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Effect of spinal tap test on the performance of sit-to-stand, walking, and turning in patients with idiopathic normal pressure hydrocephalus

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ABSTRACT

The aim of the study was to investigate the effect of the spinal tap test on sit-to-stand (STS), walking, and turning and to determine the relationship among the outcome measures of STS, walking, and turning in patients with iNPH. Twenty-seven patients with clinical symptoms of iNPH were objectively examined for STS, walking, and turning by the Force Distribution Measurement (FDM) platform connected with a video camera. Assessments were performed at before and 24 hours after spinal tap. Motor abilities were assessed by the STS time, time of walking over 3 meters, and time and number of steps when turning over 180 degrees. Significant improvements were found in the STS time ($p = 0.046$), walking time ($p = 0.048$), and turning step ($p = 0.001$). In addition, turning time was improved but not statistically significant ($p = 0.064$). Significant relationships were found among all outcome measures ($p < 0.001$). The relationship among these outcome measures indicated that the individuals had similar ability levels to perform different activities. This may serve as a new choice of outcome measures to evaluate the effect of intervention in different severity levels of patients with iNPH.

Keywords: idiopathic normal pressure hydrocephalus, gait, sit-to-stand, turn, spinal tap test

INTRODUCTION

Idiopathic normal pressure hydrocephalus (iNPH) is a syndrome consisting of clinical triad of gait disturbance, cognitive impairment, and urinary incontinence which first described by Hakim

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and Adams in 1965[1]. Gait and balance disturbances are the most common symptoms of iNPH, while cognitive impairment and urinary incontinence are inconsistent and typically appear in later stage[2]. Common abnormal gait patterns in iNPH include hypokinetic, shuffling, magnetic, and wide-based[3-5]. Gait disturbance usually presents with reductions in walking speed, stride length and floor-to-foot clearance or step height, widening base of support, increase in foot angle, hesitation upon gait initiation and turning, unsteadiness, and loss of reciprocal arm swing[6-10]. Difficulty in performing routine motor tasks may also affect the quality of life in patients with iNPH. Owing to their gait disturbance and postural instability, patients with iNPH have high potential to fall[11].

Clinical improvement following spinal tap test is one of the few established prognostic indicators of a positive response for shunt placement in patients with iNPH[12-16]. Alongside various tests for gait in iNPH, both clinical and instrumental gait measurements provide very useful information for detecting the clinical improvement. After spinal tap test, improvement of gait was found in different parameters[14,17-19]. Gait improvement usually presents in walking speed[4,17,18,20], stride length[4,6,18] and one study reported the improvement in time spent and number of steps when walking over 10-meter distance[21].

When considering the dysfunction of subcortical frontal area of iNPH in relation with hypokinetic features[4,22,23], other motor tasks may also be affected. For other motor tasks, only one study by Ravdin et al[17] reported that patients with iNPH had improvement in turning over 180 degrees as indicated by reduction in number of turning steps following spinal tap test. As study of the effect of spinal tap test on the other motor tasks remain limited, we performed the current study with our first objective was to determine the effect of spinal tap test on STS, walking, and tuning in patients with iNPH. Secondly, the relationships among outcome measures of these three motor tasks were evaluated.

METHODS

Ethical statement

Prior to collect the data, all participants were informed about details of the study and signed the informed consent approved by the Siriraj Institutional Review Board (COA no: SI 340/2014).

Data were collected during February 2015 to December 2016 at the Laboratory for gait and mobility analysis, Division of Neurology, Department of Medicine, Faculty of Medicine Siriraj Hospital.

Patients and inclusion criteria

Patients were diagnosed by neurologists or neurosurgeons according to the clinical guideline of the Japanese society of normal pressure hydrocephalus[24]. Inclusion criteria included: individuals who developed symptoms with 60 years old or older; having more than one of the clinical triad (gait disturbance, cognitive impairment and urinary incontinence); ventriculomegaly on MRI; cerebrovascular fluid (CSF) pressure of 200 mmH_2O or less; and normal CSF contents. Patients were excluded if they: could not have MRI evaluation; unable to undergo spinal tap test; or unable to be evaluated for their ability on pre-specified motor tasks. Patients were assessed for their abilities on two occasions (pre- and 24 hours post-tap tests). Of note, none of the patients complained of pain at the tap test region on the day of post-tap test evaluation.

