Phase-contrast MRI and 3D-CISS versus contrast-enhanced MR cisternography for the detection of spontaneous third ventriculostomy

IRM en contraste de phase et 3D CISS versus cisternographie RM après injection de gadolinium pour la détection d’une ventriculostomie spontanée du troisième ventricule

O. Algin a, *, B. Hakyemez b, M. Parlak b

a Department of Radiology, Atatürk Training and Research Hospital, Bilkent, Ankara, Turkey
b Department of Neuroradiology, Uludag University Medical Faculty, Gorukle, Bursa, Turkey

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Keywords
Hydrocephalus; Magnetic resonance imaging; MR cisternography; PC cine MR; Spontaneous third ventriculostomy

Summary
Purpose. — To compare the diagnostic efficacies of phase-contrast MRI (PC-MRI) and three-dimensional constructive interference in steady-state (3D-CISS) sequence for the detection of spontaneous third ventriculostomy (STV) on the basis of contrast-enhanced MR cisternography (MRC).

Patients and methods. — Eleven obstructive hydrocephalus patients with clinically-radiologically suspected STV and ten controls were examined by PC-MRI, 3D-CISS and MRC. PC-MRI and 3D-CISS sequence were applied to view the third ventricle and basal cisterns. Following injection of 0.5-1 ml intrathecal Gd-DTPA injection, postcontrast MRC images were obtained in three planes. Presence of STV was scored as follows: grade 0, no existence of STV; grade 1, STV present. Results of PC-MRI and 3D-CISS were compared with the MRC findings.

Results. — In PC-MRI, five patients were assessed as grade 0 and six cases grade 1. As a result of 3D-CISS sequence, eight cases were evaluated as grade 0 and three cases grade 1. Based on MRC, nine cases were assessed as grade 0 and two cases grade 1. False positivity was found in four cases by PC-MRI and in one case by 3D-CISS. The sensitivity, specificity and accuracy of PC-MRI and 3D-CISS sequence regarding demonstration of STV, were 100, 100, 56, 89, 64, and 91% respectively.

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* Corresponding author. Tel.: +0905327064759.
E-mail address: droktayalgin@gmail.com (O. Algin).
Introduction

Spontaneous third ventriculostomy (STV) is the development of spontaneous communication between the third ventricle and subarachnoid space as a result of obstructive hydrocephalus [1]. Although long-standing obstructive hydrocephalus is encountered rarely, it can lead to STV [2]. Accurate determination of STV bears importance in terms of treatment planning [3]. In cases with STV, progression of the symptoms and hydrocephalus can regress, thereby rendering the operation unnecessary [1]. However, in the absence of STV, progressive obstructive hydrocephalus requires surgical treatment [4–6].

In the literature, most common development site of STV is mentioned to be the inferior wall of third ventricle [2,7]. PC-MRI and 3D-CISS are noted to be helpful in evaluation of the patency of endoscopic third ventriculostomy (ETV) or detection of STV [4–8]. In the present study, we aimed to investigate the efficacy of phase-contrast MRI (PC-MRI) and three-dimensional constructive interference in steady-state (3D-CISS) sequence in detection of STV on basis of MR cisternography (MRC). As far as we know, there is no study on the use of MRC in STV diagnosis in the literature.

Patients and methods

This study was performed between September 2003 and January 2009, which included 21 cases (patient and control group), referred to our radiology department within this period. Written consent was obtained from all participants before data collection. In pediatric cases, informed consent was taken from a parent or legal guardian. The approval of the ethical committee of our faculty was obtained for the study protocol.

Patient group

Patients were consisted of 11 patients (3 women, 8 men; mean age: 17 years; range: 2-35) who were all diagnosed as progressive obstructive hydrocephalus both clinically and/or according to the routine cranial MRI findings. All of the cases were examined by an experienced neurosurgeon and an experienced radiologist before the MRC examination and no signs and symptoms of meningitis were detected. Cases demonstrating clinical meningitis or having a history of CSF diversion were excluded from the study. Symptoms and coexisting diseases of the patients were noted before MR examinations. MRI examination of one pediatric case (no: 3) was obtained under sedation.

