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Original Article

1.5T magnetic resonance imaging in evaluating fetal head and abdomen malformations: a preliminary study

Jun Duan[1], Jin-Cai Wang[1], Hui-Xian Li[2], Ling Guo[1], Li-Ke Ma[3]

[1]*Radiology Department, Shijiazhuang NO. 4 Hospital (The Obstetrics and Gynecology Hospital Affiliated to Hebei Medical University), Shijiazhuang 050000, Hebei, China;* [2]*Thoracic Surgery, Shijiazhuang People's Hospital, Shijiazhuang 050000, Hebei, China;* [3]*Internal Medicine-Cardiovascular Department, Shijiazhuang No. 3 Hospital, Shijiazhuang 050000, Hebei, China*

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Abstract: Objective: Magnetic resonance imaging (MRI) is increasingly used in the diagnosis of fetal malformations. The purpose of this study was to determine the diagnostic value of 1.5T MRI in fetal head and abdominal malformations. Methods: A total of 132 pregnant women admitted to Shijiazhuang NO.4 Hospital were included and divided into a control group (CG; n=63) and a research group (RG; n=69) according to different prenatal examination methods. Patients in CG were given ultrasound, while those in RG underwent 1.5T MRI examination. The image quality of 1.5T MRI in different amniotic fluid, different gestational weeks with normal amniotic fluid and different fetal positions with normal amniotic fluid were compared. The detection rate and diagnostic value of the two methods were also compared, with the histological and pathological results as the gold standard. Results: The image quality of 1.5T MRI was not affected by different gestational age with normal amniotic fluid, different fetal positions with normal amniotic fluid, or different amniotic fluid, indicating the feasibility of 1.5T MRI in fetal malformation examination. Histopathological diagnosis revealed 39 cases of head and abdominal deformities in CG and 50 cases in RG. Based on the results of ultrasound examination, there were 32 cases of deformities and 31 of non-deformities in CG. In RG, 1.5T MRI revealed 48 malformations and 21 non-malformations. The sensitivity, specificity, accuracy, missed diagnosis and misdiagnosis rates were 82.05%, 75.00%, 79.37%, 17.95% and 25.00% respectively in CG where ultrasonography was performed, and were 96.00%, 94.74%, 95.65%, 4.00% and 5.26% respectively in RG where 1.5T MRI was performed. The data identified significant differences in sensitivity, accuracy and missed diagnosis between RG and CG. Conclusion: 1.5T MRI is effective in diagnosing fetal head and abdominal malformations.

Keywords: Fetal malformation, head deformity, abdominal deformity, 1.5T magnetic resonance imaging

Introduction

The diagnosis rate of fetal malformations is getting higher and higher as science and technology advance. According to statistics, the incidence is 0.83-17.4% for microtia [1] and 0.03% for fetal abdominal malformation [2]. A meta-analysis suggests that some antiepileptic drugs may increase the risk of certain fetal malformations [3]. In addition, alcohol consumption, folic acid deficiency, obesity and gestational diabetes are also associated with increased risk of congenital fetus malformation [4]. Given that accurate prenatal diagnosis can increase the cure rate of fetal malformations (through surgery) [5], the means contributing to accurate diagnose of fetal malformations is a hotspot in the medical field nowadays.

Magnetic resonance imaging (MRI) is a non-invasive imaging technique that uses magnetic fields and radio waves to generate cross-sectional images, which can provide comprehensive and multi-parameter anatomical information [6, 7]. There have been studies applying MRI to the diagnosis of malformations. In addition, it has been applied in breast imaging [8], intervertebral disc imaging [9] and brain imaging [10] due to its advantages in spatial resolution and contrast. A study shows that MRI is more accurate in the diagnosis of anorectal malformations [11]. Whereas the use of MRI in fetal malformations is not so extensive, when the effect of radiation on the mother and the fetus is concerned. As to ultrasonography, it is a routine to diagnose fetal malformations, but it

