Original Research

Contribution of MRI to Ultrasound in the Diagnosis of Fetal Anomalies

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Purpose: To evaluate the contribution of MRI to ultrasound (US) in the diagnosis of fetal anomalies.

Materials and Methods: After informed consent and institutional review board approval, concomitant US and MR imaging were performed for 184 fetuses with suspected anomalies in university hospital. Postnatal final diagnoses were obtained for 183 anomalies in 151 fetuses either by radiological examination, surgery, autopsy, or inspection. The prenatal US and MR diagnoses were compared with respect to postnatal diagnoses. Sign test was used to determine the statistical significance.

Results: Both ultrasound and MR imaging correctly diagnosed 93 (50%) cases and failed in 12 (7%) cases. Ultrasound was superior in 7 (4%) cases. MR imaging was superior in 71 (39%) cases (P < 0.001). MR contributed to the prenatal diagnosis by the confirmation of the suspected US diagnosis in 13%, by demonstration of additional findings in 31% and by changing the diagnosis in 56% of the cases. The contribution rates were 55% for the central nervous system (CNS) (P < 0.001), 44% for thorax (P = 0.016), 38% for gastrointestinal system (GIS) (P = 0.031) and 29% for genitourinary system (GUS) (P = 0.003) anomalies. In facial, cardiac and extremity-skeletal system anomalies, there was not a significant contribution of MR imaging over US.

Conclusion: MR imaging can be used as an adjunct to US in the prenatal diagnosis of fetal anomalies of not only the CNS but also the non-CNS origin especially those involving the GIS, GUS and thorax.

Key Words: fetus; magnetic resonance imaging; anomalies; ultrasound; prenatal


ULTRASOUND (US) IS the standard and primary modality used for the imaging of the fetus. It is widely available, easy to apply, cost-effective, safe for the fetus and allows real-time imaging. However, it has some limitations. Especially in case of oligohydramnios, large maternal body habitus and inappropriate fetal position, its effectiveness reduces. Also in the evaluation of some body parts and complex pathologies, the results of US might be unclear (1,2). In such cases, MR imaging is being increasingly used as a complementary imaging modality.

Magnetic resonance imaging has the potential to improve diagnostic accuracy of the prenatal imaging and facilitate the pregnancy management (3–5). It offers a high spatial, temporal, and contrast resolution, which makes the detailed study of fetal pathologies possible. To date, it has not been shown that MR imaging has any adverse effects on the fetal growth or development (2,6).

Multiple studies have up to now been published to compare the effectiveness of the prenatal US and MR imaging. These studies showed that MR imaging provides additional information to US in 36% to 57% of the cases (3,4,7,8). Although this effect has been well-established for CNS anomalies, it has not been well-documented for non-CNS anomalies. Additionally, there were some important limitations of these previous studies. In most of these studies, the comparison of the imaging methods had been made without postnatal correlation and MR results had been accepted as the gold-standard. Secondly, in most of these studies, statistical analysis of the results had not been performed. In a recent large-scaled study of Santos et al (8), referral US diagnoses had been compared with the diagnoses made following the combined level II US and MR imaging evaluation at a fetal center. Since, not the results of the same center had been used in the comparison, that study was rather far from showing the contribution of MR imaging over US.

In the present study, obstetric US and fetal MR examinations performed by the trained radiologists of our university hospital were correlated with the postnatal diagnoses to compare the diagnostic efficacies of US and MR imaging and to evaluate the contribution of MR imaging to the prenatal diagnosis.
MATERIALS AND METHODS

Subjects

In this prospective study conducted between April 2007 and June 2010, 184 consecutive pregnant women more than 12 week-gestational age were directed to MR imaging after US were performed by the experienced radiologist of the university hospital because of the suspected anomalies in their fetuses. The approval for the study was obtained from the local ethical committee and a written informed consent was obtained from all the pregnant women before MR imaging. Three women were pregnant with twins. Mean gestational age of the fetuses was 24.8 weeks (range, 15–41 weeks). The indications for MR imaging were the confirmation or further assessment of fetal anomalies visualized or suspected at US carried out by our radiologists in 173 cases, high alpha fetoprotein (AFP) level in seven cases and the history of previous anomalous baby or the presence of anomalous twin in seven cases.