Control group

The control group was consisted of 10 age-matched controls (4 women and 6 men; mean age: 19; range: 5-34) who underwent an equivalent MRI protocol with no symptoms except headache. MRC was performed in all control cases. Because of the invasiveness and the need for a contrast agent in the MRC technique, the cases with intracranial arachnoid cyst (AC) constituted the control cases that had no coexisting diseases other than AC. The patients with intraventricular AC were excluded from the control group because the intraventricular ACs might have affected the CSF flow and intraventricular ACs can present with obstructive hydrocephalus [9]. Therefore, only cases which had an small size AC localized in temporal fossa, quadrigeminal cistern or convexity level and those who had no AC compressing the ventricular system or aqueduct, were enrolled in the study.

MR imaging protocol and statistical analysis

The examinations were performed with 1.5 T MRI unit (Magnetom Vision Plus, Siemens, Erlangen, Germany). The patients were in supine position during the examinations. T1 weighted (W) spin echo (SE) images (precontrast MRC) were obtained in axial, sagittal and coronal planes (TR/TE 539/12 ms, flip angle 90°, matrix 192 × 256, NEX 2, FOV 25 × 25 cm, slice thickness 4 mm except sagittal plane) before contrast medium administration. Slice thickness of sagittal T1W SE images was 2 mm. Axial-sagittal planes T2W turbo gradient SE (TGSE) sequence (TR/TE 7400/115 ms, FA 160°, NEX 1, FOV 230 mm, matrix 345 × 512, slice thickness 2 mm) and sagittal 3D-CISS sequence were obtained. Parameters of 3D-CISS sequence were as follows: TR/TE, 12.3/5.9 ms; flip angle, 70°; matrix 230 × 512; number of excitation (NEX), 2; effective thickness, 1 mm; and FOV, 26 × 26 cm. As detection of distinct third ventricle wall on 3D-CISS images was evaluated as intact third ventricle walls (grade 0, negative result), presence of a wall defect was described as STV (grade 1, positive result). Total duration of T1W, T2W, and 3D-CISS sequence was approximately 10 min.

Two-dimensional fast imaging with steady-state precession (2D-FISP) sequence with retrospective cardiac gating in two planes was applied for PC-MRI scans. Sequence parameters were as follows: TR/TE/NEX 70/15.8/2; echo delay time, 13 ms (for adequate flow coding and T2* effect); flip angle, 10°; matrix 192 × 256; FOV, 25 cm; velocity encoding, 2 cm/s; slice thickness, 4 mm. The PC-MRI and 3D-CISS sections included the level of inferior third ventricle and basal cisterns. Twelve cine images were obtained involving
Table 1  The demographical and clinical characteristics of the patient group.

<table>
<thead>
<tr>
<th>No</th>
<th>M/F</th>
<th>Age</th>
<th>Symptoms</th>
<th>Cause of hydrocephalus</th>
<th>Additional illness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>15</td>
<td>Headache</td>
<td>TVAC</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>35</td>
<td>Headache</td>
<td>TVAC</td>
<td>None</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>2</td>
<td>Increased HC</td>
<td>Aqueductal web</td>
<td>Depression</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>25</td>
<td>Headache</td>
<td>Aqueductal web</td>
<td>Epilepsy</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>20</td>
<td>Deafness</td>
<td>Septum pellicidum AC</td>
<td>Strabismus</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>17</td>
<td>Headache</td>
<td>Tectal glioma</td>
<td>NF-1</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>14</td>
<td>Headache, vomiting</td>
<td>Idiopathic AS</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>11</td>
<td>Headache, vomiting</td>
<td>TVAC</td>
<td>Forgetfulness</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>24</td>
<td>Headache</td>
<td>Aqueductal web</td>
<td>None</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>20</td>
<td>Headache</td>
<td>Intraventricular AC</td>
<td>None</td>
</tr>
</tbody>
</table>

AC: arachnoid cyst; TVAC: third ventricular AC; AS: aqueductal stenosis; HC: head circumference; NF-1: neurofibromatosis type-1.

the systolic and diastolic phases of cardiac cycle. The cine mode PC-MRI studies were interpreted directly from monitors by adjusting the window and center measures of the images. The presence of pulsatile jet flow within the third ventricle or black-white CSF flow shapes corresponding to systolic and diastolic flows (flush-fill periods) within the third ventricle were recognized as signs of STV (grade 1, positive result). The acquisition time of PC-MRI was approximately 5 min with slight fluctuation dependent on the patient’s heart rate. MRC examinations were evaluated by an experienced neuroradiologist unaware of the results of 3D-CISS sequence and MRC.

