ORIGINAL ARTICLE

MRI as complementary tool added to ultrasound in the diagnosis of fetal renal abnormalities – any added value?

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Abstract  Purpose: To assess the potential role of magnetic resonance imaging (MRI) as a complementary diagnostic tool to ultrasonography (US) in the diagnosis of fetal renal anomalies in pregnant women with oligohydramnios in the absence of amniotic membrane rupture.

Methods: Ninety pregnant women, with oligohydramnios were prospectively evaluated using both US and MRI. Prenatal findings were correlated with the babies’ outcome.

Results: MRI studies of diagnostic quality were obtained in all fetuses. The US and MRI findings were concordant in 79 (87.8%) of the fetuses. MRI modified and changed the diagnosis in 11 fetuses (12.2%), these were five fetuses in which US diagnosis was inconclusive, five cases in which the

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Genital/reproductive; MRI; Ultrasound; Kidney; Fetus

Abbreviations: APCKD, autosomal recessive polycystic kidney disease; MCDK, multicystic dysplastic kidney
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1. Introduction

Anomalies of the genitourinary system are common, accounting for 14–40% of all anomalies that can be detected pre-natally. The spectrum of malformations is wide, and varies from minor to severe and their prognosis is significantly poorer in fetuses with bilateral lesions especially if associated with oligohydramnios (1). Although antenatal diagnosis of fetal anomalies is primarily based on US (2), yet this modality has its own limitations as it is operator dependent, with small field of view, limited soft-tissue acoustic contrast, beam attenuation by adipose tissue, poor image quality in oligohydramnios and obscuration of portions of the fetal anatomy by reverberation artifacts of the bony skeleton (3).

Magnetic resonance imaging (MRI) is an imaging modality that has no harmful or ionizing effect on fetuses even with high magnetic fields. Technical advances in fetal MRI have made it an increasingly important diagnostic tool in the clinical evaluation of different fetal anomalies (4–6). It has multiphase images, excellent soft tissue contrast, and wide visual field that allowed better understanding of the relation of the adjacent structures (7). MRI has been validated as an efficient technique to evaluate equivocal fetal sonographic findings (8–10).

The aim of this study was to assess the potential role of MRI as a complementary diagnostic tool to US in the diagnosis of fetal renal anomalies in pregnant women with oligohydramnios in the absence of amniotic membrane rupture.

2. Materials and methods

2.1. Study population

This study was conducted during the period between April 2008 and April 2012. Approval from hospital research and ethics committee was obtained in addition to a written informed consent from each patient. Inclusion criteria included women of any age, any parity, singleton pregnancy, gestational age of 18 weeks or more, the patient had at least one visit in the antenatal clinics at which the condition was discovered, and amniotic fluid index was < 5 cm. Exclusion criteria included any history suggestive of premature rupture of membranes, active leaking seen on speculum examination, and positive Amniocentesis test. All patients were referred from the obstetric department with US report that showed oligohydramnios with or without renal abnormality. Those patients were re-evaluated in the radiology department using firstly US and then MRI and both were on the same day.

2.2. Ultrasonography

US was performed using Logiq E9 scanner (GE Healthcare, Wauwatosa, WI, USA) using a C1–5 MHz sector transducer. US examination was done by an operator who had more than 17 years’ experience in obstetric US.

2.3. Magnetic resonance imaging

It was performed on the same day after US examination by another operator who had 10 years’ experience in fetal MRI and he was blinded regarding the results of US examination. All patients were instructed to fast for at least 4 h before the MRI examination to reduce bowel peristalsis artifacts and to prevent postprandial fetal motion. MRI was performed on a high-performance 1.5 T superconducting system (Signa HDxt 1.5 T; GE Healthcare, Milwaukee, WI) using surface coil (HD 12 channel body array coil; GE Healthcare, Aurora, Ohio, USA). All patients were examined in supine position.

An initial 15-s localizer (Table 1) was obtained in the three orthogonal planes to determine the fetal position. This was used to guide the initial imaging plane, which was selected to be anatomic to the fetal abdomen. Subsequent sequences were acquired in planes that were axial, sagittal and coronal to the abdomen with each sequence serving as a scout for subsequent imaging. At least two sets of good quality images were obtained in each anatomic plane.

