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Correlation between ventriculomegaly on prenatal magnetic resonance imaging and the need for postnatal ventricular shunt placement

Clinical article

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Object. Pediatric neurosurgeons are increasingly called on to provide prognostic data regarding the antenatal diagnosis of ventriculomegaly. This study was designed to determine if there is a correlation between prenatal MR imaging results and the need for ventricular shunt placement during the neonatal period.

Methods. The authors retrospectively reviewed the prenatal MR imaging data of 38 consecutive patients who had been referred for neurosurgical consultation following the diagnosis of ventriculomegaly. The outcome measure was placement of a ventricular shunt. Assessed parameters included prenatal atrial diameter (AD), gestational age at MR imaging, time between imaging studies, presence of concomitant CNS anomalies, laterality of ventriculomegaly, fetal sex, and temporal evolution of ventriculomegaly. Logistic regression analysis was completed with the calculation of appropriate ORs and 95% CIs.

Results. Six patients (16%) required shunt placement, all with an AD ≥ 20 mm (mean 23.8 mm) at the time of imaging. Eight patients had presented with an AD ≥ 20 mm. Atrial diameter was the only presenting feature that correlated with shunt placement (OR 1.58, 95% CI 1.10–2.25, p = 0.01). Logistic regression analysis revealed no statistical correlation between the need for ventricular shunting and gestational age at MR imaging, time between imaging studies, fetal sex, presence of additional CNS anomalies, and laterality of the ventriculomegaly.

Conclusions. When assessed using MR imaging, an AD ≥ 20 mm at any gestational age is highly associated with the need for postnatal shunting. Patients with concomitant CNS anomalies did not require shunts at a greater rate than those with isolated ventriculomegaly. Further studies are required to assess the long-term outcome of this patient population. *(DOI: 10.3171/2009.1.PEDS08328)*

Key Words • fetal magnetic resonance imaging • fetal ventriculomegaly • neonatal hydrocephalus • neonatal cerebrospinal fluid shunting

Ventriculomegaly is the most frequently diagnosed prenatal brain abnormality. It is identified sonographically in 1–2 per 1000 pregnancies.[2,5,22] Although prenatal ultrasonography is the primary imaging screening method used to detect structural CNS abnormalities, a considerable number of antenatal anomalies are not reliably diagnosed with ultrasound alone.[2,5–7,12,14,19,23] Magnetic resonance imaging is considered to be the most sensitive prenatal imaging modality, and the development of ultrafast T2-weighted techniques has made prenatal MR imaging a practical diagnostic tool. In addition to ventriculomegaly, commonly encountered disorders include neural tube defects, Dandy-Walker complex, agenesis of the corpus callosum, and a variety of less common entities (for example, arachnoid cyst, encephalocele, stroke, and hemorrhage).

At the Center for Prenatal Pediatrics, Columbia University Medical Center, fetal ventriculomegaly is the most common diagnosis for which pregnant women seek pedi-

Abbreviations used in this paper: AD = atrial diameter; DOL = day of life; VP = ventriculoperitoneal.

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atric neurosurgical consultation. Despite the considerable literature on the developmental outcomes in patients with prenatal ventriculomegaly, the long-term implications of this condition are variable and, in a given patient, may be difficult to predict.[6,7,9–11,13,15,17,22,24,25,27] Given the complications associated with CSF diversion during infancy and the importance of parental counseling, it would be helpful to offer expectant parents accurate advice regarding the potential surgical course of a patient with prenatal ventriculomegaly.[5] In this study we specifically sought to determine the association, if any, between prenatal imaging results and the need for postnatal ventricular shunting.

