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TO STUDY CLINICAL SIGNIFICANCE OF CARDIAC GATED PHASE CONTRAST MRI IN PATIENTS WITH CHIARI MALFORMATION I

Neurosurgery

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ABSTRACT

BACKGROUND AND PURPOSE: CSF motion is a combined effect of CSF production rate and superimposed cardiac pulsations. There are several disorders like communicating and non-communicating hydrocephalus, chiari malformation , syringomyelic cyst and arachnoid cyst that can change the CSF dynamics .Flow of CSF through the foramen magnum has been implicated in the symptoms of Chiari I malformation.
The purpose of this study was to establish relationship between peak CSF velocity at the foramen magnum and symptoms in patients diagnosed with Chiari I malformation.
METHODS: Sixteen symptomatic patients of Chiari I malformations were studied with cardiac gated phase-contrast MR imaging in the axial plane at the foramen magnum preoperatively and post operatively. The flow velocity of CSF (peak systolic and peak diastolic velocity) in the foramen magnum were assessed at thirteen time frames within the r–r interval. The velocity in each of the voxels at each of the time frames was calculated and the peak systolic and diastolic velocities preoperatively and post operatively were tabulated for each patient. The association between peak CSF velocity and symptoms were assessed.
RESULTS: Sixteen patients with Chiari I malformation were studied. Peak systolic velocities significantly diminished after surgery in fifteen patients on average from 9.82 cm/s to 6.41cm/s (p= <0.05) and peak diastolic velocity diminished in fifteen patients from 8.46 cm/s to 5.42 cm/s(p =< 0.05). Decrease in systolic and diastolic CSF velocities was associated with symptom resolution.
CONCLUSION: Craniocervical decompression in Chiari I malformation decreases peak systolic and diastolic velocities with improvement of symptoms.

KEYWORDS

Chiari I, phase contrast magnetic resonance imaging, cerebrospinal fluid flow

INTRODUCTION:

Chiari I malformation is defined as caudal displacement of the cerebellar tonsils through the foramen magnum and associated with suggestive symptoms includinge headache, ataxia, weakness , numbness, tinnitus and vertigo . However, Ttonsillar herniation alone in isolation does not produce a functional deficit. Approximately one third of individuals with tonsillar herniation diagnosed by MRI are asymptomatic (1).

The degree of tonsillar herniation correlates poorly with the severity of signs and symptoms. Symptoms of Chiari I malformation may or may not develop in patients with tonsillar herniation. Signs and symptoms typical of a Chiari I malformation may occur without evident tonsillar herniation in patients with the so-called Chiari 0 malformation (2).

Most of the research workes with onthe Chiari I malformation have been focused on CSF dynamics rather than the anatomic relationships of the tonsils and brain stem. CSF flow pattern may contribute to the Chiari I symptomatology independent of tonsillar ectopia.

In healthy persons controls, CSF flow freely from the skull areacranium to the spinal area and back, driven by the heart- beats. In During the systolic phase blood rushes into the brain and forces CSF out and into the spine area and in diastolic phase of cardiac cycle this is reversed. Any process that cause disrupts or blocks the natural flow of CSF can lead to many symptoms including syrinx formation .

The rationale for measuring peak velocity is based on the consideration of fluid dynamics in at the foramen magnum. The volume of fluid (in ml/min) moving through the foramen magnum during each cardiac cycle depends less on the shape and compliance of the foramen magnum than on change in cerebral blood volume with each cardiac cycle. Velocity of flow through the foramen magnum (in cm/s) depends on the dimensions and shape of the foramen magnum. Tonsillar herniations, adhesions within the foramen magnum, or other processes that affect the capacity of the foramen magnum may increase peak CSF velocity. vVictor et al analyzed that in symptomatic patients with Chiari I, peak CSF velocities increased at the level of foramen magnum levels.(15)

During last two decades, flow sensitive MRI techniques have been increasingly used to quantitatively and qualitatively assess CSF flow dynamics. This imaging method can also provide information in preoperative and post operative follow up patients.(3)
In this article , we describe use of phase contrast MRI for the assessment of relationship between CSF dynamics and symptoms of Chiari I malformation in pre and post- operative periodly.

