İstanbul Med J 2023; 24(1): 36-9
DOI: 10.4274/imj.galenos.2023.60251

Gait Analysis in Idiopathic Normal Pressure Hydrocephalus: A Single Centre Experience

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ABSTRACT

Introduction: Gait impairment is the earliest symptom of idiopathic normal pressure hydrocephalus (iNPH). This study objectively investigates gait changes using Ambulatory Parkinson's Disease Monitoring inertial sensors after cerebrospinal fluid withdrawal in patients with iNPH.

Methods: Two-minute walkway tests were performed in eleven patients with iNPH before and after the spinal tap test (TT) or ventriculoperitoneal shunt surgery. Gait parameters were analyzed and compared for each patient individually before and after the intervention.

Results: Eleven patients with iNPH (six female, five male) with a median age of 76 (68-76) were included in the study. After the spinal TT or ventriculoperitoneal shunt surgery, patients exhibited increased cadence (steps per minute) and decreased step and stride time (p=0.008, for all).

Conclusion: APDM inertial sensors may provide a quantitative gait assessment in patients with iNPH.

Keywords: Normal pressure hydrocephalus, gait analysis, APDM

Introduction

Idiopathic normal pressure hydrocephalus (iNPH) is a syndrome characterized by a triad of progressive gait impairment, urinary incontinence, and cognitive decline with enlarged ventricles and normal cerebrospinal fluid (CSF) pressure (1). Gait impairment appears in the early stages leading to frequent falls and increased morbidity in the elderly (2). Installing a ventricle-peritoneal (VP) shunt to drain the CSF from the cerebral ventricles to the peritoneum is the most widely used treatment for NPH (3). After the initial improvement with VP shunt implants, symptoms may return despite evidence that the shunt is functioning (4). Patient selection for VPS treatment is critical, although clinical predictors for a favorable outcome are understudied and poorly recognized. The CSF tap test (TT) is a diagnostic test in which 30-50 mL CSF is removed by lumbar puncture, which may predict the iNPH patients' response to VP shunt (6). The assessment of the TT is based on clinical observation of the gait before and after the intervention. Instrumented gait analysis may objectively analyze gait and balance improvements and reveal features not commonly available through clinical observations or assessments (7). The Ambulatory Parkinson's Disease Monitoring (APDM) inertial sensor (Opals and Mobility Lab) is a wearable system that includes three-axis accelerometers, gyroscopes, and a magnetometer that can provide objective gait analysis (8,9). This study investigates the gait parameters of patients with iNPH using APDM inertial sensors before and after an intervention, such as a spinal TT or VP shunt.

Methods

Eleven patients who followed up with an iNPH diagnosis in the Neurology and Neurosurgery Departments at Koç University Hospital were included. After giving their informed consent, all patients were invited to the Motion Analysis Laboratory. They performed 2-Minute Walkway Test (2 MWT) with an APDM Mobility Lab System (APDM Inc., Portland, OR, USA). Participants wore three OPAL sensors on their feet and lumbar area to

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Received: 20.12.2022
Accepted: 05.01.2023

Cite this article as: Öztop-Çakmak Ö, Akar K, Youssef H, Kahraman AD, Özkan E, Samancı MY, Vural A. Gait Analysis in Idiopathic Normal Pressure Hydrocephalus: A Single Centre Experience. İstanbul Med J 2023; 24(1): 36-9.

assess spatiotemporal parameters, trunk angles, turning angles, and velocity during the gait task. Patients performed 2 MWT on a 10-meter back-and-forth walkway at an average speed. Participants repeated the procedure 6 h after the spinal tap and one month after VP shunt surgery. Gait parameters were documented according to the PDM Motion Lab Guidelines, and pre and postinterventional data were compared.

Statistical Analysis

Continuous variables were presented as median (interquartile range), and categorical variables as numbers and percentages. Statical analyses were performed on gait parameters before and after the interventions using Graphpad Prism software 8.4.3 (GraphPad Software Inc., La Jolla, CA, USA). Normality assumptions were performed with Anderson-Darling and D'Agostino & Pearson tests. The paired t-test and Wilcoxon tests were used to determine the difference between the dependent gait data.

