Relationship Between Idiopathic Normal-Pressure Hydrocephalus and Lumbar Spinal Stenosis

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Research Article

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Abstract

Object: To evaluate the relationship between idiopathic normal-pressure hydrocephalus (iNPH) and lumbar spinal stenosis (LSS).

Methods: With the aging of society, the numbers of patients with iNPH and LSS are likely to increase. iNPH and LSS have similar symptoms including gait disturbance and urinary dysfunction. The prevalence of dementia is higher in older adults with LSS. However, the relationship of LSS with iNPH and the prevalence of LSS in patients with iNPH are unknown. In our department between April 2011 and March 2017, 226 patients were diagnosed with iNPH and underwent shunt operation including lumboperitoneal shunts and ventriculoperitoneal shunts. Two spine surgeons evaluated LSS on magnetic resonance imaging of the lumbar spine. Age, sex, body mass index, Timed Up and Go test, Mini Mental State Examination score, and urinary dysfunction were examined before and after surgery for iNPH. Changes in these variables were compared between patients with iNPH without LSS and with iNPH and LSS.

Results: In the overall cohort, the median patient age was 78 years and there were 121 males. Among 226 patients with iNPH, 73 (32.3%) had LSS. Neurological symptoms were improved in all patients at final follow-up. The rate of symptom improvement was lower for the iNPH and LSS group compared with the iNPH without LSS group.

Conclusions: Surgery to improve gait disturbance might be difficult in patients with iNPH with LSS. When examining patients with iNPH, we should consider the possibility of concomitant LSS.

Introduction

Several diseases that cause gait disturbance in elderly patients are not improved after neurological surgery. Lumbar spinal stenosis (LSS) causes symptoms in the lower extremities, including neurogenic intermittent claudication and bladder and rectal dysfunction\textsuperscript{1,2}. Epidemiological studies reported intermittent claudication as a complication of LSS and peripheral arterial disease\textsuperscript{3,4,5,6,7,8}. Another condition that causes gait disturbances in older adults is idiopathic normal-pressure hydrocephalus (iNPH), characterized by three clinical symptoms: gait disturbance, dementia, and urinary incontinence\textsuperscript{9,10,11}, with ventricular dilation and normal cerebrospinal fluid pressure. Although the cause of iNPH is unknown, the standard treatment is a ventriculoperitoneal shunt or lumboperitoneal shunt, and an increasing number of cases require surgery because of the disturbance of cerebral spinal fluid absorption\textsuperscript{12,13}.

As the age of society advances, the number of patients with iNPH and LSS will increase\textsuperscript{12,13,14,15,16,17}. The age at which patients develop iNPH and LSS overlap; therefore, it is necessary to differentiate between gait disorders caused by these two different diseases. However, the coexistence ratio of LSS in patients with iNPH is unknown. We investigated the prevalence of LSS in patients with iNPH and
compared the characteristics and postoperative results of patients with iNPH without LSS versus those with iNPH and concomitant LSS.

**Materials And Methods**

**Participants**

We retrospectively studied the records of patients who underwent magnetic resonance imaging (MRI) of the lumbar spine prior to surgery for iNPH between April 2011 and March 2017 at the Japanese Red Cross Kagoshima Hospital.

**Demographic data**

Patient demographic and clinical characteristics including age, sex, body mass index (BMI), rates of patients with gait disturbance, dementia, urinary incontinence, and dural sac cross-sectional area (DSCSA) were collected from medical records.

The patient variables were examined before and after surgery. Gait disturbance was evaluated pre- and postoperatively via clinical examination by a neurosurgery specialist, history of walking difficulty, and the Timed Up and Go (TUG) test\textsuperscript{18,19}. Dementia was evaluated pre- and postoperatively using the Mini Mental State Examination (MMSE); patients with a MMSE score lower than 24 were defined as having dementia\textsuperscript{20}. Urinary dysfunction was defined as the presence of urinary incontinence or nocturia. Improvements in symptoms were evaluated at the first outpatient visit after discharge from the hospital, and were defined as a faster time in the TUG test, higher MMSE score, and improvement in patient satisfaction with urination compared with preoperatively.