Authors used phase-contrast MR imaging to assess the flow of CSF in the foramen magnum .(4-14)

METHODS

In this study, sixteen symptomatic patients of Chiari I malformation were evaluated in a neurosurgical department between 2016 and 2018. All patients had neurologic symptoms and signs referable to Chiari I malformation. All patients underwent MR imaginges including T1- and T2-weighted sagittal images of the cCervical spine that revealed tonsillar descent into the foramen magnum, consistent with the diagnosis of Chiari I malformation and with PC MR imaging for study of CSF flow in the foramen magnum preoperatively and post operatively within 7 days of surgery. Neurological symptoms and sign were recorded during preoperative period and postoperatively at 7 days, 3 months and 6 months period .

Patients with symptomatic Chiari I malformation with or without syringomyelia were included in this study and contraindication to MR imaging or previous surgical treatment for spinal abnormality were excluded from this study.

PHASE-CONTRAST MR IMAGING

Patients underwent imaging with the same 3-T imaging unit. Conventional T1- and T2-weighted sagittal view images of the cervical spine were obtained to evaluate tonsillar herniation and syringomyelia. Cardiac gated phase-contrast images were obtained in at the level of foramen magnum when the participant had achieved a steady heart rate. and c Commercially available phase-contrast flow measurement sequence was used: 20/5 (TR/TE); flip angle of 15 degrees; section thickness of 4 mm; field of view of 150 mm; matrix of 256 *179; encoding velocity, 12cm/s. Section orientation was axial and perpendicular to the spinal canal, and section location was chosen at the narrowest portion of the foramen magnum . Patients in whom tonsillar herniation obstructed CSF flow in the foramen magnum, the section was taken at the point below the tonsils in which sufficient CSF was present for visualization .Thirteen image frames were acquired regularly throughout the r–r interval. The peak caudaed caudal (systolic) and cranial (diastolic) velocities were recorded in all voxels.

CSF VELOCITY CALCULATION

Flow analysis was conducted with commercially available software .The 13 successive images for each time frame of the cardiac cycle were inspected to identify the subarachnoid space. A region of interest was placed to include the entire subarachnoid space (including the spinal cord) and to exclude the vertebral arteries, the region of interest placement was focused to identify the peak CSF velocities wherever they occurred in the foramen magnum. It displayed maximum, minimum, and average velocities as a function of time during the cardiac cycle. The time course of the velocity was inspected and compared with the expected shape of the curve. If the time courses failed to show the expected diastolic-systolic-diastolic flow curve, the region of interest was repositioned to eliminate a region of velocity aliasing or possible arterial flow. The peak systolic and diastolic velocities for the region of interest were recorded. In cases in which velocities did not appear uniform throughout the subarachnoid space or the temporal course for CSF velocity showed a pattern different from the usual bimodal one, the region of interest was replaced with one or more smaller ones.. For each patient one single peak diastolic and systolic velocity wereas recorded. Differences in velocities were tested with a single tail student' t-test.

RESULTS

In this study, we included sixteen patientss , ten male and six female(M:F:: 1.6:1) within an age group of 6 to 50 years. All patients had symptoms and /or signs that were suggestive of Chiari I malformation and all underwent posterior fossa decompression. All patients had tonsillar herniation that ranged from 8 to 13 mm and syrinxs.. Headache was observed in fifteen patients(93.75%), mMotor weakness was present in nine patients(56.25%), aAtaxia was present in seven patients(43.75) ,vVertigo in four patients (25%), numbness in five patients(31.25%) and one patient had scoliosis(6.25%)(table1).Patients with either an objective sign of motor weakness or a symptoms of weakness were considered as having a motor abnormality. Sign of hypoesthesia or a symptom of diminished sensation was considered as having sensory abnormality.
All sixteen patients with symptoms of Chiari malformation I underwent craniocervical decompression (midline suboccipital craniectomy and duraplasty) and (6/16) underwent C1 & C2 posterior arch removal and (2/16) underwent cerebellar tonsillectomy.(table2). Clinical evaluation wasere performed at 1 week, 3 months and 6months of following surgery . Following surgery all patients had improvement inimprovement in their symptoms .(table 3)

CLINICAL EVALUATION

Fifteen patients were presented with headache preoperatively , but by 1 week after surgery. in 8 patients headache wasere resolved in 8 patients and intensity was decreased in 7 patients headache intensity decreasedcases . Motor weakness which was present in 9 cases , improved in 5 cases .Ataxia, which was present in 7 patients , improved in 3 cases .Vertigo which was present in 4 cases ,improved in 2 cases . By 6 months after surgery all (fourteen) patients had improved . Two patients did not turn up in the follow up. Despite improvement in overall clinical symptoms, most patients continued to have residual symptoms postoperatively at each follow up interval. (table 4)

The proportion of patients who continued to have at least some symptoms following surgery was 55 % at 7 days, 35 % at 3 month and 8.34% at 6 month .The common signs and symptoms persistent after surgical treatment was headache, vertigo and numbness .

