The Vestibular Implant

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The vestibular system, located in the inner ear acts like a motion sensor. It provides the central nervous system with information about head movements and position. Together with vision and proprioception, it is an essential part of the multidimensional balance system. It allows for the generation of vestibular reflexes, which are among the fastest in the human body and results in efficient gaze stabilization and postural control. Vestibular information is influencing many other functions, such as motion perception, spatial orientation, blood regulation, memory, sleep, bone metabolism and many others. As the vestibular system functions automatically and unconsciously, as long as it is normally functioning we are not aware of it. It is perhaps one of the reasons why the vestibular system is not well recognized, not only in the general population but also among health specialists. It follows that problems associated with the loss of its function, in particular in case of bilateral involvement, are not optimally taken care of. In this thesis we demonstrated that patients with a bilateral loss of the vestibular function present a moderate to severe handicap leading to a significant decrease of their quality of life. In about 50% of the cases the etiology remains unknown. Unfortunately there is currently no evidence of efficient treatment. Based on the success of cochlear implants for hearing rehabilitation in deaf patients, the concept of a vestibular implant to restore the vestibular function has emerged. The hypothesis is that using motion modulated electrical stimulation of the vestibular nerve, the vestibular implant could provide the central nervous system with sufficient motion information to restore a useful vestibular function. The vestibular implant prototype consists of a modified cochlear implant with one up to three electrodes removed from main cochlear array and put in contact with terminal ampullary branches of the vestibular nerve. Different surgical approaches were developed for this purpose. Finally a motion sensor is fixated to the head and feeds a regular cochlear implant processor with motion information. Currently 13 patients have been implanted. With the majority of the available electrodes it is possible to elicit controlled eye movements which correspond to the restoration of the vestibulo-ocular reflex. There is a high intra individual and inter individual variability in obtained responses. The best electrodes generate responses in line with our knowledge of the vestibular physiology, indicating that a useful functional rehabilitation could be possible. To demonstrate this, a test assessing the visual acuity while walking was developed. Indeed, one of the main complaints of patients suffering a bilateral vestibular loss is blurred vision when walking. In this test patient's visual acuity was measured at different walking velocities and compared to values obtained while standing still. Compared to healthy subjects, patients with a bilateral vestibular loss had a pathological drop of their visual acuity at speed as slow as 2 km/h. Patients with a unilateral vestibular loss were also tested. The fact that their visual acuity was preserved even at high walking speed indicates that a unilateral

restitution of the vestibular function could be sufficient to improve significantly gaze stabilization. In the last part of the thesis we actually tested this assumption. 6 implanted patients performed the same dynamic visual acuity test. In all of them, a significant improvement or even a normalization of the visual acuity while walking was found. This demonstrated for the first time a clinically useful rehabilitation of the vestibular function. Based on those promising results and the gained experience, the vestibular implant prototype design will be refined, the processor software upgraded, the electrode positioning optimized and the patients' selection will be targeted. Hopefully the device will be available on the market in the coming years. In parallel, the effort to improve the awareness of vestibular disorders will be pursued and the vestibular implant prototype will give us unique opportunity to explore the vestibular physiology beyond the traditional boundaries.