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MR of Fetal Central Nervous System Abnormalities

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PURPOSE: To investigate whether MR can provide additional information on fetuses with central nervous system abnormalities as demonstrated by ultrasonography. **METHODS:** Fetal MR examinations were studied prospectively in 22 pregnant women whose fetuses showed evidence of anomalies on ultrasound performed in the High-Risk Obstetric Clinic. **RESULTS:** In 19 of 22 cases, postpartum confirmatory diagnoses were obtained by MR or CT examinations, autopsy, or surgery. In general, the image quality of MR is comparable with that of ultrasound. However, in six of 22 cases (27%), MR provided additional information that altered the ultrasound diagnosis; these included cases of infarction, diastematomyelia, normal hemimegalencephaly with early myelination, Dandy-Walker variant, and lipoma. All of these cases had postpartum confirmation. The additional information changed the treatment in three of six patients (no intervention or elective abortion). **CONCLUSIONS:** In certain situations MR can add valuable information to that obtained by sonography in the evaluation of the fetal central nervous system.

Index terms: Fetus, abnormalities and anomalies; Fetus, central nervous system; Fetus, magnetic resonance

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The application of magnetic resonance (MR) in the evaluation of fetal anomalies has been reported previously (1–5). However, ultrasound (US) remains the modality of choice in the evaluation of fetal central nervous system abnormalities (1–3, 6). It is cost-effective and readily available at most institutions. The purpose of this study was to investigate whether MR can provide additional information in fetuses with abnormal central nervous system findings demonstrated by US.

Materials and Methods

Fetal MR examinations were studied prospectively in 22 consecutive pregnant women whose fetuses showed evidence of central nervous system anomalies by US performed in the High-Risk Obstetric Clinic. All patients were studied with strict guidelines and protocol approved by the Human Subject Committee, and informed consent was obtained in all cases before the MR examinations.

Transient fetal paralysis (30 to 60 minutes) was achieved by the injection of pancuronium bromide (0.3 mg/kg fetal weight) into the umbilical vein during the cordocentesis for karyotype (routine procedure for abnormal fetus in our institution) before the MR study (7, 8). Direct injection of pancuronium into the gluteal muscle of the fetus was performed in two cases during amniocentesis again to obtain cells for karyotyping. The women were placed in the left lateral decubitus position to minimize transmitting maternal aortic pulsation during the MR examinations.

Maternal axial T1-weighted images (400–800/20–26/4 [repetition time/echo time/excitations]) were performed on a 0.5-T superconductive scanner as the initial scan to determine fetal orientation and anatomy. Serial oblique T1-weighted images were performed in order to obtain the true fetal coronal, sagittal, or axial plane with respect to the area of interest. Section thickness was 3 to 5 mm without gaps. The US examination and interpretation were performed by the obstetric and gynecology staff. Postpartum confirmatory diagnoses were obtained by MR or computed tomographic examinations, autopsy, or surgery.

Results

There was no adverse effect observed during this study. The MR findings are summarized in

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Table 1. In 19 of 22 cases, postpartum confirmatory diagnoses were obtained by MR or CT examinations, autopsy, or surgery. In general, the image quality of MR is comparable to that of US. In six of 22 cases (27%), MR provided additional diagnostic information that was not demonstrated by US (Figs 1–4). All six cases had postpartum confirmation. With the additional information, treatment was altered in three of six patients (no intervention or elective abortion).

The high signal intensity on MR suggested early myelination in a patient with hemimegalencephaly (Fig 1) and a small lipoma near the tectum in another patient. The patient with hemimegalencephaly was initially thought at US to have a brain tumor. The additional information provided by MR did not alter the final treatment of these two patients (no elective abortion of the fetus with hemimegalencephaly), although the information was invaluable in the counseling of the parents. In another case, without significant interference from the bony structures, MR enabled diagnosis of a cervical diastematomyelia in a fetus with iniencephaly (Fig 2). With this additional information, the woman decided to have an abortion. Autopsy revealed inencephaly, diaphragmatic hernia, and cleft palate. The fourth fetus had US diagnosis of a posterior fossa arachnoid cyst that was not subsequently confirmed by the fetal or postpartum MR examinations, which altered the final treatment (a shunting prodecure was contemplated based on the US findings). In the fifth case, the US findings were consistent with a posterior fossa cyst; whereas the fetal MR

