

Usefulness of additional fetal magnetic resonance imaging in the prenatal diagnosis of congenital abnormalities

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Abstract

Objective Our aim was to compare the value of fetal magnetic resonance imaging (MRI) with detailed ultrasound in the prenatal diagnosis of congenital abnormalities.

Materials and methods This retrospective study reviewed the medical records of pregnant women and their neonates who, after ultrasound, were suspected to have congenital abnormalities. They then underwent a detailed ultrasound examination and a fetal MRI in our institutions. Fetal MRI was performed in 81 cases. Each prenatal presumptive diagnosis, based on detailed ultrasound examination and fetal MRI, was compared with the postnatal confirmed diagnosis. In 58 cases, the data collected were confirmed by the postnatal diagnosis.

Results Supplemental information from fetal MRI was useful in 17 of the 22 cases involving the central nervous system (CNS), two of two cases involving the thorax, nine of nine cases involving the genitourinary system, two of eight cases involving the gastrointestinal system, and ten of ten cases involving complex malformations. Fetal MRI did not provide significantly useful information or facilitate a more accurate diagnosis except for CNS abnormalities.

Conclusion Fetal MRI was not superior to an ultrasound examination in the prenatal detection of congenital abnormalities. A detailed ultrasound examination performed by experienced obstetricians had satisfactory accuracy in the diagnosis of fetal abnormalities compared with fetal MRI. Fetal MRI might be useful in appropriate cases in Korea. Greater effort is required to increase the ultrasound knowledge and skill of competent obstetricians.

Keywords Congenital abnormalities · Detailed ultrasound examination · Fetal MRI · Prenatal diagnosis

Introduction

Prenatal ultrasound has been used for several decades as the primary imaging method for the prenatal diagnosis of fetal abnormalities because of its advantages, including safety for the mother and fetus, cost-effectiveness, and real-time imaging [1]. However, certain factors, such as maternal body habitus, low amniotic fluid volume, fetal position, fetal or maternal bone shadows, and the resolution of images, can cause severe attenuation. Furthermore, in the latter period of pregnancy, it may be difficult to obtain an optimal evaluation of the fetal structure because of fetal ossification or engagement of the fetal presenting part [2]. Such factors may result in inconclusive diagnoses, and therefore limit the optimal prediction of neonatal outcome and delay implementation of a therapeutic plan. Fetal MRI is therefore sometimes used in an effort to overcome these limitations and to make diagnoses that are more accurate.

Since Smith et al. [3] first described the use of MRI as a prenatal examination tool in 1983, many related studies have been conducted. Various studies have reported the advantages of MRI over ultrasound in diagnosing fetuses

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with abnormalities [4, 5]. In Korea, fetal MRI began to be used in the early 1990s; however, at that time, image acquisition could take several minutes, making it difficult to obtain proper images because of artifacts arising from fetal motion [6]. It was therefore necessary to sedate the mother and fetus when using MRI in a prenatal examination [7]. With the development of high-speed image acquisition, it became possible to obtain images without anesthetizing the mother and fetus [2], and the use of fetal MRI as a prenatal imaging modality for fetal abnormalities has increased. Fetal MRI is used less frequently in Korea than in other countries, however, because it still has limitations, such as artifacts caused by the movement of the mother or the fetus, the need for special hardware, low availability, high cost, and the general belief that MRI does not provide decisive clues assisting in the diagnosis. By contrast, the recent innovative advances in resolution and technological development, such as three-dimensional (3D) ultrasound, multiplanar images, and real-time 3D ultrasound, have resolved many of the limitations of ultrasound. Therefore, a comparison of the value of prenatal ultrasound and fetal MRI is needed [8]. We undertook this retrospective study to determine the usefulness of additional fetal MRI in establishing a prenatal diagnosis and determining a treatment protocol by comparing the results of prenatal examinations using ultrasound and MRI with the postnatal diagnosis.

Materials and methods

Patients and study

We performed a retrospective review of patients who, in the fetal stage, were suspected to have fetal abnormalities based on a prenatal ultrasound examination; all mothers included in the study gave consent for a detailed ultrasound and fetal MRI examinations in the Obstetrics and Gynecology Department of the Catholic University of Korea Catholic Medical Center's Seoul St. Mary's Hospital and Bucheon St. Mary's Hospital, between January 2002 and December 2010.

To compare the accuracy of diagnosis between detailed ultrasound and MRI, we included only cases in which the interval between the two examinations was ≤ 1 week. We excluded fetuses in which the postnatal diagnosis was not confirmed. Retrospectively, diagnoses by each modality were compared with the diagnosis based on the postnatal examination. The indications for fetal MRI were classified by anatomic system: central nervous system (CNS), genitourinary (GU) and gastrointestinal (GI) systems, face/neck and musculoskeletal system, thorax lesions, and complex malformations.

Technique

There is not a board examination for different ultrasound observer classes in obstetric in Korea. Therefore, detailed ultrasound was performed by an experienced obstetric specialist with more than 5 years experience in our tertiary medical institution, and supervised by a professor of obstetrics with more than 10 years experience. In most cases, an ACCUVIX XQ (Medison Co., Seoul, Korea) and GE Voluson 730 Expert (GE Medical Systems, Zipf, Austria) were used, but an SSD-5500 (ALOKA Ltd., Tokyo, Japan) or ATL HDI-3000 (Advanced Technology Laboratories, Bothell, WA, USA) was used occasionally. A 2.0–6.0 MHz 2D curved linear array and a 4.0–7.0 MHz 3D curved array were used; measurements were primarily performed at 3.5 MHz.