One patient who had scoliosis and headache, headache is was not resolved although intensity of headache was reduced .

RADIOIMAGING EVALUATION

The graphic representation of CSF flow through the cardiac cycle is generated using a ROI (region of interest) placed by the investigator in any part where CSF is identified (on the axial images).The graph reflects velocity in cm/s on the y-axis and time in ms on the x-axis. In a normal study, the diastolic flow is represented above the baseline and systole is represented below the baseline .

Preoperatively maximal caudal velocity (systolic velocity) ranged from 4.19 cm /sec to 11.9 cm/sec and maximal cephalad velocity (diastolic velocity) ranged from 4.19 cm /sec to 12 cm/sec .(table 5).

Post operatively CSF flow study was done within 7 days of surgery.

The effect of decompression on maximal CSF velocity in summarized in table 5 and fig 1 . Postoperatively maximal caudal velocity (systolic velocity) ranged from 1cm/sec to11.4 cm/sec and maximal cephalad velocity (diastolic velocity) ranged from 2.08cm/sec to 9.43 cm/sec.

The mean systolic velocities in preoperatively and post operatively are were 9.82[SD 2.78] and 6.41[SD 3.55] cm/sec respectively. and tThe differeance was found to be significant. {p =<0.05}

The mean diastolic velocities in preoperatively and post operatively are 8.46[SD 2.95] and 5.42 [SD 2.57] respectively. The differeance was statistically significant {p =<0.05} and peak systolic velocity exceeded the peak diastolic velocities in most of the patients.

Post operatively PC MR image shows decreased maximal CSF velocity in 15(93.75%) patients with improved CSF flow . In all theose patients , clinical symptoms improved .A patient with headache and scoliosis whose maximal CSF velocity was increased after surgery and showed no significant improvement seen in symptoms .

The study (Mcgirt Mj et al 2006) was foundreported that patients with scoliosis were 9 times more likely to experience treatment failure after surgery .(23)

Table 1 Pre and Post Operative Symptoms

NAME	PRE OP SYMPTOMS						POST OP (AFTER 7 DAYS)						AFTER 3 MONTH						AFTER 6 MONTH					
	H	A	W	T	V	N	H	A	W	T	V	N	H	A	W	T	V	N	H	A	W	T	V	N
NA	P	P	P	N	N	N	R	I	I	N	N	N	R	I	I	N	N	N	R	I	I	N	N	N
DE	P	N	P	N	N	N	R	N	I	N	I	N	R	N	I	N	I	N	R	N	I	N	R	N
DI	P	N	P	N	P	N	R	P	I	N	N	P	R	I	I	N	N	P	R	I	I	N	N	P
SH	P	P	P	N	N	P	R	N	N	N	N	N	R	N	N	N	N	N	R	N	N	N	N	N
SAN	P	N	N	N	N	N	D	N	P	N	N	P	D	N	I	N	N	P	R	N	I	N	N	P
SA	P	N	P	N	N	P	R	N	N	N	N	N	R	N	N	N	N	N	R	N	N	N	N	N
BH	P	N	N	N	N	N	R	P	N	N	N	P	R	I	N	N	N	P	R	I	N	N	N	I
SU	P	P	N	N	N	P	D	P	P	N	N	N	D	I	I	N	N	N	R	I	I	N	N	N
RO	P	P	P	N	N	N	R	I	N	N	N	N	R	I	N	N	N	N	R	I	N	N	N	N
KE	P	P	N	N	N	N	N	N	I	N	I	N	N	N	I	N	I	N	N	N	I	N	R	N
KA	N	N	P	N	P	N	D	N	N	N	N	N	D	N	N	N	N	N	D	N	N	N	N	N
KRI	P	N	N	N	N	N	D	N	N	N	P	N	D	N	N	N	I	N	R	N	N	N	I	N
DWA	P	N	N	N	P	N	D	N	P	N	P	N	D	N	I	N	P	N	D	N	I	N	P	N
BHA	P	N	P	N	P	N	D	N	N	N	N	N	D	N	N	N	N	N	R	N	N	N	N	N
CHA	P	N	N	N	N	N	R	I	I	N	N	P	R	I	I	N	N	P	-	-	-	-	-	-
JI	P	P	P	N	N	P	D	P	P	N	N	P	D	I	P	N	N	P	-	-	-	-	-	-
VI	P	P	P	N	N	P																		