For postcontrast MRC, 0.5—1 ml Gd-DTPA (Magnevist, Schering, Germany) was injected by a 24-26 gauge needle from intrathecal space at lower lumbar region (L4-L5) and the patient was allowed to rest in prone position in the observation room. Postcontrast images were obtained by repeating precontrast images with the same parameters in three planes during early (3—6 hours) and delayed (12—24 hours) phases. Presence of STV was scored as follows: grade 0, no existence of STV; grade 1, STV present. On the early postcontrast images, passage of the contrast-material from basal cisterns to the third ventricle without aqueductal contrast-material enhancement and/or presence of basal cisterns showing the same level of signal intensity with the third ventricle, was recognized as STV (grade 1, positive result). Following observation of contrast agent passage into the third ventricle, MRC imaging was ended and the images of the later phase images were not acquired. Duration of each postcontrast MRC was approximately 5 min. Clinical status of the patients were then followed up for 48 hours after MRC examination. MRC examinations were evaluated by an experienced neuroradiologist unaware of the results of PC-MRI and 3D-CISS sequence.

Sensitivity, specificity, predictive values, and accuracy were calculated according to Nilsson [10]. While calculating those values, MRC was recognized as the gold standard in STV diagnosis.

Results

Demographic data, additional illness, and symptoms of the patient group are summarized in Table 1. Headache (9 cases, 82%) was the most common symptom. All patients in group 1 had hydrocephalus.

MRC findings

MRC studies were well tolerated by all controls and patients. During the 48-hour-clinical follow-up period after MRC examination, no cases showed any neurological symptoms,
MRI for the detection of spontaneous third ventriculostomy

Figure 1  Sagittal PC-MRI (A, B), sagittal 3D-CISS (C), sagittal early phase (D) and sagittal-axial delayed phase postcontrast MRC images (E-F) of a 29 year-old man with the quadrigeminal cistern arachnoid cyst (AC) (control case). Spontaneous third ventriculostomy is not visible on all images (grade 0). There was communication of AC on the sagittal and axial delayed phase postcontrast MRC images (E, F).

Table 3  PC-MRI and MRC grades of patient group.

<table>
<thead>
<tr>
<th>PC-MRI: grade 1</th>
<th>MRC: grade 1</th>
<th>MRC: grade 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 patients</td>
<td>4 patients</td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>5 patients</td>
<td></td>
</tr>
</tbody>
</table>

epilepsy or allergic reactions (except postural headache which responded well to conventional painkillers or spontaneously resolved in 48 hours). In all the MRC studies of the control groups, basal cisterns were found to demonstrate earlier enhancement compared with the third ventricle. Early phase postcontrast MRC images of all the control cases exhibited a difference in signal intensity between basal cisterns and third ventricle.

Based on MRC, nine cases were assessed as grade 0 and two cases grade 1 (Table 2). Two cases showing STV in MRC and three cases who did not give consent to CSF diversion procedure (5 cases in total), were not operated on, but kept under close clinical monitoring. Six cases were operated on. While ventriculo-peritoneal shunt (VPS) was performed on four cases, cyst fenestration was applied on one case and ETV operation was applied on one case, as well. Operative findings and MRI results of the case (no. 8) subjected to ETV, were completely consistent. Following surgery, symptoms of all these cases showed a reduction.

Figure 2  The lateral ventricular arachnoid cyst of a 9-year-old male patient with headache (no: 11) is seen on sagittal 3D-CISS image (A). Spontaneous third ventriculostomy is not visible on 3D-CISS (B), PC-MRI (C, D) and early phase postcontrast MRC images (E, F). Walls of third ventricle are intact on sagittal early phase postcontrast MRC image (white arrow, E).
Table 4 3D-CISS and MRC grades of patient group.

