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Role of fetal MRI to diagnose abnormal cerebral ventricular system and associated fetal brain anomalies

Mariam Raafat[1*], Sherine M. Hosny[2], Ghada A. Sheta[1], Soha H. Talaat[1] and Engy A. Ali[1]

Abstract

Background: Abnormal cerebral ventricular system is one of the most common clinical indications for fetal MRI, mainly to detect other associated abnormalities that can be occult on prenatal ultrasonography. Although using ultrasound can identify most anomalies, MRI is known to be superior in identifying CNS anomalies as it has higher contrast resolution for brain parenchymal assessment added to the fact of being less affected by fetal positioning, oligohydramnios, maternal obesity, and reverberation artifacts. Fetal brain ventriculomegaly is defined as atrial width of > 10 mm on sonography, measured in the axial plane, at the level of the frontal horns, cavum septi pellucidi, and glomus of the choroid plexus perpendicular to the long axis of the lateral ventricle. One of the most important factors determining the fetal neurological outcome is the presence and severity of additional CNS anomalies that are better clarified by MRI. The aim of this study is to establish the role of fetal MRI in detecting the association between abnormal cerebral ventricular system and other CNS anomalies, correlation with the severity of ventriculomegaly and ventricle asymmetry.

Results: Thirty pregnancies with fetal brain abnormal ventricular system were included in this study, 5 cases with isolated corpus callosum (CC) agenesis (16.666%); 2 cases with cystic lesions [one interhemispheric and the other dorsal] (6.666%) both associated with CC agenesis; 1 case with alobar holoprosencephaly (3.333%) associated with CC agenesis; 2 cases with semi-lobar holoprosencephaly (6.666%) [associated with CC agenesis and one of them is also associated with lissencephaly]; 3 cases with Dandy–Walker Malformation (DWM) (10%) [2 isolated and 1 associated with CC agenesis]; 3 cases with Dandy–Walker Variants (DWV) (10%) [1 isolated and 2 associated with CC agenesis]; 2 cases with Joubert syndrome (6.666%); 1 case isolated lissencephaly (3.333%); 4 cases of obstructive ventriculomegaly (13.333%) (1 of which associated with CC agenesis); 1 case of Arnold Chiari malformation type II (3.333%) associated with CC agenesis; 2 cases with meningoceles (6.666%) (occipital and parieto-occipital); 1 case with Mega cisterna Magna (3.333%); 1 case with anencephaly (3.333%); 1 case with right hemimegalencephaly (3.333%) (associated with frontal meningocele and CC agenesis); and 1 case with grade IV germinal matrix hemorrhage (3.333%). The pregnancies resulted in 20 births (66.66%), 2 died directly after birth (6.66%), 5 terminations (16.66%), and 3 intrauterine fetal deaths (IUFD) (10%). We found that the frequency of associated CNS anomalies was strongly related to the width of the ventricle. The association between CNS findings and ventricle width was particularly evident in sever ventriculomegaly. The greater the width of the ventricular system, the more the risk of associated CNS anomalies. Only one case showed diffusion restriction and was diagnosed to be of hemorrhagic nature. The relation between symmetry and degree of ventriculomegaly was found to be statistically insignificant ($P = 0.115$). Assessment of different fetal brain

*Correspondence: mariam_raafat@yahoo.com
[1] Department of Diagnostic and Interventional Radiology, Faculty of Medicine, Cairo University, Cairo, Egypt
Full list of author information is available at the end of the article

congenital anomalies was not significantly affected by the using of DWI sequence as it is a functional modality rather than being a tool for assessment of anatomical gross abnormalities.

Conclusions: Fetal MRI is an important adjuvant to US in cases of ventriculomegaly particularly those associated with complex CNS anomalies. The association between CNS findings and ventricular dilatation was particularly evident in sever ventriculomegaly. The greater the width of the ventricular system, the more the risk of associated CNS anomalies. Fetal MRI may also be helpful in doubtful cases that could be misdiagnosed as ventriculomegaly including holoprosencephaly, hydranencephaly, porencephaly, and various supratentorial cystic lesions. DWI confirms the diagnosis of hemorrhage.

Keywords: Ventriculomegaly, Fetal brain, Cerebral ventricles, CNS congenital anomalies, MRI techniques

Background

Abnormal cerebral ventricular system is one of the most common clinical indications for fetal MRI, mainly to detect other associated abnormalities that can be occult on prenatal ultrasonography [1]. Although using ultrasound can identify most anomalies, MRI is known to be superior in identifying CNS anomalies as it has higher contrast resolution for brain parenchymal assessment added to the fact of being less affected by fetal positioning, oligohydramnios, maternal obesity, and reverberation artifacts [2].

Fetal brain ventriculomegaly is defined as atrial width of > 10 mm on sonography, measured in the axial plane, at the level of the frontal horns, cavum septi pellucidi, and glomus of the choroid plexus perpendicular to the long axis of the lateral ventricle. A measurement of 10–12 mm is commonly referred to as mild ventriculomegaly, while measurements of 12–15 and > 15 mm are defined as moderate and severe ventriculomegaly, respectively. Asymmetry is defined as a difference of > 2 mm between the 2 lateral ventricles [1].

Prenatal assessment of the lateral ventricular width was found to be the best to predict the need for postnatal CSF diversion at the age of 3 months (atrial width $\geq$ 15 mm predicted the need for CSF diversion postnatally) [3]. One of the most important factors determining the fetal neurological outcome is the presence and severity of additional CNS anomalies that are better clarified by MRI [2]. Some other authors reported that the only significant factor affecting outcome was the length of the fetal period after the diagnosis of hydrocephalus [4].

The aim of this study is to establish the role of multiparametric fetal MRI in detecting the association between abnormal cerebral ventricular system and other CNS anomalies, correlation with the severity of ventriculomegaly and ventricle asymmetry.