Table 2 : Operative Procedure

NAME	OPERATIVE PROCEDURE
DE	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD & REMOVAL OF C1 -C2 POSTERIOR ARCH WITH AD
DI	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH AD
SH	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH AD
SAN	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD & REMOVAL OF C1 -C2 POSTERIOR ARCH WITH AD
SA	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH AD
BH	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD & REMOVAL OF C1 -C2 POSTERIOR ARCH WITH AD
SU	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD & REMOVAL OF C1 -C2 POSTERIOR ARCH WITH AD
RO	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD & REMOVAL OF C1 -C2 POSTERIOR ARCH WITH AD
KE	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH AD
KA	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH AD
KR	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD & REMOVAL OF C1 POSTERIOR ARCH WITH AD
DW	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH AD

BHA	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD & REMOVAL OF C1 -C2 POSTERIOR ARCH WITH AD
CHA	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH AD
JI	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH ADHESIOLYSIS WITH CEREBELLAR TONSILLECTOMY WITH AD
VI	MIDLINE SUBOCCIPITAL CRANIECTOMY WITH FMD WITH REMOVAL OF POSTERIOR ARCH C1 WITH CEREBELLAR TONSILLECTOMY WITH AD

Table 3

	AT 1 WEEK	AT 3 MONTH	AT 6 MONTH
HEADACHE	8/15 (53.33%) RESOLVED ,7/15 (46.66%)DECREASED INTENSITY	8/15 (53.33%) RESOLVED, 7/15 (46.66%)DECREASED INTENSITY	12/14 (85.71%) RESOLVED. 2/14 (14.29%)DECREASED INTENSITY
ATAXIA	3/7 (42.86%) IMPROVED ,4/7 (57.14 %) NOT IMPROVED	7/7 (100 %) IMPROVED	7/7 (100 %) IMPROVED
WEAKNESS	5/9 (55.55 %) IMPROVED ,4/9 (44.45%) NOT IMPROVED	8/9 (88.88%) IMPROVED ,1/9 (11.11%) NOT IMPROVED	8/8 (100 %) IMPROVED
VERTIGO	2/4 (50 %) IMPROVED ,	3/4 (75 %) IMPROVED ,	3/4(75%) IMPROVED ,
NUMBNESS	0/5 (0%) NOT IMPROVED	0/5 (0%) NOT IMPROVED	3/3 (100%) IMPROVED
	45% SYMPTOMS IMPROVED	65% SYMPTOMS IMPROVED	91.66%SYMPTOMS IMPROVED

Table 4

NAME	AGE (IN YEARS)	SEX	TONSILLAR HERNIATION (MM)	SYRINX	PEAK SYSTOLIC VELOCITY (CM/SEC)			PEAK DIASTOLIC VELOCITY (CM/SEC)		
					PREOP	POST OP	DIFFERENCE	PREOP	POST OP	DIFFERENCE
DE	27	M	10MM	YES	11.3	7.6	3.7	12	6.86	5.14
DI	36	M	6MM	YES	8.61	3.34	5.27	11.6	7.07	4.53
SH	50	F	8MM	YES	11.9	7.34	4.56	12	7.5	4.5
SAN	15	M	8MM	YES	9.6	4.6	5	4.6	2.5	2.1
SA	20	F	10MM	YES	10.2	6.4	3.8	10.7	8.4	2.3
BH	50	M	8MM	YES	10.5	4.29	6.21	6.49	3.23	3.26
SU	26	F	13MM	YES	8.99	1	7.99	5.35	2.08	3.27
RO	26	M	12MM	YES	6.65	5.25	1.4	7.67	4.24	3.43
KE	28	F	10MM	YES	7.32	4.8	2.52	6.34	3.26	3.08
KA	30	F	13MM	YES	11.9	7.8	4.1	11.8	5.6	6.2
KRI	6	M	11MM	YES	10.6	11.4	-0.8	4.8	9.43	-4.63
DWA	24	F	9MM	YES	10.7	7.4	3.3	10.5	8.2	2.3
BHA	45	M	12MM	YES	4.19	3.97	0.22	4.19	3.04	1.15
CHA	38	M	12MM	YES	10.9	9.8	1.1	10.4	8.8	1.6
JI	30	M	6MM	YES	11.9	3.47	8.43	10.2	2.9	7.3
VI	19	M	8MM	YES	5.7	4.57	1.13	6.66	3.57	3.09