Follow-up was available for 151 fetuses. These fetuses that gained final diagnoses either by physical examination, imaging, surgery, or pathologic examination were constituted our study group. Pregnant women who did not accept the MR exam and fetuses without final diagnosis of their anomalies were excluded from the study.

Ultrasound Imaging

For prenatal US examinations, one of the two high-resolution scanners—GE Voluson Expert (General Electric, Waukesha, Wisconsin) or Siemens Sonoline Antarest (Siemens Medical Systems, Erlangen, Germany)—was used. The examinations were performed by one of the two radiologists (H.D., A.C.) in our university hospital who had experience for more than 7 years in high risk obstetric US. The examinations were performed according to ACR—ACOG—AIUM practice guideline (2007) (9).

A standard obstetrical sonogram for the anatomic survey of the fetus in the second or third trimester included the evaluation of the fetal head, face, and neck (cerebellum, choroid plexus, cisterna magna, lateral cerebral ventricles, midline falk, cavum septum pellucidum, upper lip), cardiac axis, four-chamber view of the heart and if possible, outflow tracts of the main cardiac vessels, stomach, kidneys, bladder, umbilical cord insertion site, umbilical cord vessel number and also the whole spine, legs, and arms. If any abnormality was found or suspected on the standard examination or in the pregnancies with high risk for fetal anomalies, a more detailed anatomic examination was done.

Ultrasound studies which were performed elsewhere were repeated with our radiologists, and those US findings were used in the data analysis. Time span between the performance of the US and MR imaging ranged from 0 to 7 days. More than 95% of the MR examinations were performed within 3 days of the US studies.

Magnetic Resonance Imaging

All subjects were examined by using a 1.5 Tesla (T) MR unit (Magnetom, Symphony; Siemens, Erlangen, Germany) and body phased-array coil. The patients were placed in the supine or lateral decubitus position. No maternal sedatives or contrast agents were used. The conventional MR imaging protocol included steady state free precession (SSFP) (true fast imaging with steady state precession: true FISP) (repetition time/echo time [TR/TE], 4.9/2.5; matrix, 412 × 512; FA, 80°; signal average, 1; slice thickness, 3 mm; distance factor, 30%) and half Fourier acquisition single shot turbo spin-echo (HASTE) sequence (TR/TE, 4000/86; matrix, 256 × 256; FA, 125°; signal average, 1; slice thickness, 3 mm; distance factor, 30%). Images were acquired in axial, coronal and sagittal planes relative to the head and trunk of the fetuses. The field of view (FOV) was adjusted according to fetal and patient size so that the smallest FOV is used to allow the fetal imaging without an overlap from the maternal structures. The images of each sequence were used as a scout to align the subsequent acquisition. A radiologist (S.K. or H.A.A.K.) with the knowledge of the US findings supervised the examinations. They controlled the taken images, and helped the adjustment of the imaging planes and whenever needed, added new sequences to the study for the better delineation of the suspected pathology. These sequences which used in selected cases were T2 thick-slab (slice thickness, 10 mm), T1-weighted spoiled gradient-echo (fast low angle shot: FLASH) (TR/TE, 107/4.8; matrix, 145 × 256; FA, 70°; signal average, 1; slice thickness, 5 mm; distance factor, 30%) and spin-echo planar diffusion weighted imaging (DWI) (TR/TE, 4000/94; matrix, 128 × 128; signal average, 1; slice thickness, 4 mm; distance factor, 30%, b = 0, 1000). The images were obtained for both the demonstration of the overall fetal anatomy and a more dedicated assessment of the anatomical area of interest. The total examination time was less than 30 min.

Analysis of the MR Images

All MR images were interpreted in consensus on a workstation (Leonardo, Simens) by two experienced radiologists (S.K. and A.A.) in both fetal MR imaging and neuroimaging with the knowledge of the US findings. On the images, all fetal anatomy was checked. The detailed evaluation of the main anatomical area of interest was done for the diagnosis of the suspected pathology and accompanying pathologies if exists.