Methods

Patients

This prospective observational study was conducted on 30 pregnant ladies (> 20/18 weeks of gestation calculated by 1st day of LMP and ultrasound biometry) previously assessed by ultrasound then evaluated by MRI examination. The average maternal age was 28.4 $\pm$ 6.4 years. The mean gestational age at MRI acquisition was 26.8 $\pm$ 4.1 weeks (inter-quartile range, 24–30 weeks). MRI examination of the cases was done in the Radiology department assessed in the period from April 2017 to February 2020. MRI was done at the same week of US examination. Thirty cases with abnormal cerebral ventricular system were studied thoroughly for the size, configuration of the ventricular system, and associated CNS congenital anomalies. We included in our study cases diagnosed by US to have ventriculomegaly with or without other CNS anomalies as well as cases with abnormal ventricular configuration. We excluded from our study cases with normal ventricular size and configuration as well as cases with isolated ventricular asymmetry which were diagnosed to be a normal variant.

This study was approved by the local Scientific review board Committee. An informed written consent was obtained from each lady.

Ultrasound

Ultrasound examination was performed in the department of Obstetrics & Gynecology, as a part of routine pregnancy follow-up with the patient in the supine position using a Voluson 730 sonography system equipped with a 3.5 MHz convex transducer. Full fetal neuroscan was done using transventricular, transcerebellar, transthalamic sagittal and coronal planes. We considered the case to have ventricular abnormality when prenatal ultrasound detects either: fetal brain ventriculomegaly (at least 1 lateral ventricle atrium with a width of > 10 mm), ventricular asymmetry with or without dilatation (difference > 2mm between the two lateral ventricles), or abnormal ventricular configuration (e.g., mono-ventricle).

MRI

All scans were performed by a 1.5 T superconducting magnet (Gyroscan Achieva Philips Medical Systems, Best, The Netherlands) using the synergy body coil in

supine position. Scout images were obtained to localize the fetus and also served as a general survey of the feto-placental unit. SSFSE T2-weighted sequences in 3 orthogonal planes were performed by using the following parameters: section thickness 3–4 mm; no gap; and flexible coil. Consumed time was about 35 minutes. The FOV was determined by the size of the fetal head: 24 cm for the smaller fetuses and 30 cm for the larger fetuses. The diffusion-weighted imaging sequence in axial plane was performed with the following parameters: FOV 40 cm, b values 0,1000 ms, and slice thickness 4mm with no gap. Due to fetal motion, we succeeded to perform DWI in only 10 cases with low-quality images. This sequence took about 10 minutes. Images were examined independently by two radiologists with 10-year experience in the fetal MRI field. The radiologists were not informed about the ultrasound findings before the MRI examination.

Interpretation

Measurement of the lateral ventricular width was obtained on a coronal slice at the level of the atria (with good visibility of the choroid plexuses), on an axis perpendicular to that of the ventricle at its mid-height with the caliber touching the inner surfaces of the ventricle.

Schematic assessment of the fetal brain parts was done as follows: detection of septum pellucidum, 4th ventricle assessment, the degree of sulcation and gyration, cerebral hemispheres for possibility of cortical disorders or compression secondary to ventriculomegaly, all parts of the corpus callosum, posterior fossa structures and measuring the tegmentovermian angle in case of posterior fossa anomalies, 2nd look to the fetal whole spine for possibility of neural tube defect.

Interpretation of DWIs was done by assessment of fifteen circular ROIs placed as follows: white matter (two frontal, two parietal, two temporal, two occipital, and two on the white matter of the cerebellar hemispheres), gray matter (two on the BG and two on the thalami), and one over the middle of the pons. If any other regions in the brain show bright T2 signal, DWI of this part should be carefully assessed.

Fetal outcome

In cases with continued pregnancy and surviving fetus, the antenatal diagnosis was confirmed through postnatal neuroimaging using transcranial ultrasonography, CT, or MRI. In cases of termination of pregnancy, stillbirth, or neonatal deaths, the final diagnosis of the CNS anomaly was based on autopsy after taking the parent's consent.

Statistical analysis

All the collected data were revised for completeness and logical consistency. Pre-coded data were entered on the computer using Microsoft Office Excel Software Program 2016. Pre-coded data were then transferred and entered into the Statistical Package of Social Science Software program, version 25 (SPSS), to be statistically analyzed. For qualitative variables, they were described as frequency and percentage. Comparison for qualitative variables was by using Chi-square test and Fisher exact test, where *P* value was considered significant if $P < 0.05$. For quantitative variables, they were described as mean ± sd and compared using ANOVA test, where *P* value was considered significant if $P < 0.05$.

Results

Thirty pregnancies were included in the study with fetal brain ventricular abnormalities detected during routine prenatal ultrasound examination. The mean maternal age was 28.4 ± 6.4 years. Maternal age did not differ significantly among cases of mild, moderate, and severe ventriculomegaly (28.6, 25.5, and 29.4 years) of age, respectively; ($P = 0.75$). The mean gestational age at MR imaging acquisition was 26.8 ± 4.1 weeks (inter-quartile range 24–30 weeks). There was no difference in mean gestational age among cases of mild, moderate, and severe ventriculomegaly (24.3, 29, and 27.7weeks, respectively, $P = 0.15$) (Table 1).

Cases were studied according to the malformation type, severity of ventriculomegaly, and configuration using single-shot fast spin echo T2-WIs in coronal, axial, and sagittal planes. The presence or absence of diffusion restriction was assessed in axial DWIs which was done in 10 cases.