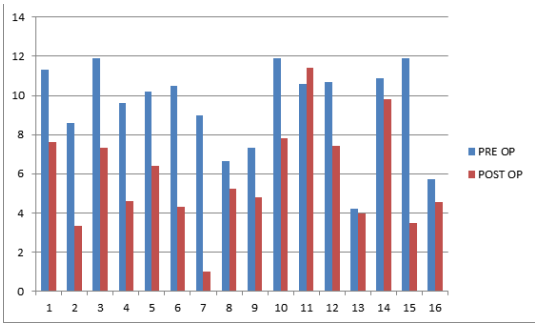
Table 5

EFFECT ON VELOCITIES AFTER SURGERY	NO OF THE PATIENTS(16)	PERCENTAGE
BOTH VELOCITIES DECRESED >30 %	9	56 .25%
SYSTOLIC VELOCITY DECRESED >30% , DIASTOLIC <30 %	2	12.5%
SYSTOLIC VELOCITY DECRESED <30% , DIASTOLIC >30 %	2	12.5%
BOTH VELOCITIES DECRESED<30 %	2	12.5%
BOTH VELOCITIES INCRESED	1	6.25%

ABBREVIATIONS

H – headache P - present
V – vomiting N – not present
T – tinnitus D– decreased intensity
W- weakness I - improved
N – nubmness R - relieved
A – ataxia AD- augmented duraplasty

A. PRE AND POST OPERATIVE SYSTOLIC CSF VELOCITY



B .PRE AND POST OPERATIVE DIASTOLIC VELOCITY

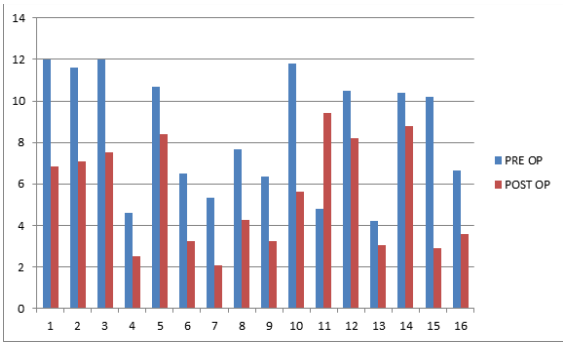


Fig 1 Graph displaying the peak systolic (Graph A) and diastolic velocities (Graph B) in cm/s in the subarachnoid space of the foramen magnum in patients with a Chiari I malformation before and after surgery. In most patients, the caudad (systolic) and cephalad (diastolic) velocities are diminished following surgery.

DISCUSSION

Patients with Chiari I malformation have boths anatomic and functional abnormalities. The anatomic changes include adhesions in the posterior fossa, crowding of neural structures, and small size of the posterior fossa (16).The functional changes include alterations in CSF flow in the foramen magnum (4– 14) and in the foramina of luschka or magendie (17). The treatment for Chiari I malformation treatment is still remain controversial (18). Studies of CSF flow in the foramen magnum with PC MR have suggested that the Chiari I malformation produces an anatomic and as well as physiologic blockage to CSF the flow of CSF inat the foramen magnum .(28,29). A functional imaging study that differentiates incidental from significant malformations of the foramen magnum would be affarmative.

In Brugieres p et al 2000 measured study , peak velocity during systole and diastole were measured in theat foramen magnum and in the cervical spine before and after surgery . in that study ,They averaged the flow measurement throughout the were averaged for the entire subarachnoid space ,whereas in our studywe measured the flow on a voxel by voxel basis .(19)

Mihorat th et al reported, the mean age of onset of Chiari I is reported to be 25 years, and women accounted for 75%(M:F::1:3) of patients .(20) While in our studyWe found the mean age of onset of Chiari I is to be 29.37 years which is similar but women account for 37.5% of total patients in our study(M:F::5:3) that is male preponderance.

