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Chiari 1 Malformation with Syringomyelia: Correlation of Phase-Contrast Cine MR Imaging and Outcome

Chiari 1 ve Syringomyeli Olgularında Faz Kontrast Sine MR ile Akım Ölçümü ve Sonuçlarla Korelasyonu

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ABSTRACT

AIM: This study was designed to determine the hemodynamics of cerebrospinal fluid flow in syringomyelia patients associated with Chiari I malformation using phase-contrast velocity-encoded-cine MRI and also to find out whether treatment outcomes may be predicted by these flow measurements.

MATERIAL and METHODS: Eighteen consecutive symptomatic patients with syringomyelia associated with Chiari 1 malformation were included. The PC VEC MRI was performed at the level of foramen magnum and syrinx cavity both preoperatively and 6 months postoperatively. Following surgery, the modified Asgari score was calculated, and the association between CSF flow pattern and clinical outcome was assessed.

RESULTS: Evaluation of clinical symptoms at postoperative 6th month revealed improvement in 11 (61%) patients and stabilization in 5 (28%) patients whereas results were poor in 2 (11%) patients. Preoperative cine MRI flow studies showed a heterogeneous pattern at the foramen magnum level in all of the patients. Postoperative cine MR flow studies demonstrated the change from heterogeneous pattern to sinusoidal pattern in 11 patients and a decrease in heterogenity in 7 patients.

CONCLUSION: Our results indicate that CSF flow measurements using PC VEC MRI can give important information regarding the prognosis and follow-up of the patients with Chiari I malformation.

KEY WORDS: Chiari 1 malformation, Cine cerebrospinal fluid flow studies, Phase-contrast magnetic resonance, Syringomyelia

ÖZ

AMAÇ: Chiari tip 1'e eşlik eden siringomyeli olgularında faz kontrast sine MRI ile preoperatif ve postoperatif beyin omurilik sıvı akım çalışmaları yapıldı. Bu akım çalışmalarının tedavi sonuçlarında yol göstericiliği araştırıldı.

YÖNTEM ve GEREÇ: Suboksipital kraniektomi, C1 laminektomi ve duraplasti uygulanan 18 erişkin hasta dahil edildi. Cerrahi öncesinde ve 6. ay sonrasında faz kontrast sine MRI ile foramen magnum ve sirinks kavitesinden akım ölçümleri yapıldı. Modifiye Asgari skoru ile elde edilen klinik sonuçlar ve akım çalışması sonuçları değerlendirildi

BULGULAR: Postoperatif 6. ay 11 (61%)hastada iyileşme, 5 hastada (28%) semptomlarda stabilizasyon, 2 hastada(11%) kötüleşme saptandı. Preoperatif faz contrast sine MR da bütün hastalarda foramen magnum düzeyinde inhomogen akım paterni saptandı. Postoperatif dönmede 11 hastada (61%) sinusoidal akıma dönüş, 7 hastada (39%)ise inhomojen akım paterninde kısmi düzelme saptandı.

SONUÇ: Faz kontrast sine MR kullanılarak yapılan beyin omurilik sıvısı akım çalışması, Chiari 1 ve eşlik eden syringomyeli olgularının takibinde önemli bilgiler vermektedir .

ANAHTAR SÖZCÜKLER: Chiari 1 malformation, Faz kontrast manyetik rezonans, Sine serebrospinal sıvı akım çalışması, Syringomyeli

INTRODUCTION

The Chiari 1 malformation is a dynamic disease and has been associated with hydromyelia in 30-70% of the patients (8, 10). It is characterized by displacement of the cerebellar tonsils more than 5 mm, caudally through the foramen magnum. Sagittal magnetic resonance imaging (MRI) of the craniospinal junction is used for the diagnosis of CM (6, 21).