Results

Eleven patients with iNPH (six female, five male) with a median age of 76 (68-76) were included in the study. The demographic and clinical features of the patients are shown in Table 1. Three patients could not walk without support before the intervention, so the pre-intervention data from these patients were missing.

The number of steps per minute, counting steps made by both feet (cadence), was significantly increased after the intervention (p=0.008). The duration of the step is measured as the period from initial contact of one foot to the following initial contact of the opposite foot (step time) and the duration of a full gait cycle, measured from the left foot's initial contact to the next initial contact of the left foot (stride time) were significantly decreased after the intervention (for both, p=0.008), Figure 1. There was no difference in other gait parameters before and after the intervention. All analyzed gait parameters are summarized in Table 2.

Discussion

Wearable inertial sensors are small-sized mobile systems and are easy to use. Accumulating data demonstrate that portable systems are promising methods for gait analysis (13). Additionally, the quantitative measurement of gait parameters shows subtle changes in gait that may provide precious information in the assessment of TT response, which is being used as an indicator of surgery in patients with iNPH patients.

It has been demonstrated that gait and balance parameters are helpful for measuring changes after external lumbar drainage in patients with iNPH (10-12). Here, our results also support that instrumented gait analysis could detect subtle changes in gait after CSF removal interventions. We showed a significant increase in cadence, on the other hand, decrease in step and stride time parameters.

Improvement of gait velocity after the CSF removal test was determined by Stolze et al. (14), and the authors connected increased gait velocity with increased stride length rather than the cadence. However, He et al. (15) showed that stride length and cadence were increased after the external lumbar drainage. Similar to He et al. (15), our data confirmed a marked improvement in cadence. Further studies are required for verification.

Table 1. Demographic and clinical features of the patients

Parameters	Patients (n=11)
Age, years Median (IQR)	76 (68-76)
Female/male	6 (55%)/5 (45%)
Duration of symptoms, years median (IQR)	2 (1-4)
Intervention-surgery (n)	8 (73%)
Intervention-LP (n)	3 (27%)

IQR: Interquartile range, LP: Lumbar puncture, n: Number

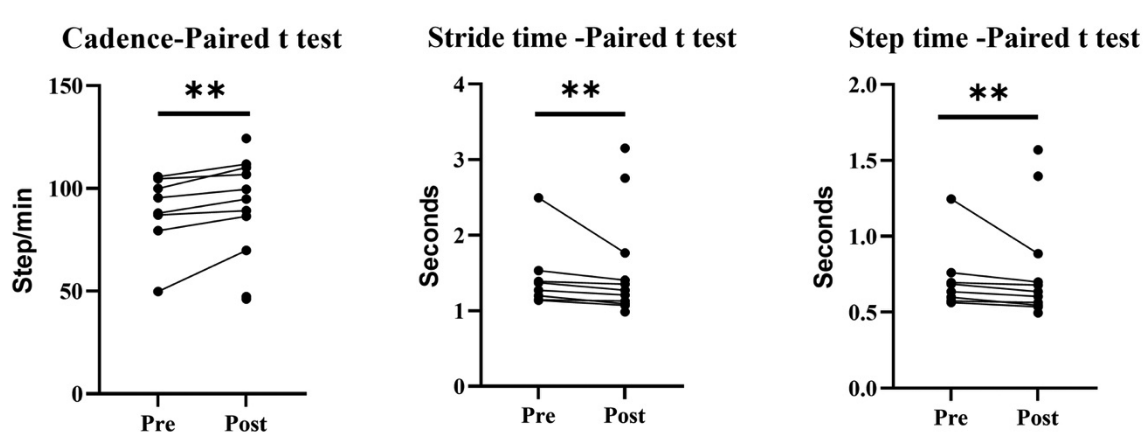

Figure 1. Differences in the cadence, stride time, and step time before and after intervention in the iNPH patients. The mean values of measurements done for each participant before and after the intervention are shown as dots. **Refers to p<0.01

iNPH: Idiopathic normal pressure hydrocephalus

In this study, we observed a significant decrease in stride time and step time that can be attributed to an increased gait velocity after an intervention such as a spinal TT or ventriculoperitoneal shunt consistent with previous studies (16-18). Spatial gait parameters such as stride length, were not observed in our cases, which may be due to the limited number of participants and the relatively early assessment of gait after the intervention.