Table 1. Baseline data

	Control group	Research group	X^2/t	P
Age	30.15±2.13	31.01±1.97	1.620	0.108
Body mass index	20.37±0.53	20.29±0.48	0.910	0.364
Gestational week	29.54±1.81	30.42±1.92	0.792	0.429
Amniotic fluid volume			0.841	0.657
Normal	48	57		
Polyhydramnios	9	7		
Oligohydramnios	6	5		
Fetal position			1.392	0.499
Cephalic presentation	51	52		
Breech presentation	9	10		
Transverse presentation	3	7		
Pregnancy stage*			1.196	0.232
Second trimester	21	30		
Last trimester	42	39		

Note: *those with 13-27 weeks of gestation are in the second trimester, and those with more than 27 weeks of gestation are in the last trimester.

may still produce unsatisfactory results due to physical and other factors [12, 13]. MRI, on the other hand, can effectively improve the diagnostic accuracy of fetal brain malformations, overcome the limitations of ultrasonography and provide accurate imaging information for the diagnosis of fetal malformations [14, 15].

For now, there are few studies on the application of 1.5T MRI in evaluating fetal malformations. Accordingly, 132 pregnant women were included and divided into a control group (CG) for Color Doppler ultrasonography and a research group (RG) for 1.5T MRI to compare the differences in detection rate and diagnostic value, in order to explore the application value of 1.5T MRI in the diagnosis of fetal malformations.

Materials and methods

Baseline data

This is a retrospective study. One hundred and thirty-two pregnant women admitted to Shijiazhuang NO.4 Hospital were included and divided into CG and RG according to different diagnostic methods. In CG (n=63), the mean age was 30.15±2.13 years (range: 23-41), the mean body mass index (BMI) was 20.37±0.53 kg/m^2, and the mean gestational age was 29.54±1.81 weeks (range: 24-35); there were 48 cases with normal amniotic fluid, 9 with polyhydramnios and 6 with oligohydramnios; 51 cases had fetus in cephalic presentation, 9 had fetus in breech presentation, and 3 had fetus in transverse presentation. In RG (n=69), the mean age was 31.01±1.97 years (range: 24-43), the mean BMI was 20.29±0.48 kg/m^2, and the mean gestational age was 30.42±1.92 weeks (range: 23-35); there were 57 cases with normal amniotic fluid, 7 with polyhydramnios and 5 with oligohydramnios; 52 cases had fetus in cephalic presentation, 10 had fetus in breech presentation, and 7 had fetus in transverse presentation. Age, BMI, gestational age, amniotic fluid volume and fetal position were similar in the two groups, indicating the feasibility for follow-up study (**Table 1**). The internal ethics committee approved this research (Approval No.: 20200025), and all the participants signed an informed consent in accordance with the *Declaration of Helsinki*.

Inclusion and exclusion criteria

The pregnant women were included in the study if they fulfilled the following criteria: (1) age ≥20 years; (2) first pregnancy with a single fetus; (3) 1.5T MRI examination suggested by the obstetrician; (4) gestational age >14 weeks; (5) voluntary participation. Exclusion criteria: pregnant women (1) with mental disorders; (2) with contraindications to 1.5T MRI or ultrasound; or (3) who could not hold breath for 20 seconds or breath-hold repeatedly.

Methods

The pregnant women were allocated into CG and RG according to different examination methods. Patients in RG received 1.5T MRI with the 1.5T Aera 6-Channel Body Anterior MRI Coil (Siemens, Japan). The setting of MRI scan: T2 Haste, layer thickness: 4 mm, interlayer spacing: 20%; T2 turfi, 4 mm, no spacing. The examination lasted for 10-20 min, with an average of 15 min. The instrument scanned the head and abdomen of the fetus. After scan-