Thirty-nine patients with iNPH diagnosed by neurologists or neurosurgeons were recruited in the study. Tap test with CSF removal around 30–50 cc was performed by neurosurgeon. On the day of pre-tap test, 5 persons were excluded because they were not able to ambulate. On the day

Table 1 Characteristics of the patients (n = 27)

Variables	Values
Age (years)	77.30 ± 6.92 (Range 60–89)
Weight (kg)	60.50 ± 8.12 (Range 47–75)
Height (cm)	160.85 ± 9.26 (Range 140–180)
Gender (number)	Male (n = 16)
	Female (n = 11)
Ambulatory-assisting device (number)	None (n = 15)
	Cane (n = 4)
	Walker (n = 8)
Assistance requirement during ambulation (number)	None (n = 13)
	Mild (n = 9)
	Moderate (n = 5)
Comorbidity (number)	Hypertension (n = 13)
	Diabetes mellitus (n = 7)
	Dyslipidemia (n = 5)
	Musculoskeletal pain/surgery (n = 5)
	Stroke (n = 5)
	Parkinson's disease (n = 3)
	Dementia/Alzheimer disease (n = 3)
	Renal disease (n = 2)
	Heart disease (n = 3)
	Cancer (n = 1)
MMSE-Thai 2002 (scores)*	15.50 ± 6.14 (Range 2–25) (n = 26)

*Uncompleted

of post-tap test, 7 persons were excluded from the study (1 person with exacerbation of herpes zoster, 4 persons with headache from deprivation of sleep, and 2 persons with extreme tiredness). Thus, 27 patients were included in the study. Characteristics of the patients are demonstrated in the Table 1. Averaged age, weight, and height were 77.30 ± 6.92 years, 60.50 ± 8.12 kg, and 160.85 ± 9.26 cm, respectively. They were 16 males and 11 females. Number of participants of ambulatory-assisting device using, assistance requirement ambulation, and comorbidity were reported. The MMSE-Thai 2002 (Mini-Mental State Examination in Thai version) was used to ascertain the level of cognitive impairment. However, there was missing data of the MMSE. Thus, the uncompleted cognitive score was 15.50 ± 6.14 scores.

Motor task assessment

The tasks composed of STS, walking, and tuning were assessed as the components in Time Up and Go (TUG) test, using the Force Distribution Measurement Platform (FDM) with a sampling frequency of 100 Hz synchronized with a video camera. To control the accuracy for each data collection, patients received the same explanation and demonstration of the testing task. They were instructed to initiate movement when they saw a light signal from camera, which placed at the end of the platform. Then, stood up from chair and walked over a 3-meter walkway, then turned and walked back to the starting position. During testing, a physical therapist walked together with the patients to provide assistance as needed to prevent stumbling or falling. Data were assessed for 2–3 trials, depending individual's capability and averaged data were used in the comparison process.

Outcome measures included the time spent during these 3 tasks, which are STS, 3-meter walk, and 180-degree turn. In addition, number of turning steps over 180 degrees was counted for explaining the ability of turn.

Statistical analysis

Kolmogorov Smirnov Goodness of Fit test demonstrated normal distribution of the data. Descriptive statistics was used for reporting the demographic data. Paired *t*-test was used to compare time of STS, walking, and turning and number of step in turning over 180 degrees between pre- and post-tap tests. In addition, relationships among the outcomes at pre- and post-tap tests and the relationships among changed scores of outcomes were assessed by the Pearson correlation coefficient. The results were considered significant at $p < 0.05$.

RESULTS

Comparisons of STS time, walking time, turning time, and turning steps between pre- and post-tap tests are demonstrated in Table 2. Significant differences ($p < 0.05$) of STS time, walking time, and turning steps were found between pre- and post-tap tests, whereas there was no statistically significant difference of the turning time.

Correlations of STS time, walking time, turning time, and turning steps at pre and post-tap tests are demonstrated in the Table 3–4. Moderate to good correlations were found in all pairs of the variables.

At pre-tap test, there were significant correlations of STS time and walking time ($r_p = 0.655$, $p < 0.001$), STS time and turning time ($r_p = 0.752$, $p < 0.001$), STS time and turning step ($r_p = 0.733$, $p < 0.001$), walking time and turning time ($r_p = 0.688$, $p < 0.001$), walking time and turning step ($r_p = 0.600$, $p < 0.001$), and turning time and turning step ($r_p = 0.868$, $p < 0.001$).