Methods

Between 1998 and 2007, the Center for Prenatal Pediatrics at the Columbia University Medical Center performed > 1000 prenatal MR imaging studies after abnormalities were detected on screening ultrasonography. Based on images from this group, 38 patients were referred for pediatric neurosurgical evaluation for prenatal ventriculomegaly. In each case, ventriculomegaly alone or in the presence of another CNS anomaly was diagnosed in the fetus. Pediatric neurosurgical consultation was requested in cases of isolated ventriculomegaly or when the associated anomalies were not considered to be incompatible with life. In addition to a clinical follow-up, each child underwent postnatal imaging that included CT, MR imaging, or ultrasonography, or an autopsy procedure was performed.

We assessed factors that might indicate the requirement for future CSF shunting in a population whose need for CSF diversion has yet to be well established. In contrast, it has been well established that children with myelomeningocele or Dandy-Walker complex require CSF diversion in up to 96% of cases. The inclusion of such patients in the present study would not contribute novel clinical data and may dilute our findings. Thus, we excluded those patients in whom a myelomeningocele or Dandy-Walker complex was diagnosed.[1,8,16,20,21]

Two radiologists (R.D. and S.L.N.) and 1 pediatric neurosurgeon (R.C.E.A.) reviewed all images. We obtained T2-weighted single shot fast spin echo images using a Siemens 1.5-T magnet and a torso coil. A radiologist was present throughout the procedure to verify that adequate images were obtained in each of the 3 cardinal planes. Ventricular AD was measured using axial images at the level of the posterior margin of the choroid plexus. Imaging sessions were conducted at 2 time points in all patients: during the late second or third trimester and postnatally or immediately before electively terminating the pregnancy. Mild ventriculomegaly was defined as an AD of 10–15 mm. Severe ventriculomegaly was defined as an AD > 15 mm.

Patients were divided into 2 groups based on the presence or absence of CNS anomalies in addition to the ventriculomegaly. Twenty-five children (66%) were included in the isolated ventriculomegaly group (no abnormality aside from the ventriculomegaly) and 13 (34%) in the group with ventriculomegaly and other CNS anomalies. Patients were further divided into 3 groups based on the evolution of the ventricular size between the pre- and postnatal studies: resolution, no change, or progression.

The primary outcome measure was the placement of a ventricular shunt. The criteria for postnatal shunting were very similar to those previously described by Drake and colleagues[4] with regard to VP shunt malfunction. These criteria included both the clinical signs of elevated intracranial pressure (tense fontanel, episodes of apnea and bradycardia, splayed sutures, or a rapidly increasing head circumference) and the presence of postnatal ventriculomegaly. Prenatal ventriculomegaly was not a criterion for shunt insertion. Logistic regression analysis was completed using Stata, version 8.0 (StataCorp), and included the following variables: prenatal AD, gestational age at MR imaging, time between prenatal and postnatal imaging, patient sex, laterality of the ventriculomegaly (that is, unilateral or bilateral), and the presence of additional CNS anomalies.

Results

Isolated Ventriculomegaly

Isolated ventriculomegaly was prenatally diagnosed in 25 patients ([66%]; Fig. 1). The mean prenatal AD in this group was 15.2 mm (range 10–30 mm). Postnatal radiological outcomes showed resolution in 9 patients ([36%]; Fig. 2), no change in 13 ([52%]; Fig. 3), and progression in 3 (12%). Four patients (16%) required a VP shunt, and 1 pregnancy (4.0%) was terminated. Among the 17 patients with an AD ≤ 15 mm, ventriculomegaly resolved in 8 (47%) and was stable in 9 ([53%]; Tables 1 and 2).

Shunt placement occurred on DOL 1 (2 patients), DOL 25 (1 patient), and DOL 60 (1 patient). Of the 9 patients whose ventriculomegaly resolved, none required a VP shunt. One (7.7%) of 13 patients with stable ventriculomegaly required a VP shunt on DOL 25 (Fig. 3). All 3 patients with progressive ventriculomegaly required a VP shunt. All 4 patients who received a shunt demonstrated clinical evidence of symptomatic hydrocephalus (Table 3).

