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SHORT COMMUNICATION

REHABILITATION COMBINED WITH VENTRICULOPERITONEAL SHUNT FOR PATIENTS WITH CHRONIC NORMAL PRESSURE HYDROCEPHALUS DUE TO ANEURYSM SUBARACHNOID HAEMORRHAGE: A PRELIMINARY STUDY

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Objective: **The aim of this study was to compare activities of daily living and cognitive function after 6 months' rehabilitation training with or without ventriculoperitoneal shunt in patients with chronic normal pressure hydrocephalus following aneurysm subarachnoid haemorrhage.**

Patients and methods: **Thirty-nine subjects diagnosed with chronic normal pressure hydrocephalus following aneurysm subarachnoid haemorrhage, based on clinical deterioration or non-improvement of gait ataxia, cognitive disturbance, and/or urinary incontinence during rehabilitation, were included in the study. A treatment group ($n=24$) underwent ventriculoperitoneal shunt operation, and a control group ($n=15$) did not undergo the operation.**

Results: **Following the operation there was a significant difference in Barthel Index scores between treatment and control groups at 1 month ($p<0.05$) and 6 month follow-ups ($p<0.01$). Similar improvements in Mini Mental Status Examination results were observed at 1 month ($p<0.01$) and 6 month follow-ups ($p<0.01$) in the treatment group.**

Conclusion: **Rehabilitation alone did not result in improvements in patients with chronic normal pressure hydrocephalus, but rehabilitation combined with ventriculoperitoneal shunt resulted in improvements in activities of daily living and cognitive function. The importance of early diagnosis of chronic normal pressure hydrocephalus is stressed.**

Key words: rehabilitation, normal pressure hydrocephalus, aneurysm, subarachnoid haemorrhage, ventriculoperitoneal shunt.

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INTRODUCTION

Subarachnoid haemorrhage (SAH) causes only 5% of strokes, but aneurysm rupture causes approximately 85% of cases (1). Aneurysm SAH is a common cause of stroke in patients under the age of 45 years. Hydrocephalus, a complication of aneurysm subarachnoid haemorrhage (aSAH), was first described in 1928 (2). Hydrocephalus is broadly defined as an excess of cerebrospinal fluid (CSF) in the head, usually in the ventricular system. Although hydrocephalus can present with headache, nausea, vomiting, coma, and a gradual slowing of intellectual and motor activity, the most typical criterion remains the clinical presentation; that is, a syndrome of gait ataxia, cognitive disturbance, and urinary incontinence (3–4). The symptoms are potentially reversible, and the diversion of CSF, using a ventriculoperitoneal, ventriculoatrial, or lumboperitoneal shunt, can be successful provided that a correct diagnosis has been made. Ventricular enlargement can occur either immediately after the haemorrhage or at a later stage. Vale et al. (5) divided hydrocephalus into 3 stages: acute (0–3 days after SAH), subacute (4–13 days after SAH), and chronic (≥14 days after SAH).

Patients with aSAH are often transferred to a rehabilitation ward with hemiplegia, cognitive dysfunction, speech dysfunction, and/or urinary incontinence following initial treatment in the neurosurgical ward or stroke unit. Neurological treatment often lasts for 2–3 weeks, depending on the patient's condition. Chronic hydrocephalus usually occurs during the rehabilitation treatment.

There are 2 categories of hydrocephalus: high pressure hydrocephalus (the pressure of the CSF drainage using a lumbar catheter is >180 mmH_2O) and normal pressure hydrocephalus (NPH; the pressure is between 80 and 180 mmH_2O). The difference between these 2 types appears to be the severity of obstruction and the ability of the brain to adapt to whatever lesion caused the ventricular enlargement. Chronic normal pressure hydrocephalus (CNPH) is a difficult complication to treat. NPH was first described by Adams et al. (6), and is the most frequent form of chronic hydrocephalus in adults.

Opinions on the treatment of CNPH differ. Patient selection for CSF diversion in CNPH is difficult, and is a diagnostic and therapeutic challenge because many patients do not have a classical clinical presentation. In some patients, the symptoms of CNPH are very subtle, while in others symptoms cannot be differentiated easily from those of the coexisting neurological disorder. Because patients with suspected CNPH may also have significant symptoms of the coexisting neurological disorder, shunt procedures do not always result in clinical improvement (7).