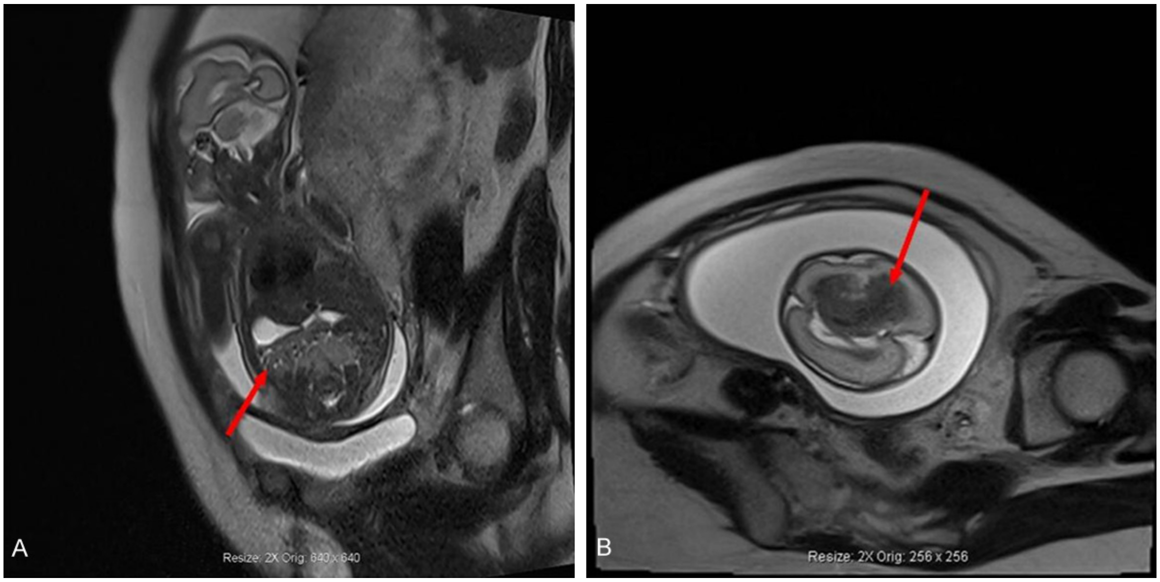

Figure 1. 1.5T MRI images of head deformities. A: Displacement. B: Cerebral hemorrhage.

ning, the slightly misaligned image was reconstructed in the same direction at a small angle of no more than 30° to make the image more correct for accurate diagnosis, otherwise scanning was re-performed. Participants in CG received Pulsed Color Doppler ultrasonography with the apparatus purchased from Philips, Japan. The probe frequency was set at 2-4 MHz, and a comprehensive screening of the fetus in the abdomen was applied in CG. Ultrasound and 1.5T MRI images were read by professionals for evaluation and diagnosis.

Outcome measures

The detection rates in RG and CG were compared based on the postpartum histopathology diagnosis results. Head deformities include congenital hydrocephalus, cranial stenosis, brain perforating deformation, megacephaly and microcephaly. Abdominal malformations cover gastrointestinal atresia, umbilical hernia and abdominal fissure. The two groups were compared with respect to sensitivity, specificity, accuracy, misdiagnosis rate and missed diagnosis rate. The image quality of 1.5T MRI in different amniotic fluid volume, different gestational weeks with normal amniotic fluid and different fetal positions with normal amniotic fluid was also compared.

Statistical analysis

SPSS 22.0 (IBM, USA) was used for statistical analysis. The measurement data were recorded in the form of mean ± standard deviation, and were compared statistically by the independent sample t-test. The counting data were expressed as cases (%), and were compared by the Chi-square test. Receiver Operating Characteristic Curve (ROC) was used to determine the diagnosis value of 1.5T MRI with Pulsed Color Doppler ultrasonography as a control. The comparison was statistically significant when the P value was less than 0.05. All statistical comparisons were two-tailed.