Ventriculomegaly With Other CNS Abnormalities

Ventriculomegaly in the presence of an associated CNS anomaly was diagnosed in 13 patients (34%). Associated anomalies included agenesis of the corpus callosum (6 patients), spinal anomalies (3 patients), porencephaly (2 patients), extraaxial mass (1 patient), and evidence of a migrational disorder (1 patient). The mean prenatal AD in this group was 16.4 mm (range 10–26 mm). Postnatal radiographic outcomes showed resolution in 2 patients (15%), no change in 11 (85%), and progression in none. Two patients (15%), both of whom had stable ventriculomegaly but clinical evidence of hydrocephalus, required CSF shunting (Table 3). One shunt was placed on DOL 2 and the other on DOL 26. One pregnancy (7.7%) was terminated. Two live-born patients (15%) did not survive to discharge from the hospital. One suffered cardiopulmonary arrest on DOL 3, and another suffered persistent respiratory failure and care was withdrawn on DOL 66. Neither patient underwent ventricular shunting (Tables 1 and 2).

Patients Requiring Shunt Placement

All 6 patients (16%) who required a shunt had a pre-

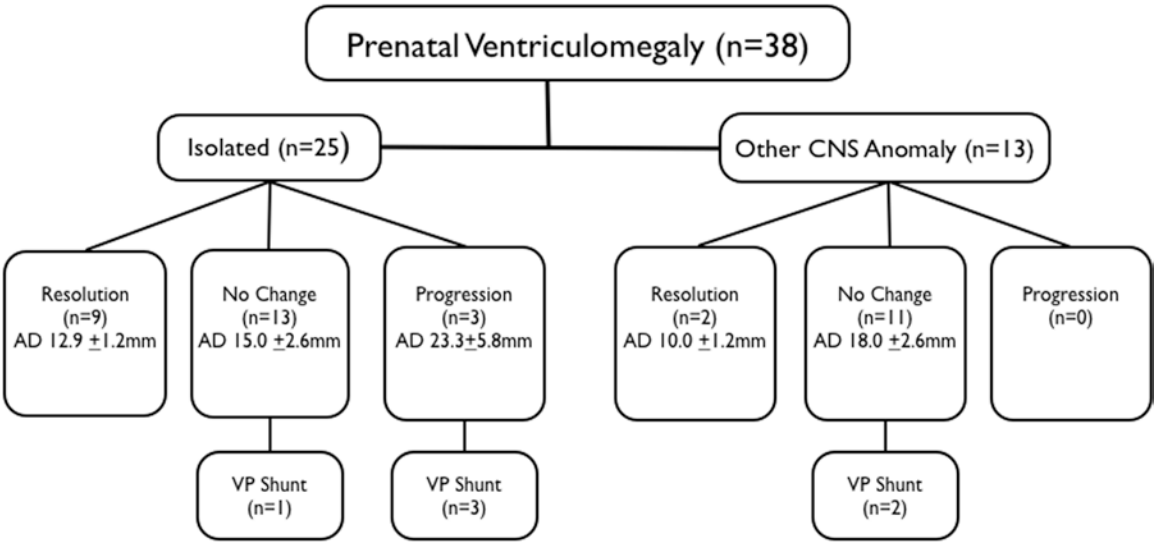

FIG. 1. Schematic depicting the progression of ventriculomegaly diagnosed with MR imaging in 38 fetuses.

natal AD of at least 20 mm (mean 23.8 mm), regardless of their gestational age at the time of imaging (Table 3). There were 8 patients (21%) with ventricles of at least 20 mm (mean 23.8 mm) on prenatal MR imaging. The 2 patients who did not require ventricular shunting had ADs of 22 and 25 mm. Both presented with ventriculomegaly in addition to other CNS anomalies and had no change in ventricular size. No patient whose prenatal ventricles were < 20 mm required shunt placement. Thirteen patients (34%) presented with ADs > 15 mm. Of these, 6 (46%) required ventricular shunting. Follow-up in all patients who did not require CSF diversion was at least 20.6 months, with a median of 68.8 months.