Heavily T2-weighted images (Table 1) were the mainstay of all our examinations and were acquired using a single-shot fast spin-echo (SSFSE) sequence. Repetition of some sequences was required because the images were either degraded by fetal motion during acquisition or because fetal motion between

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Localizer</th>
<th>SSFSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>2D</td>
<td>2D</td>
</tr>
<tr>
<td>Pulse sequence</td>
<td>SSFSE</td>
<td>SSFSE</td>
</tr>
<tr>
<td>Frequency</td>
<td>256</td>
<td>512</td>
</tr>
<tr>
<td>Phase</td>
<td>192</td>
<td>224</td>
</tr>
<tr>
<td>Shim</td>
<td>Auto</td>
<td>Auto</td>
</tr>
<tr>
<td>Phase FOV</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>FOV</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Slice thickness in mm</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Spacing in mm</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>TE</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>TR</td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Band width</td>
<td>83.33</td>
<td>83.33</td>
</tr>
<tr>
<td>Scan time</td>
<td>17 s</td>
<td>Around 20 s</td>
</tr>
</tbody>
</table>
sequences resulted in images that are not in the true anatomic planes. Scanning time/slice was less than 1 s/image.

Image quality of the MRI studies were estimated subjectively using the following scale: (1) poor image quality and the fetus details were hardly seen; (2) accepted image quality in some sequences and fetus details were adequately obtained; (3) excellent image quality with the fetus details were assessed reliably.

For each fetus the following parameters were assessed: (a) amniotic fluid, whether normal or diminished, (b) visualization of urinary bladder, (c) and the presence, size and appearance of the kidneys.

2.4. Post-natal evaluation

Post-natal evaluation included post-natal US examination and kidney function tests. The postnatal US examination was performed using Logiq E9 scanner (GE Healthcare, Wauwatosa, WI, USA) using a ML 6–15 MHz linear transducer. Examinations were done by the same operator who did the prenatal US but at that time he was blinded regarding the results of the previous examination.

2.5. Statistical analysis

Descriptive statistics were calculated for patients’ age, parity, gestational age at diagnosis, amniotic fluid volume, image quality, and type of renal abnormality if any. Fetal MRI findings were correlated with US findings in all cases and both were then compared with results of postnatal examination.

Statistical analysis was performed using Minitab software version 12.2 for Windows. Results were expressed as mean ± standard deviation.

3. Results

Study included 90 pregnant women who fulfilled the inclusion criteria. The mean age was 26.6 ± 5.6 years, the mean parity was 3.16 ± 1.67, and the mean gestational age at diagnosis was 29 ± 5.5 weeks. MRI examinations were tolerated by all the women, fetal movement did not alter the image quality, and no sedation was used. An average of seven (5–12) sequences was obtained for every examination, with mean time of 17 ± 4.5 min.

On prenatal US examination, 41 had oligohydramnios (AFI < 5 cm) while others, 49, had anhydramnios (no single pocket free of cord or limbs). According to our subjective scale, 67 fetuses (74%) had an excellent MRI imaging quality while the other 23 (26%) had an accepted quality.

The results of the prenatal US and MRI scans, as well as the post-natal assessment, are shown in Table 2. Concordant findings for the prenatal US and MRI scans were seen in 79 fetuses (87.8%); and when results were stratified according to renal affections, similar findings were observed in 100% of the autosomal recessive polycystic kidney disease (APCKD), 96% of the bilateral multicystic dysplastic kidneys (MCDK), 92.9% of bilateral normal kidneys, and in 75.7% of bilateral renal agenesis.

Thirteen fetuses had normal kidneys (Fig. 1) by US and MRI, these findings were confirmed post-natally. 17 and 19 fetuses (Table 2) had PCKD (Fig. 2) and MCDK (Fig. 3), respectively by both prenatal US and MRI scans. Post-natal evaluation confirmed these findings.

Thirty-one fetuses were diagnosed by pre-natal US as having bilateral renal agenesis (Table 2), and when MRI was performed, this agenesis was detected in 25 while the remaining six had only unilateral agenesis with the other kidney structurally normal in one case and MCDK in the remaining five, post-natal evaluation confirmed the MRI diagnosis in 23 fetuses and eight fetuses died before evaluation.