At post-tap test, there were significant correlations of STS time and walking time ($r_p = 0.903$, $p < 0.001$), STS time and turning time ($r_p = 0.653$, $p < 0.001$), STS time and turning step ($r_p = 0.699$, $p < 0.001$), walking time and turning time ($r_p = 0.711$, $p < 0.001$), walking time and turning step ($r_p = 0.699$, $p < 0.001$), and turning time and turning step ($r_p = 0.807$, $p < 0.001$).

Correlations of the changed score of STS time, walking time, turning time, and turning steps between pre- and post-tap tests are demonstrated in Table 5. There was significant relationship between STS time changed score and turning time changed score ($r_p = -0.429$, $p = 0.026$), walking time changed score and turning time changed score ($r_p = 0.520$, $p = 0.005$), walking time changed score and turning steps changed score ($r_p = 0.397$, $p = 0.040$), and turning time changed score and turning steps changed score ($r_p = 0.554$, $p = 0.003$).

Table 2 Comparisons of sit-to-stand (STS) time, walking time, turning time, and turning steps between pre- and post-tap tests (n = 27)

Variables	Pre-tap test (Mean ± SD)	Post-tap test (Mean ± SD)	t	df	p-value*
STS time (s)	5.58 ± 2.99	5.06 ± 2.91	2.100	26	0.046
Walking time (s)	15.49 ± 12.48	12.04 ± 6.58	2.076	26	0.048
Turning time (s)	7.53 ± 4.86	6.64 ± 3.66	1.934	26	0.064
Turning step (number)	8.61 ± 3.11	7.59 ± 2.39	3.885	26	0.001

*Statistical significant tested by the paired t-test at $p < 0.05$

Table 3 Correlations of sit-to-stand (STS) time, walking time, turning time, and turning steps at pre-tap test (n = 27)

Variables	STS time	Walking time	Turning time	Turning steps
STS time	1.000	0.655*	0.752*	0.733*
		< 0.001	< 0.001	< 0.001
Walking time		1.000	0.688*	0.600*
			< 0.001	0.001
Turning time			1.000	0.868*
				< 0.001
Turning steps				1.000

*Statistical significance tested by the Pearson correlation at $p < 0.05$

Table 4 Correlations of sit-to-stand (STS) time, walking time, turning time, and turning steps at post-tap test (n = 27)

Variables	STS time	Walking time	Turning time	Turning steps
STS time	1.000	0.903*	0.653*	0.699*
		< 0.001	< 0.001	< 0.001
Walking time		1.000	0.711*	0.699*
			< 0.001	< 0.001
Turning time			1.000	0.807*
				< 0.001
Turning steps				1.000

*Statistical significance tested by the Pearson correlation at $p < 0.05$

Table Correlations of the changed score of sit-to-stand (STS) time, walking time, turning time, and turning steps between pre- and post-tap tests (n = 27)

Variables	STS time changed score	Walking time changed score	Turning time changed score	Turning steps changed score
STS time changed score	1.000	–0.031	–0.429*	0.219
		0.878	0.026	0.272
Walking time changed score		1.000	0.520*	0.397*
			0.005	0.040
Turning time changed score			1.000	0.554*
				0.003
Turning steps changed score				1.000

*Statistical significance tested by the Pearson correlation at $p < 0.05$

DISCUSSION

Some patients were excluded from the study at the day of pre- and post-tap tests due to different reasons as mentioned earlier. Our patients included both responders and non-responders to the spinal tap test. High averaged age and several comorbidity diseases presented in our patients are typical for patients with iNPH. The results of their motor abilities were somewhat low when compared to those from a previous study by Ravdin et al[17]. In the previous study, patients spent time around 14 sec for walking over 10-meter distance and spent time around 5.6 sec for turning over 180 degrees[17]. Whereas, the patients in our study spent time around 15 sec for walking over 3-meter distance only and spent time around 7.5 sec for a similar degree of turning. Although the severity seems to be greater, but we were still able to observe the improvement of STS, walking, and turning after spinal tap test.

Of these parameters, time and number of step are convenient and practical to use in the clinical setting. They are sensitive to detect motor improvement after spinal tap test. By using a stopwatch for timing the walk over 10-meter and counted number of steps over this known distance, useful gait variables such as stride length, stride time, and gait velocity can be extracted[4,17]. In clinic, gait scores such as the Dynamic Gait Index (DGI), TUG, and Tinetti were popular[25-27], but they are unlikely to detect small changes and may be questionable about sensitivity and specificity of these tools. Other method, video capture is practically used for detecting gait behaviors. Health professionals are able to repeatedly analyze movement behavior and variables related to the length, time, and counted number more accurate than using only a stopwatch or visual observation only. Nonetheless, a video camera with sufficient resolution is recommended in clinic to detect changes with a high sensitivity level.