<table>
<thead>
<tr>
<th></th>
<th>MRC: grade 1</th>
<th>MRC: grade 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D-CISS: grade 1</td>
<td>2 patients</td>
<td>1 patient</td>
</tr>
<tr>
<td>3D-CISS: grade 0</td>
<td>None</td>
<td>8 patients</td>
</tr>
</tbody>
</table>

**PC-MRI findings**

None of the controls displayed a black or white flow between the third ventricle and basal cisterns on PC-MRI studies (grade 0) (Fig. 1). In PC-MRI, six patients were assessed as grade 1 and five cases grade 0. PC-MRI and MRC results of seven cases (64%) were totally consistent (Tables 2 and 3) (Fig. 2). Four cases which have been assessed as grade 1 in the PC-MRI study were evaluated as grade 0 (negative result) by the MRC examination (false positive) (Fig. 3). Three of those four cases, did not exhibit STV in the 3D-CISS examination as well. The sensitivity, specificity, negative predictive value, positive predictive value, and accuracy of PC-MRI regarding demonstration of STV, were 100, 56, 33, 100, and 64% respectively.

**3D-CISS sequence findings**

All the cases in the control group demonstrated distinct third ventricle walls on 3D-CISS images (Fig. 1). Third ventricular walls were normal in all the controls (grade 0). As a result of 3D-CISS sequence; eight patients were evaluated as grade 0 and three patients grade 1 (Tables 2 and 4).

3D-CISS sequence and MRC examination results of 10 patients (91%) were totally consistent (Fig. 4). One case, assessed as grade 1 in the 3D-CISS examination, was evaluated as grade 0 by MRC (false positive) (Fig. 5). The sensitivity, specificity, negative predictive value, positive predictive value, and accuracy of 3D-CISS regarding demonstration of VPS, were 100, 89, 67, 100, and 91% respectively.

**Discussion**

The STV is a very rare condition that occurs with the spontaneous rupture of a third ventricle, resulting in a communication between the ventricular system and the subarachnoid space [1—3,11]. Although STV is mentioned to occur secondary to intra- and periaqueductal pathologies in the literature, as we showed in our study, it can cause...
obstructive hydrocephalus and STV in third ventricular ACs [1–7]. Clinicians should be aware of STV demonstrable on PC-MRI and 3D-CISS because it may obviate the need for a CSF diversion [1,11].

The majority of reported STV have involved inferior wall of the third ventricle [2,7]. The STV occurred along the floor of the third ventricle between the mamillary bodies and tuber cinereum in a location similar to that used for surgical ETV [1]. The STV has not been described in acute obstructive hydrocephalus and is thought to be the result of the normal elasticity of the ventricular walls [3]. In chronic-progressive obstructive hydrocephalus, the floor of the third ventricle, in some cases, is thinned due to long-standing CSF pressure against it [11]. If spontaneous relief of headache occurred in the management of chronic obstructive hydrocephalus, a PC-MRI and 3D-CISS study would be mandatory to search for STV [3–6]. In the current study, two (18%) of the 11 cases in the patient group had STV, therefore, CSF diversion procedure was deemed unnecessary and patients were put under close clinical monitoring.

PC-MRI has been increasingly used during the last decade for evaluating CSF flow [9,12]. Although PC-MRI is noted as a useful modality in diagnosis of STV, PC-MRI has some limitations in diagnosis of STV [5,13]. Complex CSF flows generated secondary to pulsations of the arteries following a course close to the inferior wall of the third ventricle, can lead to false positive results in PC-MRI. In the current study, we found no STV by MRC in the four patients who displayed positive PC-MRI results. Three of those four cases did not exhibit STV in the 3D-CISS examination as well. We believe that the reason behind those false positive results observed in PC-MRI examinations, is either the pulsations of arterial structures in the basal cisterns or complex-turbulent flows arising secondary to obstructive hydrocephalus. While PC-MRI is a considerably successful method in showing the CSF flow, it may yield false positive results in the presence of complex or turbulent flows [6,9,12].

