A sound understanding of inner ear balance organs

Sound is normally conducted to the inner ear where it excites receptors within the cochlea and produces the sensation of hearing. The inner ear consists of two main receptor types – the cochlea and the five vestibular end organs. The vestibular apparatus end organs are known to signal head rotation and acceleration and vestibular signals make important contributions to stabilising the eyes and maintaining balance. Although nearly all the sound energy entering the inner ear is directed to the cochlea, a small amount also stimulates vestibular receptors. This can be detected using loud sounds and averaging the effects on certain muscles in the neck and around the eyes when activated (termed ”VEMPs”: vestibular evoked myogenic potentials). These recordings show characteristic responses beginning less than 10 ms (1/100 of a second) after the onset of the sound. Hearing is not required and these reflexes can be obtained even with severe deafness. Evidence from animals has shown that one of vestibular organs, the saccule, has the lowest threshold to sound. The saccule normally senses vertical acceleration and has been particularly difficult to assess in humans.

The basis of the sound sensitivity is not known, but may relate to either the location of the saccule or its physical properties. It is one of two otolith organs, the other being the utricle, so named for the calcium crystals that make up part of the receptors. Together they measure linear accelerations, both vertical and horizontal. Vibration of the skull (i.e. bone conducted sound) and head taps have also been shown to be effective means of activating these reflexes.

The use of VEMPs is a means of examining the function of the two otolith end organs non-invasively in humans. VEMPs have established a role in diagnosis of vestibular disorders, the most notable being Superior Canal Dehiscence, in which there is a defect in the bone overlying the superior semicircular canal, another vestibular receptor. In this condition, due to a larger amount of sound energy entering the vestibular system, there are large sound-evoked VEMPs and they have much lower thresholds than normal. VEMPs show abnormalities in a number of other vestibular disorders and have increased our ability to make accurate diagnoses of vestibular diseases.

The evidence for selective activation of the saccule by bone conducted sound is less clear and saccular reflexes are thought to be weak for eye muscles. This investigation concerned patients with vestibular neuritis, a condition that often selectively affects just the superior branch of the vestibular nerve and spares the inferior one. Recordings of both neck VEMPs and eye VEMPs were made for patients using a variety of stimuli. It is accepted that the saccular fibres mediating the neck VEMP travel in the inferior part of the nerve and are therefore usually spared with the common form of vestibular neuritis. However, utricular fibres travel through the superior part and, if they also contribute to the neck response (as some have argued), this will cause a reduction of the size of the response with a lesion solely affecting the superior part of the nerve, compared to the opposite, normal response. Using this logic it was possible to deduce that the sound-evoked neck VEMP was mainly of saccular origin while, for the ocular VEMP, it appeared that the response was mainly due to utricular activation. Our investigation has thus clarified the relative role of the two otolith organs in neck and ocular VEMPs and thereby indicates that the choice of reflex allows assessment of either the saccular or utricular function non-invasively, using sound.

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