Thirty pregnancies with fetal abnormal cerebral ventricles were included in the study, 5 cases with isolated corpus callosum (CC) agenesis (16.666%); 2 cases with cystic lesions [one interhemispheric and the other dorsal] (6.666%) both associated with CC agenesis; 1 case with alobar holoprosencephaly (3.333%) associated with CC agenesis; 2 cases with semi-lobar holoprosencephaly (6.666%) [associated with CC agenesis, one of which was also associated with lissencephaly; (Fig. 1)]; 3 cases with Dandy–Walker Malformation (DWM) (10%) [2 isolated

Table 1 Relation between maternal and gestational age to the severity of ventriculomegaly

	Ventriculomegaly			*P* value
	Mild	Moderate	Severe	
Patient age mean ± sd	28.6 ± 7.4	25.5 ± 2.1	29.4 ± 6.8	0.75
Gestational age (wks) mean ± sd	24.3 ± 2.1	29.0 ± 4.2	27.7 ± 4.5	0.15

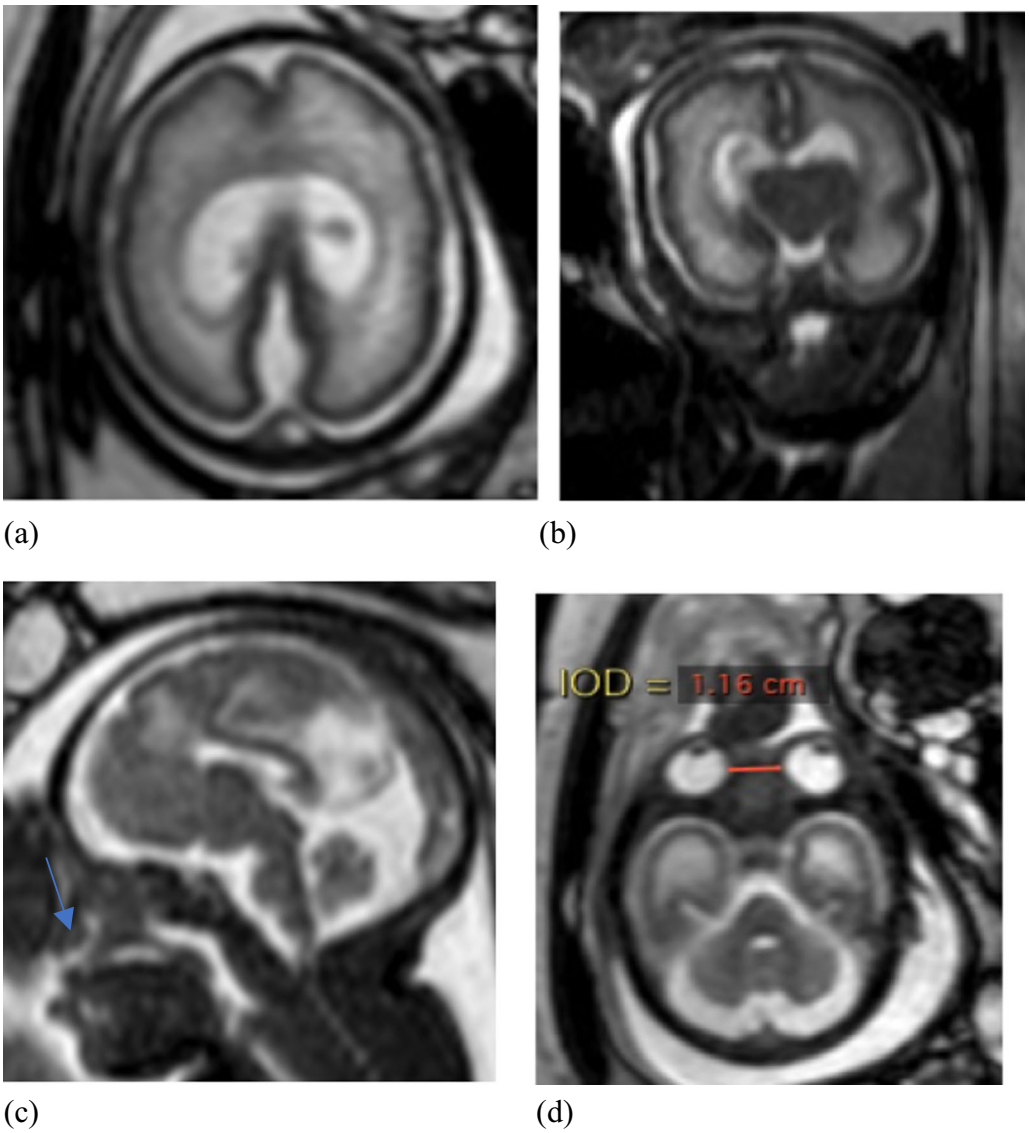

Fig. 1 Twenty-eight-week gestation; prenatal ultrasound revealed absent septum pellucidum; and mono-ventricle and unilateral cleft palate. SSFSE T2WIs axial and coronal planes at the level of lateral ventricle **a**, **b** revealed absent septum pellucidum with partially cleaved anterior cerebrum and abnormal configuration of lateral ventricles that appears as mono-ventricle with partially developed occipital and temporal horns, but deficient frontal horns and incomplete falx cerebri. Incompletely formed interhemispheric fissure, especially anteriorly. Attempts of 3rd ventricle formation with partially fused thalami. Smooth surface of the brain with minimal attempts of sulcation. Sagittal plane (**c**) showed the most posterior portion of corpus callosum is seen with deficient anterior part. Sagittal and axial planes **c**, and **d** revealed midline facial anomalies in the form of hypotelorism [IOD = 12 mm (< 5% percentile), (N for GA = 17.7 mm)] and unilateral cleft lip (arrow). MRI diagnosis: Semi-lobar holoprosencephaly associated with lissencephaly and facial anomalies in the form of hypotelorism and cleft lip. Recommendation: Termination of pregnancy.

and 1 associated with CC agenesis]; 3 cases with Dandy–Walker Variants (DWV) (10%) [1 isolated and 2 associated with CC agenesis]; 2 cases with Joubert syndrome (6.666%); 1 case with lissencephaly (3.333%); 4 cases of obstructive ventriculomegaly (Fig. 2) (13.333%) [1 of which associated with CC agenesis]; 1 case of Arnold Chiari malformation type II (3.333%) associated with CC agenesis; 2 cases with meningoceles (6.666%) [occipital and parieto-occipital]; 1 case shows Mega cisterna Magna (3.333%); 1 case with anencephaly (3.333%); 1 case with right hemimegalencephaly (3.333%) [associated with frontal meningocele and CC agenesis] (Fig. 3); and 1 case with grade IV germinal matrix hemorrhage (3.333%) (Fig. 4).