Results

1.5T MRI image quality evaluation

Typical images of head and abdominal deformities in 1.5T MRI examination are shown in **Figures 1** and **2**. The 1.5T MRI image quality in patients with normal amniotic fluid at different gestational weeks, with different fetal positions and normal amniotic fluid, or with different amniotic fluid volume was counted. When the amniotic fluid was normal, the image quality of the second trimester was excellent in 20 cases, good in 4 cases and poor in 2 cases; the image quality of late trimester was excellent in 18 cases, good in 8 case and poor in 5 case (**Table 2**). Also under the condition of normal amniotic fluid, the image quality of head presentation was excellent in 31 cases, good in 9 cases and poor in 5 cases; the image quality of breech presentation was excellent in 5 cases, good in 2 cases and poor in 1 case; the image quality

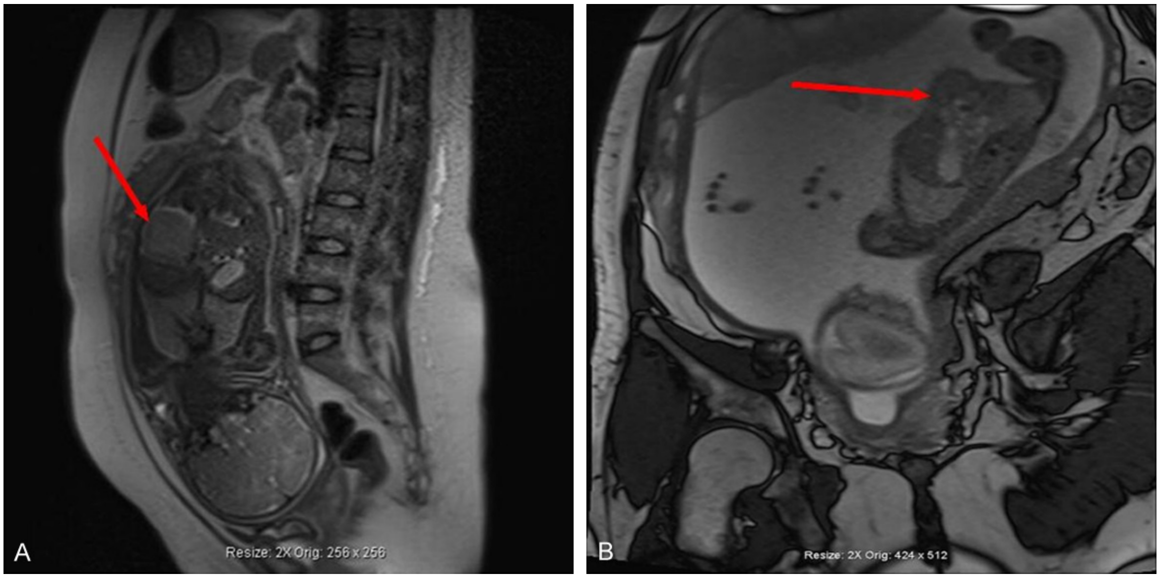

Figure 2. 1.5T MRI images of abdominal deformities. A: Mesodermal nephroma. B: Bulging liver.

Table 2. Quality assessment of 1.5T MRI images in patients with normal amniotic fluid at different gestational weeks (n=57)

	Second trimester	Last trimester	X^2	P
Excellent	20	18		
Good	4	8		
Poor	2	5		
Total	26	31	2.303	0.316

of transverse presentation was excellent in 2 cases, good in 1 case and poor in 1 case (**Table 3**). When the amniotic fluid was normal, the image quality was excellent in 38 cases, good in 12 cases and poor in 7 cases. In the case of hyperhydramnios, the image quality was excellent in 4 cases, good in 1 case and poor in 2 cases; while in the case of oligohydramnios, the image quality was excellent in 3 cases, good in 1 case and poor in 1 case (**Table 4**). The above statistical results demonstrate that the image quality of 1.5T MRI is not affected by different gestational age with normal amniotic fluid, different fetal positions with normal amniotic fluid, or different amniotic fluid, indicating the feasibility of 1.5T MRI in detecting fetal malformations.

