

Fundamental studies to assess and restore vestibular function in patients with severe bilateral vestibular loss

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Summary of PhD thesis by M. Pleshkov

Chapter 2 describes a group of patients diagnosed with bilateral vestibulopathy (BVP) according to the Bárány Society diagnostic criteria. It was demonstrated that due to the heterogeneity of this disorder, different results are obtained with different vestibular tests. Therefore, it is imperative to standardize diagnostic tests and to obtain laboratory-specific normative values. In addition, it was shown that the caloric test and video head impulse test are most sensitive to detect vestibular function impairment. In contrast, the torsion swing test is more suited to measure the residual function. Finally, it was demonstrated that 76% of BV patients were eligible for vestibular implantation. Therefore, a thorough assessment of the vestibular function of all five end organs (two otoliths and three semicircular canals) is essential before vestibular implantation is possible.

Chapter 3 shows that the electro-oculography (EOG) method can be potentially applied to perform the head impulse test. Comparison of simultaneously performed EOG and video-oculography (VOG) during testing of horizontal saccades and during horizontal head impulse testing (HIT) showed a good concordance regarding recorded eye velocities in a group of healthy volunteers. The EOG method has several advantages over the VOG method, such as the absent phenomenon of goggle slippage and no pupil detection problems. Therefore, an EOG-based head impulse test device might be considered as an alternative to video HIT, especially in cases when pupil detection or goggle fixation is not possible.

Chapter 4 presents a new and fast approach for testing motion perception in clinical practice. A six degrees of freedom motion platform was used to estimate six rotational (yaw left-right, pitch forward-backward, and roll left-right) and six translational self-motion perception thresholds (translations forward-backward, left-right, and up-down) within an hour. This test for vestibular perception showed comparable patterns in perceptual thresholds compared to more research-oriented, lengthy tests. This might pave the way for self-motion perception testing in clinic, in order to diagnose vestibular dysfunction, or to assess effects of therapy (e.g., rehabilitation, vestibular implant) on self-motion perception.

Chapter 5 compares two clinical approaches for assessing self-motion perception: the 2-option and 12-option approach. The thresholds measured using the 2-option paradigm were lower than those measured with the 12-option paradigm, most likely because of the higher chance of guessing in the first case (8% vs. 50%, respectively), although the additional psychometric influence cannot be ruled out. These findings imply that each approach to assess self-motion perception, should have its own normative values.

Chapter 6 shows the morphometric parameters of the semicircular canals in the guinea pig and rat. The obtained 3D models of the bony labyrinths can serve as a basis for precise morphometric measurements and future finite element modeling.

Chapter 7 presents the electrical impedance measurements in the guinea pig inner ear *in vitro* and its simulation using the equivalent circuit model. The most significant physical phenomena determining the electrical impedance of the inter-electrode space were quantified: electrode polarization (electrical double layer) and medium polarization (alpha-dispersion at low frequencies due to cell membranes and tissue-tissue interface). Electrical double layer properties were identified in a saline solution experiment. The Randles equivalent circuit was fitted to the measured impedance and was used for simulating the propagation of the electrical pulses through the inner ear tissues. The capacitive effects present in the interelectrode space distorted the voltage pulses passing the interelectrode space, which might hinder electrical stimulation of vestibular afferents.

Chapter 8 demonstrates another approach for modelling electro-conductivity of the inner ear, including two compartments (the bony labyrinth and the temporal bone) and using the 3D Finite Element approach. It was shown that the FEM approach matched the previously measured impedances (Chapter 7) relatively well using the “grid search algorithm”, although the “least squares method” applied in the equivalent circuit model eventually showed a better fit. However, in contrast to the equivalent circuit model, the FEM approach provided more detailed information on the electrical potential distribution, e.g. for each neural branch separately. Furthermore, it was found that the presence of the temporal bone surrounding the bony labyrinth, significantly influences the electrical parameters of the whole system, when the bony labyrinth is stimulated. Not only the conductivity, but also the permittivity properties of

the tissues are essential for accurate simulations of the electrical current propagation through the inner ear tissues. Eventually, from a clinical perspective, the electrical impedances measured between electrodes in the vestibular organ are the crucial parameters determining whether electrical stimulation will result in the desired neural response.