Reports mostly agree that the problem is located at the level of foramen magnum; flow impairment at the craniospinal junction is considered to be responsible for the clinical findings of this disease. Tonsillar herniation is thought to partially obstruct the flow of cerebrospinal fluid (CSF) between the cranium and the spinal canal, affecting the local craniocervical hydrodynamics (1, 6). Different mechanisms for the pathogenesis of the syrinx have been suggested. Gardner (14) and Williams (30) have proposed that the obstruction of CSF flow at the craniovertebral junction causes CSF to enter the cervical central canal. These two theories require communication of the fourth ventricle with the central canal. These mechanisms do not completely explain the pathology especially in patients with craniovertebral junction blockage. According to the other Oldfield theory, the entrance of CSF to the spinal cord is explained by the Wirshow-Robin space with arterial pulsations (23). In support of this theory, Stoodley et al (28) showed an experimental model in which any obstruction to the flow of CSF in the central canal, such as at the foramen of Magendie, caused cavity formation that could enlarge.

Various surgical approaches have been suggested for Chiari 1 with syringomyelia. However, the gold standard in treatment of hindbrain with syringomyelia is the suboccipital decompression with duraplasty. A combination of many procedures including obex plugging, syringosubarachnoid shunting and resection of cerebellar tonsils may also be used (4,15,18,23).

Nowadays, CSF flow studies are being performed with MRI (1,19,20,24,26). In the literature only a little is known about predictions regarding this issue. Sakas et al. (27) studied CSF flow dynamics and Arora et al. (3) studied radionuclide cisternography before and after foramen magnum decompression surgery in a patient with Chiari 1 malformation. In our prospective study, our aim was to determine the CSF hemodynamics preoperatively and postoperatively at the craniocervical junction and syrinx cavity with the use of phase-contrast velocity-encoded-cine (PC VEC) MRI and to find out whether surgical and clinical outcomes may be predicted by these measurements.

PATIENTS and METHODS

Patient Characteristics and Follow-up

Eighteen (7 females, 11 males) symptomatic patients with an age range of 19-56 years (mean 34.5 years) with syringomyelia associated with Chiari 1 malformation who underwent surgical treatment in our department from 2002 to April 2006 were included in this study. The study was approved by the Hospital Ethics Committee. Written informed consent was obtained from all subjects.

Preoperative signs and symptoms are listed in Table I. Follow-up time after surgery was 8 to 52 months, with a mean of 26 months. All patients were evaluated by MRI with cine flow studies preoperatively and postoperatively at month 6. Patients were examined at regular intervals; signs and symptoms were evaluated at the 3rd and 6th postoperative months; a scoring system defined by Asgari et al. (4) as mild, moderate and severe was used and modified according to the clinical conditions of our patients. In this scoring system we excluded the term “able to walk only with someone else’s help or with the aid of a frame” and chair-bound or bedridden” because none of our patients

Table I: Preoperative signs and symptoms

Signs and Symptoms	Case	%
Neck pain and Headache	4	%77
Sensory disturbances	8	%44
Motor weakness of upper extremities	8	%44
Motor weakness of lower extremities	7	%38
Thermoanalgesia	6	%33
Pyramidal tract signs	6	%33
Cerebellar signs	4	%22
Cranial Nerve Deficit	3	%16

had this clinical sign preoperatively or postoperatively. We added the term “neck pain and headache” and scored it with 1 point. The modified score system is listed in Table II.

Table II: Scoring system for pre-postoperative clinical evaluation modified from Asgari et al.

Functional disorders	Scores
Neck pain and headache	1
Signs of spinal cord disease but no difficulty in using the upper extremities and walking	1
Involvement of cranial nerves	2
Slight difficulty in using the upper extremities and/or walking which does not prevent full-time employment	2
Moderate inability to use the upper extremities	2
Complete inability to use the upper extremities	3
Difficulty in walking which prevents full-time employment or the ability to do all housework, but which is not so severe as to require someone else's help to walk	3

Operative Treatment

The operations were performed in the standard prone position. All patients underwent suboccipital craniectomy of approximately 3x4 cm and C1 laminectomy. The posterior elements of C2 in three patients and C3 in one patient were removed. Out of the 18 patients, 5 had no associated arachnoid adhesions at the major cistern at surgery. Communication between the 4th ventricle and artificial cisterna magna was established with radical dissection of arachnoid adhesion in thirteen patients, and opening of the foramen of Magendie and adequate CSF flow was observed. Obex plugging wasn’t performed in any of the cases. The cerebellar tonsils were coagulated and resected by subpial suction in 16 patients. Adequate CSF flow was observed in each case peroperatively. The procedure was completed with a wide duraplasty (approximately 3x4 cm) of lyophilized dura.

