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Trunk sway in idiopathic normal pressure hydrocephalus—Quantitative assessment in clinical practice

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ABSTRACT

Background: In diagnosis and treatment of patients with idiopathic normal pressure hydrocephalus (iNPH), there is need for clinically applicable, quantitative assessment of balance and gait. Using a body-worn gyroscopic system, the aim of this study was to assess postural stability of iNPH patients in standing, walking and during sensory deprivation before and after cerebrospinal fluid (CSF) drainage and surgery. A comparison was performed between healthy elderly (HE) and patients with various types of hydrocephalus (ventriculomegaly (VM)).
Methods: Trunk sway was measured in 31 iNPH patients, 22 VM patients and 58 HE. Measurements were performed at baseline in all subjects, after CSF drainage in both patient groups and after shunt surgery in the iNPH group.
Results: Preoperatively, the iNPH patients had significantly higher trunk sway compared to HE, specifically for the standing tasks ($p < 0.001$). Compared to VM, iNPH patients had significantly lower sway velocity during gait in three of four cases on firm support ($p < 0.05$). Sway velocity improved after CSF drainage and in forward-backward direction after surgery ($p < 0.01$). Compared to HE both patient groups demonstrated less reliance on visual input to maintain stable posture.
Conclusions: INPH patients had reduced postural stability compared to HE, particularly during standing, and for differentiation between iNPH and VM patients sway velocity during gait is a promising parameter. A reversible reduction of visual incorporation during standing was also seen. Thus, the gyroscopic system quantitatively assessed postural deficits in iNPH, making it a potentially useful tool for aiding in future diagnoses, choices of treatment and clinical follow-up.

1. Introduction

The cardinal symptoms of idiopathic normal pressure hydrocephalus (iNPH) are impaired gait and balance, cognitive impairment and urinary incontinence [1]. Typically, brain imaging shows ventricular enlargement with an Evan's index >0.3 [1]. The onset age for iNPH is about 70 years [2]. The prevalence has been reported to be 0.2% (70–79 years), 5.9% (≥80 years) and 1.4% (65 years and older) based on Swedish and Japanese populations respectively [3,4]. INPH is commonly surgically treated by inserting a cerebrospinal fluid (CSF) shunt between the ventricles of the brain and the abdomen, with success rates varying from 30 to 90% across studies [5].

CSF drainage is commonly used as a predictive test for positive response to shunting, and gait and postural stability are generally the symptoms that improve the most [6,7]. However, generally accepted assessment methods for objective and standardized gradings of gait and balance disturbances are lacking [8]. According to the current iNPH guidelines [1], two out of nine patterns describing gait should be positive for the diagnosis of iNPH. This means that vague and imprecise expressions such as "increased trunk sway during walking", and "impaired walking balance" have to be assessed". Today, apart from gait velocity, coarse tests with ordinal scales, e.g. Romberg's test [9] and Tinetti's performance-oriented assessment of mobility [10], are commonly used. This makes the clinical assessment subjective and insensitive to subtle differences, and provides for a low inter-rater and test-retest reliability.

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There have been attempts to objectively describe the postural function in iNPH using force plates or dynamic posturography, with findings like increased sway angle and sway velocity [7,11,12]. Limitations are that these are expensive, stationary and space requiring. Gyroscopes, i.e. angular velocity sensors, allow for the assessment of angular and angular velocity deviations of the body part that the sensor is attached to. Thus, trunk sway may be estimated by attaching the sensor at the trunk level, close to the centre of mass (COM) [13]. Small size, applicability regardless of location together with high validity and sensitivity [14] make these sensors suitable for application in clinical practice.

This is the first prospective study where trunk sway, measured with body-worn gyroscopes, is used to estimate postural stability in iNPH patients, patients with various types of hydrocephalus (ventriculomegaly) and healthy elderly (HE). The aim of this study was to assess postural stability in standing, walking and during sensory deprivation before and after CSF drainage and surgery, and to compare it to HE and patients with various types of hydrocephalus.