Thus, the CNS anomalies diagnosed by MRI included 16 cases with CC abnormality, 10 fetuses with posterior

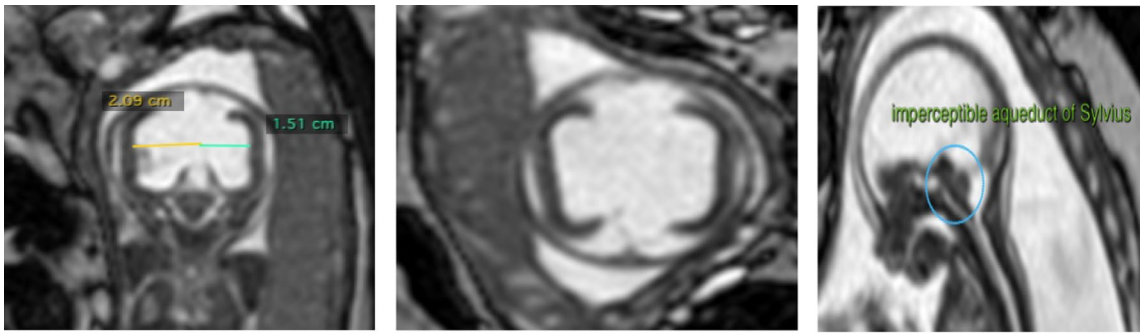

Fig. 2 Twenty-six-week fetus. SSFSE T2WIs in different planes; coronal, axial, and sagittal images **a**, **b** show asymmetric severe dilatation of lateral ventricle (right reaching 21 mm while the left reaching 15 mm in atrial width), secondary obliteration of the extra-axial spaces and thinning out of the cerebral parenchyma. There is a focal cortical destruction in both frontal and the left occipital lobes (spontaneous ventriculostomy). **c** The aqueduct of Sylvius cannot be visualized. Incomplete separation of both lateral ventricles because of interruption of septum pellucidum secondary to sever ventriculomegaly that could resemble mono-ventricle of holoprosencephaly; however, normal anterior and posterior cleavage of the cerebrum rules out the diagnosis of holoprosencephaly. MRI diagnosis: Severe supratentorial ventriculomegaly secondary to aqueduct stenosis. Recommendation: Termination of pregnancy.

fossa anomalies, 4 cases of neural tube defect (namely: 1 case of anencephaly; 1 case with encephalocele and 2 cases with meningocele), 4 cases with obstructive ventriculomegaly, 3 cases showed absent septum pellucidum, 3 cases with cortical disorders, 2 fetuses with intracranial cystic lesions, and 1 case with germinal matrix hemorrhage (Table 2).

The risk of CNS findings appeared to be strongly related to the width of the ventricle. The association between CNS findings and ventricular width was particularly evident in sever ventriculomegaly. The more the width of the ventricular system, the more the risk of associated CNS anomalies (Table 3).

Severe ventriculomegaly was detected in 56.7%, while mild and moderate ventriculomegaly comprised 23.3% and 6.7% of the cases, respectively. Abnormal ventricular configuration that could not be described as ventriculomegaly represented 13.3% of cases. CNS abnormalities in symmetric ventriculomegaly (69.2%) were more compared with asymmetric ventriculomegaly (30.8%). Only one of the ten cases who we managed to acquire DWIs showed restricted diffusion and was diagnosed to be of hemorrhagic nature (Fig. 5), while the rest showed no areas of diffusion restriction).

The relation between symmetry and degree of ventriculomegaly was found to be statistically insignificant ($P = 0.115$) (Table 4).

More than half of cases were found to have corpus callosum abnormalities (16 cases, 53.3%) with or without other anomalies.

15 cases (50%) were found to have colpocephaly with strong relation to sever ventriculomegaly (80% of cases of colpocephaly), while in mild and moderate ventriculomegaly colpocephaly was present in 13.3% and 6.7%, respectively. The correlation between colpocephaly and ventricular symmetry shows that two-thirds (66.7%) of cases is symmetric in width (Table 5).

Assessment of different fetal brain congenital anomalies was not affected by using DWI sequence as it is considered as a functional modality rather than a tool for assessment of anatomical gross abnormalities.

The pregnancies resulted in 20 births (66.66%), 2 died directly after birth (6.66%), 5 terminations (16.66%), and 3 intrauterine fetal deaths (IUFD) (10%).

Discussion

The most important clinical considerations in a fetus with ventricular abnormality are the severity of the ventricular dilatation and the presence or absence of other CNS abnormalities, which can be better delineated and confirmed by using MRI examination. Prayer et al. [5] stated that fetal MRI provides additional information in 5.7% of fetuses with normal ultrasound findings, even when using only a basic protocol consisting of T1- and T2-weighted sequences.

Di mascio et al. [6] stated that it would be better to perform MRI in the third trimester of pregnancy, as most of the anomalies coexisting with ventriculomegaly, such as cortical, white matter, or hemorrhage, become more evident after 24-week gestation. In our study, the median gestational age at MRI acquisition was 26.8 ± 4.1 weeks (inter-quartile range 24–30 weeks).