Statistical Analysis

Ultrasound and MR imaging findings were compared for discrepancies and consistencies. The diagnoses were classified as confidently true, suspected, partially true or wrong/not diagnosed with respect to the final diagnoses. Sign test were used to compare the diagnostic performances of the two methods. A P value of less than 0.05 was considered to be significant.
RESULTS

Thirty-three fetuses without final diagnosis—11 of them were quit to follow-up, and in 22 cases, no autopsy was performed—and three pregnant women who refused the MR exam were excluded from the present study.

Postnatally, 165 structural anomalies were diagnosed in 133 fetuses. Eighteen fetuses MR imaged for suspected anomalies were diagnosed as normal postnatally (Table 1). Final diagnoses were provided by postnatal physical and radiological examinations and surgery in 114 (62.3%) cases and by postnatal autopsy and inspection after the termination of the pregnancy or spontaneous abortion in 69 (37.7%) cases. Suspected and/or diagnosed anomalies were belonged to central nervous system (CNS) in 76 (41.5%) and were non-CNS in 107 (58.5%) cases.

Ultrasound and MR imaging confidently diagnosed 53.0% and 84.7% of the anomalies, respectively (Table 2). Diagnostic performance of MR imaging was significantly higher than that of the US ($P < 0.001$). The comparison of the imaging findings according to the anomaly groups was shown in Table 3.

In case of CNS anomalies, MR imaging made a positive contribution to US in 55.3% of the cases ($P < 0.001$). In case of the neural tube defects, the prenatal MR imaging improved the diagnosis in 13 (46.4%) of the 28 cases. Two of the 11 encephalocoeles and three of the eight Dandy-Walker malformations could only be diagnosed by MR imaging. In two cases imaged for suspected cerebral anomaly, MR imaging showed the presence of the pontocerebellar hypoplasia. In two cases imaged for the suspected posterior fossa anomaly, MR imaging showed hydrocephaly but normal posterior fossa. MR findings improved the diagnosis in four of the five holoprosencephaly cases. Agenesis of corpus callosum in all four cases was diagnosed by MR imaging. MR images contributed to the diagnosis in four of the five cases with germinal matrix hemorrhages (Fig. 1). In a fetus with Galenic arteriovenous malformation, accompanying cerebral ischemic changes could only be detected by prenatal MR imaging. In a fetus with small posterior fossa, MR imaging showed the presence of kinked midbrain, cerebral-cerebellar dysplasia, and cerebral heterotopias (Fig. 2). In a case with cardiac rhabdomyoma, MR images showed the presence of the subependymal tubers. In a fetus with hemimegalencephaly, accompanying cerebellar dysplasia was detected by MR imaging.

The contribution rate of MR imaging to US was 29.3% in GUS anomalies ($P = 0.004$). MR imaging confirmed the suspected US diagnosis in two cases: one with multicystic dysplastic kidney and the other with posterior urethral valve. MR additionally detected the presence of the cross-fusion in the sonographically diagnosed ectopic kidney of a fetus. It correctly changed the diagnosis in nine cases. A case with testicular heterogeneity on US was normal at MR imaging. In a second fetus evaluated for suspected unilateral renal agenesis and abdominal cyst, MR imaging revealed ectopic kidney with dilated collecting system but missed the duplication of the collecting system. The third fetus was thought to have