Among various tested variables, moderate to excellent levels of relationship were found in this study. Of these, excellent degree of relationship between turning steps and turning time was found both in pre- and post-tap tests. The results are not surprising because it was evaluated from the same turning task, but presented in different viewpoint of the variables. Small steps accompanied by protracted time spent during turning may affect the patients to be at risk of stumbling, exhaustion from excessive energy consumption and fall[9,18].

The strong relationships of tested variables derived from different motor tasks may imply the consistency among tests. The results may lead to a choice of selection in evaluation method. For instance, the STS parameters may be exploited as a surrogate for motor ability assessment before and after the tap test for patients with iNPH who are unable to walk at all or are unable to walk for a long distance. For the change score, there was no relationship in some pairs of parameters. It is possibly because of differences in gap of improvement after providing the intervention for each parameter.

Lack of the control group, or the group who did not receive any treatment was a limitation of this study. This may be subjected to the ethical constrained and was not proper in clinical routine. The enhancement of motor skills in the present study was found in all three tasks and was corresponding to walking ability of previously results[20,25]. These improvements were unlikely to come from practice effect because data were tested only 2–3 trials. In addition, previous evidences supported that several repetitions of practice are required to change neurons and connections in the brain[28,29].

CONCLUSION

The ability to perform STS, walking, and turning in patients with iNPH can be improved after spinal tap test. The relationships among outcome measures indicated individuals had similar and consistent level of ability to perform different motor activities. This relationship may serve as a choice of task and outcome measures for evaluation of the effects of diagnostic or therapeutic interventions on gait/mobility changes in clinic.

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CONFLICTS OF INTEREST

The authors have no conflict of interest to report.

REFERENCES

1) Hakim S, Adams RD. The special clinical problem of symptomatic hydrocephalus with normal cerebrospinal fluid pressure. Observations on cerebrospinal fluid hydrodynamics. *J Neurol Sci*, 1965; 2: 307–327.
2) Tsakanikas D, Relkin N. Normal pressure hydrocephalus. *Semin Neurol*, 2007; 27: 58–65.
3) Marmarou A, Black P, Bergsneider M, Klinge P, Relkin N, International NPH consultant group. Guidelines for management of idiopathic normal pressure hydrocephalus: progress to date. *Acta Neurochir Suppl*, 2005; 95: 237–240.
4) Bugalho P, Guimarães J. Gait disturbance in normal pressure hydrocephalus: a clinical study. *Parkinsonism Relat Disord*, 2007; 13: 434–437.
5) Nowak DA, Topka HR. Broadening a classic clinical triad: The hypokinetic motor disorder of normal pressure hydrocephalus also affects the hand. *Exp Neurol*, 2006; 198: 81–87.
6) Stolze H, Kuhtz-Buschbeck JP, Drucke H, Johnk K, Diercks C, Palmie S, et al. Gait analysis in idiopathic normal pressure hydrocephalus: which parameters respond to the CSF tap test? *Clin Neurophysiol*, 2000; 111: 1678–1686.
7) Relkin N, Marmarou A, Klinge P, Bergsneider M, Black PM. Diagnosing idiopathic normal-pressure hydrocephalus. *Neurosurgery*, 2005; 57: S4–16.
8) Kuba H, Inamura T, Ikezaki K, Inoha S, Nakamizo A, Shono T, et al. Gait disturbance in patients with low pressure hydrocephalus. *J Clin Neurosci*, 2002; 9: 33–36.
9) Soelberg Sorensen P, Jansen EC, Gjerris F. Motor disturbances in normal-pressure hydrocephalus. Special reference to stance and gait. *Arch Neurol*, 1986; 43: 34–38.
10) Stolze H, Kuhtz-Buschbeck JP, Drücke H, Jöhnk K, Illert M, Deuschl G. Comparative analysis of the gait disorder of normal pressure hydrocephalus and Parkinson's disease. *J Neurol Neurosurg Psychiatry*, 2001; 70: 289–297.
11) Blomsterwall E, Svantesson U, Carlsson U, Tullberg M, Wikkelso C. Postural disturbance in patients with normal pressure hydrocephalus. *Acta Neurol Scand*, 2000; 102: 284–291.
12) Marmarou A, Bergsneider M, Klinge P, Relkin N, Black PM. The value of supplemental prognostic tests for the preoperative assessment of idiopathic normal-pressure hydrocephalus. *Neurosurgery*, 2005; 57: S17–28.
13) Wikkelso C, Andersson H, Blomstrand C, Lindqvist G, Svendsen P. Normal pressure hydrocephalus. Predictive value of the cerebrospinal fluid tap-test. *Acta Neurol Scand*, 1986; 73: 566–573.
14) Sand T, Bovim G, Grimse R, Myhr G, Helde G, Cappelen J. Idiopathic normal pressure hydrocephalus: the CSF tap-test may predict the clinical response to shunting. *Acta Neurol Scand*, 1994; 89: 311–316.
15) Walchenbach R, Geiger E, Thomeer RT, Vanneste JA. The value of temporary external lumbar CSF drainage in predicting the outcome of shunting on normal pressure hydrocephalus. *J Neurol Neurosurg Psychiatry*, 2002; 72: 503–506.
16) Meier U, Konig A, Miethke C. Predictors of outcome in patients with normal-pressure hydrocephalus. *Eur Neurol*, 2004; 51: 59–67.
17) Ravdin LD, Katzen HL, Jackson AE, Tsakanikas D, Assuras S, Relkin NR. Features of gait most responsive to tap test in normal pressure hydrocephalus. *Clin Neurol Neurosurg*, 2008; 110: 455–461.
18) Bugalho P, Alves L, Miguel R. Gait dysfunction in Parkinson's disease and normal pressure hydrocephalus: a comparative study. *J Neural Transm (Vienna)*, 2013; 120: 1201–1207.
19) Bugalho P, Alves L. Normal-pressure hydrocephalus: white matter lesions correlate negatively with gait improvement after lumbar puncture. *Clin Neurol Neurosurg*, 2007; 109: 774–778.
20) Schniepp R, Trabold R, Romagna A, Akrami F, Hesselbarth K, Wuehr M, et al. Walking assessment after