In Victor m et al study, the peak diastolic velocities(4cm/s) exceeded the peak systolic velocities(3cm/s) (15) while in our study the peak systolic velocities are exceedinged { mean9.82} the diastolic velocities {mean 8.46} .

In our study, a wide degree range of CSF flow velocities and variable symptom were observed with similar extents of tonsil herniation . The wide variability in severity of symptoms observed with Chiari I malformation may be explained by the variability in csf CSF flow

dynamics rather than the degree of tonsilar herniation . The degree of CSF flow obstruction correlated with symptomatology and predicted response to surgery but not extent of tonsil herniation.

The observation in our study was we observed decreased maximal systolic and diastolic velocity after craniocervical decompression in patients with Chiari I malformation (93.75%), which lends support to the theory that the Chiari I malformation is associated with abnormal CSF flow in the foramen magnum and which is consistent with the previous studies.(21, 22)

In one patient in whom csf CSF velocity not didn't decrease,d symptomatics was not improvement was also not observedd . (table 4)
Other observation of oOur study also showed correlation between changes in maximal CSF velocities and degree of clinical improvement. Patients with reduction in both the systolic and diastolic velocities (15/16) had also experienced improvements of in the severity of theirir symptoms. Patients(9/16) with reduction in both systolic and diastolic velocities post operatively (more than 30%) had experienced earlier decreased of symptoms than those with less reduction(less than 30%) in both velocities (table 6).

Most of symptoms (91.66%) resolved within 6 month following decompression consistent with previous reports(70-90%) (23,24,25,26,27) and however some patients had continued to have residual symptoms, mainly headache ,numbness and vertigo. Stevans et al. reported that ataxia was clinical features least likely to improve after surgery but in our study ataxia was improved in all patients .(22)

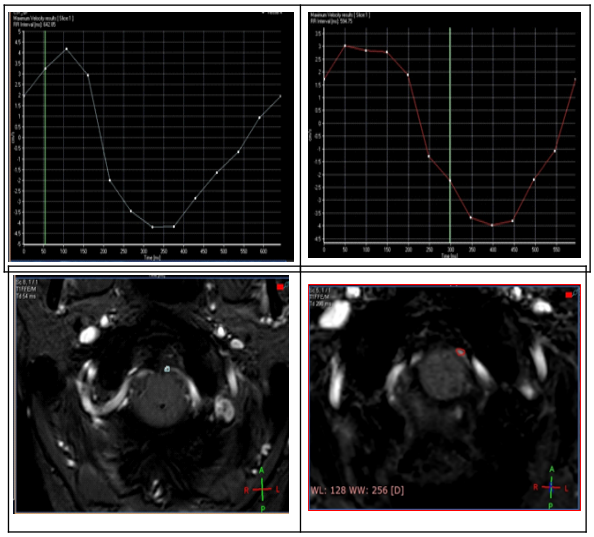
Our results support the hypothesis that altered CSF dynamics contribute to the pathogenesis of clinical manifestations in patients with Chiari I malformations.

Patients with Chiari I malformation, tThe arterial pressure wave in the cranial vault of patients with Chiari I malformation produces and an enlargedgreater cervical subarachnoid pressure wave that may contribute to the development of a syrinx and toas well as clinical signs and symptoms. Our results are consistent with the theory of a physiologic block of CSF flow in the Chiari I malformation. A surgically produced decrease in physiological obstruction would likely reduce the maximal velocities.

CONCLUSION

The study shows that craniocervical decompression decreasesd peak systolic and diastolic velocities in most of the Chiari I patients and showsas well as correlation between changes in maximal CSF velocities and degree of clinical improvement. Early clinical improvement was seen in patients with who showed both reduction in both systolic and diastolic peak velocities decreased as compare to other group . Thisese data supports the theory that good surgical procedure of in a Chiari I malformation is associated with decreased obstruction of CSF with reduction of CSF velocities and improvements of symptoms.