Fetal MRIs were not performed as a screening tool, and only fetuses with abnormalities detected by ultrasound were referred for fetal MRI. Before the fetal MRI was performed, all the patients and guardians were informed in writing or orally about the safety of the technique and the process and method of the procedure, and the fetal MRI was performed only when they understood and gave their consent. The radiologist was provided with information on the clinical history and the findings of the detailed ultrasound. All fetal MRIs were performed on a 1.5 T Excite Twin-Speed MR scanner (Signa; GE Medical Systems, Milwaukee, WI, USA) using a single-shot fast spin echo (SSFSE). The body phased-array coil was used in all cases. No contrast or maternal sedation was administered. The mothers were positioned in the supine or left lateral position to minimize discomfort during the examination. Signals were collected from the abdominal area. The fetus was scanned through the sagittal, coronal, and axial planes based on the long axis of the fetus. The section thickness of the image was 4.7 mm, the field of view was 34×34 cm, and the acquisition matrix was 128×320 .

The results of the ultrasound and fetal MRI were discussed by the Catholic Congenital Abnormalities Center, a multidisciplinary board consisting of obstetricians, neonatologists, radiologists, and specialists in related divisions, such as pediatric neurosurgery, pediatric surgery, pediatric urology, pediatric cardiothoracic surgery, and laboratory medicine. After discussion, the mothers and their guardians received prenatal counseling from the multidisciplinary board.

Results

Eighty-one fetuses were investigated with ultrasound and fetal MRI. Of these, postnatal diagnoses were confirmed in 58 neonates. Nineteen cases were lost to follow-up or

Table 1 Diagnoses at detailed ultrasound and fetal MRI (cumulated data)

Pathology of postnatal diagnosis	Postnatal Numbers of diagnosis	Prenatal detailed ultrasound			Fetal MRI		
		Findings	False positive	False negative	Findings	False positive	False negative
Central nervous system							
Ventriculomegaly	3	8	5	0	6	3	0
Agenesis of corpus callosum, complete or partial	7	6	0	1	7	0	0
Megacisterna magna	2	3	1	1	3	2	0
Arachnoid cyst	2	2	1	0	2	0	0
Dandy–Walker malformation or variant	1	3	3	0	2	1	0
Hemorrhage	2	1	1	2	0	0	2
Holoprosencephaly	1	1	0	0	1	0	0
Tumor, cystic	1	2	1	0	2	1	0
Other	2	1	0	1	2	0	0
Genitourinary system							
Renal cystic disease	6	6	0	0	6	0	0
Assessment of kidney, agenesis, ectopis or horseshoes	3	3	0	0	3	0	0
Posterior Urethral Valves	1	1	0	0	1	0	0
Cyst, ovarian or adrenal	2	3	1	0	2	0	0
Hydrocolpos	1	1	0	0	1	0	0
Others	2	4	2	0	4	2	0
Gastro-intestinal system							
Enteric duplication	1	1	0	0	1	0	0
Bowel obstruction, duodenal, jejuna or ileal	6	7	1	0	6	0	0
Bowel perforation, meconium peritonitis, meconium pseudocyst	5	2	0	3	1	0	4
Others	3	3	0	0	3	0	0
Musculo-skeletal system							
Chest	3	3	0	0	3	0	0
Extremity	3	4	1	0	3	1	0
Neck and face	4	5	1	0	5	1	0
Sacroccygeal teratoma	1	1	0	0	1	0	0

transferred to another hospital, and two did not have a diagnostic examination after birth, and thus a final diagnosis was not confirmed. Postnatal diagnoses were confirmed for 23 of 37 neonates with CNS abnormalities, 17 of 23 neonates with GU and GI abnormalities, 6 of 10 neonates with face/neck and musculoskeletal system abnormalities, and 2 of 5 neonates with thoracic abnormalities. Ten neonates had complex malformations, with all their diagnoses confirmed by postnatal examinations. Table 1 shows the number of false-positive and false-negative findings for pathology of the suspected affected sites to be examined through fetal MRI (cumulative data).

