wondered why there was no vestibular prosthesis – something akin to a hearing aid or cochlear implant for those with severe hearing loss, or glasses, contact lenses or cataract surgery for the visually impaired. Determined to change that, I drew on my clinical experience, background in physics and biology and countless conversations with patients and colleagues to help develop vestibular prostheses: the balance belt and the vestibular implant (VI).

I met Prof Jean-Philippe Guyot in Geneva, a pioneer in vestibular implant research, and we began collaborating, driven by our shared passion for helping these patients. In 2012, our teams in Geneva and Maastricht made history by implanting the world's first vestibular implant in a human. I still remember my tears of joy when, in the operating room, we saw the first patient's eye movements upon activation of the implant. Now, 12 years later, after implanting 24 patients, we have proven that the VI works – it can restore balance and image stabilisation. I believe that in a few years, it will be available on the market, offering hope to many. However, unfortunately the surgery necessary for implantation carries a risk to hearing, so it would be great to find a non-invasive alternative.

Anticipating this need, I began developing the balance belt—a device that measures trunk movement and tilt, then translates this information into specific vibration patterns via 10 small vibrators embedded in a belt around the waist (Figure 1). The vibration pattern helps patients regain a sense of body orientation relative to gravity. When a patient leans left, a vibration is felt on the left; when leaning right, the sensation shifts to the right; forward leaning triggers a vibration in the front, and backward leaning in the back. This system enhances somatosensory perception of tilt, functioning as somatosensory substitution.

This concept was originally introduced by Paul Bach-y-Rita to aid blind individuals in navigation. A simpler version was later used for rehabilitation via biofeedback, now known as the Vertiguard. However, the balance belt was designed as a true vestibular prosthesis – fully ambulatory and intended for continuous daily use, much like a hearing aid for the hearing impaired.

After 19 years of research – refining hardware and software with invaluable patient feedback – we developed a functional prototype. We produced five balance belts and loaned them to patients to try at home. Many were so impressed by the improvement in their balance and mobility that they refused to return the devices after the trial period, often becoming emotional at the thought of losing them. Their enthusiasm motivated me to continue development alongside engineers at Maastricht University.

In 2021, the final prototype was turned into the commercially available 'BalanceBelt' by Elitac, a company specialising in vibratory haptic stimulation. With sufficient units available, we expanded testing on a larger scale, evaluating the belt in real-life conditions, including walking, biking, shopping, and navigating busy streets. Through this process, we refined our understanding of which patients benefited most and began to unravel the precise mechanisms through which the belt improved balance and mobility. Before I explain that in detail, I will first share the results of our clinical study, conducted between 2001 and 2003. We recruited 121 patients referred to our clinic with severe bilateral vestibular loss (BVL), confirmed by extensive vestibular testing (calorics, vHIT, rotatory chair, etc.), excluding those with neurological pathology. These patients varied in how they rated their balance and mobility. We asked them to score themselves on a visual analogue scale from 0 to 10 – the Balance and Mobility Score (BMS) – where zero indicated an inability to walk without support and 10 represented their pre-vestibular-loss condition. Most patients scored between three and five. We then asked them if they would like to try the BalanceBelt for two hours while walking around the hospital. After this trial, 89 patients opted to try the belt at home for at least two weeks. One month later, 80 of them reported significant improvement and chose to keep using the belt in daily life. During the COVID-19 pandemic, we lost contact with 15 patients (six of whom had passed away), but 65 patients have continued wearing the belt daily for over two years (see Figure 2).

So, we concluded that while the BalanceBelt does not help every BVL patient, it provides substantial benefits for many. A BMS improvement of at least two points appeared to be clinically significant – patients meeting this threshold wanted to keep the belt. Increased balance and mobility also reduced anxiety, encouraged patients to go out again and improved their social lives, profoundly impacting their quality of life.

However, while the vestibular implant restores the vestibulo-ocular reflex and dynamic visual acuity, the BalanceBelt does not improve oscillopsia (impaired image stabilisation), a common issue in BVL patients. Interestingly, among the 32 patients who did not find the belt helpful after the initial two-hour trial, most reported that they found the vibration disturbing. In contrast, patients who responded positively often reported that, over time, they stopped noticing the vibration, until they forgot to wear the belt and immediately felt its absence. We also began testing the BalanceBelt in congenital deaf toddlers with bilateral vestibular areflexia who had received cochlear implants. Many of these children exhibit motor delays and, in our initial evaluation of five cases, all showed improvements in balance and mobility – a promising but still preliminary finding.

Now, in December 2024, I am no longer disheartened as I was in 2003. More often than not, patients are crying tears of happiness rather than frustration. With two viable solutions – the BalanceBelt, available now, and the vestibular implant on the horizon – we can finally offer many severe BVL patients a path to improved balance, mobility and quality of life.

Figure 1: The BalanceBelt provides a vibration pattern around the waist using 10 tactors (T1–T10) evenly distributed every 36 degrees. These tactors are activated via a microprocessor using a transfer function based on trunk movement and tilt detected by a 6DOF sensor (S). By simultaneously activating two tactors at different intensities (linear interpolation), virtually any point around the waist can be stimulated.

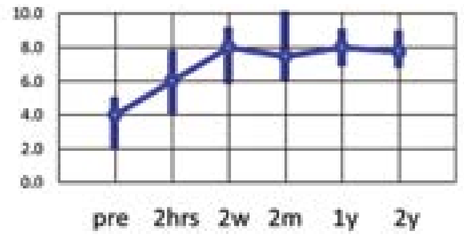

Figure 2: Median and range (n=65) of the Balance and Mobility Score (0 –10 on the y-axis) over time: pre = before starting to wear the belt; 2hrs= two hours in the hospital; 2w = after two weeks; 2m = after two months; 1y = after one year; 2y = after two years of wearing the belt daily. Of the 89 patients who initially tried the belt, 65 continued to wear it daily after two years.

Further reading

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