In addition, shunt dysfunction is common with all types of shunts, usually due to delayed outflow or obstruction of the

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peritoneal catheter (8). The rate of post-surgical complications reported in the literature is in the range 20–40%, but serious complications (death or severe residual deficit) do not exceed 5–8% of shunted patients. This is in agreement with other studies (9). Hence, the usefulness of a shunt is questionable. The most common evaluations used to gauge changes in functional status over the course of NPH diagnosis and treatment are neurological (10) and neuropsychological (11, 12) evaluations, but, to date, there has been no research describing the change in activities of daily living (ADL) and cognition specifically in patients with CNPH treated with a combination of VPS and rehabilitation training.

The aim of this study was therefore to determine whether CNPH among patients with aSAH should be treated with VPS during rehabilitation, and to evaluate functional and cognitive outcome in these patients.

METHODS

Patients

The records of all patients referred to Xuanwu Hospital of Capital Medical University, Beijing, China, from June 2004 to June 2008 were retrospectively reviewed and 54 patients with hydrocephalus following aSAH identified. Nine subjects were excluded due to treatment refusal, intercurrent disease, changed address, or missed follow-up. Six subjects were diagnosed with high-pressure hydrocephalus through lumbar puncture. Of the 39 subjects eligible for the study, 24 (11 men and 13 women) underwent VPS, while the other 15 (7 men and 8 women) did not undergo VPS due to their, or their close relatives', refusal and/or because they could not afford the cost of the operation. These subjects comprised the control group. No subjects had prior neurodegenerative conditions such as Alzheimer's or Parkinson's disease.

Procedure

All 39 subjects fulfilled the clinical criterion of presumed CNPH. The time after aSAH ranged from 3 weeks to 6 months. The opening pressure of the lumbar puncture ranged from 80 to 180 mmH_2O. Clinical diagnosis of hydrocephalus was based on the following: (*i*) 1–3 of the 3 symptoms of the triad (gait disturbance, cognitive dysfunction, and urinary incontinence); and (*ii*) one experienced neuroradiologist reviewing the computed tomographic (CT) scan images and calculating the width of the third ventricle (III) and cella media index (CMI = B/A, where A is the greatest width of the outer layer of the skull and B is the width of the lateral ventricles at the same layer). Values of CMI above 0.25 and values of III above 7 mm were considered pathological (13).

The decision to perform surgery was based on clinical presentation and neuroimaging. All shunts were ventriculoperitoneal and were installed right frontally in 18 patients and right occipitoparietally in 6 patients. All patients were treated according to a standardized rehabilitation protocol comprising physical, occupational and speech therapies.

Functional assessments

Functional assessments consisted of Barthel Index (BI) for ADL (14, 15) and Mini Mental Scale Examination (MMSE) for cognition. The BI comprises the items: toileting, feeding, grooming, dressing, toilet transfers, walking and climbing stairs and has 3 or 4 categories, ranging from total assistance to independence. The MMSE comprises 30 items assessing domains of orientation, registration, attention and calculation, recall, and language. The maximum score is 30 points, and cut-off scores of 25 or 23 are commonly used thresholds for detection of impairment (16, 17).

The treatment and control groups were evaluated at baseline, and at 1 and 6 months after VPS surgery. If shunt failure was confirmed and the shunt was replaced, only the MMSE and BI at 1 month and 6 months after the last operation were recorded.

Statistical analysis

The subjects' clinical characteristics are reported as means (and standard deviations) for the continuous variables, and as frequency and percentage for the categorical variables. Sphericity assumption was identified by analysis of variance (ANOVA) for repeated measures, but as the result shows $p < 0.05$, this analysis cannot be used; thus a rank-sum test was used to analyse the data. The treatment effect was determined by comparing the scores on admission, and at 1 month and 6 months after VPS between the treatment group and the control group using the Kruskal-Wallis H Test (group × time). Findings were considered significant for p-values ≤ 0.05.

RESULTS

There were no statistically significant differences for any variable at baseline between the patients' clinical characteristics in the control and treatment groups (Table I).