Central nervous system

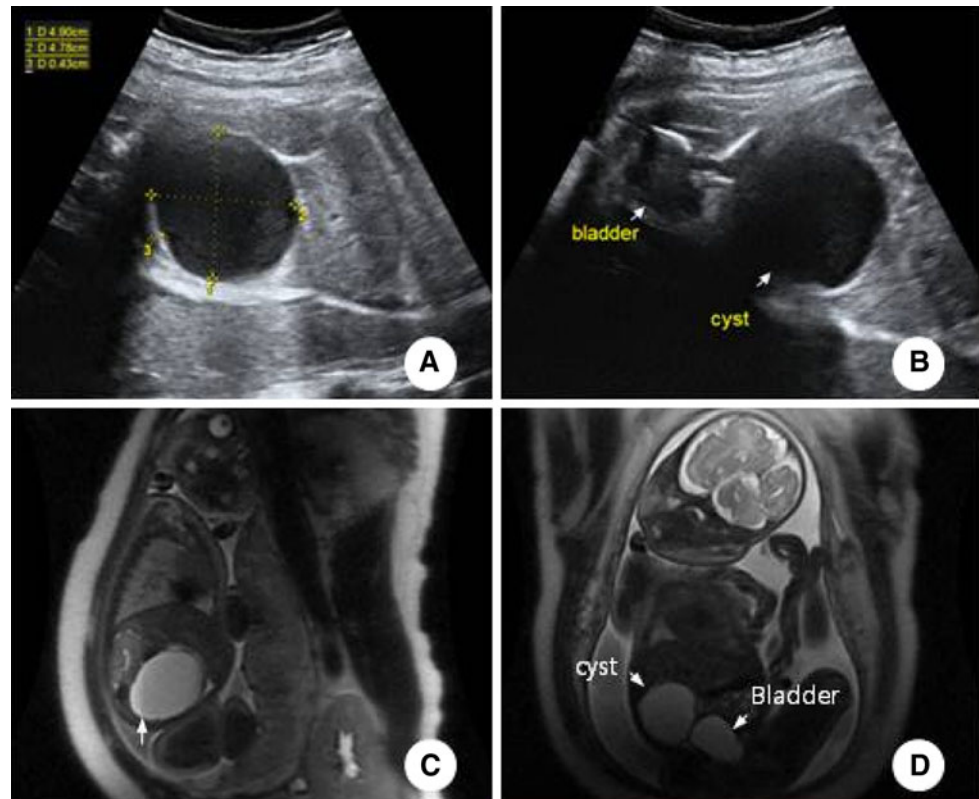
Individual diagnoses of cases assessed by fetal MRI for suspected cerebral abnormalities detected by ultrasound

were ventriculomegaly, mega cisterna magna (MCM), Dandy–Walker malformation or variant, corpus callosum agenesis (ACC), arachnoid cyst, unspecified brain cyst, holoprosencephaly and macrocephaly. Of these 23 cases, 21 were of gestational age more than 24 weeks.

In five cases, the results of fetal MRI were more consistent with the postnatal diagnoses than were the detailed ultrasound results. In 12 cases, the results of both modalities were consistent with the postnatal diagnosis, but the fetal MRI increased the accuracy of the diagnosis or confirmed the presence of accompanying abnormalities. In four cases, the results of both modalities were inconsistent with the postnatal diagnoses, and in two cases, the results of the detailed ultrasound examination were more consistent than the fetal MRI with the postnatal diagnosis (Table 2).

MRI provided valuable additional information in 17 (74 %) of the 23 fetuses. In 12 of these 17 cases, fetal MRI

Fig. 1 A 36-week female fetus with ovarian hemorrhagic cyst. Ultrasound (a) shows a hypoechoic cyst, but clear separation of the cyst from the bladder is difficult (b). Magnetic resonance (c) images show a cyst with fluid–fluid level (arrow) and low-signal area representing a hemorrhagic cyst



confirmed the diagnosis and the absence of accompanying abnormalities, and, consequently, fetal MRI facilitated the consultation with the patient, including the determination of a treatment plan. Moreover, in five cases, the diagnosis was narrowed or changed. For example, sagittal images are very helpful in evaluating the corpus callosum when there is mild ventriculomegaly; MRI therefore helped to confirm ACC. Another example is that in MCM, MRI, in conjunction with ultrasound, can determine the presence of vermis, thus allowing the Dandy–Walker variant to be ruled out. Isolated MCM has no adverse clinical outcome. Our precise diagnosis influenced patient counseling and the clinical plan. In two cases of macrocephaly ($n = 4$), the diagnosis was changed from normal brain to intracranial abnormalities, that is, subdural fluid and germinal matrix hemorrhage.

Genitourinary and gastrointestinal systems

Seventeen cases underwent fetal MRI for suspected abnormalities involving the GU or GI system. The ultrasound findings were five abdominal cysts, five bowel obstructions, four kidney abnormalities, and three others (unspecified abdominal mass, ascites, and meconium peritonitis).

GU abnormalities were secondarily evaluated by MRI in nine fetuses, and in five cases, both modalities and postnatal imaging studies were in agreement. In these cases, fetal MRI provided images of higher quality, in which the