MRI, Cine MRI

All MRI studies were performed on a 1.5-T MR scanner (Philips Gyroscan Intera Master, Einthoven, Netherlands) with a 30 mT/m maximum gradient strength and a 150 mT/m per millisecond slew rate using a head coil. Patients were layed in the supine position.

The PC VEC MRI (TR/TE:16.8/7.9, FOV: 200, matrix: 256x256, FA: 15?) was obtained using peripheral gating and 16 phases were evaluated for each cardiac cycle. CSF flow was measured with a velocity encoding (VEC) value of 5-10cm/s. The study was completed in 10 ± 3minutes in all subjects.

Image analysis and measurements were carried out by one radiologist. Interpretation time for each patient was approximately 8-10 minutes.

All patients had Type I Chiari malformation as defined by the radiological criteria (6,21). Radiological evaluation included measurement of tonsillar ectopia, the volume of the enlarged cisterna magna in the midsagittal plane, and syrinx size in the axial plane. Postoperative reduction in syrinx size less than 30% was defined as unchanged.

PC VEC MRI was performed at the level of foramen magnum and syrinx cavity in all patients preoperatively and at 6 months postoperatively (Figure 1 and Figure 2). Volumetric CSF analyses were studied by the manufacturer’s software on MR machine.

Figure 1: Post-decompression midsagittal T2-weighted MRI. The line is drawn through the region of interest at the foramen magnum level.

Figure 2: Midsagittal T2-weighted MRI before decompression. The line drawn through the region of interest at the syrinx indicates the plane where the subsequent phase-contrast axial images are taken.

Flow pattern: Normal CSF flow at foramen magnum has a sinusoidal pattern. Heterogeneous pattern is an impaired CSF pulsation with shortened CSF systole and impairment of diastolic flow causing multiple short upward and downward pulsations in one cardiac cycle. Decrease in heterogenity means improvement in the number of upward and downward pulsations during one cardiac cycle.

RESULTS

Clinical Results:

Preoperative MRI showed the inferior border of the cerebellar tonsil at the C1 level in 14 (78%) patients and at the C2 level in 4 (22%) patients. Cervical instability was not seen in any patient. One patient was re-operated for CSF fistula formation during the early postoperative period.

Assessment of the clinical outcome proved to be a difficult task, and clinical results were evaluated by a modified scoring system defined by Asgari et al (4). Evaluation of signs and symptoms on the postoperative 6th month revealed improvement in 11 (61%) patients, stabilization in 5 (28%) patients and worsening in 2 (11%) patients. Among the latter two patients, one was re-operated and severe arachnoid scarring was seen intraoperatively. A syringosubarachnoid shunt was placed after the intraarachnoid dissection.

Clinical outcome, MRI and cine MRI findings are summarized in Table III and Table IV.

Cisterna magna and symptoms: MRI revealed that cisterna magna was very expanded in 11 (61%), moderately expanded in 4 (22%) and minimally expanded in 3 (17%) patients. Clinical symptoms were improved in 10 and remained unchanged in 1 of 11 patients with a very expanded cistern. Deterioration was detected in 2 of 3 patients with minimal expansion and in 4 patients with moderate expansion; symptoms of one were improved while three remained stable.

Syrinx diameter and symptoms: The syrinx diameter was reduced in 11 (61%) patients, all of whom recovered clinically. Syrinx diameter was minimally decreased (less than 30% compared with preoperative values) in 5 (28%) and unchanged in 2 (11%) patients whose symptoms deteriorated.