Statistical Analysis

Statistical testing included logistic regression analysis, using ventricular shunt placement as the outcome. Among the variables assessed, only prenatal ventricular size correlated with the need for postnatal shunting (OR 1.58, 95% CI 1.10–2.25, p = 0.01), indicating that for every 1-mm increase in ventricular size above 10 mm, there was a 58% increase in the likelihood of postnatal shunting. There was no statistical correlation between the need for ventricular shunting and gestational age at prenatal MR imaging, time between imaging studies, fetal sex, presence of additional CNS anomalies, or the laterality of ventriculomegaly. Prenatal ventricular size had no statistically significant association with the postnatal radiographic outcome (that is, resolution of, no change in, or progression of ventriculomegaly).

Discussion

Pediatric neurosurgeons are increasingly called on to provide prognostic data to the prospective parents of children with prenatal CNS abnormalities. This study is an initial effort to establish MR imaging parameters that correlate with the need for CSF diversion in patients with prenatal ventriculomegaly. Our results indicated that an antenatal ventricular AD ≥ 20 mm is associated with the need for postnatal CSF diversion in 75% of cases. No patient with a prenatal AD < 20 mm required shunting. These results held true in patients with isolated ventriculomegaly as well as those with ventriculomegaly accompanied by additional CNS anomalies.

Previous studies have demonstrated that AD is a re-

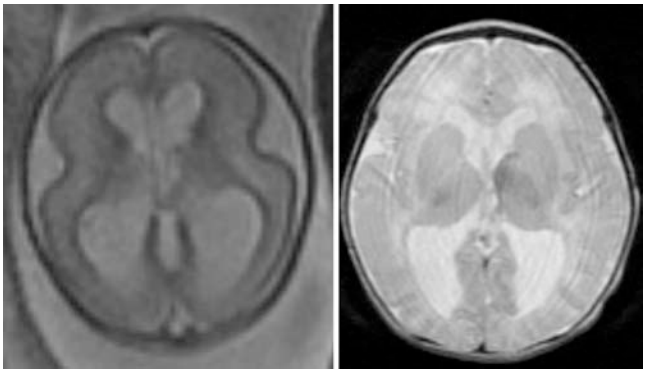

FIG. 2. Prenatal MR image *(left)* demonstrating severe isolated ventriculomegaly (AD 18 mm). Postnatal MR image *(right)* revealing slight improvement. The patient did not require a ventricular shunt.

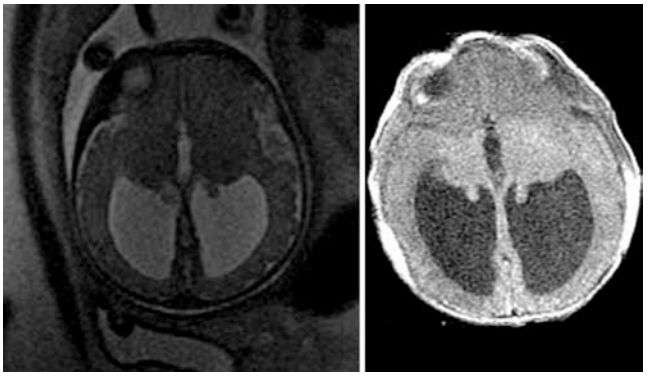

FIG. 3. Prenatal MR image (*left)* demonstrating severe isolated ventriculomegaly (AD 23 mm). Postnatal MR image *(right)* showing no change. The patient required a ventricular shunt on DOL 25.