**Table 1**

<table>
<thead>
<tr>
<th>Postnatal diagnoses</th>
<th>n (%)$^a$</th>
<th>Postnatal diagnoses</th>
<th>n (%)$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central nervous system</td>
<td>76 (41.5%)</td>
<td>Gastrointestinal system</td>
<td>16 (8.7%)</td>
</tr>
<tr>
<td>Neural tube defect</td>
<td>28</td>
<td>Anterior abdominal wall defect</td>
<td>7</td>
</tr>
<tr>
<td>Encephalocoele</td>
<td>11</td>
<td>Intestinal obstruction</td>
<td>5</td>
</tr>
<tr>
<td>Ventriculomegaly</td>
<td>6</td>
<td>Esophageal atresia</td>
<td>1</td>
</tr>
<tr>
<td>Dandy-Walker malformation</td>
<td>6</td>
<td>Mesenteric cyst</td>
<td>1</td>
</tr>
<tr>
<td>Isolated corpus callosum agenesis</td>
<td>2</td>
<td>Abdominal tumor</td>
<td>1</td>
</tr>
<tr>
<td>Germinatal matrix hemorrhage</td>
<td>5</td>
<td>Normal</td>
<td>1</td>
</tr>
<tr>
<td>Holoprosencephaly</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerebral-cerebellar dysplasia</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuberous sclerosis</td>
<td>1</td>
<td>Lung hypoplasia</td>
<td>8</td>
</tr>
<tr>
<td>Galen vein malformation</td>
<td>1</td>
<td>Cystic adenomatoid malformation</td>
<td>3</td>
</tr>
<tr>
<td>Arachnoid cyst</td>
<td>1</td>
<td>Diaphragmatic hernia</td>
<td>2</td>
</tr>
<tr>
<td>Normal</td>
<td>8</td>
<td>Bronchogenic cyst</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pleural effusion</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ectopia cordis</td>
<td>1</td>
</tr>
<tr>
<td>Genitourinary system</td>
<td>41 (22.4%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal agenesis</td>
<td>10</td>
<td>Extremity and skeletal system</td>
<td>12 (6.6%)</td>
</tr>
<tr>
<td>Renal ectopia</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renal dysplasia</td>
<td>4</td>
<td>Facial</td>
<td>6 (3.3%)</td>
</tr>
<tr>
<td>Cystic kidney disease</td>
<td>4</td>
<td>Cardiac</td>
<td>4 (2.2%)</td>
</tr>
<tr>
<td>Hydronephrosis</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior urethral valve</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urethral atresia</td>
<td>3</td>
<td>Others</td>
<td>12 (6.6%)</td>
</tr>
<tr>
<td>Hydrometrocolpos</td>
<td>2</td>
<td>Normal</td>
<td>6</td>
</tr>
<tr>
<td>Ovarian cyst</td>
<td>1</td>
<td>Hydrops</td>
<td>5</td>
</tr>
<tr>
<td>Normal</td>
<td>3</td>
<td>Idiopathic infantile arterial calcification</td>
<td>1</td>
</tr>
</tbody>
</table>

$^a$n = number of cases and in between parenthesis given the percentages of cases.
hydronephrosis but diagnosed as normal at MR imaging. In the fourth case, unilateral renal agenesis was thought at US but cross-ectopia was diagnosed at MR imaging. In the sixth fetus, large renal cysts were suspected but duplication of the collecting system with dilatation of the superior collecting system was diagnosed on MR images. In another fetus of 18 weeks gestation, gastroschisis was suspected on US but massive ascites, bladder dilatation, and renal dysplasia were correctly diagnosed on MR images. In two fetuses with abdominopelvic cyst, hydrometrocolpos was diagnosed at MR imaging (Fig. 3).

The contribution rate of MR imaging to US was 37.5% in GIS anomalies (P = 0.025). It confirmed the suspicious US diagnoses in cases of an omphalocele and a mesenteric cyst. It additionally detected the presence of the liver in the omphalocele sac of another fetus. It correctly changed the diagnosis in three cases. In a 22-week fetus, omphalocele was thought at US, but no abdominal wall defect was detected on MR images or postnatally. In another fetus, large abdominal mass of hemangiopericytoma was thought to be intra-abdominal sacrococcygeal teratoma at US, but partially diagnosed as nonadrenal intra-abdominal tumor at MR imaging. In the third fetus with polyhydramnios, esophageal atresia was diagnosed at MR imaging (Fig. 4). Microcolon in a fetus with Prune-belly syndrome and duodenal duplication cyst with multiple intestinal atresias in another fetus (Fig. 5) could be detected neither at US nor at MR imaging.

The contribution rate of MR imaging to US was 43.8% in thoracic anomalies (P = 0.016). In seven cases with congenital diaphragmatic hernia (CDH), massive pleural effusion, urinary system anomaly or hydrops accompanying lung hypoplasia could only be detected by MR imaging (Fig. 6).

In case of extremity-skeletal system anomalies, there was no difference between the diagnostic efficacies of the two imaging methods (P = 1.000). MR imaging contributed to the US only in a third case.