Tonsillar ectopia and syrinx diameter: Measurement of tonsillar ectopia in two patients that demonstrated deterioration in their clinical symptoms, unchanged syrinx cavity diameter and syrinx and foramen magnum flow patterns revealed tonsillar ectopias of 22mm and 26mm (mean 24mm). In five patients these clinical outcomes remained unchanged and syrinx cavity reduction remained below 30%; tonsillar ectopia measurement range was 14-21mm (mean 17.4mm). In 11 patients with improvement in the clinical findings, the foramen magnum/ syrinx flow patterns with cine MR findings showed a reduction of syrinx diameter >30% while tonsillar ectopia measurements were 9-19mm with a mean of 11.6mm. Measurements of tonsillar ectopia, pre- and post-operative syrinx diameter and percentage changes are given in Table V.

Cine MRI findings:

Foramen magnum Cine MRI: The flow pattern of the foramen magnum was evaluated preoperatively and postoperatively at the 6th month. Preoperative cine MRI flow studies revealed a heterogeneous pattern at foramen magnum level (Figure 3). Cephalic flow range was 0.31-3.82cm/s, caudal flow range was 0.7-3.89cm/s and flow volume range was 0.01-0.6ml/s.

Following surgical decompression, the resistance to CSF flow was reduced in the subarachnoid space at the foramen magnum.

Postoperative cine MR flow studies demonstrated alteration of the heterogeneous

Table III: CSF flow patterns and flow velocities obtained from the foramen magnum level and syrinx cavity at the preoperative and postoperative periods

Patient number	MRI period	Foramen magnum			Syrinx cavity		
		Flow pattern	Cephalic velocity (cm/s)	Caudal velocity (cm/s)	Flow pattern	Cephalic velocity (cm/s)	Caudal velocity (cm/s)
1	Preoperative	Heterogeneous	3.82	3.89	Heterogeneous	0.4	0.76
	Postoperative	Sinusoidal	3.86	6.04	No flow	0	0
2	Preoperative	Heterogeneous	0.63	2.49	Heterogeneous	1.43	0.24
	Postoperative	Sinusoidal	1.85	3,49	Sinusoidal	0.06	0.02
3	Preoperative	Heterogeneous	0.31	2.00	Heterogeneous	1.49	2.71
	Postoperative	Heterogeneous	1.32	1.44	Heterogeneous	1.88	1.05
4	Preoperative	Heterogeneous	2.03	1.42	Heterogeneous	0.36	0.65
	Postoperative	Sinusoidal	3.17	3.47	No flow	0	0
5	Preoperative	Heterogeneous	1.14	1.83	Heterogeneous	1.05	0.8
	Postoperative	Sinusoidal	3.56	2.89	No flow	0	0
6	Preoperative	Heterogeneous	1.18	1.24	Heterogeneous	0.54	1.12
	Postoperative	Sinusoidal	3.05	3.49	No flow	0	0
7	Preoperative	Heterogeneous	0.78	0.7	Heterogeneous	1.61	1.27
	Postoperative	Heterogeneous	1.28	1.35	Heterogeneous	1.03	0.78
8	Preoperative	Heterogeneous	1.03	1.67	Heterogeneous	1.37	0.7
	Postoperative	Sinusoidal	3.89	3.01	No flow	0	0
9	Preoperative	Heterogeneous	0.64	1.52	Heterogeneous	2.89	2.46
	Postoperative	Heterogeneous	2.76	1.46	Heterogeneous	2.32	2.21
10	Preoperative	Heterogeneous	1.38	1.09	Heterogeneous	0.78	0.71
	Postoperative	Sinusoidal	3.2	4.5	No flow	0	0
11	Preoperative	Heterogeneous	1.47	1.58	Heterogeneous	0.9	0.9
	Postoperative	Sinusoidal	2.98	3.43	No flow	0	0
12	Preoperative	Heterogeneous	1.11	1.79	Heterogeneous	0.05	0.01
	Postoperative	Sinusoidal	3.46	3.09	No flow	0	0
13	Preoperative	Heterogeneous	1.04	1.13	Heterogeneous	0.18	0.48
	Postoperative	Heterogeneous	1.62	1.44	Heterogeneous	0.12	0.34
14	Preoperative	Heterogeneous	0.54	1.72	Heterogeneous	1.22	3.35
	Postoperative	Heterogeneous	1.76	2.46	Heterogeneous	0.74	2.39
15	Preoperative	Heterogeneous	2.25	2.03	Heterogeneous	0.56	0.38
	Postoperative	Sinusoidal	2.84	2.85	No flow	0	0
16	Preoperative	Heterogeneous	1.89	1.11	Heterogeneous	1.02	1.35
	Postoperative	Heterogeneous	2.14	1.46	Heterogeneous	0.81	0.67
17	Preoperative	Heterogeneous	2.34	1.96	Heterogeneous	0.67	0.44
	Postoperative	Sinusoidal	2.91	2.48	No flow	0	0
18	Preoperative	Heterogeneous	1.07	1.41	Heterogeneous	0.89	0.72
	Postoperative	Heterogeneous	1.55	1.92	Heterogeneous	0.43	0.38