Study Limitations

The main limitations of this study are the small sample size and the lack of a control group. Furthermore, we included patients who underwent two different interventions. However, studies have pointed out that gait improvement was noticeably better after shunt surgery than after CSF draining, which has both prognostic and functional relevance (19). Thus,

Table 2. Gait parameters before and after the intervention

	Pre	Post	p-value
Cadence, step/min Median (IQR)	91.72 (81.32-103.5)	97.24 (87.10-109.3)	**0.008**
Gait speed: m/s Mean ± SD	0.540±0.24	0.580±0.29	0.360
Stride length, m Mean ± SD	0.689± 0.25	0.697±0.29	0.860
Step time, s Median (IQR)	0.660 (0.581-0.743)	0.620 (0.550-0.695)	**0.008**
Stride time, m Median (IQR)	1.32 (1.15-1.49)	1.24 (1.10-1.39)	**0.008**
Stance phase, GCT (%) Median (IQR)	64.44 (63.60-68.14)	63.41 (62.94-67.86)	0.250
Swing phase, GCT (%) Median (IQR)	35.56 (31.86-36.40)	36.59 (32.14-37.06)	0.250
Double support phase, GCT (%) Median (IQR)	28.90 (27.31-36.36)	26.84 (25.96-35.95)	0.250
Terminal double support phase, GCT (%) Median (IQR)	14.35 (13.70-18.05)	13.36 (12.97-18.02)	0.190
Single-limb support, GCT (%) Median (IQR)	35.60 (31.76-36.28)	36.58 (31.91-36.97)	0.250
Elevation at the midswing, cm Median (IQR)	1.30 (0.496-2.09)	1.35 (0.748-2.19)	0.360
Lateral step variability, cm Mean ± SD	2.49±0.80	2.54±1.14	0.830
Circumduction, cm Median (IQR)	1.43 (0.817-3.20)	1.64 (0.942-3.22)	0.840
Foot strike angle, degree Median (IQR)	9.69 (4.68-17.79)	7.07 (2.85-19.04)	0.640
Toe-off angle, degree Mean ± SD	24.12±4.62	25.01±6.40	0.540
Toe out angle	16.71 (12.43-18.61)	13.53 (6.69-16.92)	0.070
Lumbar Coronal ROM, degree Mean ± SD	5.60±2.07	5.49±2.53	0.840
Lumbar Sagittal ROM, degree Mean ± SD	4.61±1.28	4.46±1.58	0.710
Lumbar Transverse ROM, degree Mean ± SD	7.37±1.66	7.24±1.94	0.800
Turn angleand degree Mean ± SD	135±48.58	147.4±35.63	0.340
Turn duration, s Mean ± SD	2.51±0.56	2.70±0.33	0.500
Turn velocity, degree/s Mean ± SD	103.5±34.37	112±28.62	0.120

Significant p-values are shown in bold.
IQR: Interquartile range, GCT: Ground contact time, ROM: Range of motion, SD: Standard deviation

further studies comparing the effects of a single intervention in larger patient populations may provide more objective parameters to use in managing patients in daily practice.

Conclusion

Quantitative measurement of gait analysis in iNPH may improve the clinical assessment of TT response and follow-up after VP surgery. In particular, cadence, step, and stride time parameters should be interpreted for the clinical evaluation of patients with iNPH patients.

Ethics Committee Approval: The ethics committee approval was granted by the Ethics Committee of Koç University (approval number: 2020,418,IRB1,157).

Informed Consent: It was obtained.

Peer-review: Externally peer-reviewed.

Authorship Contributions: Surgical and Medical Practices - M.Y.S., A.V.; Concept - Ö.Ö.Ç., K.A., H.Y., E.Ö., A.V.; Design - Ö.Ö.Ç., K.A., H.Y., E.Ö., A.V.; Data Collection or Processing - Ö.Ö.Ç., K.A., H.Y., A.D.K., E.Ö., M.Y.S., A.V.; Analysis or Interpretation - Ö.Ö.Ç., K.A., H.Y., A.D.K., E.Ö., M.Y.S., A.V.; Literature Search - Ö.Ö.Ç., K.A., H.Y., A.D.K., E.Ö., M.Y.S., A.V.; Writing - Ö.Ö.Ç., K.A., H.Y., A.D.K., E.Ö., M.Y.S., A.V.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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