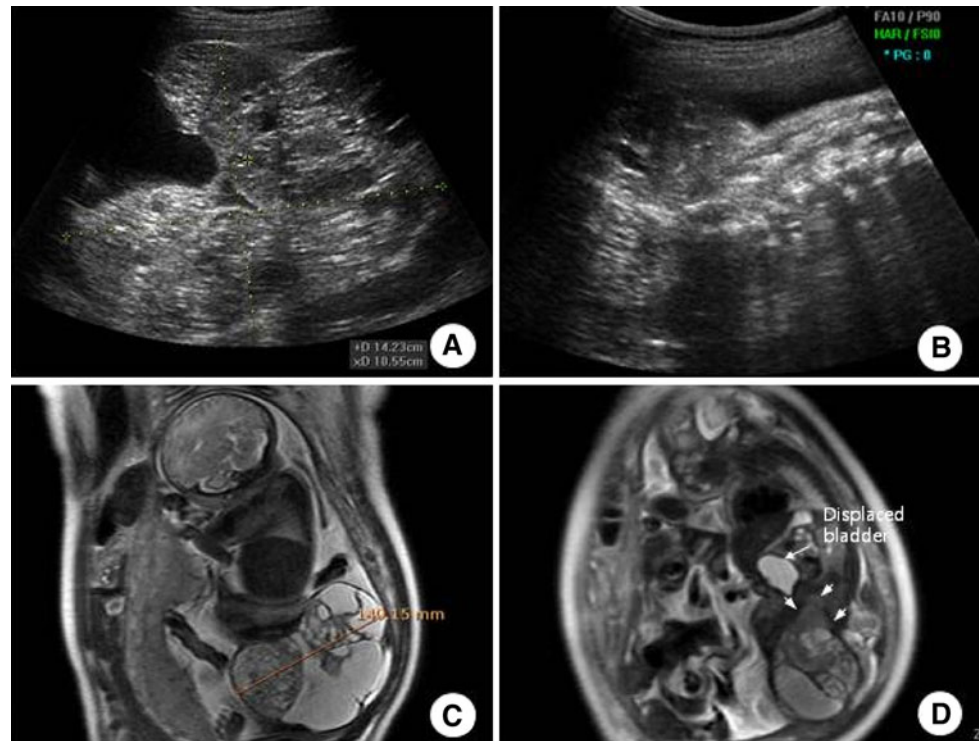
boundaries of the kidneys were clear, allowing confirmation of the diagnosis. Fetal MRI confirmed the presence of accompanying abnormalities, and therefore was helpful during consultation on the prognosis. In three of the other cases, diagnosis by fetal MRI was more detailed and accurate as follows: cystic masses diagnosed by ultrasound were narrowed down to hemorrhagic cysts through fetal MRIs in two cases (Fig. 1), and fetal MRI narrowed down the list of possible diagnoses in the other case.

In eight cases, fetal MRIs were performed for GI abnormalities as the major indication. In one of the cases, diagnosis by fetal MRI was superior, and in three cases, diagnosis by detailed ultrasound was more consistent with the postnatal diagnosis (Table 2). In another case, a prenatal diagnosis of ascites that was observed through ultrasound and fetal MRI was not misdiagnosed, but resolved naturally with advancing gestational age. The prognosis of isolated ascites is diverse and can differ according to the presence of accompanying abnormalities; in this case, fetal MRI confirmed the absence of accompanying abnormalities. In two cases, the diagnoses by ultrasound and MRI were consistent with each other, but differed from the postnatal final diagnosis.

Neck and chest

Five cases underwent fetal MRIs for sonographically suspected chest abnormalities: two cases of congenital

Fig. 2 A 31-week fetus with a sacrococcygeal teratoma. Precise delineation is difficult on one shot by ultrasound (a). Quality of image (b) is decreased by shadowing from the sacrum. MRI (c) clearly shows a complex mass in the sacrococcygeal region. MRI (d) definitely shows the mass is mainly external with a small internal pelvic component



diaphragmatic hernias (CDH), two cases of congenital cystic adenomatoid malformations (CCAM), and one case of pulmonary sequestration. Postnatal diagnosis was confirmed for one case of CDH and one case of CCAM. In all of the cases, fetal MRI did not change the diagnosis made by detailed ultrasound, but fetal MRI clarified the boundaries of organs and was helpful for consultation on the prognosis and therapeutic planning. In the case with CDH, the position of the liver, which is an important factor in the prognosis, was ascertained and clear boundaries made it possible to measure accurate lung capacity. In the case with CCAM, the boundary with normal pulmonary parenchyma could be clearly defined. Fetal MRI was performed in three cases of neck abnormalities (a neck mass, submandibular lymphangioma, and cystic hygroma). In one case, the result of prenatal ultrasound was inconsistent with the fetal MRI; specifically, a neck mass was diagnosed by ultrasound, and a teratoma, hemangioma, or fibroma was diagnosed by fetal MRI. After birth, the case was confirmed as a hemangioma.

