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Postural function in idiopathic normal pressure hydrocephalus before and after shunt surgery: A controlled study using computerized dynamic posturography (EquiTest)

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ABSTRACT

Introduction: Postural dysfunction is one of the major features of idiopathic normal pressure hydrocephalus (iNPH). With computerized dynamic posturography (CDP) balance can be assessed objectively. The primary aim of this study was to describe the postural function in iNPH patients pre- and post-operatively in comparison with healthy individuals (HI) using CDP.
Subjects and methods: Thirty-five patients (16 M, 19 F) with a mean age of 73 (range 49–81) with iNPH, and sixteen HI (7 M, 9 F) aged 73 (62–89) were included. iNPH patients were operated on with a ventriculo-peritoneal shunt. Patients and HI were tested regarding motor function, balance and cognition. CDP, EquiTest (NeuroCom International, Clackamas, OR), was performed before and three months after shunt surgery and twice in HI, with a three-month interval.
Results: Pre-operatively, the 35 patients had poorer balance measured with the Sensory Organizing Test (SOT) score in every condition ($p = 0.01$ in SOT 1 and $p < 0.001$ in SOT 2–6) compared to the HI. The greatest difference was in test conditions measuring mainly vestibular function, where loss of balance (LOB) was frequent. Twenty patients were evaluated three months after shunt surgery and 18/20 (90%) of them were considered shunt responders, with a mean improvement of motor score of 26% (range 5–67%). There was an improvement post-operatively in the weighted composite SOT score ($p < 0.05$) but no significant change in any of the SOT conditions. LOB was not significantly reduced in any of the test conditions.
Conclusion: CDP showed that the patients had a poorer balance than the HI. The greatest difference was in SOT 5–6, indicating that the postural disturbance is of primarily central vestibular origin. There was a slight improvement of balance post-operatively.

1. Introduction

Postural disturbance is an important symptom of idiopathic normal pressure hydrocephalus (iNPH) and is, together with the motor dysfunction, responsible for the most striking symptom, namely gait difficulties [1]. The other classical symptoms of iNPH are impaired cognition and urinary urgency [1]. The symptoms usually exist together, but the severity may range from subtle to disabling [2]. iNPH usually affects older individuals with a mean age of around 70 y [3,4] and the prevalence has been estimated to be as high as 1.4% in elderly Japanese people [5]. iNPH is characterized by a ventricular enlargement secondary to a cerebrospinal fluid (CSF) disturbance, where the CSF-pressure is within the normal limits. There have been a few studies addressing the issue of postural dysfunction in iNPH. Soelberg-Sörensen et al. found a decreased postural stability [6] and Blomsterwall et al. went further and concluded that postural dysfunction is partly responsible for the gait difficulties, and that improvement after shunt surgery is more profound in tests assessing balance [7]. In a later study, Blomsterwall et al. used a force platform to assess balance in patients with normal pressure hydrocephalus (NPH) and subcortical arteriosclerotic encephalopathy. In this study, no difference regarding balance could be detected between the groups of patients, but compared to HI the hydrocephalic patients had significantly larger sway area and showed higher backward velocity [8].

Postural function is dependent on vision, peripheral vestibular sense, proprioception and a central integration. With advancing

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Table 1
Clinical data for iNPH vs. HI.

	iNPH $n=35$	HI $n=16$
Male/female	16/19	7/9
Age (mean years, range)	73 (49–81)	73 (62–89)
Disease duration (mean months, range)	36 (6–120)	N/A
Cardiovascular risk factors		
Hypertension	17	4
Diabetes mellitus	10	3
Stroke	7	1
Heart disease	9	1

age there is impairment in these functions, and if there is a selective impairment in one of them, greater demands are placed on the remaining functions in order to maintain a good balance [9]. It is of great importance to assess balance in the elderly properly to identify individuals at risk of falling, since the consequences of traumatic injuries can be enormous, both for the individual and also for society.

There are many bedside clinical tests for assessing balance. The oldest, and one that is still performed, is Romberg's test [10], other examples are the Tinetti balance and gait test [11] and the Berg Functional Balance Scale [12]. They are easy to perform but have the problems of ceiling effects and poor specificity [13].

Instrumental methods have been developed for assessing balance more accurately. Computerized dynamic posturography (CDP) is a method involving the measurement of ground reaction forces from which the centre of pressure and sway may be calculated [14]. The simplest equipment is a force plate. A more advanced equipment is EquiTest (version 4.04 NeuroCom International, Clackamas, OR); a diagnostic tool that measures the sway in several conditions. CDP can potentially differentiate between different causes of postural dysfunction, such as vestibular, proprioceptive and visual. The method has never been used before to evaluate patients with hydrocephalus.