Our study showed that the association between ventricle width and CNS findings is more evident in sever

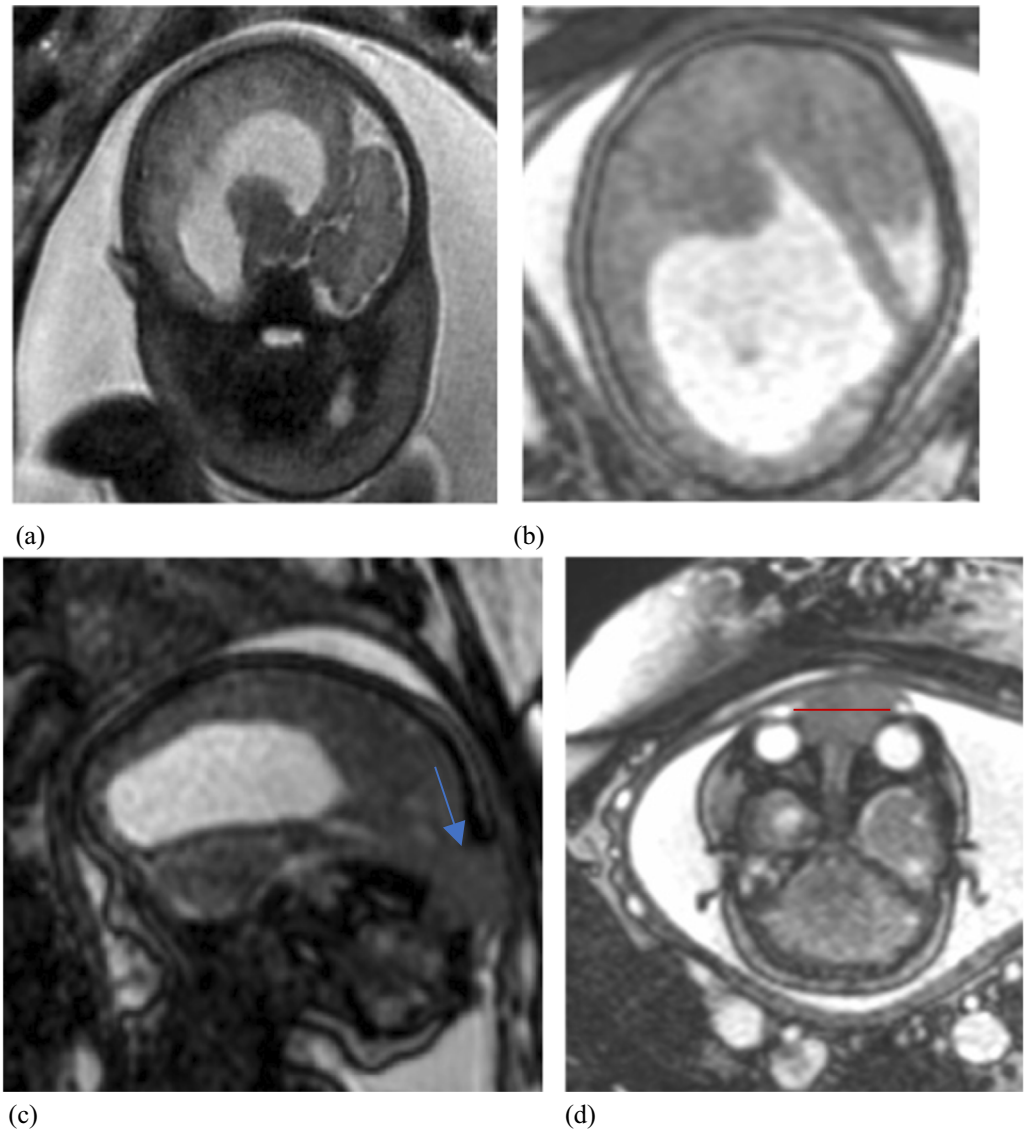

Fig. 3 Thirty-five-week fetus; prenatal ultrasound revealed sever left ventricular dilatation. SSFSE T2WIs coronal, axial planes **a**, **b** revealed enlarged left cerebral hemisphere, with dilated left lateral ventricle (reaching 30 mm) that shows colpocephaly. Small right cerebral hemisphere with attenuated right lateral ventricle. Sagittal and axial images at the frontal level **c**, **d** showed herniating brain parenchyma seen protruding through frontal cortical defect measures 2 cm (arrow) and extends antero-inferiorly between the eye globes that show mild hypertelorism (IOD = 2.7 cm). No CSF signal seen surrounding the lesion. The corpus callosum could not be completely identified. MRI diagnosis: Left hemimegalencephaly with sever ipsilateral ventriculomegaly and frontal encephalocele as well as CC dysgenesis. Recommendation: Termination of pregnancy.

ventriculomegaly (56.7%). The relatively low incidence of anomalies in cases of mild ventriculomegaly (6.7%) may merit re-evaluation of the cost-effectiveness of fetal MRI in cases with mild ventriculomegaly. Barzilay et al. [1] stated that the association between CNS findings and ventricle width was particularly evident in moderate ventriculomegaly, in which each 1-mm increase in ventricular width increases the risk for both minor and major CNS finding. Katz et al. [7] have reported that CNS and non-CNS congenital anomalies are mostly seen among cases of sever ventriculomegaly.