Table IV: Postoperative outcome and MRI findings

Patient Number	Preop Score	Postop Score	OVERALL OUTCOME	CISTERNA MAGNA	POSTOP SYRINX
1	5	3	Good	Very Expanded	Decreased
2	4	2	Good	Very Expanded	Decreased
3	2	5	Worse	Minimally Expanded	Unchanged
4	6	2	Good	Very Expanded	Decreased
5	6	4	Good	Very Expanded	Decreased
6	7	4	Good	Moderately Expanded	Decreased
7	5	5	Stable	Moderately Expanded	Minimally decreased
8	6	4	Good	Very Expanded	Decreased
9	4	6	Worse	Minimally Expanded	Unchanged
10	3	1	Good	Very Expanded	Decreased
11	4	2	Good	Very Expanded	Decreased
12	5	4	Good	Very Expanded	Decreased
13	3	3	Stable	Very Expanded	Minimal decreased
14	7	7	Stable	Minimally Expanded	Minimally decreased
15	4	1	Good	Very Expanded	Decreased
16	6	6	Stable	Moderately Expanded	Minimally decreased
17	7	5	Good	Very Expanded	Decreased
18	4	4	Stable	Moderately Expanded	Minimally decreased

Table V: Measurements of tonsil ectopy and syrinx cavity

Patient number	Tonsil ectopy (mm)	Syrinx cavity (mm)		
	Preoperative	Preoperative	Postoperative	% change
1	9	12	4	67
2	15	9	6	33
3	26	15	15	0
4	19	5	2	60
5	13	6	2	67
6	9	4,5	2	56
7	19	15	12	20
8	9	3	1	67
9	22	15	15	0
10	9	9	6	33
11	12	6	3	50
12	9	4	2	50
13	16	11	8	27
14	21	10	7.5	25
15	11	7	4	43
16	14	9	7	22
17	13	6	3	50
18	17	10	8	20

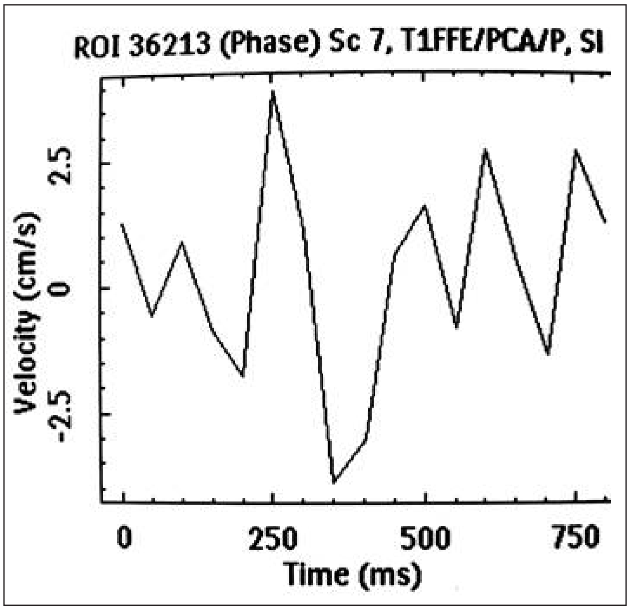


Figure 3: Preoperative CSF velocity-time graph obtained at the foramen magnum level demonstrates a heterogeneous flow pattern.