FIGURE 1



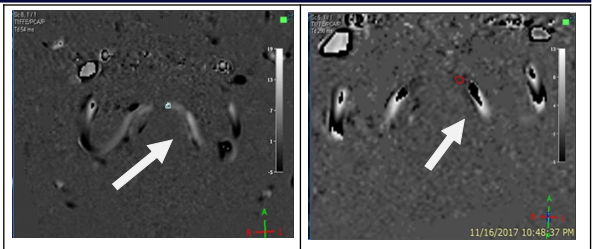


FIGURE 1 PRE OP	FIGURE 1 POST OP
Pre op phase contrast image showed csf flow at the13 time points between R-R interval .maximum systolic (between190 ms and 560ms) and diastolic csf flow velocity(first 190 and last 90 ms) . maximum velocity during systole and diastole are 4.19cm/s. last image showed occlusion of csf circulation at the posterior column .	Post op phase contrast image showed csf flow at the13 time points between R-R interval .maximum systolic (between225 ms and 510ms) and diastolic csf flow velocity(first 225 and last 40 ms) . maximum velocity during systole and diastole are 3.97 and 3.04cm/s respectively.. Post op image contrast image showed flow also seen in posterior column

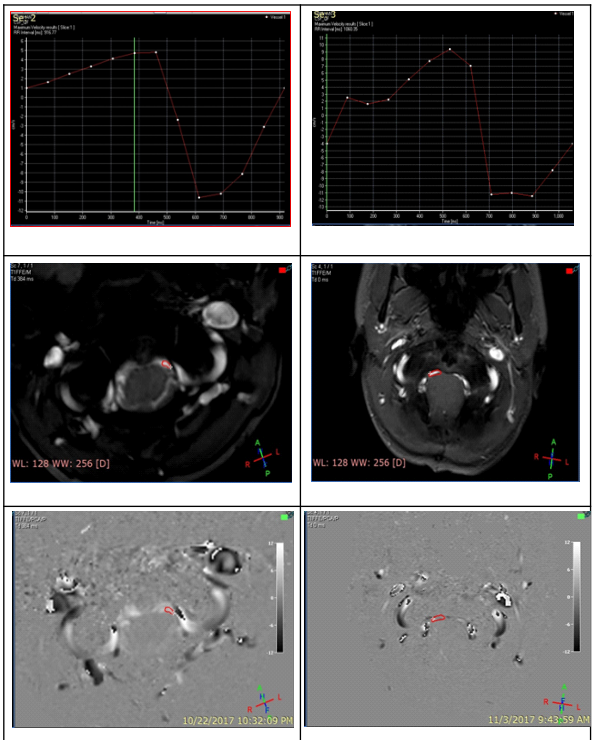


FIGURE 1 PRE OP	FIGURE 2 POST OP
Pre op phase contrast image showed csf flow at the13 time points between R-R interval .maximum systolic (between520 ms and 900ms) and diastolic csf flow velocity(first 520 and last 17 ms) . maximum velocity during systole and diastole are 10.6 and 4.8 cm/s respectively.	Post op phase contrast image showed csf flow at the13 time points between R-R interval .maximum systolic(first 60and last 400 ms) and diastolic csf flow velocity(between 60 ms and 660 ms) . maximum velocity during systole and diastole are 11.4 and 9.43cm/s respectively.

REFERENCES

1. Meadows j, kraut m, guarnieri m, haroun ri, carson bs. Asymptomaticchiari type i malformations identified on magnetic resonance Imaging. J neurosurg 2000;92:920–926
2. Iskandar bj, hedlund gl, grabb pa, oakes wj.The resolution ofsyringohydromyelia without hindbrain herniation after posterior Fossa decompression. J neurosurg 1988;89:212–216
3. yildiz h, yazici z, hakyemez b, erdogan c, parlak m. Evaluation of CSF flow patterns of posterior fossa cystic malformations using CSF flow mr imaging. Neuroradiology 2006;48:595–605.
4. Quencer rm, post mj, hinks rs. Cine mr in the evaluation ofnormal and abnormal CSF flow: intracranial and intraspinal studies. Neuroradiology 1990;32:371–391