We have found that symmetric ventriculomegaly was associated with more CNS findings than asymmetric ventriculomegaly. (69.2% of cases were symmetric.) This is in agreement with Barzilay et al. [1], who stated that the prevalence of associated CNS abnormalities was significantly higher (P =.005) in symmetric ventriculomegaly compared with asymmetric ventriculomegaly

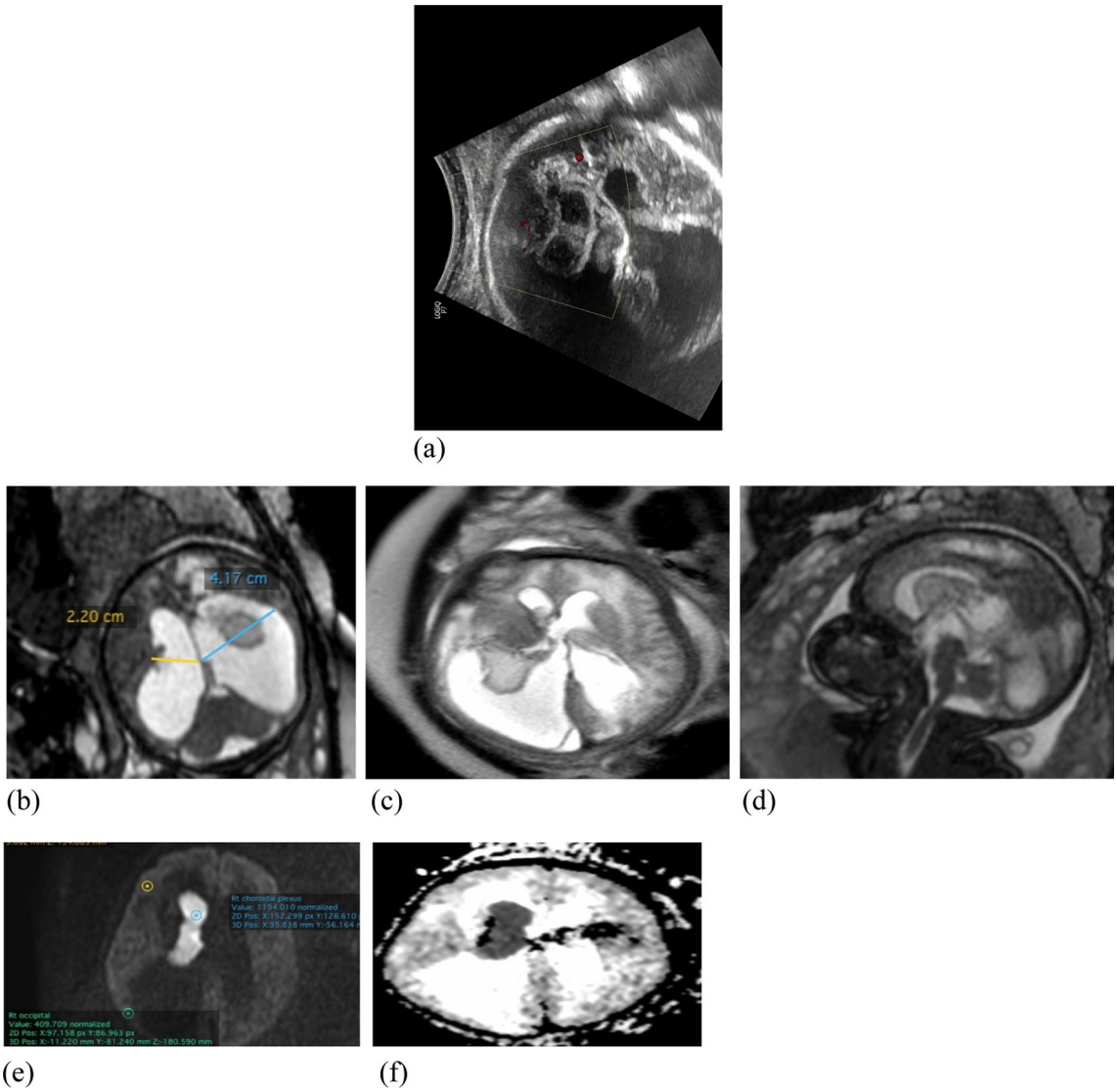

Fig. 4 Thirty-six-week fetus; prenatal US revealed ventriculomegaly and echogenic structure within the right lateral ventricle (**a**). SSFSE T2WIs axial planes **b**, **c** revealed supratentorial hydrocephalic changes reaching about 4 cm at the level of right atrium with ballooned occipital horns (colpocephaly), enlarged right choroid plexus (measuring 4.2 × 1.2 cm) eliciting intermediate signal with cystic changes, extending to the frontal horn and cerebral parenchyma in the frontoparietal regions. Sagittal plane **d** shows agenesis of the corpus callosum with absent precentral gyrus. DWI and ADC **e**, **f** revealed evident diffusion restriction within the enlarged right choroid plexus with no diffusion restriction noted within the brain parenchyma. MRI diagnosis: Intraventricular hemorrhage with extension to the adjacent brain parenchyma and sever hydrocephalic changes down to the aqueduct (grade IV germinal matrix hemorrhage) with CC agenesis. Recommendation: Immediate delivery. Outcome: CS delivery followed by admission to NICU; the neonate died after few days.

(38.8% versus 24.2%, respectively, for all CNS abnormalities and 20% versus 7.1%, respectively, for major CNS abnormalities).

In our study, 53.3% of cases were found to include corpus callosum abnormalities mostly in the form of complete agenesis (81.3%), either as an isolated anomaly (31.2%) or more commonly associated with other CNS anomalies (68.8%). It was noted that most cases with sever ventriculomegaly were associated with callosal pathology (70.6%). Di mascio et al. [6] reported that the large majority of ventriculomegaly-associated malformations undetected on ultrasound comprised a callosal anomaly.

