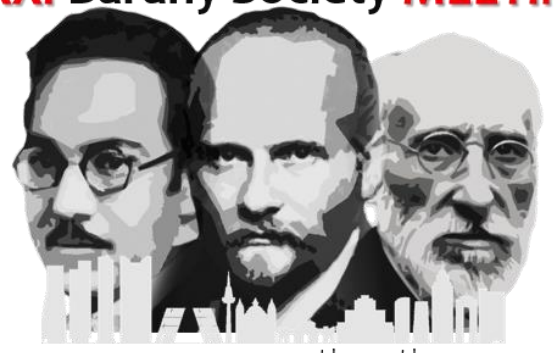
XXXI Bárány Society MEETING



MADRID, MAY 9th-11th 2022

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VESTIBULAR IMPLANT 1

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MADRID, MAY 9th-11th 2022

FREE PAPER FORM

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- Are you eligible and do you want to apply for the WON-SANG LEE AWARD?
  (•) Yes ( ) No

- ABSTRACT TITLE:
  Development of a Combined Audio-Motion System to Drive Cochleo-Vestibular Implants

- **A BRIEF** (<400 WORDS) DESCRIPTION OF THE THEME AND TARGET AUDIENCE:

We present a wearable audio-motion system, which has been developed to drive the cochleo-vestibular implants that have been implanted at the Geneva University Hospitals and at the Maastricht University Medical Centre. These implants are used daily by people with both severe hearing loss and bilateral vestibular loss but only for hearing restoration. Electrodes placed in the semicircular canals allow laboratory-controlled investigations into electrical stimulation of the labyrinth. The presented system therefore provides a new research platform for combined stimulation in subjects with hearing and vestibular loss. It consists of an off-the-shelf audio processor, a novel motion processor, and a transmitting coil. As in a standard cochlear implant system, sound from the environment is recorded with microphones and processed by the audio processor. In addition, the motion of the head is recorded with a 6-axis inertial measurement unit, and transformed into stimulation commands in the motion processor. Both the audio and motion command signals are then merged within the motion processor and transmitted via an inductive link to a cochleo-vestibular implant, which stimulates the semicircular canals of the vestibular organ and the cochlea accordingly through a custom electrode array.

The presented work gives insights into the system architecture of the device for combined stimulation and shows first results. The presentation is intended for audiences who are interested in combined vestibular and cochlear implant technologies, and may additionally be interesting for clinicians.

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- Are you eligible and do you want to apply for the WON-SANG LEE AWARD?
  ○ Yes ◉ No

- ABSTRACT TITLE:

Ionic Direct Current Vestibular Prosthesis Initiative at Johns Hopkins University

- **A BRIEF** (<400 WORDS) DESCRIPTION OF THE THEME AND TARGET AUDIENCE:

Vestibular prostheses designed to replace semicircular canal function in patients with bilateral vestibular disorders use biphasic charge-balanced stimuli to excite neural activity. Because biphasic pulses cannot inhibit activity, to generate bidirectional encoding of motion, implants must artificially elevate the verstibular afferents' spontaneous rate and then modulate around this increased baseline. The VOR responses to this stimulation modality are severely attenuated in both directions of motion (toward and away from the implanted side). The elevated baseline of activity delivered by pulsatile stimuli was shown to lead to synchronous unnatural activation of the vestibular afferents that then cause attenuation of the PVP neural responses in the vestibular nucleus that receive their inputs.

In our laboratory, we are developing a novel vestibular implant that is capable of delivering ionic direct current (iDC) instead of biphasic pulses to modulate vestibular nerve activity. This has not been possible before because direct current delivered to metal electrodes causes electrochemical reactions. Our implant, called Freeform Stimulator (FS) uses a microfluidic circuit to convert biphasic pulses delivered to electrodes positioned inside the device to direct ionic current delivered to the neural targets.

Over the past five years we, along with multiple other invstigators at Johns Hopkins University made considerable strides toward technology development, toward our understanding of how iDC can be delivered to the vestibular labyrinth, and toward how it can be used to deliver the sensation of head velocity independently about the three spatial axes of head motion. Our initial experiments were conducted in gentamicin-treated chinchillas to ablate normal vestibular sensation and implanted with intra-labyrinthine microcatheter tubes that deliver iDC. These

experiments show that the range of encoding of head motion toward the implanted side using cathodic stimulation is approximately 2-3x that of pulsatile modulation. The range of head velocities in the direction away from the stimulated canal using anodic current to inhibit firing rate is approximately 2x that of pulsatile modulation. These results are especially exciting because the responses are achieved with reduced error in alignment of VOR eye response to desired angle of motion compared to pulsatile stimulation, including when the stimulation is delivered via multiple canals simultaneously to span the range of possible angles in 3D space. In follow-up in-vitro experiments, we characterized the afferent responses to iDC stimulation and identified that these responses are remarkably similar to the normal responses to mechanical stimuli.