pattern to a sinusoidal pattern in 11 patients (Figure 4A) and decreased heterogenity in 7 patients (Figure 4B) at the foramen magnum level. Cephalic flow range was 1.28-3.89cm/s and caudal flow range was 1.35-6.04cm/s while the flow volume range was 0.02-0.7ml/s.

Syrinx Cine MR: Preoperatively, the flows obtained from the syrinx showed a heterogeneous pattern (Figure 5A) and the cephalic flow range was 0.05-2.89cm/s, the caudal flow range was 0.01-3.35cm/s, and the flow volume range was 0.01-0.04ml/s.

There were changes in the CSF flow at the syrinx cavity following surgery. Flow in the syrinx was not seen in 10 patients (Figure 5B) and a sinusoidal flow pattern was observed at the foramen magnum level in all patients. In the other 8 patients, alteration of the heterogeneous pattern to a sinusoidal pattern was seen in one and improvement of heterogenity in 7. The cephalic flow range was 0-06-1.03cm/s and caudal flow range was 0.02-1.39cm/s while the flow volume range was 0-0.02ml/s.

In two patients who did not benefit from surgery, the flow patterns of the syrinx cavity remained heterogeneous and the size of the syrinx cavity did not reduce. The cephalic flow range was 1.88-2.32cm/s and the caudal flow range was 1.05-2.21cm/s while the flow volume range was 0.01-0.04ml/s.

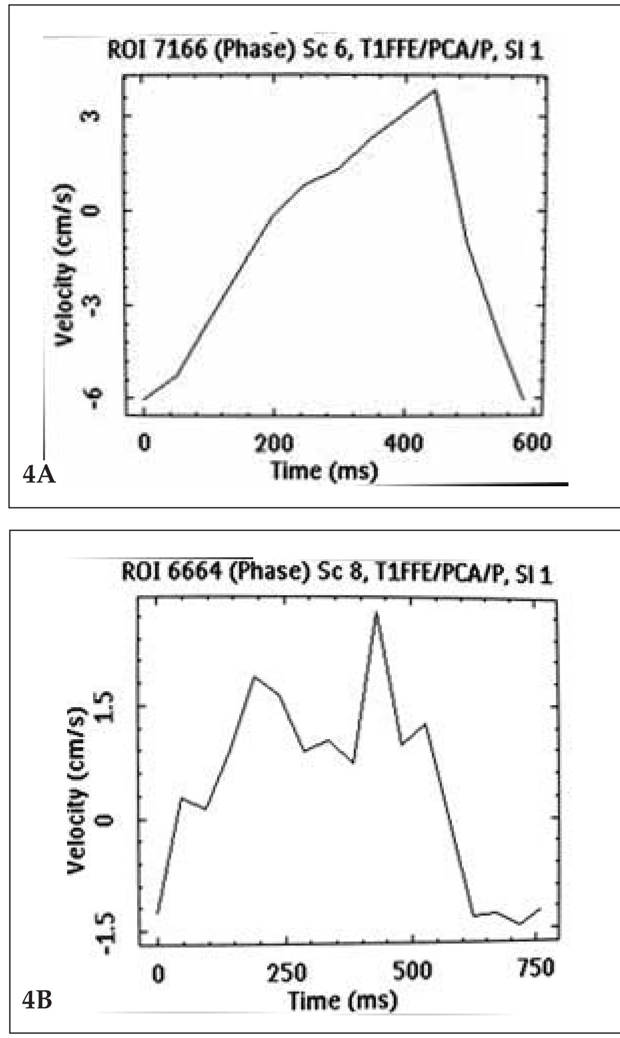
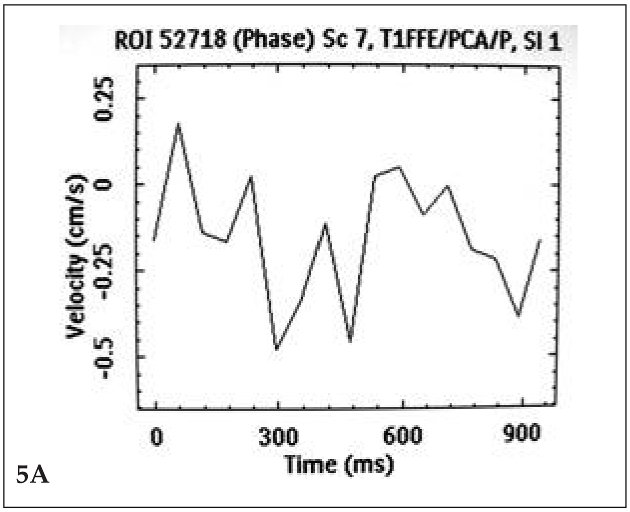