TABLE 1: Summary of patient data and radiologic findings

Case	Diagnosis	Gestational Age (Weeks)	Confirmed By	US Findings	MR Findings	Useful Information Provided by MR
1	Hydrocephalus and tectal lipoma	31	P	Hydrocephalus	Hydrocephalus and tectal lipoma	+
2	Dandy-Walker	20	P	Dandy-Walker	Dandy-Walker	–
3	Hydrocephalus	32.5	P	Hydrocephalus	Hydrocephalus	–
4	Hemimegaencephaly	35	P	Unilateral ventriculomegaly or proencephalic cyst and probable tumor	Normal and abnormally enlarged hemisphere including ventricles as well as accelerated myelinationon	+
5	Iniencephaly	31	P	Hydrocephalus, short and hyperextended neck, diaphragmatic hernia	Hydrocephalus, short and hyperextended neck, diastematomyelia, diaphragmatic hernia	+
6	Aqueductal stenosis	21	P	Hydrocephalus	Hydrocephalus	–
7	Hydrocephalus	23	P	Hydrocephalus and absence of extremeties	Hydrocephalus and absence of extremeties	–
8	Hemiproencephaly	42	A/P	Hemiproencephaly	Hemiproencephaly	–
9	Hydrocephalus	28	N	Hydrocephalus	Hydrocephalus	–
10	Alobar proencephaly	26	N	Alobar proencaphaly	Alobar proencephaly	–
11	Agenesis of the corpus callosum	21.5	P	Agenesis of the corpus callosum	Agenesis of the corpus callosum	–
12	Holoencephaly	20	P/A	Holoencephaly, hypotelorism	Holoencephaly, hypotelorism	–
13	Holoprosencephaly	23	A	Holoprosencephaly with probuscis	Holoprosencephaly with probuscis	–
14	Choroide plexus papilloma	40.5	S	Probable brain hemorrhage or tumor	Probable choroid plexus tumor	–
15	Dandy-Walker variant	31	P	Posterior fossa cyst	Hydrocephalus, hypoplastic cerebellum, 4th ventricle connected with cyst (Dandy-Walker Variant)	+
16	Hydrocephalus	30	P/A	Hydrocephalus	Hydrocephalus	–
17	Dandy-Walker	24	P	Dandy-Walker variant	Dandy-Walker variant	–
18	Holoprosencephaly	37.5	A/P	Holoprosencephaly	Holoprosencephaly	–
19	Hydrocephalus	21	A	Hydrocephalus	Hydrocephalus	–
20	Infarction	35	A	Large subarachnoid cyst	Multiple middle and anterior cerebral artery infarctions	+
21	Hydrocephalus	20	N	Hydrocephalus	Hydrocephalus	–
22	Normal	21	P	Posterior fossa cyst	Normal	+

Note.—A indicates autopsy; N, unconfirmed; P, postpartum follow-up; and S, surgery.