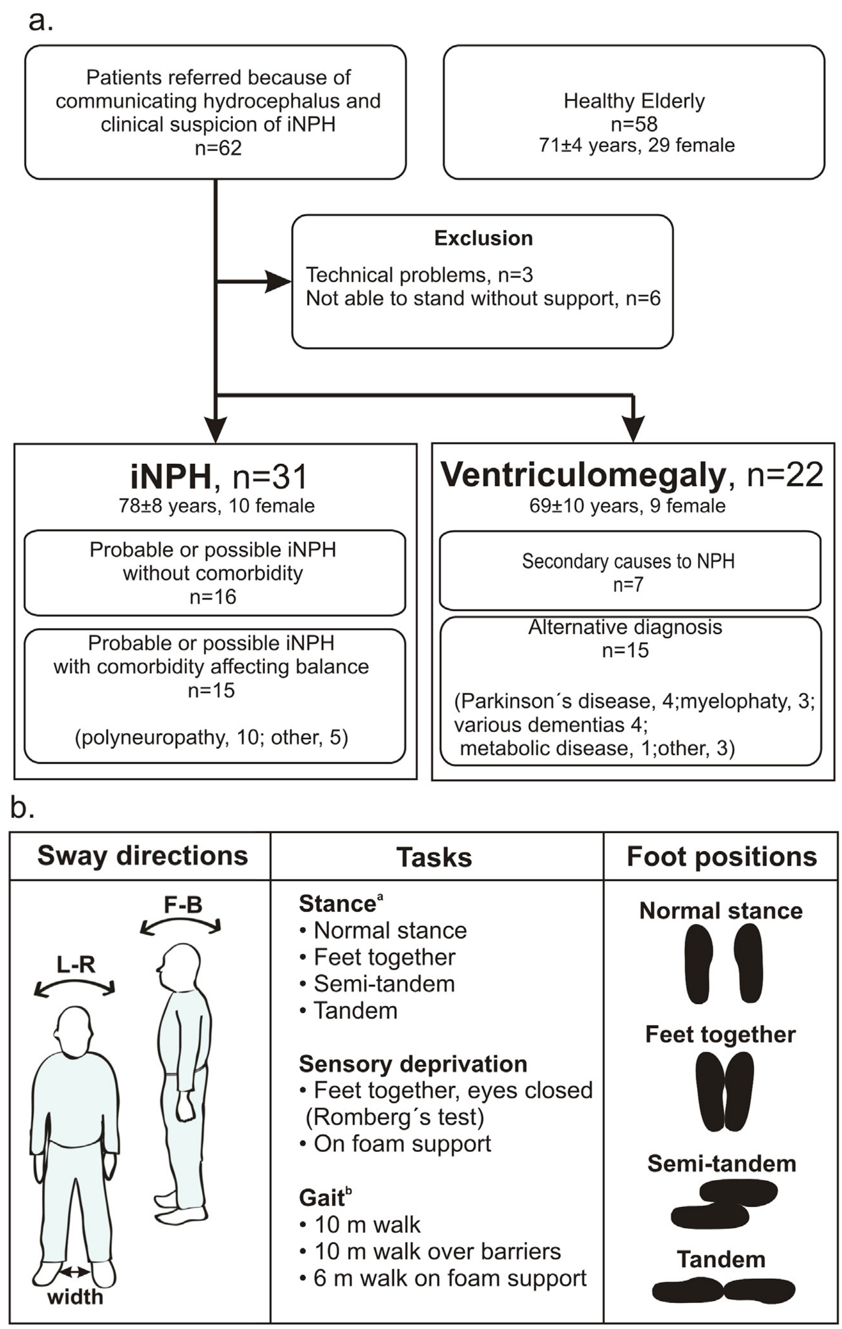

Fig. 1. a. Characteristics of the participants included the study. Age is presented as mean ± standard deviation. b. Patient sway directions, left-right (L-R) and forward-backward (F-B), and tasks performed.
[a]Standing tasks, increasing difficulty in descending order. In all "normal stance" tasks the positions of the feet were self-selected. Barriers (n = 2): 24 cm high consisting of 4*2 cm wooden slats loosely placed on top of boxes evenly spaced along the walkway. Foam support: three 205*80*10 cm foam rubber mattresses placed in a raw to form a 6 m track (foam density 35 kg/m^3).
[b]Gait tasks were performed at self-selected pace.