Journal of Vestibular Research 21 (2011) 73–75
DOI 10.3233/VES-2011-0404
IOS Press

Oral Session 3: Vestibular Function

3–1 [#3040]

Complementarities of utricular and semicircular canal tests

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The human vestibular system comprises five motion detectors, being the three semicircular canals for rotation detection and two otolith organs for linear acceleration detection. Whereas Unilateral Centrifugation (UC) [1] is used for over a decade to evaluate the utricle, the ocular vestibular evoked myogenic potential (oVEMP) test is a very recent test, claiming to be also a utricular test. The current study investigates to which extent there is a similarity between the asymmetry for utricular and horizontal canal function, using ENG, UC and oVEMP.

We tested 257 patients with vestibular problems, visiting the department of otolaryngology in the Antwerp University Hospital. After the clinical investigation, the patients were referred to AUREA where either ENG and oVEMP was performed ($N = 177$), either ENG and UC ($N = 80$). For the ENG data, we used caloric asymmetry (%) as the outcome variable, based on the Jongkees formula for the slow component velocity at maximum. For UC testing we used utricular asymmetry, based on the ocular counter rolling, and for oVEMP we used the asymmetry between right and left side amplitude of the EMG signal of the inferior oblique muscle upon bone vibration with a Bruel and Kjaer minishaker at the forehead.

Results: None of the correlations (ENG – UC) or (ENG – oVEMP) was statistically significant, with R^2 values below 10%. These results indicate that evaluation of the function of horizontal semicircular canal and the otoliths is very independent, and conclusions on asymmetry in one system due to a lesion are not valid for the other system.

Reference

[1] K.I. Buytaert, S.A. Nooij, X. Neyt, P.F. Migeotte, R. Vanspauwen, P.H. Van de Heyning and F.L. Wuyts, A new model for utricular function testing using a sinusoidal translation profile during unilateral centrifugation, *Audiol Neurotol* **15**(6) (2010), 343–352.

3–2 [#3059]

Vestibular prosthesis tested in non-human primates: Oculomotor, perceptual, and postural effects

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Vestibular dysfunction causes prominent perceptual, postural, and oculomotor (e.g. visual) symptoms. To alleviate these vestibular-mediated symptoms, we have been developing and testing a semicircular canal prosthesis that senses head rotation in three dimensions and provides this information to the brain by modulating activity in all six canal ampullary nerves through direct electrical stimulation.

We are testing the efficacy of this prosthesis in rhesus monkeys by characterizing percepts of head orientation (using a method derived from the subjective visual vertical), postural control (by measuring sway during quiet stance, during voluntary head turns, and during tilt of the support surface), and the angular vestibulo-ocular reflex (VOR) in three dimensions in normal monkeys, monkeys with marked bilateral vestibular hypofunction (BVH), and BVH monkeys with chronic prosthetic stimulation.

Our results to date demonstrate that the prosthesis can produce a compensatory VOR that reduces motion

ISSN 0957-4271/11/$27.50

of images on the retina during head motion, shows evidence of adaptation (gain, axis, symmetry) and normal spatial orientation properties. Preliminary results indicate that perceptual and postural responses a re impaired by bilateral vestibular damage and that these deficits can be reversed in part with chronic prosthetic stimulation.

These findings suggest that providing vestibular information to the brain with a prosthetic device can improve vestibular-mediated behaviors when these are abnormal. While we have focused to date on canal (rotational) information, otolith (gravito-inertial) information could also be provided to the brain with a prosthesis, although the challenges are greater given the complexity of the otolith maculae compared to the relative simplicity of the canal cristae.