Figure 4: CSF volumetric flow waveforms on flow velocity-time graph through the foramen magnum. **A**. Heterogenity is completely resolved; a sinusoidal flow pattern near to normal is obtained. **B**. Improvement of heterogenous pattern is seen.

CSF flow patterns, flow velocities and flow volumes are summarized in Table III.

DISCUSSION

MR imaging provides the necessary anatomic information on structural parameters such as the degree of tonsillar herniation, size of the syrinx and the presence of other anatomical lesions in skull base. Increasing widespread use of Cine-MR flow studies provide additional information about CSF flow velocity and patterns. Several MR studies have analyzed the changes in CSF flow by phase contrast MR imaging in Chiari 1 patients. Many studies used mid-sagittal sections (2,31) while some investigators used axial projection (17,25).



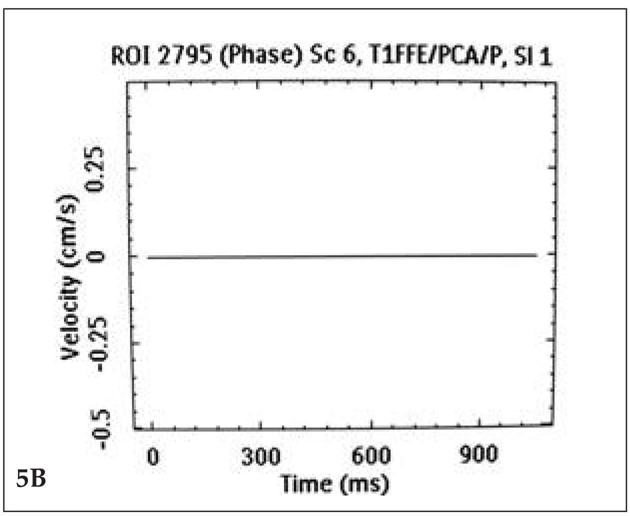


Figure 5: A) CSF flow waveforms through the syrinx cavity preoperatively. Heterogeneous flow pattern on the CSF flow velocity-time graph at foramen magnum is seen. **B**. Note that there is a dramatic decrease in CSF flow through the remaining syrinx after surgical decompression. No flow is observed at the syrinx cavity on CSF flow velocity-time graph postoperatively.

CSF flow dynamics are known to be altered in the foramen magnum region in patients with Chiari I malformation (19,20). It has been postulated that the downward tonsillar displacement somewhat obstructs the rapid bidirectional CSF passage across the foramen magnum, which normally occurs during each cardiac cycle in response to the pulsatile expansion and contraction of the brain (16). This creates greater cervical subarachnoidal pressure waves that compress the spinal cord and force CSF to penetrate into the spinal cord, propagating syrinx fluid caudally with each heartbeat (24). The craniocervical decompression and durapasty removes the blockage in the foramen magnum and re-establishes the normal communication between the cranial and spinal subarachnoidal spaces.