Recently, 3D-CISS sequence has been introduced to assess the normal and pathological features of the aqueduct, ventricles, basal cisterns and cerebellopontine angle, and proven to be superior to the conventional T2W sequence because of the heavy T2W effect and high spatial resolution [4,6]. Also, the value of this technique has been demonstrated in hydrocephalus and ETV [6]. 3D-CISS is a gradient-echo imaging technique with high third ventricular wall-to-CSF contrast [4,9]. It provides anatomical information about morphology-relationships of ventricles before surgery [13,14]. 91% of cases in our patient group showed consistent 3D-CISS and MRC results. Only one case showed false positivity. False positive results on 3D-CISS images have been reported in the literature, as well [6]. We believe that false positivity may be occurring because of the complex anatomy of the enlarged third ventricle walls due to hydrocephalus which hinders visualization of the inferior wall. By using high tesla MR devices, acquisition of images with thinner sections and higher resolutions can help overcome this limitation [6].

Contrast-enhanced MRC has a modality with recently growing popularity that can provide physiological and morphological data together. MRC is used in investigation of CSF leak and detection of communication in ACs [9,15]. Intrathecal administration of Gd-DTPA was safe and thus consistent with the recent literature [15–20]. On the other hand, intrathecal administration of Gd-DTPA is not accepted worldwide [9,16]. While MR or CT ventriculography are recognized as the gold standard in the investigation of STV presence or evaluation of ETV patency, those tests are considerably invasive and may cause serious complications [13,17,21]. MRC is a less invasive alternative with a high soft tissue resolution which allows multiplanar images and involves no radiation [9,15,18–21]. Therefore, in the present study, we evaluated the efficacies of PC-MRI and 3D-CISS over detection of STV on basis of MRC. In the current study, contrast media diffused in the subarachnoid space and details of structures containing CSF became visible in all cases. MRC examination successfully helped us to evaluate third ventricular CSF flow and existence of STV.

The most influential limitation of our study was the low number of cases. Due to rarity of STV cases, we could not increase the number of our patients. One of the limitations of our study was the failure of comparing 3D-CISS, PC-MRI, and MRC results with the findings of CT or MR ventriculography, recognized as gold standard in STV diagnosis, due to ethical concerns. Another important limitation in our study was the lack of comparison between MRI results and operation findings, because, since the patients diagnosed with

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**Figure 5** A 2-year-old male patient with third ventricular AC (septum pellicidum cyst) subjected to MRI by the obstructive hydrocephalus (no: 3). Sagittal PC-MR images showed a jet flow consistent with spontaneous third ventriculostomy (STV) (grade 1) (A, B). Consistent with the STV, sagittal 3D-CISS image displaying a defect in the wall of anterior third ventricle (C) Septum pellicidum cyst is observed to narrow and obstruct the aqueduct on the precontrast sagittal MRC image (D). Early phase postcontrast sagittal MRC image demonstrating an intact inferior wall of third ventricle (E) Sagittal-axial delayed postcontrast MRC image demonstrating flow of contrast-material into the anterior portion of third ventricle (partial aqueductal stenosis) (F, G). Third ventricle is observed to be significantly more hypointense compared with the basal cisterns on delayed postcontrast MRC images (STV negative, grade 0). Ventriculoperitoneal shunt was applied to the case. Control CT images acquired at postoperative 1st and 6th months showing remission of ventriculomegaly (H, I).
obstructive hydrocephalus are treated with VPS procedure in our hospital and our STV cases were not operated on. Therefore, we did not have the chance to compare ETV findings with the MR results. We believe that in order to determine the roles of 3D-CISS, PC-MRI, and contrast-enhanced MRC, there is a need for further comprehensive studies encompassing comparison of these MRI techniques results with the findings of the ETV.

**Conclusion**

Since PC-MRI and 3D-CISS are non-invasive, they should be the first choice in STV detection. Complex CSF flows can cause false positive results on PC-MRI images. 3D-CISS appears to be superior to PC-MRI in detection of STV. If PC-MRI and 3D-CISS both give negative results, MRC can be deemed as unnecessary. MRC should be performed on patients who demonstrate suspected STV findings on PC-MRI and 3D-CISS sequences. MRC may prevent false positive results.

**Conflict of interest statement**

We declare that we have no conflict of interest.

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**References**