TABLE 1: Imaging characteristics of 38 patients with prenatal ventriculomegaly at presentation*

Parameter	Isolated Vmeg	Vmeg w/ CNS Anomalies	Total
no. of patients	25	13	38
mean GA at MRI (wks)	29.6	27.8	29.0
mean AD (mm)	15.2	16.4	15.6
AD in mm (no. of patients)			
10–15	17	8	25
>15	8	5	13
≥20	4	4	8

* GA = gestational age; Vmeg = ventriculomegaly.

TABLE 2: Shunt rates based on the presence or absence of concomitant CNS anomalies and the temporal evolution of ventriculomegaly

Status of Vmeg	Isolated Vmeg		Vmeg w/ CNS Anomalies		Total	
	Total	No. w/ Shunts (%)	Total	No. w/ Shunts (%)	Total	No. w/ Shunts (%)
resolution	9	0 (0.0)	2	0 (0.0)	11	0 (0.0)
no change	13	1 (7.7)	11	2 (18.2)	24	3 (12.5)
progression	3	3 (100)	0	0 (0.0)	3	3 (100)
total	25	4 (16.0)	13	2 (15.4)	38	6 (15.8)

producible and stable measure of ventricular size through the second 2 trimesters of normal gestation.[3,5,6,10,18,28] Mild ventriculomegaly has been described as an AD of 10–15 mm, and severe ventriculomegaly as > 15 mm.[2,5,10,19,24] Cardoza and associates[3] have found that in 100 healthy patients, the mean AD was 7.6 ± 0.6 mm. According to these definitions, 6 (46%) of 13 patients with severe ventriculomegaly in our study required CSF diversion, and all patients who required CSF diversion presented with severe ventriculomegaly.

Magnetic resonance imaging is recognized as the most sensitive imaging modality for detecting prenatal CNS abnormalities.[2,5,12,13,18,22,23,26] Miller and colleagues[19] have used prenatal MR imaging to evaluate CNS anomalies that may require surgical intervention, and Lee and colleagues[14] have concluded that neurosurgeons should be cautious when giving prognostic data based on prenatal ultrasonography alone, as many abnormalities may not be detected with this method of visualization. More specifically, these latter authors have suggested that MR imaging should be a component of the prenatal evaluation of patients with ventriculomegaly. In our study we did not compare the accuracy and reliability of MR imaging and ultrasonography. Although we perform prenatal MR imaging for a range of prognostic purposes, our finding that only the AD correlates with the need for ventricular shunt placement does not exclude the possibility that ultrasonography alone may be sufficient to predict which patients will require ventricular shunting.

Our ventricular shunting rate is consistent with that documented by other authors. Lee and colleagues[14] have presented their experience with 44 patients who had been referred for neurosurgical consultation based on prenatal ultrasonography findings of ventriculomegaly. Ventriculoperitoneal shunting was undertaken in 7 patients (16%), and all 7 had an AD ≥ 18 mm. These authors did not attempt to assess risk factors for VP shunt placement. Miller and colleagues[19] used prenatal MR imaging to evaluate CNS anomalies that might require surgical intervention in 24 patients. Patients with mild ventriculomegaly were not included in their study. Twelve patients (50%) had brain anomalies, and 4 (33.3%) of these had presented with ventricles > 15 mm. Similarly, of the 13 patients in our study with ventriculomegaly and concomitant CNS anomalies, 5 (38%) presented with ADs > 15 mm. With regard to CSF shunting in the study by Miller and colleagues, 3 (25%) of 12 patients with ventriculomegaly and CNS anomalies required CSF diversion; 2 (15%) of our 13 patients required CSF diversion. Miller and colleagues' focus on patients with severe ventriculomegaly likely contributed to the difference in the shunting rates between the 2 studies.

