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Measurement of peak CSF flow velocity at cerebral aqueduct, before and after lumbar CSF drainage, by use of phase-contrast MRI: Utility in the management of idiopathic normal pressure hydrocephalus

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Abstract

Objective: Since it was first described, normal pressure hydrocephalus (NPH) and its treatment by means of cerebrospinal fluid (CSF) shunting have been the focus of much investigation. Whatever be the cause of NPH, it has been hypothesized that in this disease there occurs decreased arterial expansion and an increased brain expansion leading to increased transmantle pressure. We cannot measure the latter, but fortunately the effect of these changes (increased peak flow velocity through the aqueduct) can be quantified with cine phase-contrast magnetic resonance imaging (MRI). This investigation was thus undertaken to characterize and measure CSF peak flow velocity at the level of the aqueduct, before and after lumbar CSF drainage, by means of a phase-contrast cine MRI and determine its role in selecting cases for shunt surgery.
Patients and methods: 37 patients with clinically suspected NPH were included in the study. Changes in the hyperdynamic peak CSF flow velocity with 50 ml lumbar CSF drainage (mimicking shunt) were evaluated in them for considering shunt surgery.
Results: 14 out of 15 patients who were recommended for shunt surgery, based on changes peak flow velocity after lumbar CSF drainage, improved after shunt surgery. None of the cases which were not recommended for shunt surgery, based on changes in CSF peak flow velocity after lumbar CSF drainage, improved after shunt surgery (2 out of 22 cases).
Conclusion: The study concluded that the phase-contrast MR imaging, done before and after CSF drainage, is a sensitive method to support the clinical diagnosis of normal pressure hydrocephalus, selecting patients of NPH who are likely to benefit from shunt surgery, and to select patients of NPH who are not likely to benefit from shunt surgery.

Keywords: NPH; Phase-contrast MRI; Shunt surgery; Failed surgery; Aqueduct; Flow velocity; Lumbar CSF drainage

1. Introduction

Since it was first described in 1964 [1,2], NPH and its treatment by means of cerebrospinal fluid (CSF) shunting have been the focus of much investigation. Whatever may be the cause of NPH, it has been hypothesized that in this disease there occurs decreased arterial expansion and an increased brain expansion, leading to increased transmantle pressure and resultant increased peak flow velocity through aqueduct as a result of increased brain expansion and thus more pumping of CSF through ventricles [3]. We cannot measure the latter, but effect of these changes (increased peak flow velocity through the aqueduct) can be quantified with cine phase-contrast MRI [4–6].

Normal pressure hydrocephalus (NPH) is remarkable for two reasons: (1) it is one of the few treatable causes of dementia, and (2) neuroradiologists are usually involved in making the diagnosis and guiding the treatment.

Patients with NPH have increased flow in the aqueduct as compared to healthy volunteers, which can be explained by decreased arterial expansion and increased brain expansion [7]. The decrease in arterial expansion could be explained by a decreased compliance of the artery and/or an increase in vascular resistance. This creates the prerequisites for increased pulsatile vascular (brain) expansion, which can be transmitted centripetally to the ventricles causing large CSF pulsations recorded in the aqueduct [8]. A number of MR observations and techniques have been employed to take advantage of

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increased flow through the aqueduct. Aqueductal CSF flow void noted on routine MR images was the first indication of CSF motion [9]. Today, most investigators are using phase-contrast techniques [10–12].

Result of Management of NPH is based mainly on articles providing data on percentage of benefit and shunt related complications [13,14]. Between 1966 and 1976, publications on postsurgical results were disappointing, the rates of frank improvement frequently not exceeding 25–30% [15,16]. Later, shunt procedures in NPH seemed more rewarding which was attributed to increasing diagnostic accuracy and improved surgical techniques.

Determining which older patients with ventriculomegaly and suspected NPH should undergo surgical shunting remains difficult. In separate observations, Jack et al. [17], Bradley et al. [18,19] and Krauss et al. [20] observed hyperdynamic CSF flow in patients with idiopathic NPH characterized by enlargement of the CSF flow void within the cerebral aqueduct and the fourth ventricle on axial T2-weighted magnetic resonance imaging (MRI) scans.