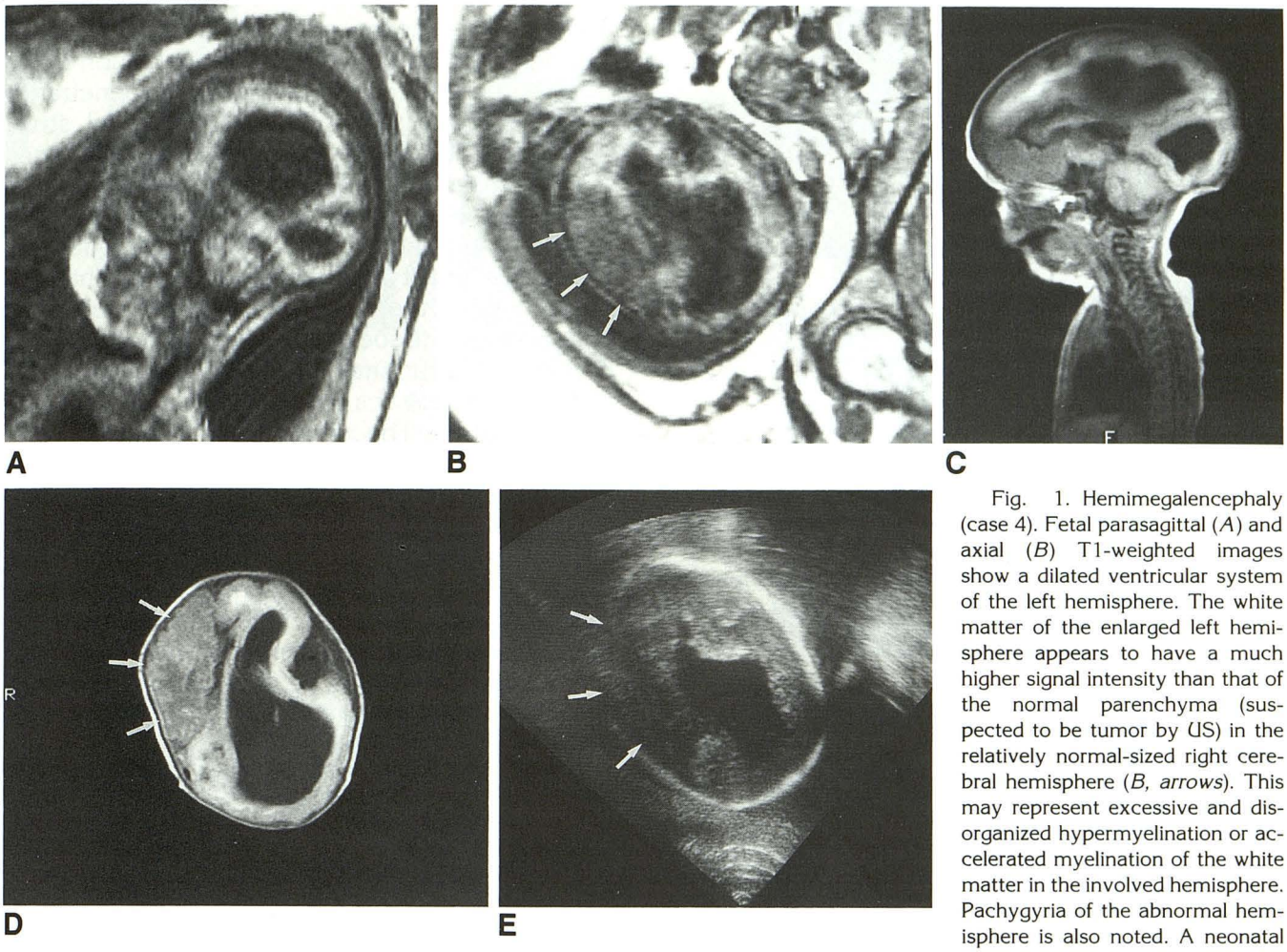

Fig. 1. Hemimegalencephaly (case 4). Fetal parasagittal (*A*) and axial (*B*) T1-weighted images show a dilated ventricular system of the left hemisphere. The white matter of the enlarged left hemisphere appears to have a much higher signal intensity than that of the normal parenchyma (suspected to be tumor by US) in the relatively normal-sized right cerebral hemisphere (*B, arrows*). This may represent excessive and disorganized hypermyelination or accelerated myelination of the white matter in the involved hemisphere. Pachygyria of the abnormal hemisphere is also noted. A neonatal parasagittal T1-weighted image (*C*) corresponding to *A* and an axial T1-weighted image (*D*) corresponding to *B* show a dilated ventricular system in the enlarged left cerebral hemisphere. Similar to the fetal brain (*B*), normal neonatal brain parenchyma (*D, arrows*) appears hypointense on the relatively T1-weighted images, which is the typical finding during the first year of life because of excess water content. The parenchymal signal intensity of the abnormal left hemisphere (*C* and *D*) is similar to that of the typical adult brain on T1-weighted images. Again note the pachygyria of the left cerebral hemisphere. Axial US image (*E*) of the fetal head (grossly approximating *B*) shows unilateral dilatation of the left lateral ventricle and an echogenic area in the right hemisphere (*arrows*), which was thought to be a tumor. Abnormal myelination and pachygyria cannot be appreciated by US. (Fig 1B from Wenstrom et al [2].)

showed a Dandy-Walker variant (Fig 3). Postpartum MR examination substantiated the diagnosis evidenced by the hypoplastic cerebellum and a communication between the posterior fossa cyst and the fourth ventricle (Fig 3). Finally, brain infarction demonstrated by MR (Fig 4) was initially misdiagnosed with US as a midline subarachnoid cyst. Because of the MR findings, the parents chose to have an abortion. Autopsy showed the absence of brain tissue along the anterior and middle cerebral artery distribution.