lumbar puncture in normal-pressure hydrocephalus: a delayed improvement over 3 days. *J Neurosurg*, 2017; 126: 148–157.

21) Abram K, Bohne S, Bublak P, Karvouniari P, Klingner CM, Witte OW, et al. The Effect of spinal tap test on different sensory modalities of postural stability in idiopathic normal pressure hydrocephalus. *Dement Geriatr Cogn Dis Extra*, 2016; 6: 447–457.
22) Miyoshi N, Kazui H, Ogino A, Ishikawa M, Miyake H, Tokunaga H, et al. Association between cognitive impairment and gait disturbance in patients with idiopathic normal pressure hydrocephalus. *Dement Geriatr Cogn Disord*, 2005; 20: 71–76.
23) Fraser C, Stark SW. Gait disorder in older adults: is it NPH? *Nurse Pract*, 2011; 36: 14–20.
24) Mori E, Ishikawa M, Kato T, Kazui H, Miyake H, Miyajima M, et al. Guidelines for management of idiopathic normal pressure hydrocephalus: second edition. *Neurol Med Chir (Tokyo)*, 2012; 52: 775–809.
25) Chivukula S, Tempel ZJ, Zwagerman NT, Newman WC, Shin SS, Chen CJ, et al. The Dynamic Gait Index in evaluating patients with normal pressure hydrocephalus for cerebrospinal fluid diversion. *World Neurosurg*, 2015; 84: 1871–1876.
26) Marmarou A, Young HF, Aygok GA, Sawauchi S, Tsuji O, Yamamoto T, et al. Diagnosis and management of idiopathic normal-pressure hydrocephalus: a prospective study in 151 patients. *J Neurosurg*, 2005; 102: 987–997.
27) Jusue-Torres I, Lu J, Robison J, Hoffberger JB, Hulbert A, Sanyal A, et al. NPH Log: validation of a new assessment tool leading to earlier diagnosis of normal pressure hydrocephalus. *Cureus*, 2016; 8: e659.
28) Doyon J, Benali H. Reorganization and plasticity in the adult brain during learning of motor skills. *Curr Opin Neurol*, 2005; 15: 161–167.
29) Doyon J. Motor sequence learning and movement disorders. *Curr Opin Neurol*, 2008; 21: 478–483.