5. Hofmann e, warmuth-metz m, bendszus m, solymosi l. Phasecontrastmr imaging of the cervical CSF and spinal cord: volumetric Motion analysis in patients with Chiari I malformation.ajnr am j neuroradiol 2000;21:151–158
6. Armonda ra, citrin cm, foley kt, ellenbogen rg. Quantitativecine-mode magnetic resonance imaging of Chiari I malformations: An analysis of cerebrospinal fluid dynamics. Neurosurgery 1994;35:214–224
7. Levy lm, di chiro g. Mr phase imaging and cerebrospinal fluidflow in the head and spine. Neuroradiology 1990;32:399–406
8. Bhadelia ra, bogdan ar, wolpert sm, lev s, appignani ba,heilman cb. Cerebrospinal fluid flow waveform: analysis in patients with Chiari I malformation by means of gated phase-contrastmr imaging velocity measurements. Radiology 1995;196:195–202
9. Enzmann dr, pelc nj. Normal flow patterns of intracranial andspinal cerebrospinal fluid defined with phase-contrast cine mr imaging. Radiology 1991;178:467–474
10. Enzmann dr, pelc nj. Cerebrospinal fluid flow measured byphase-contrast cine mr. Ajnr am j neuroradiol 1993;14:1301–1307
11. Greitz d, wirestam r, franck a, nordell b, thomsen c, stahlbergf. Pulsatile brain movement and associated hydrodynamics studied by magnetic resonance phase imaging: the monro-kellie doctrinerevisited. Neuroradiology 1992;34:370–380
12. Heiss jd, patronas n, devroom hl, et al. Elucidating the pathophysiologyof syringomyelia. J neurosurg 1999;91:553–562
13. Wolpert sm, bhadelia ra, bogdan ar, cohen ar. Chiari Imalformations: assessment with phase-contrast velocity mr. Ajnr am j neuroradiol 1994;15:1299–1308
14. Pujol j, roig c, capdevila a, et al. Motion of the cerebellar tonsilsin chiari type i malformation studied by cine phase-contrast mri.neurology 1995;45:1746–1753
15. victor m. Haughton, frank r. Korosec, joshua e. Medow,maria t. Dolar, et al: peak systolic and diastolic CSF velocity in theforamen magnum in adult patients with chiari I malformations and in normal control participants. Ajnr :2003;24:169-176
16. Karagoz f, izgi n, kapijcijoglu sencer s morphometric measurements of the cranium in patients with chiari I malformation And comparison with the normal population. Acta neurochir (wien) 2002;144:165–171
17. Santamarta d, kusak me, de campos jm, sierra jm. Increased cerebrospinal fluid flow through the foramen of magendie after decompression for Chiari I malformation. J neurol neurosurg psychiatry 1999;66:799
18. Cohen ar, gaskill sj. Chiari I malformation. Neurosurg focus 2001;11: introduction www.neurosurgery.org/focus/july 01/11-1-1
19 brugieres p , idy-peretti i, iffenecker c, et al :CSF flow measurement in syringomyelia.ajnr am j neuroradiol 2000;21:1785-1792
20. Milhorat th, chou mw,trinidad em, kula rw, mandell m, wolpert c, et al:chiari 1 malformation redefined: clinical and radiolographic findings for 364 symptomatic patients.neurosurgery 44:1005-1017,1999.
21 maria t dolar, victor m haughton, bermans j iskandar , et al :effect of craniocervicaldecompression on peak CSF velocities in symptomatic patients with Chiari I malformation .ajnr am j neuroradiol 25:142-145, january 2004
22. Stevens JM , Serva WA,Kendall BE, ValentineAR,Ponsford JR:Chiari malformation in adults :relation of morphological aspect to clinical features and operative outcome . J Neurol Neurosurg Psychiatry56:1072-1077,1993.
23 . mc girt mj,nimjee sm,fuchs he,george tm, et al :relationship of cine phase contrast mri to outcome after decompression for chiari 1 malformation . Neurosurgery july 2006;58.
24 guyotat j, bret p, jouanneau e, ricci ac, lapras c: syringomyelia associated with type i chiari malformation. A 21-year retrospective study on 75 cases treated by foramen magnum decompression with a special emphasis on the value of tonsils resection. Acta neurochir 140:745–754, 1998.
25 paul ks, lye rh, strang fa, dutton j: arnold-chiari malformation. Review of 71 cases. J neurosurg 58:183–187., 1983.
26. Tubbs rs, mcgirt mj, oakes j: surgical experience with 130 pediatric Chiari I malformations. Journal of neurosurgery, in press.
27. Weinberg js, freed dl, sadock j, handler m, wisoff jh, epstein fj: headache and Chiari I malformation in the pediatric population. Pediatr neurosurg 29:14–18., 1998.
28. Heiss sd, patronas n, devroom hl, et al. Elucidating the pathophysiology of syringomyelia. J neurosurg 1999;91:553–562
29 oldfield eh, muraszko k, shawker th, patronas nj. Pathophysiology of syringomyelia associated with Chiari I malformation of the cerebellar tonsils. J neurosurg 1994;80:3–15