Table 3
Comparison of US and MR Imaging Findings

<table>
<thead>
<tr>
<th>Anomalies</th>
<th>n*</th>
<th>Both US and MRI correct</th>
<th>Both US and MRI failed</th>
<th>MRI confirmed the suspicious US diagnosis</th>
<th>MRI showed additional findings</th>
<th>MRI changed US diagnosis</th>
<th>MRI failed**</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNS</td>
<td>76</td>
<td>29 (38%)</td>
<td>5 (7%)</td>
<td>5 (7%)</td>
<td>16 (21%)</td>
<td>21 (28%)</td>
<td>-</td>
</tr>
<tr>
<td>GUS</td>
<td>41</td>
<td>28 (68%)</td>
<td>-</td>
<td>2 (5%)</td>
<td>1 (2%)</td>
<td>9 (22%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>GIS</td>
<td>16</td>
<td>8 (50%)</td>
<td>2 (13%)</td>
<td>1 (6%)</td>
<td>2 (13%)</td>
<td>3 (19%)</td>
<td>-</td>
</tr>
<tr>
<td>Thorax</td>
<td>16</td>
<td>9 (56%)</td>
<td>-</td>
<td>-</td>
<td>2 (13%)</td>
<td>5 (31%)</td>
<td>-</td>
</tr>
<tr>
<td>Ext-skeletal</td>
<td>12</td>
<td>7 (58%)</td>
<td>3 (25%)</td>
<td>-</td>
<td>-</td>
<td>1 (8%)</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Facial</td>
<td>6</td>
<td>1 (17%)</td>
<td>1 (17%)</td>
<td>1 (17%)</td>
<td>1 (17%)</td>
<td>-</td>
<td>2 (33%)</td>
</tr>
<tr>
<td>Cardiac</td>
<td>4</td>
<td>1 (25%)</td>
<td>1 (25%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2 (50%)</td>
</tr>
<tr>
<td>Other</td>
<td>12</td>
<td>10 (83%)</td>
<td>-</td>
<td>-</td>
<td>1 (8%)</td>
<td>-</td>
<td>1 (8%)</td>
</tr>
<tr>
<td>Total</td>
<td>183</td>
<td>93 (50%)</td>
<td>12 (7%)</td>
<td>9 (5%)</td>
<td>22 (12%)</td>
<td>40 (22%)</td>
<td>7 (4%)</td>
</tr>
</tbody>
</table>

*n = number of cases.
**In this group US diagnoses were partially or completely correct but MRI diagnoses were wrong.

US = ultrasound, MRI = magnetic resonance imaging.
**Figure 1.** A 33-week fetus with germinal matrix hemorrhage and hydrocephalus. 

**a:** Axial US image of the fetal brain shows marked ventriculomegaly (dotted line measures the ventricular diameter of 22 mm) and intraventricular clot.  

**b:** Axial T2-weighted MR image of the fetal brain shows low signal intensity hemorrhagic focus (arrow) in the germinal zone in addition to ventriculomegaly and intraventricular hemorrhage.  

**c:** Postnatal axial T2-weighted MR image of that case confirms the prenatal findings. White arrow shows the germinal matrix hemorrhage and black arrows show the intraventricular hemorrhages.

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**Figure 2.** A 34-week fetus with cerebro-cerebellar dysplasia, kinked midbrain and Dandy-Walker variant.  

**a:** Axial sonogram shows marked ventriculomegaly and some irregularities on the ventricular borders.  

**b:** Axial T2-weighted MR image shows abnormal multiple shallow sulci and cortical irregularity and multiple subependymal nodular masses (arrows) surrounding the lateral ventricles. The diagnoses was diffuse polymicrogyria and subependymal heterotopias.  

**c:** Sagittal T2-weighted MR image shows hypogenesis of cerebellar vermis, kinked midbrain (arrow), enlarged posterior fossa and cystic dilatation of the fourth ventricle. Prenatal MR imaging findings were all confirmed postnatally.  

**d:** Postnatal axial T2-weighted image shows bilateral diffuse polymicrogyria and subependymal heterotopias (arrows).
trimester fetus with neural tube defect by showing the accompanying clubfoot.

The difference between the diagnostic efficacies of US and MR was not significant ($P = 0.782$) in facial anomalies. MR imaging contributed to the US diagnosis by the confirmation of the presence of nasolacrimal duct cyst in a case and by the detection of accompanying ocular hypoplasia in another case with proboscis, agnathia, and maxillary hypoplasia.