**Definitions of iNPH and LSS**

All patients with a clinical diagnosis of iNPH underwent a lumbar tap to obtain a definitive diagnosis. iNPH was diagnosed in accordance with the diagnostic criteria of the iNPH guidelines\textsuperscript{12}. Patients were diagnosed with LSS when the most narrowed part of the DSCSA was narrower than 75 mm\textsuperscript{2} on MRI\textsuperscript{21,22,23,24,25} using the Magnetom Avanto 1.5T (Siemens Healthineers, Erlangen, Germany).

The radiological assessments were performed by two spine specialists, including one spine surgeon, who was an instructor accredited by the Japanese Society for Spine Surgery and Related Research. A neurosurgeon performed the shunt operation to treat iNPH. We mainly performed lumboperitoneal shunts (LPS) and performed ventriculoperitoneal shunts (VPS) in cases of lumbar spinal canal stenosis or when the patient requested it.

**Statistical analysis**

The data were examined using Wilcoxon's test and Fisher's exact test. Pearson's correlation coefficient analysis was performed to assess the correlation between variables. P values less than 0.05 were
considered statistically significant. Statistical analyses were performed using JMP software (version 15: SAS Institute, Cary, NC, USA).

Results

Patient characteristics

Overall, 226 patients with iNPH were enrolled in this study (Fig. 1). Among these 226 patients, 73 (32.3%) had LSS (iNPH-LSS group) and the remaining 153 (67.7%) did not (iNPH group). The demographic and clinical characteristics of the NPH and iNPH-LSS groups are shown in Table 1. The mean BMI was significantly higher in the iNPH-LSS group than the iNPH group. Pearson’s correlation coefficient analysis showed an inverse correlation between the DSCSA and age ($r = -0.19$) and BMI ($r = -0.18$), and between the preoperative TUG result and BMI ($r = -0.20$) and preoperative MMSE score ($r = -0.43$) (Table 2).

Table 1

| Preoperative patient characteristics in the iNPH and iNPH-LSS groups. |
|---------------------------------------------------------------|
| **iNPH group** | **iNPH-LSS group** | **p** |
| (n = 153) | (n = 73) | |
| Age (years) | 78 (73–82) | 79 (75.5–83.5) | 0.09 |
| Sex (male) (n) | 79 | 42 | 0.48 |
| BMI (kg/m$^2$) | 22.0 (19.8–24.6) | 23.5 (20.4–26.1) | 0.02 |
| TUG (sec) | 24 (18–44) | 21.5 (16–32.3) | 0.08 |
| TUG (steps) | 28 (22–39) | 25 (20–36) | 0.06 |
| MMSE (points) | 22 (17–25.5) | 21 (16–24) | 0.26 |
| Urinary dysfunction (n) | 135 | 68 | 0.35 |

Data are presented as the median (25% quartile–75% quartile) or the number of patients (n).

iNPH group: patients with idiopathic normal-pressure hydrocephalus; iNPH-LSS group: patients with idiopathic normal-pressure hydrocephalus and concomitant lumbar spinal stenosis; BMI: body mass index; TUG: Timed Up and Go test; MMSE: Mini Mental State Examination score.
Table 2
Analysis of the correlations between variables.

| Variables                  | Correlation coefficient |
|----------------------------|-------------------------|
| DSCSA                      |                         |
| Age (years)                | −0.19**                 |
| BMI (kg/m²)                | −0.18**                 |
| Preoperative TUG (sec)     | 0.11                    |
| Preoperative MMSE (points) | 0.09                    |

| Variables                  | Correlation coefficient |
|----------------------------|-------------------------|
| Preoperative TUG (sec)     |                         |
| Age (years)                | 0.10                    |
| BMI (kg/m²)                | −0.20**                 |
| DSCSA (mm²)                | 0.11                    |
| Preoperative MMSE (points) | −0.43**                 |

**p < 0.01

Data were analyzed using Pearson's correlation analysis.