Discussion

US is the imaging modality of choice in the evaluation of fetal abnormalities because of its proved record of accuracy and safety in addition to its easy access, low cost, and real-time capability (9, 10). Since the introduction of MR into clinical imaging, a number of MR studies of the fetus reported that MR may be complementary to US in difficult cases (1, 2, 6). The advantages of US and MR are well known. Both imaging modalities are noninvasive, involve no ionizing radiation, and can provide images in multiple planes. Our study shows that MR may provide additional information to US in some cases (27%), which may alter the treatment of patients (50%). Although our series is small, the results indicate that there are some advantages of MR over US, including providing characteristic soft-tissue signal, excellent soft-tissue contrast, and better vis-

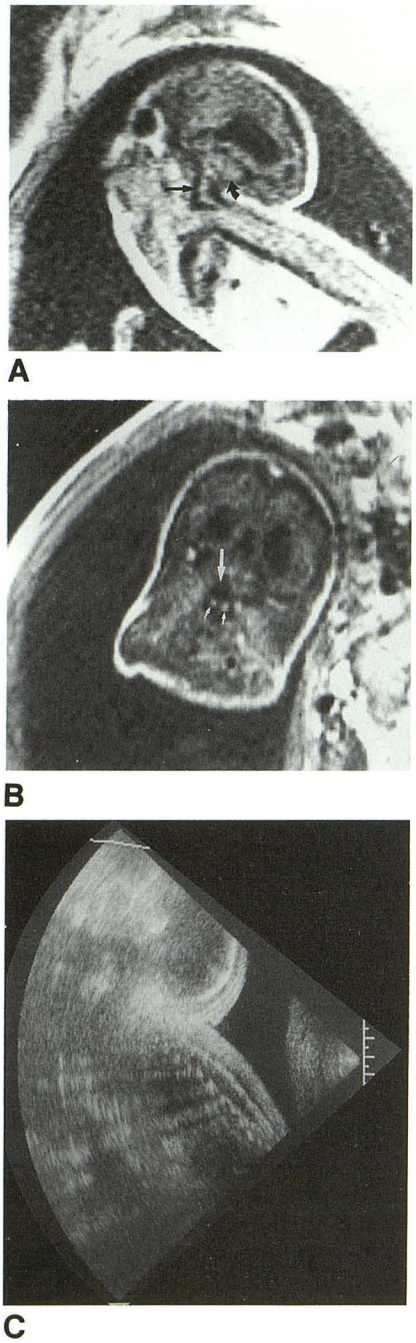

Fig. 2. Iniencephaly (case 5). Iniencephaly is a complex developmental anomaly that is characterized by the imperfect formation of the skull base at the foramen magnum, a rather wide cervical spina bifida, and marked backward flexion of the head and spine.

A, Fetal parasagittal T1-weighted image shows normal fetal position, polyhydramnios, dilated ventricular system, and hyperextended neck (stargazer). The cerebellum (*curved arrow*) and brain stem (*arrow*) appear to be intact.

B, Fetal axial T1-weighted image shows splitting of the cervical spinal cord. More cranially, a linear structure (*long arrow*) between the two halves of the spinal cord (*small arrows*) may represent a bony spicule or a fibrous band, supporting the diagnosis of diastematomyelia of the cervical cord.

C, Sagittal US image of the fetal head and thorax shows hyperextension of the neck similar to MR findings; however, diastematomyelia was not demontrated on US because of significant attentuation by the cervical spine at 31 weeks gestation. (Fig 2*B* from Williamson et al [6].)

ualization of the posterior fossa structures and spinal canal. Therefore, when reassurance is needed in some instances, MR may be used as an adjunctive means, especially for optimal care.