Complex malformations, musculoskeletal system, and others

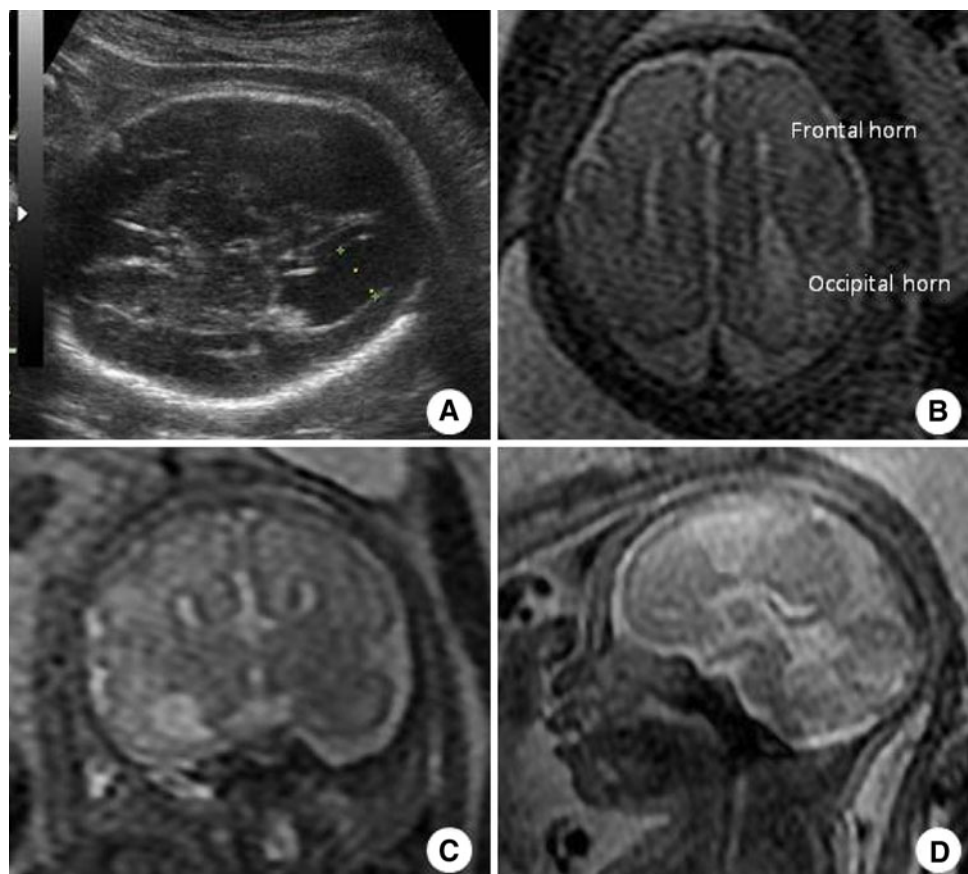
Supplemental information by fetal MRI was helpful in all cases of complex malformations. However, fetal MRI still had limitations for the evaluation of cardiac malformations and musculoskeletal abnormalities, except CNS abnormalities. Three cases had fetal MRIs for musculoskeletal

abnormalities as a major indication. In one of these cases, unilateral lower extremity edema was detected by prenatal ultrasound and also diagnosed by fetal MRI, but a postnatal MRI using a contrast agent diagnosed the neonate with congenital diffuse lymphangiomatosis limited to one lower extremity (Fig. 2). In another case, which was a sacrococcygeal teratoma, the accurate position and size were confirmed using wide-field images from fetal MRI, and the grade could be clarified because of good tissue contrast (Fig. 3). These merits were helpful in planning treatment, including surgery. However, in these cases, the information from the fetal MRI did not change the diagnosis or therapeutic plan. In another case, there was intrauterine growth restriction with short extremities accompanied by oligohydramnios and placentomegaly; an MRI was performed to check short and long bones and the presence of accompanying abnormalities. It was confirmed that the placentomegaly was caused by a subchorionic hematoma.

Discussion

A prenatal diagnosis of fetal abnormalities provides basic information for parental counseling regarding the suspected prognosis, treatment plan, and maintenance of pregnancy. Thus, the accuracy of diagnosis is very important. Ultrasound is the preferred method of imaging fetal abnormalities, because it is safe for the mother and fetus, and easily accessible to obstetricians. However,

Fig. 3 A 29-week fetus with agenesis of the corpus callosum. Prenatal axial ultrasound (a) shows mild ventriculomegaly, 1.1 mm in size. Fetal MRI (b) shows that the ventricles have a ‘teardrop’ shape with widening of the atria and occipital horns. The MRI (c) finding of ‘trident-shaped ventricles’ was important for diagnosis as the ‘teardrop sign’ was not clearly observed by ultrasound because of mild ventriculomegaly. Sagittal T2W1 MRI of callosal agenesis, showing no corpus callosum, can be seen above the third ventricle (*arrow*). The cingulate gyrus is absent, with the remaining gyri arranged in a radial pattern (d)



when additional information is needed to care for pregnant patients, MRI is sometimes used. MRI allows for visualization of the fetal anatomy when ultrasound is insufficient for an adequate diagnosis; furthermore, it has improved resolution, uses no ionizing radiation, and permits imaging in more than one plane.

Although MRI is not recommended during the first trimester of pregnancy because its safety has not been established [2], fetal MRI on a commercially used 1.5 T MR scanner is reported to have little impact on the fetus or the mother [9]. The advantages of MRI include its good tissue characterization, imaging from various directions, and consequent accurate observation of affected sites [8]. As MRI provides wide-field images, it allows an overview of the anatomic localization of fetal structures and pathology, as shown in the case of sacrococcygeal teratoma in the present study (Fig. 2). Moreover, in contrast to ultrasound, MR images can be read by other readers, which can provide information that is more objective.