3–3 [#3037]

Computerized posturography incorporating static and dynamic head tilts

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Head position or movement can increase sway in healthy persons during balance tests, which has led to the development of more sensitive balance tests for astronauts returning to terrestrial gravity after returning from space. This study evaluated measures of computerized dynamic posturography during static and dynamic pitch head tilts using a large sample of 113 healthy student military aviators. Postural equilibrium was measured with the NeuroCom EquiTest® Sensory Organization Tests (SOTs). Each subjects performed SOTs with his/her head upright (control), during static 30° posterior head tilt, and during ± 30° dynamic head pitch movements. SOT5 (eyes closed, unstable support), which is considered the most vestibular-dependent SOT, proved to be the most useful test for distinguishing head upright from head tilt or movement conditions. SOT5 equilibrium scores were significantly worse in the head tilt/movement conditions (versus head upright). Moreover, falls during SOT5 occurred in only 0.3% of head erect trials, but were observed in 1.5% of static head tilt trials, and 4.1% of dynamic head pitch trials. Although there were more falls with dynamic (versus static) head tilts, the equilibrium scores were similar for static and dynamic tilts. This study supports other experiments suggesting that head tilt or movement while balancing with eyes closed on a moving platform is a difficult variant of the balance test which may prove useful for postural testing of aviation personnel and astronauts. Static head tilts should be especially useful for assessing astronauts following spaceflight, since they are not as provocative as dynamic tilts nor as likely to cause readaptation during testing.

3–4 [#3025]

Behavioral and kinematic measures in simple screening tests of vestibular function

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Few simple but well validated screening tests of the vestibular system are available for use at remote landing sites and other situations where limited test facilities are available. The goal of this study is to develop a valid and reliable screening battery that will a) indicate the presence or absence of a vestibular impairment, b) take no more than 15 minutes, and c) be performed and interpreted with minimal equipment by staff without significant technical expertise in the vestibular system. The new battery includes tests of dynamic visual acuity for indirect testing of the vestibulo-ocular reflex [1], standing balance test on compliant foam with eyes closed [2], tandem gait with eyes closed [3], and clinically well accepted head thrusts and Dix-Hallpike maneuvers. Kinematic measures were obtained from inertial measurement unit (IMU) sensors attached to the head and torso during the performance of these tests. Subjects included 50 normals, aged 21 to 79, and 50 patients with unilateral caloric weakness or post-acoustic

neuroma resection. Preliminary analyses of the behavioral and kinematic measures suggest that patients with vestibular impairments are significantly impaired on performance of these tests. These data support previous work showing that performance of some balance tests is sensitive to vestibular disorders. Therefore this test battery should be useful for screening post-flight crewmembers at landing.

Acknowledgements: Supported by NIH grant RO1-DC009031 and by the National Space Biomedical Research Institute through NASA NCC 9–58. We thank the staff of the Center for Balance Disorders for their invaluable technical assistance.

Reference

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3–5 [#3016]

Metrics of balance control for use in screening tests of vestibular function

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Decrements in balance control have been documented in astronauts after space flight. Reliable measures of balance control are needed for use in post flight field tests at remote landing sites. Diffusion analysis (DA) is a statistical mechanical tool that shows the average difference of the dependent variable on varying time scales. DA techniques have been shown to measure differences in open-loop and closed-loop postural control in astronauts and elderly subjects. The goal of this study was to investigate the reliability of DA measures of balance control. Eleven subjects were tested using the Clinical Test of Sensory Interaction on Balance: the subject stood with feet together and arms crossed on a stable or compliant surface, with eyes open or closed and with or without head movements in the pitch or yaw plane. Subjects were instrumented with inertial motion sensors attached to their trunk segment. The DA curves for linear acceleration measures were characterized by linear fits measuring open- (D_s) and closed-loop (D_l) control, and their intersection point (X-int, Y-int). D_s and Y-int showed significant differences between the test conditions. Additionally, D_s was correlated with the root mean square (RMS) of the signal, indicating that RMS was dominated by open-loop events (< 0.5 seconds). The Y-int was found to be correlated with the average linear velocity of trunk movements. Thus DA measures could be applied to derive reliable metrics of balance stability during field tests.

Acknowledgement: Supported by National Institutes of Health grant RO1-DC009031 and by the National Space Biomedical Research Institute through NASA NCC 9-58 (SA02001).