Comparison of the deformity detection rate between the two groups

In this study, the malformations were detected in both groups, and the results are shown in **Table 5**. In CG, 32 deformities were detected, including 11 cases of congenital hydrocephalus, 8 cases of cranial stenosis, 6 of brain perforating deformation, 2 of megacephaly, 3 of microcephaly, and 1 of gastrointestinal atresia, umbilical hernia, and abdominal fissure. In RG, 48 deformities were detected, including 13 cases of congenital hydrocephalus, 6 cases of cranial stenosis, 3 of brain perforating deformation, 7 of megacephaly, 9 of microcephaly, 6 of gastrointestinal atresia, and 4 of umbilical hernia and abdominal fissure. According to the results of postpartum histological and pathological analysis, there were 39 cases of head and abdominal deformities in CG and 50 cases in RG, demonstrating a significantly higher deformity detection rate in RG.

Diagnostic value of 1.5T MRI in fetal malformations

This study compared the diagnostic value of 1.5T MRI and ultrasound in the diagnosis of malformations, and the results are shown in **Tables 6** and **7**. With the results of histopathological examination as the gold standard, we found 39 cases of malformations and 24 cases of non-malformations in CG, while 50 cases of malformations and 19 cases of non-malformations in RG (**Table 6**). Further, we compared the diagnostic value of ultrasound and 1.5T MRI based on the above results (**Table 7**). The sensitivity, specificity, accuracy, missed diag-

Table 3. Quality evaluation of 1.5T MRI images in patients with different fetal positions and normal amniotic fluid (n=57)

	Head presentation	Breech presentation	Transverse presentation	χ^2	P
Excellent	31	5	2		
Good	9	2	1		
Poor	5	1	1		
Total	45	8	4	0.911	0.923

Table 4. Quality evaluation of 1.5T MRI images in patients with different amniotic fluid volume (n=69)

	Normal amniotic fluid normal group	Polyhydramnios group	Oligohydramnios group	χ^2	P
Excellent	38	4	3		
Good	12	1	1		
Poor	7	2	1		
Total	57	7	5	1.505	0.825

Table 5. Deformity detection rates in two groups

	Control group (n=63)	Research group (n=69)	χ^2	P
Congenital hydrocephalus	11/15	13/14		
Cranial stenosis	8/9	6/7		
Brain perforating deformation	6/8	3/3		
Megacephaly	2/2	7/7		
Microcephaly	3/3	9/9		
Gastrointestinal atresia	1/1	6/6		
Umbilical hernia and abdominal fissure	1/1	4/4		
Total	32/39	48/50	4.690	0.03

nosis and misdiagnosis rates were 82.05%, 75.00%, 79.37%, 17.95% and 25.00% respectively in CG where ultrasonography was performed, and they were 96.00%, 94.74%, 95.65%, 4.00% and 5.26% respectively in RG where 1.5T MRI was performed. The data identified significant differences in sensitivity, accuracy and missed diagnosis between RG and CG, while no distinct differences in specificity and misdiagnosis rate. Moreover, the ROC curve determined that the area under the curve of 1.5T MRI in the diagnosis of malformations was 0.9569 (**Figure 3**; 95% CI: 0.9214-0.9793).

Discussion

Fetal malformations refer to structural/functional defects caused by abnormal development of embryo or fetus, with various triggers. Gene defects or gene-environment interactions can alter the normal development of fetus and cause abnormal organ development [16]. Besides, environment plays an important part in fetal malformations. Fetal malformation is a grave global health problem, affecting the health of millions of newborns around the world [17]. In addition, fetal malformations are the major cause of perinatal death, which leads to adverse birth outcomes [18]. A study points out that most fetal malformations are idiopathic and that effective prenatal ultrasound examination may help reduce perinatal morbidity and mortality [19], suggesting that effective prenatal examination is beneficial to ameliorate the adverse outcome caused by fetal malformations.