We reported only one case with grade IV germinal matrix hemorrhage that was diagnosed in late third trimester during regular prenatal FU although there was no

Table 2 Number of cases grouped according type of malformation

Anomaly	Number of cases	Percentage
Corpus callosal abnormality	16	53.3
Posterior fossa anomalies	10	33.3
Neural tube defect	4	13.3
Obstructive	4	13.3
Absent septum pellucidum	3	10
Cortical disorders	3	10
Cystic lesions	2	6.7
Hemorrhagic	1	3.3

maternal history of medical concern regarding trauma or coagulation defects. Applying DWI tool in such case helped in confirmation of diagnosis that showed diffusion restriction. Tavil et al. [8] stated that the most common cause of fetal brain hemorrhage especially in the third trimester is fetal hematological disorders rather than being related to maternal trauma.

In our study, we found that posterior fossa anomalies constituted 33.3% of cases. Out of ten cases with posterior fossa anomaly findings, seven cases were diagnosed with Dandy–Walker spectrum. This type of anomalies mostly showed mild ventriculomegaly (6 out of 10 cases) representing 85.7% of all cases reported to have mild ventriculomegaly. All cases showed symmetric ventricular dilatation. It is worth noted that tegmento-vermian angle measurement helped in differentiation between Dandy–Walker spectrum anomalies and posterior fossa arachnoid cyst.

We reported 4 cases (13.3%) with obstructive ventriculomegaly due to aqueduct stenosis. All of them showed sever ventricular dilatation and one case was complicated by spontaneous ventricular rupture. Diagnosis was supported by measuring the AP diameter of aqueduct of Sylvius at midsagittal view (mean was about 0.4 mm) and compressed cerebral mantle against the bony calvarium.

Our cases were diagnosed at the gestational age 24–26 WG. Emery et al. [9] stated that the prenatal diagnosis of fetal aqueduct stenosis is often suspected at the time of the anatomic survey ultrasound at 18- to 22-week gestation.

We also reported 4 cases (13.3%) with neural tube defect. Upon ultrasound revision, a case of occipital meningocele was suspected to have sacral defect, after second look to midsagittal view of MRI whole spine, diagnosis of a small sacral meningocele was confirmed.

In our study, we had 3 cases (10%) of septum pellucidum abnormalities. All of them were accompanied by callosal anomaly and one case of semi-lobar HPE showed facial anomaly. Kousa et al. [10] stated that as a rule of thumb, more than half of the total volume of the frontal lobes should be separated to classify as lobar HPE; otherwise, the diagnosis of semi-lobar HPE is more appropriate.

In our study, abnormal ventricles as an association with cortical malformation were found in 3 cases. Cases were diagnosed at 26- and 35-weeks' gestation. Tonni et al. [11] stated that intra uterine MRI can identify fetal lissencephaly between 20 and 24 weeks, but false positives should be expected. At 28-week gestation, lissencephaly is usually clear and the diagnosis is more confident.

We reported two cases with cystic lesions associated with ventriculomegaly. Yahal et al. [12] stated that the incidence of ventriculomegaly associated with arachnoid cyst is low (~ 10%) and usually due to large supratentorial cysts causing obstruction of CSF flow.

We found that 15 cases (50%) had colpocephaly with strong relation to sever ventriculomegaly, while in mild and moderate ventriculomegaly it represented 13.3% and 6.7%, respectively. The correlation between colpocephaly and ventricular symmetry shows that two-thirds of cases were symmetric in width. All cases of colpocephaly were

Table 3 Distribution of anomalies in relation to severity of ventriculomegaly

Anomaly	Ventriculomegaly						*P* value
	Mild *n* (%)		Moderate *n* (%)		Severe *n* (%)		
Neural tube defect	0	0.0%	1	50.0%	2	11.8%	0.15
CC	2	28.6%	1	50.0%	12	70.6%	0.16
Septum pellucidum	0	0.0%	0	0.0%	1	5.9%	0.76
Posterior fossa anomalies	6	85.7%	0	0.0%	3	17.6%	0.004
Obstructive	0	0.0%	0	0.0%	4	23.5%	0.29
Cystic lesions	0	0.0%	1	50.0%	1	5.9%	0.058
Cortical disorders	1	14.3%	0	0.0%	1	5.9%	0.71
Hemorrhagic	0	0.0%	0	0.0%	1	5.9%	0.76