One of the problems with US evaluation of the fetus is the interference of US beam penetration by skeletal, fatty, or gas-filled maternal structures. MR is less susceptible to such interferences, and visualization of deep structures generally is not a problem, although motion artifact from blood vessels and bowel peristalsis may degrade the image quality. Another advantage that MR has over US is the characteristic soft-tissue signal and excellent tissue contrast. Fatty contents in myelinated structures or lipomas have distinct signal characteristics on MR, which can be readily demonstrated. The multiplanar capability, improved soft-tissue contrast, and lack of bony interference also allow for the evaluation of spinal cord lesions and vascular disruptions. Tissue-signal characteristics demonstrated by MR (different from acoustic impedence) may bring out anatomic and pathologic features in some cases that may not be readily demonstrated by US.

US may not always be optimal in the visualization of the posterior fossa in fetuses older than 33 weeks gestational age, because of the ossification of the calvarium. In addition, the fetal head may be deeply engaged in the maternal pelvis and may be difficult to study by abdominal US, although this usually can be resolved by transvaginal or translabial US. Both the ossification of the calvarium and the deeply located fetal head may be the reasons for the US misdiagnosis of the posterior fossa lesions in two patients.

One of the challenges of MR in prenatal evaluation is the image degradation caused by poorly controlled fetal motion and vascular pulsation artifact, mainly from the maternal aorta. Transient fetal paralysis induced by pancuronium and the maternal lateral decubitus position used in our small series seem to be effective in controlling the motion artifacts. Because pancuronium injected into the fetus does not cross the placenta to cause maternal injury, and fetal oxygenation does not require respiratory movement, fetal oxygenation during whole-body paralysis can be satisfactorily maintained by adequate maternal blood pressure and oxygenation. This method of fetal sedation is different from other sedatives such as morphine, which can cross the placenta and may cause maternal hypotension and respiratory depression, a potential hazard to the fetus. However, with the introduction of echo-planar imaging, the problem with fetal motion may be solved without the need for either maternal sedation or transient fetal paralysis (11–13).

In summary, although US remains the imaging

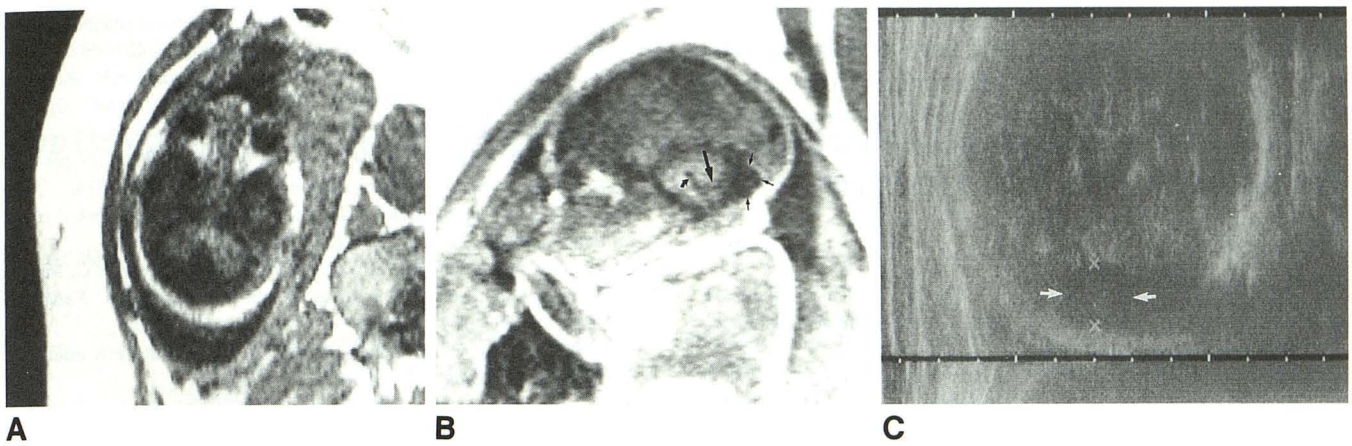

Fig. 3. Dandy-Walker variant (case 15).

A, Fetal axial T1-weighted image demonstrates a hypoplastic inferior cerebellum and a connection between the fourth ventricle and the posterior fossa cyst.

B, Fetal near-parasagittal T1-weighted image shows a posterior fossa cyst (*small arrows*) with a connection (*long arrow*) to the fourth ventricle (*curved arrow*).