BMI: body mass index; TUG: Timed Up and Go test; MMSE: Mini Mental State Examination score; DSCSA: dural sac cross-sectional area.

Follow-up After Surgery For Inph

The rate of improvement in the gait disturbance was significantly lower in the iNPH-LSS group than in the iNPH group (P < 0.01) (Table 3). Table 4 shows the results of the assessment of the improvements in symptoms postoperatively compared with preoperatively. There were no significant differences between the iNPH-LSS and iNPH groups in the rates of improvement in dementia and urinary dysfunction. Both groups showed improvements in the TUG time and MMSE score postoperatively. The TUG number of steps was significantly improved postoperatively in the iNPH group, but not in the iNPH-LSS group.
Table 3
Comparison of the postoperative improvements in symptoms in the iNPH and iNPH-LSS groups.

|                          | iNPH group (n = 153) | iNPH-LSS group (n = 73) | p     |
|--------------------------|----------------------|-------------------------|-------|
| Improvement in gait disturbance (n) | 138                  | 59                      | 0.008 |
| Improvement in dementia (n)       | 90                   | 46                      | 0.57  |
| Improvement in urinary dysfunction (n) | 104                 | 51                      | 0.86  |

Data were analyzed using Fisher’s exact test.

iNPH group: patients with idiopathic normal-pressure hydrocephalus; iNPH-LSS group: patients with idiopathic normal-pressure hydrocephalus and concomitant lumbar spinal stenosis.

Table 4
Postoperative improvements in the TUG and MMSE in the iNPH and iNPH-LSS groups.

|      | iNPH group | iNPH-LSS group |
|------|------------|----------------|
|      | Preoperative | Postoperative | p    | Preoperative | Postoperative | p    |
| TUG (steps) | 28 (22–39) | 22 (18–30) | < 0.001 | 25 (20–36) | 25 (20–38.5) | 0.13 |
| TUG (sec)    | 24 (18–44) | 18 (14–27.5) | < 0.001 | 21.5 (16–32.3) | 18 (13.5–28) | 0.047 |
| MMSE        | 22 (17–25.5) | 24 (20–28) | < 0.001 | 21 (16–24) | 24 (18.5–28) | < 0.001 |

Data are presented as the median (25% quartile–75% quartile) and were analyzed using the paired t-test.

iNPH group: patients with idiopathic normal-pressure hydrocephalus; iNPH-LSS group: patients with idiopathic normal-pressure hydrocephalus and concomitant lumbar spinal stenosis; TUG: Timed Up and Go test; MMSE: Mini Mental State Examination score.

Discussion
To the best of our knowledge, this is the first report of an epidemiological investigation into iNPH and LSS. The typical triad of iNPH comprises gait disturbance, dementia, and urinary dysfunction. However, gait disturbance and urinary dysfunction can also be caused by LSS. Furthermore, the number of patients with dementia and LSS is increasing in the current aging society. We investigated the relationship between iNPH and LSS because the symptoms of iNPH and LSS are similar. We found that 32.3% of the patients with iNPH patients had LSS. Previous studies reported a prevalence of LSS of 6% in 850 lumbar myelograms or 13.1% in 17,744 patients. Furthermore, the risks of LSS and iNPH were reported to be significantly higher in older adults compared with younger individuals. The reason for the increased
prevalence of LSS in our study compared with previous studies may be that our participants were patients with iNPH and had a relatively old mean age.

Obesity affects pain related to spinal stenosis and is associated with mechanical forces in addition to the presence of chronic circulating inflammatory chemicals from active adipose tissue\textsuperscript{29}. Our study showed that a higher BMI was characteristic of patients with iNPH with LSS. In addition, we found that a smaller DSCSA correlated with older age and a higher BMI. Therefore, our findings suggest that older age and a higher BMI may be useful predictors of LSS in patients with iNPH.