BI scores were not significantly different between the 2 groups at baseline ($\chi^2 = 3.035$, $p = 0.081$), but were significantly improved in subjects with VPS at 1 month ($\chi^2 = 4.527$, $p < 0.05$) and 6 month follow-ups ($\chi^2 = 20.201$, $p < 0.01$) (Table II). The changes in BI at baseline, and at 1 month and 6 month follow-ups after VPS indicate a significant difference between the 3 assessments in the treatment group ($\chi^2 = 38.639$, $p < 0.01$); however, no corresponding significant difference was seen in the control group ($\chi^2 = 0.298$, $p > 0.05$).

MMSE scores were not significantly different between the 2 groups at baseline ($\chi^2 = 2.471$, $p = 0.116$), but were significantly improved in subjects with VPS at 1 month ($\chi^2 = 9.627$, $p < 0.05$) and 6 month follow-ups ($\chi^2 = 26.410$, $p < 0.01$) (Table III). The changes in MMSE between baseline, 1 month and 6 month follow-ups were significant in the treatment group ($\chi^2 = 40.579$, $p < 0.01$), but not in the control group ($\chi^2 = 0.289$, $p > 0.05$).

Table I. *Patients' clinical characteristics at baseline*

Variables	Treatment group (*n* = 24)	Control group (*n* = 15)
Age at aSAH, years		
Mean (SD)	56.8 (11.5)	57.4 (10.6)
Median (range)	56.8 (44–72)	57.4 (43–77)
Gender, women, *n* (%)	13 (54.2)	8 (53.3)
Time since aSAH, months		
Mean (SD)	3.2 (0.92)	3.7 (0.82)
Median (range)	3 (2–5)	3.5 (2–6)
Barthel Index		
Mean (SD)	39 (15.1)	47.3 (14.3)
Median (range)	39 (25–75)	47 (20–70)
MMSE		
Mean (SD)	17.8 (3.9)	19.1 (2.8)
Median (range)	18 (14–24)	19 (13–25)
Gait disturbance, *n* (%)	23 (95.8)	14 (93.3)
Cognitive dysfunction, *n* (%)	22 (91.7)	13 (86.7)
Urinary incontinence, *n* (%)	20 (83.3)	11 (73.3)

aSAH: aneurysm subarachnoid haemorrhage; MMSE: Mini Mental Status Examination; SD: standard deviation.

Table II. *Comparison of Barthel Index scores at baseline, and 1 month and 6 month follow-ups after ventriculoperitoneal shunt (VPS) between the control group and the VPS group*

	Baseline	1 month follow-up	6 month follow-up	χ^2	p
Treatment group, mean (SD) ($n=24$)	39.0 (15.1)	57.3 (15.5)	82.3 (17.0)	38.6†	<0.01
Control group, mean (SD) ($n=15$)	47.3 (14.3)	47.0 (12.5)	46.3 (13.0)	0.3	0.9
	$\chi^2=3.0$ $p=0.1$	$\chi^2=4.5$* $p<0.05$	$\chi^2=20.2$† $p<0.01$		

*$p<0.05$, †$p<0.01$.

It was observed that ventricular enlargement reduced, and effusion around it diminished, after shunt surgery in 75% of subjects who had good but late outcomes. This may decrease pressure on the ventricular walls, resulting in an increase in periventricular microcirculation. This may explain the clinical and neurophysiological improvement in our patients after shunting. In our experience, ventricular shrinking and reduction in effusion around the ventricular walls usually occur at least 2–3 weeks after VPS, sometimes even longer.

Not all of the patients in the present study showed significant improvement after VPS. One patient developed symptoms of infection, with a low-grade fever for 3 weeks. Although sensitive antibiotics were given in response to a positive CSF culture, the infected shunt had to be removed. VPS dysfunction was more frequent than infection; we found a 16% incidence of shunt malfunction, which is consistent with other studies (18).

DISCUSSION

As chronic hydrocephalus is a common complication after aSAH, it is an important factor in SAH rehabilitation (19). The main aim of this study was to compare the impact of combined VPS with rehabilitation training alone on ADL and cognitive function in patients with CNPH after aSAH.

Evaluation of clinical and functional response to CSF drainage is considered an accurate method of selecting patients with NPH for VPS (20). Occupational therapy and physiotherapy assessments, including ADL, mobility, and cognition, were used to demonstrate sensitivity to change and predictive value in patients with suspected NPH undergoing cerebrospinal fluid drainage (21).