It is known that in cases with SSFSE, most of the anatomic structures in the fetus can be confirmed, even at a gestational age of 18 weeks [10]. Many studies have reported that fetal MRI allows more detailed observation than prenatal ultrasound, and therefore provides additional information to confirm or change a diagnosis and possibly

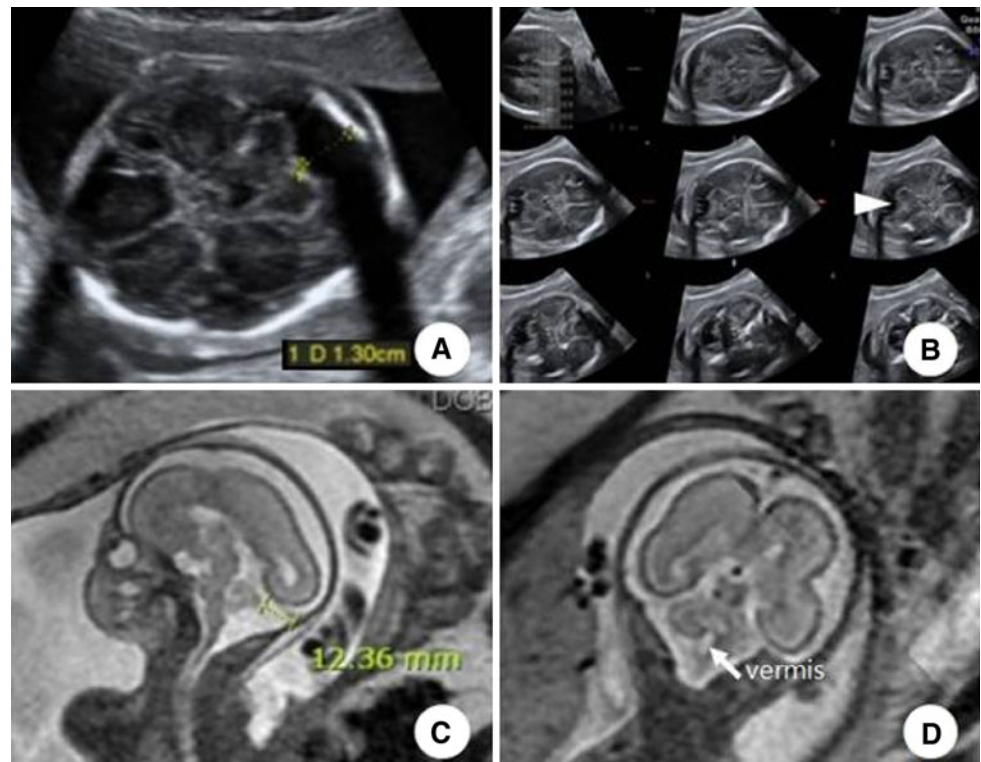
alter a clinical plan [11–15]. Specifically, many studies have indicated that MRI is most valuable in further characterizing fetal CNS abnormalities detected by ultrasound. However, a recent study by Santos and coworkers [16] reported that the postreferral diagnosis of CNS abnormalities changed in 43 % of cases, and additional findings were discovered in 29 % of cases when both ultrasound and MRI were used, although the fetal MRI did not instigate changes in counseling per se. In our study, additional information from MRI for the evaluation of cerebral abnormalities was consistent with the postnatal diagnosis in 77.3 % of cases. This may be because of the advanced gestational age at the time of imaging in our study [14]. The usefulness of additional fetal MRI was most pronounced in fetuses with ACC and Dandy–Walker variant (Figs. 3, 4) [12, 13]. We found MRI to be helpful in establishing the presence of a normal corpus callosum in a fetus with mild ventriculomegaly, and in diagnosing ACC in a fetus when the sonographic finding showed only ventriculomegaly (Table 3). MRI was also useful in visualizing the posterior fossa structure, particularly in demonstrating the presence of the inferior vermis in fetuses with ultrasound indications of suspected MCM, Dandy–Walker variant, or congenital vermian hypoplasia. This was remarkable in T2-weighted images. This information

Table 2 Cases in which detailed US proved more accurate than MRI

Prenatal				Postnatal	
Weeks at diagnosis	Referral US finding	Detailed US finding	Fetal MRI finding	Final diagnosis	Gold standard
28	VM	VM	VM, DWv	VM	Brain CT
30	Macrocephaly, possible MCM	Not specific	MCM	Not specific	Brain US
28	Possible jejuna atresia, polyhydramnios	Duodenal atresia	Proximal jejunal atresia	Duodenal atresia	Spiral intestinal CT
19	Echogenic bowel, oligohydramnios	Meconium peritonitis	Not specific	Meconium peritonitis, imperforated anus	Surgical finding
33	Fetal abdominal distension, echogenic bowel, polyhydramnios	Meconium peritonitis, ilial or jejunal atresia	Massive intraabdominal lymphangioma	Meconium peritonitis, bowel atresia, bowel perforation	Surgical finding

US ultrasound, VM ventriculomegaly, DWv Dandy–Walker variant, MCM megacisterna magna

Fig. 4 A 28-week fetus with megacisterna magna (a, c). The presence of cerebellar vermis was confirmed by prenatal ultrasound (b), but hypoplasticity of the vermis could not be determined. Fetal MRI clearly showed that the vermis was intact (d)



was important and helpful in counseling parents. We did not find additional fetal MRI to be useful in a fetus with holoprosencephaly. However, when the sonographic finding is equivocal for characterizing brain abnormalities in cases in which termination may be offered, such as alobar holoprosencephaly or schizencephaly, fetal MRI may be helpful. We therefore suggest that additional fetal MRI is used for the evaluation of cerebral abnormalities in the above-mentioned cases.