In the present study, we used the TUG test as an index of gait ability and used the MMSE as an index of dementia. The TUG test and MMSE had a relatively strong negative correlation. General cognitive function was reported to be associated with improvements in the physical performance of patients with mild cognitive impairment\textsuperscript{30}. The TUG test is a sensitive and specific measure of the risk of falls\textsuperscript{31}. Previous studies reported that patients with LSS have a mean raw TUG test time of 10.2 seconds before surgery\textsuperscript{32} and that patients with iNPH have a median TUG test time of 15.2 (11.7–21) seconds\textsuperscript{19}. In our study, the median TUG test time was 23 (17–38.5) seconds, and these were patients with relatively severe symptoms.

Although VPS is the main surgical procedure for iNPH, therapeutic intervention with LPS was also reported to be effective\textsuperscript{33}. The efficacy and safety of adjustable LPS are comparable with VPS for the treatment of patients with iNPH. LPS may be the best treatment because it is less invasive and avoids damage to the brain, despite the relatively high rate of shunt failure\textsuperscript{33,34}. In this study, we mainly performed LPS in patients without lumbar spinal canal stenosis.

After surgery, the rate of improvement in gait disturbance was significantly lower in the iNPH-LSS group compared with the iNPH group. This suggests that some of the patients who did not improve after surgery for iNPH might have been affected by LSS symptoms. One patient in the iNPH-LSS group underwent lumbar decompression surgery after shunt surgery. Four patients in the iNPH group underwent shunt surgery after lumbar decompression surgery.

There were several limitations in our study. First, this was a retrospective single-center study; thus, selection bias may have occurred. We should perform a multicenter study to confirm our findings. Second, patients were diagnosed with LSS alone, by evaluating medical records, on the basis of the most narrowed part of the DSCSA being narrower than 75 mm\textsuperscript{2} on MRI. We could not evaluate more detailed comprehensive physical examination findings of LSS, such as the presence of numbness and pain of the lower extremities. Considering the possibility of LSS in patients with iNPH, we should keep in mind that elderly patients who present with gait disturbance may not have a single disease, but may also have a comorbidity.

**Conclusions**
The factors associated with LSS in patients with iNPH are older age and a higher BMI. It may be more
difficult to perform surgery to treat iNPH and improve gait disturbances in patients with iNPH with LSS
compared with those with iNPH alone. When examining patients with iNPH, we should consider the
concomitant presence of LSS.

Declarations

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Conflicts of interest The authors have no conflicts of interest to disclose.

Availability of data and material Data are available upon request.

Ethics approval This research protocol was approved by the Ethics Committee on Clinical Research at the
Japanese Red Cross Kagoshima Hospital (approval no. 2018-9-1). All methods were carried out in
accordance with the relevant guidelines and regulations.

Consent to participate All patients gave written informed consent for their data to be used in the study.

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**Figures**

**Figure 1**

Patients who underwent lumbar spine magnetic resonance imaging before surgery for iNPH between April 2011 and March 2017

(n = 266)

↓

**Preoperative data**

Evaluation of symptoms (TUG, MMSE, interview about urinary incontinence)

(n = 237)

↓

**Postoperative data**

Evaluation of symptoms (TUG, MMSE, interview about each patient’s satisfaction with urination compared with their preoperative status)

(n = 226)

**Figure 1**

Flowchart of the study. We examined the records of 266 patients who underwent lumbar spine magnetic resonance imaging before surgery for iNPH between April 2011 and March 2017. The TUG, MMSE, and
presence of urinary incontinence were evaluated preoperatively in 237 patients and postoperatively in 226 patients. iNPH: idiopathic normal-pressure hydrocephalus; TUG: Timed Up and Go test; MMSE: Mini Mental State Examination.