In the prenatal diagnosis of the cardiac anomalies, US was superior to MR imaging in two of four cases. A case of mitral atresia and hypoplastic left ventricle and another case of ventricular septal defect were correctly diagnosed on US but was not demonstrated on MR images. However, there were no statistical significance ($P = 0.166$) probably because of the low number of the cases.

In the present study, there were 12 miscellaneous cases. Five of those imaged for the high AFP level or
the presence of the family history of the anomalous baby or twin were truly diagnosed as normal by both imaging methods. In five fetuses with hydrops, no accompanying structural anomaly was detected on the prenatal imaging. In another fetus, Chiari malformation was suspected at US but not confirmed at MR imaging or postnatally. In a fetus with idiopathic infantile arterial calcification, a vascular pathology was suspected by MR imaging and could truly be diagnosed after a second look US.

As a result, in the prenatal diagnosis of fetal anomalies MR imaging provided a valuable contribution to US in 38.8% of the cases ($P < 0.001$). The contribution of MR imaging was significant in CNS, thorax, GIS, and GUS anomalies. However, in facial, cardiac and extremity-skeletal system anomalies, there was not a significant contribution of MR imaging to US (Table 4). There was no neck mass with postnatal diagnosis in the present study.

DISCUSSION

In this exclusive prospective study—including many fetal anomalies of both CNS and non-CNS origin—both US and MR imaging examinations performed in the same institution and postnatal findings used as a reference. With this study, we have statistically confirmed that diagnostic performance of MR imaging is higher than that of the US in fetal anomalies. MR imaging provided valuable diagnostic information to US in 39% of the cases and it was mainly by changing the diagnosis. This contribution of MR imaging was highly significant in case of CNS, thorax, GIS, and GUS anomalies. Nevertheless, there is no doubt about the crucial role of US in the prenatal diagnosis. It is relatively inexpensive, easy to apply, has real-time imaging capability. The findings provided by US most of the time provide a preliminary diagnosis and it guides the MR examinations. MR imaging can be used as a complementary method in prenatal imaging to improve diagnosis.

Consistent with the previous studies (3,4,7,8,10,11), in the present study, the most important contribution of MR imaging was in the CNS anomalies. MR imaging was especially beneficial in the diagnosis of the callosal, cerebral cortical, and posterior fossa anomalies and the destructive pathologies of the brain parenchyma. On the other hand, major disagreement between pre- and postnatal findings was in the

![Figure 5](image1.png)

Figure 5. Duodenal duplication cyst and multiple intestinal atresias in a fetus at 24 weeks gestation. a: Coronal sonogram of the fetal abdomen shows round cyst in the right upper quadrant near the hepatic hilum. b: Axial T2-weighted image through the upper abdomen of the fetus shows subhepatic tubular cystic mass (arrow). S = stomach. c: On coronal T2-weighted image small bowel loops appear normal. The right sided subhepatic cyst was thought to be a choledochal cyst but postnatally the patient was operated and it was found to be a duodenal duplication cyst. There were also multiple atresias along the small bowel.

![Figure 6](image2.png)

Figure 6. Axial true FISP T2-weighted images of lung in two fetuses. a: A 31-week healthy fetus with normal hyperintense signal intensity of the lungs. b: A 30-week fetus with lung hypoplasia related to massive ascites. Small lungs have relatively low signal intensity when compared with normal one. This subject developed pulmonary hypertension postnatally.
evaluation of ventriculomegaly. Mild–moderate ventriculomegaly diagnosed prenatally in our three cases was turned out to be normal postnatally. This inconsistency between pre- and postnatal findings might be explained by the postnatal resolution of the isolated mild ventriculomegaly which is a common occurrence as reported by Goldstein et al (12) or by the artificial decrease in the ventricle diameters during the neonatal period as hypothesized by Falip et al (13). Nevertheless, the important point about the mild ventriculomegaly is not its continuation or resolution but the presence or absence of associated anomalies which predict the outcome and MR imaging seems highly accurate in this respect (14).