In the medical literature, the rate of syrinx reduction is very high after post fossa decompression at 70-100% (5,7,12,13,29). Kleakamp et al. described the results of clinical series with clinical stabilization obtained in 86% and decrease in syrinx size in 87% of the cases with a maximum follow-up of 8 years (18).

Continuation of syrinx may be due to irreversible spinal cord changes secondary to progressive gliosis (2). In the comparative study of Tognetti et al. (29), the authors concluded that although MRI findings are better after shunting, the clinical results improve after decompressive surgery. It has been reported that 13 to 30% of the patients required more than one operation in different series (15,22). Failure of surgery for the Chiari malformation is not rare and arachnoid adhesions are the most common cause. The incidence of arachnoid adhesions associated with Chiari malformation varies with values up to almost 100% (18,26).

The clinical stabilization results obtained in 16 patients (89%) in our study were comparable to those of Kleakamp et al, but a decrease in syrinx size in our series was observed in 11 patients (61%), which is lower than in the series of Kleakamp et al (18). A striking finding in our series is the clinical deterioration observed in two cases at postoperative 6th month with minimal cisterna magna expansion and the unchanged syrinx diameter with one patient requiring surgery. We believe that arachnoid adhesions prevent normalization of flow pattern even after the creation of cisterna magna by decompression surgery. Thus, intraarachnoid dissection seems to be important in patients with severe arachnoid adhesions.

Although there are reports on non-correlation between the clinical outcome and postoperative MRI findings (11,26), Asgari et al (4) showed a correlation to be present. In our series, the correlation was prominent; the clinical outcome was poor and postoperative cisterna magna was minimally expanded, and there was no reduction in syrinx size in two cases while 10 of 11 patients with very expanded cisterna magna postoperatively showed clinical improvement with reduced syrinx size.

Sakamoto et al (26) reported no significant differences in either the volume ratio or the extent of the herniated tonsils between the improved and unchanged groups. In our study, the clinical outcome correlated with the degree of tonsillar descent; tonsillar ectopia was 22 and 26 mm in two cases with poor clinical outcome, 4-21mm (mean 17.4 mm) in patients with stable clinical findings and tonsillar descent was 9-19 mm (mean 11.6 mm) in 11 clinically improved patients.

Arora et al (3) described the results of radionuclide cisternography, an invasive technique. Posterior decompression and duraplasty provides maximum clinical relief in patients with significant foramen magnum blockage, while those with normal flow have experienced reduced relief. Sakas et al (27) showed that posterior cervical flow increased after surgery and this increase was not related to the progression of the syrinx. However, syrinx flow was not studied in their study. Some studies showed that abnormal CSF flow reverts to normal and parallels symptomatic improvement after posterior fossa decompression (9,16). In our study, preoperative and postoperative cine MRI findings of 18 patients demonstrated reduction in caudal flow in two patients (number 3 and 9)who showed clinical deterioration with stable syrinx cavity, and the heterogeneous pattern was also prominent in these patients.

Continuation of heterogeneous flow pattern in the syrinx was seen in patients with a heterogeneous flow pattern in the cisterna magna in our study. It is important to provide not just a wider cistern, but also a functionally working sinusoidal flow pattern in cisterna magna. The evaluation can be performed postoperatively with cine MRI, a noninvasive technique. On follow-up, it is important to look for postoperative flow pattern since the increase in CSF flow in the posterior cervical region and also the presence of syrinx flow or alteration of the sinusoidal pattern are other important factors.

This present study has shown that Cine MRI can be used to evaluate CSF flow in the cisterna magna and syrinx cavity. We created an artificial cisterna magna with the operation and an increase in posterior cervical CSF flow velocity plus a reduction in syrinx flow velocity were observed.

CONCLUSION

CSF flow measurements at the level of foramen magnum and syrinx cavity using PC VEC MRI provided important information regarding treatment guidance, prognosis and follow-up of patients with Chiari I malformation.

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