Ultrasound, the preferred means of prenatal examination, is a reliable diagnostic tool for prenatal screening of fetal central nervous system malformations [20]. However, although economical and convenient to operation as it is, it still has many limitations. For example, ultrasound often misses information about specific deformities, leading to doctors' wrong assessment of the severity of deformities [21]. MRI, on the other hand, is an emerging technology with multi-plane capabilities, high resolution and wide field of vision, which can compensate the limitations of ultrasound examination [22]. MRI is shown to be essential in fetal cardiovascular monitoring [23], indicating that MRI has an optimistic prospect of prenatal screening for fetal malformations. Another study points out that MRI can provide vital structural and functional information in monitoring fetal urinary defects, thus improving the accuracy of screening results [24]. In the present study, it was found that the image quality of 1.5T MRI was not affected by different gestational age with nor-

Table 6. Comparison of diagnostic results between the two groups

Pathology	n	Ultrasound		Pathology	n	1.5T MRI	
		Deformity	Non-deformity			Deformity	Non-deformity
Deformity	39	32	7	Deformity	50	48	2
Non-deformity	24	6	18	Non-deformity	19	1	18
Total	63	38	25	Total	69	49	20

Table 7. Diagnostic value of 1.5T MRI and ultrasound for fetal malformations

	Control group	Research group	χ^2	P
Sensitivity	82.05 (32/39)	96.00 (48/50)	4.690	0.03
Specificity	75.00 (18/24)	94.74 (18/19)	3.031	0.08
accuracy	79.37 (50/63)	95.65 (66/69)	8.201	0.004
Missed diagnosis rate	17.95 (7/39)	4.00 (2/50)	4.690	0.03
Misdiagnosis rate	25.00 (6/24)	5.26 (1/19)	3.031	0.08

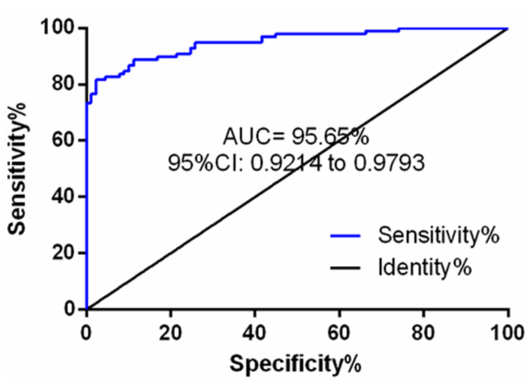

Figure 3. ROC determined the diagnosis value of 1.5T MRI, with the results of pulsed color doppler ultrasonography as the control. AUC: area under the curve; CI: confidence interval.

mal amniotic fluid, different fetal positions with normal amniotic fluid, or different amniotic fluid, indicating that 1.5T MRI is feasible in fetal malformation imaging. Then, we compared the detection rate of 1.5T MRI and ultrasound in fetal malformations and determined higher detection rate in the former. In regard to diagnostic value, 1.5T MRI was superior in sensitivity and accuracy over ultrasound, with a lower missed diagnosis rate; and though difference was insignificant, 1.5T MRI was higher in specificity and lower in misdiagnosis rate compared with ultrasound. These results demonstrate that 1.5T MRI benefits the detection of fetal head and abdominal malformations. Arko et al. hold the opinion that the application of MRI in neonatal examination can effectively facilitate decision on the timing of treatment and intervention [25].

Although this study preliminarily determined the diagnostic value of 1.5T MRI in prenatal screening, there is still room for improvement. As aforementioned, though ultrasound may miss some deformity information, it is low in cost and simple to operate. 1.5T MRI has a high economic cost, so it can be combined with ultrasound examination in future prenatal examination. Nevertheless, it is suggested that 1.5T MRI should be performed in patients with fetal abnormalities or suspected abnormalities diagnosed by ultrasound. In addition, the sample size included in this study was small due to time constraints. In future studies, more participants will be recruited to provide more reliable scientific data.

To sum up, this paper argues that 1.5T MRI has considerable diagnostic value in the early diagnosis of fetal malformations and is worthy of extensive popularization and application. In future prenatal screening, the combination of ultrasound and 1.5T MRI can be considered to further improve the accuracy of malformation screening.

Disclosure of conflict of interest

None.

Address correspondence to: Jin-Cai Wang, Radiology Department, Shijiazhuang NO. 4 Hospital (The Obstetrics and Gynecology Hospital Affiliated to Hebei Medical University), No. 16 Tangu North Street, Changan District, Shijiazhuang 050000, Hebei, China. Tel: +86-0311-89927139; E-mail: jincaiwang12@outlook.com

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