In the present study, findings provided by MR imaging also made significant contribution to US in the diagnosis of the GUS anomalies \( (P = 0.004) \). The contribution rate was 29%. It had been reported between 31 and 39% in the previous studies (15–18). Although urinary system anomalies were usually well assessed by US, MR imaging played an important role in the detection of fetal anatomy in the case of oligo-anhydramnios. Dilatation of urinary collecting system was usually assessed by US, MR imaging played an important role in the detection of urinary obstructed cases (19). Limited our evaluation. Cardiac triggering might be applied to enhance the image quality but it has not been tested yet on human fetuses (29). On the other hand, US is highly effective in both anatomical and functional evaluation of the heart.

Fetal MR imaging with presently available technology is limited in the evaluation of the fetal face, extremity-skeletal system and heart. However, it may be that in the future, with the hardware modifications and emergence of the new imaging techniques and sequences tailored to gestational age and suspected anomaly, these limitations of fetal MR imaging in the detection of some non-CNS anomalies might be overcome.

There were some limitations of the present study. One main limitation was that the fetuses only with possible or definite anomalies identified by US were imaged by MR. This selection bias might cause higher benefit rate by the addition of MR to the prenatal imaging, because these are the cases that probably benefits more from the advanced imaging. The second limitation was that the radiologists interpreting the MR images were not blinded to US findings. Although patterns of signal intensity were present in that case. Studies must continue to more clearly document the different MR imaging patterns in different GIS anomalies and T1-weighted images must be obtained routinely for the fetal abdomen.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Contribution of MR Imaging to the Prenatal Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anomalies</td>
<td>Contribution of MR imaging</td>
</tr>
<tr>
<td>CNS</td>
<td>42/76</td>
</tr>
<tr>
<td>GUS</td>
<td>12/41</td>
</tr>
<tr>
<td>GIS</td>
<td>6/16</td>
</tr>
<tr>
<td>Thorax</td>
<td>7/16</td>
</tr>
<tr>
<td>Ext-skeletal</td>
<td>1/12</td>
</tr>
<tr>
<td>Facial</td>
<td>2/6</td>
</tr>
<tr>
<td>Cardiac</td>
<td>0/4</td>
</tr>
<tr>
<td>Other</td>
<td>1/12</td>
</tr>
<tr>
<td>Total</td>
<td>71/183</td>
</tr>
</tbody>
</table>

\( n^* = \) number of cases with additional findings on MR imaging/whole number of cases.

CNS = central nervous system, GUS = genitourinary system, GIS = gastrointestinal system, Ext-skeletal = extremity-skeletal system.
this is the way routinely used for prenatal evaluation, it also may contribute to the higher efficacy of MR imaging. Thirdly, the small number of patients in some anomaly groups—facial, extremity-skeletal and cardiac—limited the statistical comparison of the methods in these groups. Another limitation was that, although we used diagnoses obtained at the same center with experienced radiologists and with high-quality images and used standardized exam protocol, the interpretation of US may show large inter and intra-observer variability. Lastly, in the determination of the usefulness of fetal MR imaging over US, the most important criteria is whether the additional information provided by MR imaging does change the patient management and/or counseling (2). It is difficult to objectively evaluate and quantify this effect and we have not attempted to do it in the present study.

In conclusion, we have shown that MR imaging has an important complementary role and adds important diagnostic information to US. It is not only effective in CNS but also in non-CNS anomalies of GIS, GUS, and thorax. On the other hand, in the diagnosis of facial, cardiac and extremity-skeletal system anomalies, there was not a significant contribution of MR imaging. At present, we think that MR imaging can be used as an adjunct to US in the prenatal diagnosis of CNS, GIS, GUS, and thorax anomalies especially when they are complex and difficult to visualize on US. However, for the success of the fetal MR imaging, protocols must be adjusted according to the suspected pathologies and T1-weighted images must routinely be obtained. Further quantitative and statistically supported studies with large samples to demonstrate the effectiveness of MR imaging in non-CNS anomalies and to demonstrate its role on patient management and counseling might be helpful. In addition, studies on tailored sequences for the skeletal and functional cardiac imaging and three-dimensional surface imaging are necessary to be able to increase the application areas and the effectiveness of fetal MR imaging.

REFERENCES