MRI can measure the volume more accurately than ultrasound, and fetal MRI may be more helpful than

ultrasound in providing a postnatal prognosis for thoracic abnormalities, especially for those such as CDH, in which the position of the liver and the volume of the lungs have a significant impact on the prognosis. This indicates that MRI can be useful [17, 18]. Rajeswaran et al. [19] reported that MRI provided a greater number of confident diagnoses in fetal thoracic abnormalities when compared with that by ultrasound. However, we have found that fetal MRI did not change or affect the diagnosis by detailed ultrasound in all the cases of thoracic abnormalities. Similarly, Santos et al. demonstrated that postreferral imaging for CDH did not

Table 3 Cases in which MRI proved more accurate than detailed US

Prenatal				Postnatal	
Weeks at diagnosis	Referral US finding	Detailed US finding	Fetal MRI finding	Final diagnosis	Gold standard
28	MCM	MCM	MCM with normal cerebellar vermis	Normal range	Brain US
32	VM	VM, DWv	VM	VM	Brain CT
28	VM, MCM, DWv	VM, MCM, DWv	MCM with normal cerebellar vermis	MCM	Brain MRI
32	VM	VM	Normal range	Normal	Brain US
31	VM	VM	Normal range	Normal	Brain MRI
32	Brain cyst	Brain cyst	Brain cyst with partial ACC	Partial ACC with dorsal interhemispheric cyst	Brain US
33	Macrocephaly	Normal range	Subdural fluid in cerebral hemispheres	Asymmetric widening of the subarachnoid space	Brain US
36	VM	VM, possible ACC	VM, ACC	ACC	Brain MRI
31	Unilateral mild VM	Unilateral mild VM	Minimal subdural fluid collection as normal finding	Cystic change of GMH	Brain US
36	VM	Possible partial ACC	Partial ACC	Partial ACC	Brain US
23	Holoprosencephaly, possible partial ACC	Holoprosencephaly, Possible partial ACC	Holoprosencephaly, Partial ACC	Holoprosencephaly, Partial ACC	Autopsy
28	Ascites, mild VM	Possible IVH, Mild VM	Right GMH c bilateral IVH (Grade IV), VM (obstruction.),	IVH, Intracranial hemorrhage (chronic) in basal ganglia	Brain MRI
25	Polyhydramnios,	Possible esophageal atresia	Idiopathic hydramnios	Normal	Physical examination

US ultrasound, MCM mega cisterna magna, VM ventriculomegaly, DWv Dandy-Walker variant, ACC agenesis of corpus callosum, GMH germinal matrix hemorrhage, IVH intraventricular hemorrhage

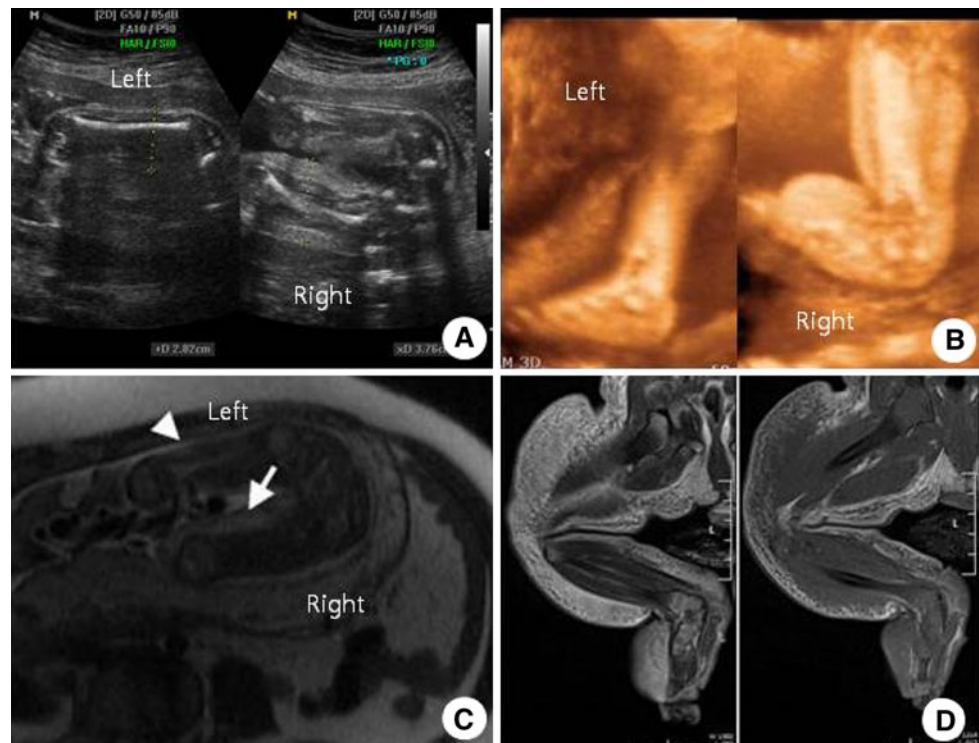
change or affect the diagnosis [16]. We consider that this occurred because of the increasing likelihood of prenatal diagnoses by ultrasound for abnormal findings that could not be detected in the past [1]. Ultrasound has enabled the measurement of accurate volume through advances in 3D ultrasound technology and improvements in resolution. In addition, the use of color Doppler ultrasound to identify feeding vessels is critical to diagnosing thoracic abnormalities, such as CCAM or pulmonary sequestration. Therefore, we could not conclude that fetal MRI is of greater value than ultrasound in the evaluation of thoracic abnormalities, and do not recommend the use of fetal MRI to confirm the sonographic diagnosis for thoracic abnormalities. Instead, we consider that the periodic repetition of detailed ultrasounds on the affected area was more useful than additional fetal MRI. However, further research should be conducted on thoracic abnormalities with a larger number of subjects.