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- Are you eligible and do you want to apply for the WON-SANG LEE AWARD?
  ○ Yes ◉ No

- ABSTRACT TITLE:
  First-in-Human Trial of the Labyrinth Devices Multichannel Vestibular Implant – Interim Results After 1-5 Years of Continuous Daily Use

- **A BRIEF** (<400 WORDS) DESCRIPTION OF THE THEME AND TARGET AUDIENCE:

Background: Bilateral loss of vestibular sensation is disabling. Affected individuals suffer chronic disequilibrium, increased fall risk and inability to maintain stable vision during head movement. To determine whether prosthetic electrical stimulation via intra-ampullary electrodes targeting semicircular branches of the implanted ear's vestibular nerve is feasible, safe and effective, we initiated a first-in-human clinical trial of continuous motion-modulated prosthetic stimulation using the MVI™ Multichannel Vestibular Implant System developed by Labyrinth Devices LLC and MED-EL GmbH.

Methods: Ten subjects (5 male, 5 female, age 52-66 years at implantation) with bilateral vestibular hypofunction proven by caloric nystagmography, video head impulse testing, rotary chair testing, history and examination underwent unilateral implantation from August 2016 to July 2021. Seven had ototoxic loss due to intravenous or intratympanic injection; three had idiopathic loss. Duration since onset of symptoms ranged from 2-24 years. We assessed pre-op and post-activation performance using binocular 3-dimensional vestibulo-ocular reflex (3D VOR) responses to head rotation (yaw, LARP and RALP head-on-body impulses delivered by a Labyrinth Devices aHIT motorized system; 0.1-2 Hz whole-body yaw rotation via rotary chair), pure tone and speech audiometry, dynamic visual acuity, clinical tests of posture and gait, and validated patient-reported outcome instruments for disability

(Dizziness Handicap Inventory, Vestibular Activities of Daily Living) and health-related quality of life (SF36 and Health Utilities Index [HUI3]).

Results: Every subject has worn the system's external component daily since device activation. Six wear it 24 hr/day; 4 take it off while in bed. All subjects have electrically-evoked VOR responses (typically ranging from ~5-100°/s and aligned approximately with the stimulated canal) for at least one electrode for each of the three implanted canals. VOR responses are significantly greater with motion-modulated stimulation than without. Motion perception thresholds are below VOR thresholds. Hearing sufficient for unaided telephone use has been preserved in 6 of 10 implanted ears. Posture, gait metrics, dizziness handicap, vestibular disability and health-related quality of life (quantified by SF36-derived SF6D utility) improved significantly compared to preop for the group. HUI3, which more heavily weights hearing, did not significantly change.

Conclusions: The Labyrinth Devices MVI™ vestibular implant system can be implanted in an outpatient surgery, generates motion percepts and 3DVOR responses consistent with semi-selective stimulation of each of the three implanted canals, can be implanted with a preservation of useful hearing, and yields significant improvement in postural stability, gait, patient-reported disability and quality of life.

Support: NIH R01DC13536, U01DC0019364; Labyrinth Devices LLC; MED-EL GmbH

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MADRID, MAY 9th-11th 2022

Clinical results of otolith electrical stimulation using a vestibular implant in patients with bilateral vestibular loss .

Speaker: Angel Ramos Macias[1]

Co-Authors: Andrzej [2] , Manuel Manrique[3], Maurizio Barbara[4], Carl van Himbeeck[5] , Angel Ramos de Miguel[1]

Type: ORAL PRESENTATION

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2. Otolaryngology Dept . University Hospital , Antwerp. Belgium
3. Otolaryngology Dept . Navarra University . Spain
4. Otolaryngology Dept . Sapienza University . Rome . Italy
5. Cochlear AG . Switzerland.

Objective:

The objective of this study is to analyze the clinical outcomes in patients with Otolith chronic electric stimulation by using a cochlea/vestibular implant .

Material and Methods:

11 patients with bilateral vestibular loss (BVL) were recruited for unilateral cochleo/vestibular research implant (CVI) for Otolith chronic electric stimulation .We use a two electrode array stimulation (Cochlear and Otolith) were three Full-band electrode

array were implanted close to the to the saccular area, and 19 were located intracochlear in a second independent array. The objective was to analyse the effect of chronic electrical stimulation and the adaptation to electrical stimulation of the vestibular system in humans when the otolith organ is stimulated with a constant pulse train to mitigate imbalance due to bilateral vestibular dysfunction.