C, Axial US image of the fetal head shows a cystic structure in the posterior fossa behind the cerebellar hemisphere (*arrows*); however, the connection between the fourth ventricle and the posterior fossa cyst was not demonstrated on US. (Fig 3*A* from Wenstrom et al [2].)

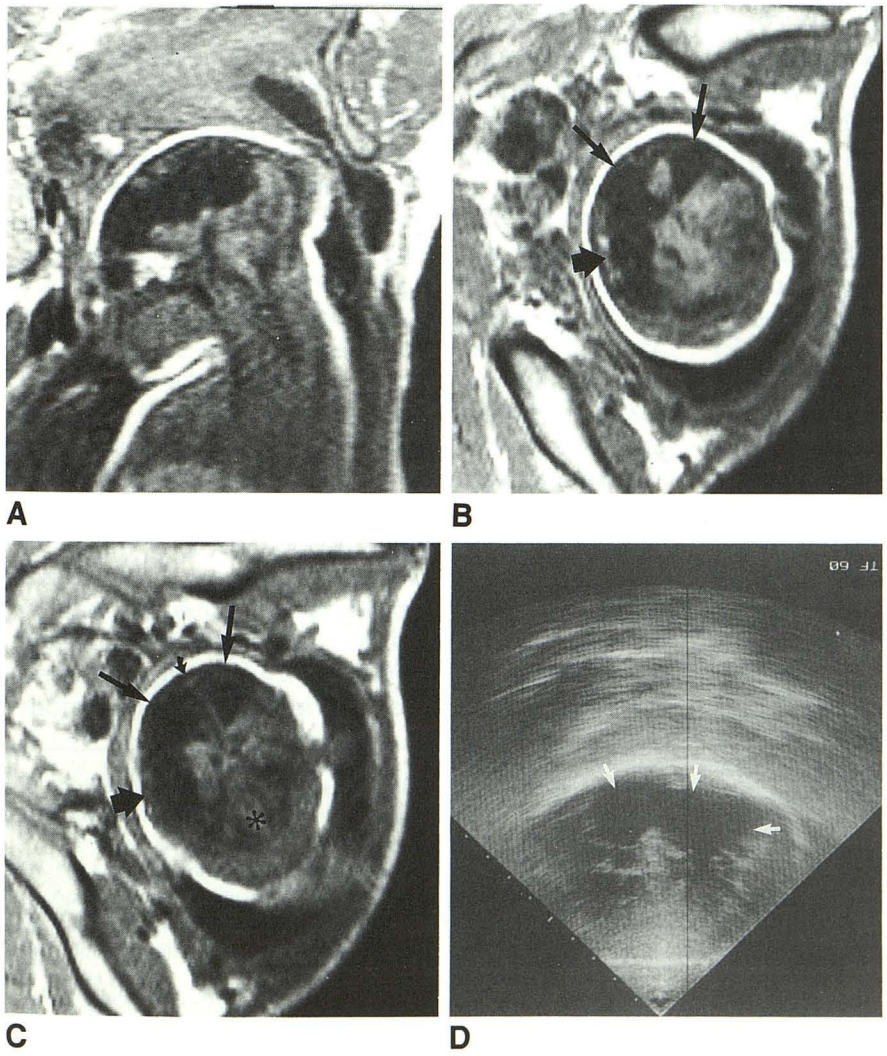

Fig. 4. Infarction (case 20).

A, Fetal near-midsagittal T1-weighted image shows microcephaly and area of low signal intensity without significant mass effect. Fetal near-coronal T1- weighted images from anterior (*B*) to posterior (*C*) show the midline structure (falx: *curved arrow*) and brain loss in the distribution of anterior (*long arrows*) and middle (*short arrows*) cerebral arteries. Posterior circulation is relatively intact as evidenced by the preservation of the cerebellum (*B, asterisk*) and occipital lobe.

C, Sagittal US image of the fetal head, oriented to match *A*, shows a large cystic structure (*arrows*), which was thought to represent a large subarachnoid cyst.

modality of choice and should be the initial method for the evaluation of fetal central nervous system anomalies, in circumstances in which the US diagnosis is unclear or antenatal intervention might be considered, MR may provide additional information for better care of these patients.

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