Efforts to measure CSF flow have focused on quantifying flow within the cerebral aqueduct [3,4,6,21–25]. Many parameters of CSF flow dynamics have been studied. These include temporal [26], flow volume [4,6,21,27], and velocity [3,4,22–25] as parameters. Several authors have used peak CSF velocity to characterize CSF dynamics. As we understand form the flow mechanics, peak flow velocity is in the centre of the streamline flow, thus if field of view is drawn covering most of aqueduct by different observers, peaked flow velocity should not show inter-observer variation. However, flow volume which depends upon varied parameters, require meticulous measurement of different parameters to calculate flow volume and thus is prone to greater inter-observer variation. Thus, we used peak flow velocity for characterizing CSF flow, which we thick is less prone to inter-observer variation.

This investigation was thus undertaken to characterize and measure peak CSF flow velocity at the level of the aqueduct by means of a phase-contrast cine MRI. Changes in the hyperdynamic peak CSF flow velocity with 50ml lumbar CSF drainage (mimicking shunt) were also evaluated in clinically suspected NPH patients for considering shunt surgery.

2. Patients and methods

37 patients (Tables 1 and 2) with clinically suspected idiopathic NPH (based on detailed higher mental function and neuropsychological testing with objective MMSE score apart from the examination of motor, sensory and cerebellar system and reflexes) were included in this prospective study as cases. 13 age-matched individuals, who did not have any neurological disease, were included in the control group (Table 1). A qualified neurologist clinically examined all the patients.

Table 1
Age (years)

Average Age	Group I	Group II	Group III
Years	71.47	68.36	64.9

Table 2
Sex ratio

Sex	Number (group I)	Number (group II)	Number (group III)
Males	14	20	8
Females	1	2	5

2.1. MRI examination protocol

MRI (1.5-T Sonata; Siemens Medical Systems, Erlanger, Germany) was performed on all patients, by acquiring spin echo T1WI (500/15/2 [TR/TE/N], 5-mm scan thickness) and T2WI (2000/90/2 [TR/TE/N], 5-mm scan thickness) in axial and sagittal planes.

The cine phase-contrast imaging sequence was typically performed with retrospective ECG cardiac gating with velocity encoding of 10–20 cm/s. A two-dimensional fast imaging with steady-state precession gradient echo image with the following measurement parameters were used: a low flip angle (15°); 30–40/10–15/2 (TR/TE/excitations); slice thickness 5 mm; matrix size 256 mm × 256 mm; 16 cm × 16 cm field of view; excitations (2) with acquisition time of 5–6 min. Quantification of CSF flow {which requires special commercially available software (Argus, Flow Analysis; Siemens Medical System)} was done in the transverse plane perpendicular to the midcollicular level (Fig. 1) of aqueduct in terms of peak systolic velocity. Aqueduct is identified and circular region of interest (ROI) is placed in it.

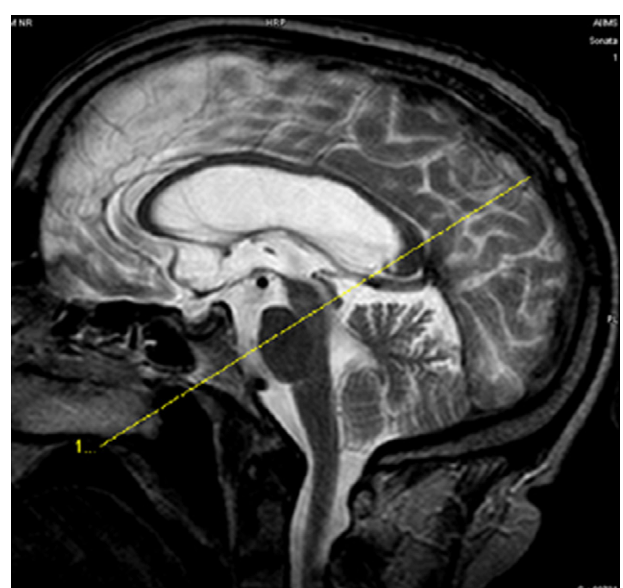

Fig. 1. Transverse plane through the midcollicular level at aqueduct, defining the plane of measurement for the CSF flow velocity.