In the present study, we examined several parameters to identify those that might be associated with the need for postnatal CSF shunting. Among the assessed parameters, only ventricular size correlated with the need for postnatal CSF shunting. As previously stated, AD has been shown to be stable throughout the second 2 trimesters of normal gestation.[3,5,6,10,18,28] This information is consistent with our findings that gestational age at prenatal MR imaging and the time between studies do not correlate with the need for ventricular shunting. With our study we intended to assist the pediatric neurosurgeon during counseling of prospective parents in the prenatal setting. Thus, we did not examine the relationship between the gestational age at birth and the postnatal AD or need for CSF shunting. Our results on the evolution of mild isolated ventriculomegaly (resolved in 47% of patients and stable in 53%) are consistent with those of Parilla and colleagues,[24] who examined 63 fetuses using ultrasonography (resolved in 41% and stable in 43%). The absence of a statistical difference between those who presented with unilateral or bilateral ventriculomegaly may reflect a true lack of difference or insufficient power to detect an existing difference (Type II error).

Authors of many studies have reported that the overall prognosis is considerably better in patients with isolated antenatal ventriculomegaly when compared with those who present with concomitant CNS or systemic anomalies.[6,9,13,14,18,25] As most pediatric neurosurgeons do not monitor patients with nonsurgical CNS anomalies, we did not attempt to assess clinical outcome but instead considered the need for ventricular shunting. With regard to this parameter, the presence of additional anomalies was not associated with the need for ventricular shunting: 16% of patients with isolated ventriculomegaly and 15% of those with concomitant anomalies required shunting. The lack of a difference between the group with isolated disease and those with other anomalies cannot be explained by a high rate of pregnancy termination (7%) or perinatal death

TABLE 3: Characteristics of patients who required ventricular shunting*

Case No.	Patient Sex	Group	Ventricle Size (mm)	Temporal Change	Laterality	Shunt DOL	Surgical Indication
1	F	isolated	23	no change	bilat	25	increasing OFC, tense fontanel
2	F	isolated	30	progression	bilat	1	progressive Vmeg, HC-48 cm, splayed sutures
3	F	isolated	20	progression	unilat	60	increasing OFC, septal fen DOL 9
4	F	isolated	20	progression	bilat	1	progressive Vmeg
5	F	w/ anomaly	26	no change	bilat	2	tense fontanel, HC-45 cm, splayed sutures
6	M	w/ anomaly	24	no change	bilat	26	increasing OFC, tense fontanel

* OFC = occipital-frontal circumference; fen = fenestration.

(15%) in the latter group. A more plausible explanation may be that referral bias led to the exclusion of the most severely affected fetuses from our population, as patients with neurological abnormalities incompatible with life would not have been referred for additional counseling. Anomalies known to result in a high rate of severe postnatal impairment or fetal demise can include aneuploidy, deletion/duplication anomalies, trisomy 13, trisomy 18, and intrauterine infection by pathogens such as cytomegalovirus and *Toxoplasma gondii*. Additionally, as a large referral center, the Center for Prenatal Pediatrics at Columbia University evaluates some patients who receive further care at their original institution without consultation with the Division of Pediatric Neurosurgery. These patients would not have been included in our analysis.

It is intuitive that patients with larger ventricles are most likely to require CSF diversion. Although 75% of our patients with ADs ≥ 20 mm and none with diameters between 15 and 20 mm required shunting, this study represents an initial investigation with a small number of patients. Thus, we do not propose that 20 mm represents a strict value for a surgically relevant AD, but rather that it may serve as a guideline for future study and clinical practice until further investigations can be completed.

Conclusions

Prenatal MR imaging is a sensitive and growing second-line imaging modality for patients who demonstrate ventriculomegaly on screening ultrasonography. In this study, 75% of patients who presented with ADs ≥ 20 mm required ventricular shunting, regardless of the presence of other CNS anomalies or the gestational age at the time of MR imaging. Pediatric neurosurgeons should provide prospective parents with reliable information regarding the potential surgical sequelae of this condition, the most common of which is the need for postnatal CSF diversion. Larger prospective studies are required to assess the long-term outcome of this patient population and to more precisely describe the surgically significant threshold of isolated and complex prenatal ventriculomegaly.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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