In this research we will present the postoperstive results with a minimum follow up of 6 months up to 1 year. Dynamic Visual Acuity testing (DVA), subjective visual horizontal and vertical tests, Dizziness Handicap Index (DHI), Timed Up and Go Test (TUG) and Dynamic Gait Index (DGI) were used.

Results:

The analysis revealed a statistically significant benefit when the vestibular implant system is in “switch on” test condition , compared with the “switch off” situation, in all tests.

Preliminary Conclusions:

These results demonstrate that gaze stabilization abilities can be restored by using a chronic electrical otolith stimulation delivered by a vestibular research implant. The otolith implant shows considerable promise of being an effective therapeutic alternative for patients with a BVL.

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- Are you eligible and do you want to apply for the WON-SANG LEE AWARD?
  ○ Yes ○ No

- ABSTRACT TITLE:
  Electrical stimulation of the human semicircular canals and possible other solutions for bilateral vestibulopathy

- **A BRIEF** (<400 WORDS) DESCRIPTION OF THE THEME AND TARGET AUDIENCE:

The Geneva-Maastricht team currently investigates the Vestibular Implant (VI). This is a modified cochlear implant that restores hearing as well as vestibular function. It comprises a cochlear array that is inserted into the cochlea, and 3 vestibular arrays that are inserted into the semicircular canals or directly onto the nerves. Thirteen patients have been implanted. The main results are: 1) electric vestibular stimulation is feasible and safe in humans; 2) an electrically evoked vestibulo-ocular reflex can be elicited in all frequency domains; 3) perceptual symptoms can be elicited by VI-stimulation; 4) canal stimulation also stimulates the otolith organs: electrically evoked VEMPs and postural responses have been obtained; 5) the dynamic visual acuity can be improved. Although many biomechanical issues still need to be addressed before it can be clinically applied, these results show that the VI is feasible as a therapeutic device in the near future.

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- Are you eligible and do you want to apply for the WON-SANG LEE AWARD?
  ○ Yes ◉ No

- ABSTRACT TITLE:
  Vestibulo-cochlear implants in humans: rehabilitation of the inner ear

- **A BRIEF** (<400 WORDS) DESCRIPTION OF THE THEME AND TARGET AUDIENCE:

Bilateral vestibulopathy is a heterogeneous disorder resulting in many disabling symptoms, including imbalance, oscillopsia, reduced mobility, and increased risk of falling. It has even been associated with cognitive impairments. Unfortunately, the prognosis is poor and currently available treatment options have very low efficacy.

Vestibular implants are medical devices that aim to restore vestibular function in patients with severe bilateral vestibulopathy using motion modulated electrical stimualtion. Our group, the Geneva-Maastricht team, developed an original concept based on a modified cochlear implant. This Vestibulo-Cochlear implant, developed in close collaboration with MED-EL (Innsbruck, Austria), provides 1 to 3 extra-cochlear electrodes which are implanted in the vicinity of vestibular afferents in addition to the "standard" cochlear implant array. Since 2007, 17 deaf ears in 17 patients with severe bilateral vestibulopathy have been implanted without surgical or medical complications.

Humans have demonstrated surprising adaptation capabilities to the artificial vestibular electrical stimulation. Successful restoration of the vestibulo-ocular reflex in the mid- to high- frequency range has been demonstrated using standard clinical tests (rotatory chair and video-head impulse test). We also showed that it is possible to activate the vestibulo-collic reflex using measures of cervical myogenic vestibular evoked potentials. Controlled postural responses could also be obtained with our prototype vestibular implant device. Finally, visual abilities in

dynamic settings were restored with the vestibular implant. The latter is a major step forward, providing the first ever demonstration of useful rehabilitation of this patient population.

Recent refinement of the electrodes design and the use of peroperative monitoring of the electrode insertion has allowed otpimization of the surgical procedure. Thanks to the new wearable "Auditory-Motion-Processor", implanted patients are currently beeing tested in close to real life conditions. Hearing performance and potential interference with the vestibular stimulation are also being assessed.

Results obtained so far in humans are very encouraging. We hope that the increasing interest in this field and the substantial research efforts allocated lead to a clinical application in the near future. It should also be mentioned that the vestibular implant opens new possibilities for exploring several fundamental issues: balance function, the adaptive capacities of the brain, the processes of temporal integration of sensory information necessary for equilibrium, and probably for better understanding vestibular physiology and vestibular disorders. Therefore, the vestibular implant opens new perspectives, not only as an effective therapeutic tool, but also pushes us to go beyond current knowledge and well established clinical concepts.