To our knowledge, this preliminary study is the first to compare the effect and rehabilitation prognosis of 6-months combined VPS vs rehabilitation training alone on quality of life and cognitive function. Statistically and clinically significant improvements in functional independence and cognition were observed for the treatment group. In addition, the results of this study demonstrate that VPS is an effective treatment for CNPH in patients following aSAH.

The incidence of development of post-haemorrhagic hydrocephalus as a complication of the rupture of an intracranial aneurysm has been reported to range from 7% to 37% (22, 23). Some mechanisms have been proposed to explain the development of hydrocephalus after aSAH. Hydrocephalus may be caused by impaired CSF absorption due to fibrosis and arachnoidal adhesions (24). Based on the pathophysiology of NPH, Adams et al. (6) suggested that there is an initial rise in CSF pressure, which leads to ventricular enlargement, and that this enlargement is maintained despite normal pressure due to Laplace's law. Although the pressure returns to normal, the enlarged ventricular area reflects the increased force on the ventricular wall.

We used the BI to analyse changes in ADL before and after VPS placement. Factors such as urinary incontinence, poor walking dynamic balance, and cognitive disturbance can contribute to a decrease in ADL before VPS placement. After VPS and rehabilitation for 1 month, the BI scores were significantly different between the treatment and control groups. Similar differences were observed for the BI at the 6 month follow-up. However, in the control group, which underwent rehabilitation only, there was no significant difference in BI scores after 1 and 6 month follow-ups compared with baseline.

Some patients experienced relief from headache or dizziness; symptoms which had disrupted their daily active rehabilitation therapy. There were improvements in upper limb activities (dressing, eating, washing, bathing, etc.) and lower limb activities (standing, transferring, walking, etc.). Bathing was the most difficult task for patients to finish independently. This might be due to a lack of adaptive devices in the bathrooms, insufficient training, or fear of falling. Great improvements were found in cognitive function. After VPS operation there were improvements in short-term memory, orientation in time and space, and mental arithmetic, especially at follow-up.

CNPH is not well understood by all physicians. An interview study at Yale University School of Medicine with 166 practising physicians who graduated from 50 US and 33 foreign medical schools showed that almost one-third of them had not heard of NPH, one-fifth had learned of NPH in medical school, and approximately half had learned of it after medical school (25).

Our study has a number of limitations. First, it is a retrospective, non-randomized study, with a control group smaller than the treatment group. Although the 2 groups show similar results in a number of tests (Table I), further description of the most important disturbances, such as gait and bladder function, hemiparesis and aphasia, should have been included. Secondly, there is a possibility of floor and ceiling effects with insensi-

Table III. *Comparison of Mini Mental Status Examination scores at baseline, and 1 month and 6 month follow-ups after ventriculoperitoneal shunt (VPS) between the control group and the VPS group*

	Baseline	1 month follow-up	6 month follow-up	χ^2	p
Treatment group, mean (SD) ($n=24$)	17.8 (3.9)	22.3 (3.9)	26.4 (2.4)	40.6†	<0.01
Control group, mean (SD) ($n=15$)	19.1 (2.8)	18.6 (2.6)	18.5 (2.9)	0.3	0.9
	$\chi^2=2.5$ $p=0.1$	$\chi^2=9.6$* $p<0.05$	$\chi^2=26.4$† $p<0.01$		

*$p<0.05$, †$p<0.01$.

tivity in detecting and quantifying subtle differences in very severe impairment and very mild impairment, respectively. The use of MMSE and BI scales to measure patients' recovery is also limited by the characteristics of these measures. Thirdly, differential diagnosis between chronic hydrocephalus and brain atrophy is sometimes difficult. In order to reduce false-positive diagnoses in uncertain cases, consensus concerning ambiguous images was negotiated with another more experienced neuroradiologist and neurosurgeon.

In conclusion, CNPH is an important factor in rehabilitation following aSAH, which can affect functional outcome. Early diagnosis and VPS placement may improve functional outcome or prevent further functional deterioration. Further studies are necessary to determine which patients are likely to benefit from VPS and rehabilitation, as well as how to avoid complications such as infection, shunt malfunction and overdrainage of VPS.

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