The primary aim of this study was to describe the postural function in iNPH patients by CDP pre-and post-operatively and in comparison with HI.

2. Subjects and methods

Thirty-five patients (16 males, 19 females) with mean age 73 (49–81) (Table 1) diagnosed as probable iNPH with modified iNPH guidelines [1] were consecutively included. They were recruited from the outpatient clinic of Neurology, University of Linköping.

Clinically there had to be a gait disturbance affecting both legs, including difficulties with tandem walking, multistep turning, decreased step length and a straddled gait where no other condition could be the cause. Patients with neurological symptoms of cortical origin, such as aphasia, apraxia and agnosia, were excluded. Decreased cognitive function and urgency of micturition might exist.

Radiologically, a symmetrical communicating ventricular dilatation without cortical infarcts or other lesions of clinical importance except lacunar infarcts (<1 mL), Evans index $\geq$0.3, relative enlargement of temporal horns and third ventricle had to be present. Moderate cortical atrophy and moderate subcortical ischaemic white matter hyperintensities were accepted.

Patients with ICP > 18 mmHg, cerebrospinal fluid (CSF) changes compatible with a secondary normal pressure hydrocephalus, difficulties in handling the tests, or short expected survival time were excluded.

3. Healthy individuals

Sixteen HI (7 males, 9 females) aged 73 (62–89) were consecutively recruited mainly from relatives and friends to staff members (Table 1). They were subjectively healthy and had a normal gait, balance and cognition on examination. Medication and diseases not impairing gait and cognitive status were not considered reasons for exclusion.

3.1. Clinical assessment

The patients were assessed neurologically (FL), and an MRI of the brain was performed. A physiotherapist assessed the motor function by using the following tests: time needed for a 10-m walk in seconds (w10mt) and number of steps (w10ms) at a self-selected speed and with their usual walking aid [8]. A timed up and go test measuring seconds (TUGt) and steps (TUGs). This is a timed test for standing up from a chair, walking three metres, turning and walking back to the chair and sitting down [15]. For balance, Romberg's test, modified after Blomsterwall et al., was used. It was performed standing, with the feet together, eyes closed and hands on the chest. Seconds to correction up to 60 s were registered [8]. An occupational therapist performed cognitive testing with MMSE [16]. CSF pressure was measured at a lumbar puncture. Cells and proteins were analyzed in order to exclude patients with secondary NPH.

The patients received a programmable Codman-Hakim (Codman/Johnson & Johnson, Raynham, MA) ventriculo-peritoneal shunt ($n=31$) with an opening pressure of mean 110 (60–150) mm H_2O or a fixed pressure valve, medium high, Codman-Hakim (Codman/Johnson & Johnson, Raynham, MA) ($n=3$). One patient did not undergo shunt surgery because the pre-operative examination indicated an unfavourable prognosis according to a consensus discussion. The patients were re-examined three months after surgery. Improvement was defined as a 5% improvement in a motor score (MOS). MOS was calculated as a composite score with the percentage change of each item expressed as follows:

$$\frac{\Delta\text{w10mt} + \Delta\text{w10ms} + \Delta\text{TUGt} + \Delta\text{TUGs}}{4}.$$

Shunt dysfunction was considered if the patient did not reach the pre-defined improvement in MOS. A computer tomography of the brain and a plain radiograph were carried out, and if there were still doubts about the feasibility of a working shunt a CSF-dynamic test was performed. There were no adjustments made during the first three months after surgery.

The HI were examined for time needed for a 10-m walk in seconds and number of steps at a self-selected speed. Romberg's test for assessing balance and an MMSE for evaluating cognitive status were performed.

3.2. Computerized dynamic posturography

Computerized dynamic posturography (CDP), EquiTest (version 4.04. NeuroCom International, Clackamas, OR) was used in which the patient stands on a dual force plate and a visual surround is enclosed. The feet were placed straight ahead with a distance of 15 cm between. The platform measures the force between the ground and the feet in a horizontal antero-posterior direction and from that the sway can be estimated. (NeuroCom International, Clackamas, OR) Patients and HI are examined in six separate conditions (Sensory Organizing Test, SOT); (1) eyes open, fixed surface and visual surround. (2) eyes closed, fixed surface; (3) eyes open, fixed surface, sway referenced visual surround; (4) eyes open, sway referenced surface, fixed visual surround; (5) eyes closed, sway referenced surface; (6) eyes open; sway referenced surface and visual surround (Fig. 1). The