There is an increasing number of reports on the usefulness of fetal MRI in evaluating GU abnormalities [20, 21]. In cases of renal abnormality, oligohydramnios may occur. This may result in attenuation of the ultrasound image and the abnormality not being properly observed. However, MRI

is not restricted, even if the amniotic fluid volume is low, and may therefore be superior to ultrasound in diagnosing abnormal findings involving GU systems. In the current study, the prenatal diagnosis or treatment plan did not change after fetal MRI in five of six cases. Even in three cases, diagnosis by detailed ultrasound was superior (Table 2). Although the boundaries of the observed sites, such as the distinct shape and margin of the kidneys, were clear in T2-weighted images, it is unlikely that fetal MRI is highly useful in confirming or changing the diagnosis or therapeutic plan. We therefore recommend the serial use of ultrasound, rather than additional fetal MRI, for confirming the diagnosis of GU abnormalities. However, if targeted structures are difficult to visualize and evaluate by ultrasound in cases with severe oligohydramnios or anhydramnios, additional fetal MRI may be worth considering. In such cases, fetal MRI might be useful in confirming the diagnosis and checking for the presence of accompanying abnormalities. Further evaluations are needed to assess whether fetal MRI is able to distinguish between the severity of oligohydramnios and the normal range of amniotic fluid.

The results of prenatal diagnosis by fetal MRI may be inconsistent with the postnatal diagnosis [5, 12]. One of the

Fig. 5 A 28-week fetus with congenital right leg lymphangiomatosis. Prenatal ultrasound (a) shows an edematous right lower limb. A three-dimensional ultrasound image shows that the of the left leg was edematous as compared with right (b). Fetal MRI image (c) shows edema of the right lower limb. A scan performed with techniques to study the accompanying abnormalities found no particular abnormality. Postnatal MRI (d) for the right lower limb shows diffuse swelling of the subcutaneous tissue. After infusion of contrast media, reticular enhancements are seen in the subcutaneous layer (d)



possible causes of the difference is that fetal MRI does not use a contrast agent. The contrast agent, gadolinium, is not recommended for use during pregnancy because gadolinium enters the fetus through the placenta and is then excreted into the amniotic fluid through the bladder, is swallowed again and potentially reabsorbed from the gastrointestinal tract; thus, the half-life of gadolinium is unknown [22]. In the current study, the case of congenital diffuse lymphangiomatosis of the unilateral lower extremity confirmed by MRI after birth had been diagnosed prenatally as edema of the unilateral lower extremity by 3D ultrasound and fetal MRI (Fig. 5). The difference is likely because diffuse lymphangiomatosis can be diagnosed only when extended lymph nodes are confirmed using a contrast agent, and this case shows the limitation of fetal MRI when a contrast agent cannot be used.

The limitation of our study was that the radiologist reading the MR images was informed about the region of interest. This could promote a bias toward the diagnosis, which may be a limitation. Nevertheless, in our study, with the exception of CNS abnormalities, MRI did not lead to any significant changes to the diagnoses and treatment plans based on ultrasound. Even if we accept that the different image quality of MRI was useful in the diagnosis of GU systems, we cannot conclude that fetal MRI is superior to ultrasound in every case. Fetal MRI is not efficient in terms of cost, time, or ease of use, and fetal MRI does not provide crucial indications for diagnosis. Thus, the use of fetal MRI as a routine or primary imaging method for

identifying fetal abnormalities is not appropriate. Nevertheless, fetal MRI is important, and should be considered in the following situations: multiple abnormalities; accompanying brain lesions critical for prognosis; checking the cerebellar vermis for MCM or Dandy–Walker malformations and the corpus callosum for mild ventriculomegaly, among other abnormalities in the CNS; when attenuation of images is severe due to low amniotic fluid volume resulting from abnormalities in the GU system; when the kidneys cannot be examined accurately; and when the image of fetal MRI is crucial for diagnosis, such as in cases of lymphangiomatosis. The results of the current study differed from those of previous studies in that fetal MRI did not appear to be superior to ultrasound. This discrepancy was previously attributed to an accumulation of obstetric ultrasound knowledge. In contrast, we suggest that this discrepancy occurred because the use of fetal MRI is relatively less frequent in Korea, which may influence the radiologist in reading fetal MRI in accordance with the results of prenatal ultrasound. Ultrasonic diagnosis is a diagnostic imaging method that relies heavily on the examiner, and the results vary depending on the knowledge and skill of the examiner. Thus, greater effort is required to ensure that competent obstetricians have comprehensive ultrasound knowledge and skills. In our institution, the use of fetal MRI was helpful in counseling patients and their guardians to maintain pregnancies. Thus, the use of fetal MRI for abnormalities in appropriate cases may be worth considering.

Conflict of interest None.

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