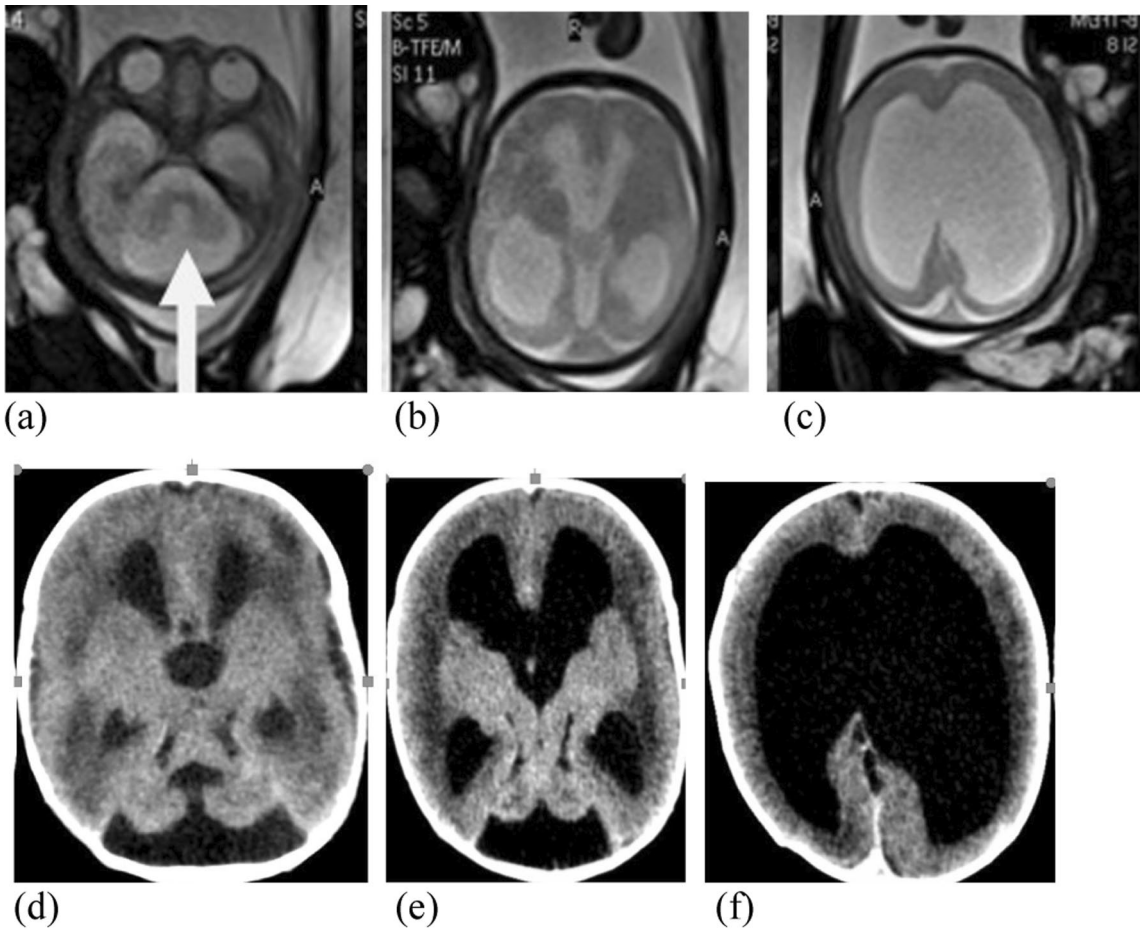

Fig. 5 Twenty-nine-week gestation; SSFSE T2WIs axial planes at the level of posterior fossa and lateral ventricle revealed hypoplastic vermis with dilated fourth ventricle which is seen communicating with the enlarged retro-cerebellar CSF space (**a**); associated supratentorial hydrocephalus (**b**, **c**). MRI diagnosis: Dandy–Walker malformation. Recommendation: Postnatal shunting. Postnatal CT images (**d**–**f**), confirmed the same diagnosis of DWM

Table 4 Relation between ventricular symmetry and severity of ventriculomegaly

	Ventriculomegaly						*P* value
	Mild		Moderate		Severe		
Symmetry							
Symmetrical	7	100%	1	50%	10	58.8%	0.115
Asymmetrical	0	0.0%	1	50%	7	41.2%	

Table 5 Relation between severity of ventriculomegaly and presence or absence of colpocephaly

Ventriculomegaly	Colpocephaly		*P* value
	Number	Percentage	
Mild	2	13.3	0.05
Moderate	1	6.7	
Sever	12	80	

seen accompanied by callosal anomalies. Ragaji et al. [13] stated that corpus callosum agenesis typically shows colpocephaly.

DWI was successfully done in 10 cases. The rest of cases failed to obtain good quality images due to maternal-fetal motion artifacts. Only the case of germinal matrix hemorrhage showed restricted diffusion in areas of hemorrhage (choroid plexus and frontoparietal parenchymal

region). Yaniv et al. [14] stated that a decrease in ADC values in fetal brains with ventriculomegaly is associated with metabolic compromise and subsequent tissue damage.

Strengths and limitations of the study

The major advantage of our study is that it is MRI-based, gaining the benefit of large field of view, no image degradation from the overlying fetal skeleton, minimal or no image degradation from maternal obesity or oligohydramnios, superior soft tissue contrast resolution and specific tissue characterization of fat, blood components, meconium, and signal void within the vessels.

Small sample size and being observational non-randomized design with no control group are our limitations.

Conclusions

Fetal MRI is an important adjuvant to US in cases of ventriculomegaly particularly those associated with complex CNS anomalies. The association between CNS findings and ventricular dilatation was particularly evident in sever ventriculomegaly. The greater the width of the ventricular system, the more the risk of associated CNS anomalies. Fetal MRI may be helpful in doubtful cases that could be misdiagnosed as ventriculomegaly including holoprosencephaly, hydranencephaly, porencephaly, and various supratentorial cystic lesions. DWI confirms the diagnosis of hemorrhage.

Also, fetal MRI is used in medicolegal issues when termination of pregnancy is recommended.

Recommendations

Fetal MRI is highly recommended in cases of ventriculomegaly (especially moderate and sever cases), abnormal ventricular configuration, and complex CNS anomalies. Fetal whole spine MRI is mandatory in cases of small posterior fossa or encephalocele. DWI sequence of the brain is important in cases suspected to have intracranial hemorrhage.

Abbreviations

iuMRI: Intrauterine magnetic resonance imaging; CNS: Central nervous system; DWI: Diffusion-weighted image; CSF: Cerebrospinal fluid; LMP: Last menstrual period; FOV: Field of view; SSFSE: Single shot fast spin echo; MRS: Magnetic resonance spectroscopy; ROI: Region of interest; FU: Follow-up.

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Authors' contributions

MR contributed to the study conception and design and writing and editing the manuscript. SH: helped in referral of cases. GS collected patients' data and follow-up of the cases. ST helped in the study deign and statistical analysis. EA helped in collecting and interpretation of data. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analyzed during current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Written informed consent was signed by all patients before examination. The study was approved by the ethics committee of faculty of medicine, Cairo University. Reference number is not applicable.

Consent for publication

All patients included in this research are above 16 years, and all gave written informed consent to publish the data contained within this study.

Competing interests

The authors declare that they have no competing interests.

Author details

[1]Department of Diagnostic and Interventional Radiology, Faculty of Medicine, Cairo University, Cairo, Egypt. [2]Department of Obstetrics and Gynecology, Kasr Alainy School of Medicine, Cairo, Egypt.

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