Five fetuses (5.6%) had inconclusive findings by US. In one fetus, kidneys were not visualized by US due to extremely obese mother and when MRI was done it confirmed bilateral structurally normal kidneys. In one fetus, kidneys were not visualized by US and when MRI was done it showed small bilateral MCDK. In two fetuses, difficult fetus position prevented visualization of the kidney region optimally and when MRI was performed bilateral renal agenesis was confirmed. In the remaining one fetus, both kidneys were not visualized although the urinary bladder was visualized and when MRI was performed unilateral agenesis with structurally normal other kidney was detected (Table 2). Post-natal evaluation by US confirmed the MRI diagnosis and all the five fetuses and the findings were confirmed by the laboratory tests.

<table>
<thead>
<tr>
<th>Table 2 Pre-natal diagnosis by US and MRI compared to postnatal evaluation.</th>
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<tbody>
<tr>
<td><strong>Prenatal US diagnosis</strong></td>
</tr>
<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>Bilateral renal agenesis</td>
</tr>
<tr>
<td>Bilateral normal kidneys</td>
</tr>
<tr>
<td>Bilateral MCDK</td>
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<tr>
<td>Bilateral APCKD</td>
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<tr>
<td>Inconclusive findings</td>
</tr>
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</table>

MCDK: multicystic dysplastic kidney disease; APCKD: autosomal recessive polycystic kidney disease.
Fig. 1 Normal kidneys: (A) MRI axial T2 WI SSFSE; (B) Ultrasound.

Fig. 2 Autosomal recessive polycystic kidney disease: (A) MRI coronal T2 WI SSFSE shows enlarged both kidneys with bright signals, and multiple tiny cysts; (B) Ultrasound shows enlarged kidneys with hyperechogenic parenchyma.

Fig. 3 Multicystic dysplastic kidney disease: (A) MRI sagittal T2 WI SSFSE shows enlarged kidney with bright signals, and multiple variable size cysts; (B) Ultrasound shows enlarged kidney with multiple variable sized cysts.

Table 3 Urinary bladder visualization by prenatal US and MRI.

<table>
<thead>
<tr>
<th>Renal disease (US diagnosis)</th>
<th>Prenatal US</th>
<th>Prenatal MRI</th>
</tr>
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<tbody>
<tr>
<td>Bilateral renal agenesis (n = 31)</td>
<td>All non-visualized</td>
<td>Same as US diagnosis</td>
</tr>
<tr>
<td>Bilateral normal kidneys (n = 13)</td>
<td>All visualized</td>
<td>All visualized except 1</td>
</tr>
<tr>
<td>Bilateral MCDK (n = 24)</td>
<td>All non-visualized</td>
<td>Same as US diagnosis</td>
</tr>
<tr>
<td>Bilateral APCKD (n = 17)</td>
<td>8 Cases visualized and 9 cases non-visualized</td>
<td>Same as US diagnosis</td>
</tr>
<tr>
<td>Inconclusive findings (n = 5)</td>
<td>1 Case visualized and 4 cases non-visualized</td>
<td>Same as US diagnosis</td>
</tr>
</tbody>
</table>

MCDK: multicystic dysplastic kidney disease; APCKD: autosomal recessive polycystic kidney disease.
The urinary bladder was visualized in 22 cases by US (24.4%) and in 21 cases by MRI (23.3%). Bladder visualization by type of renal disease, for US and MRI, is shown in (Table 3).

Among the 90 fetuses involved in the study, postnatal evaluation was missed in 13 fetuses because they died immediately after birth. Eight of these were diagnosed by US as having bilateral renal agenesis and when MRI was performed the diagnosis was confirmed in seven, while the remaining one had unilateral renal agenesis while the other kidney was MCDK. The remaining five cases had the diagnosis of bilateral MCDK by both US and MRI.

4. Discussion

In this work we evaluated the role of MRI as complementary imaging modality to US in the evaluation of fetal renal anomalies in women with oligohydramnios. MRI was helpful in the inconclusive cases and of limited value in the remaining cases. No sedation was used.

Artifacts due to fetal movements were very minimal and never constituted a problem during scanning since the acquisition of a single section lasts around 1 s and the acquisition of a complete set of images never exceeded 25 s. The mainstay for diagnosis was heavily T2 that provided good visualization of different fetal organs (9,11). Moreover, the use of 12-channels phased array surface coil in our patients increased the signal-to-noise ratio that improved the final image resolution. These technical improvements increased the quality of images obtained in our study and made them of diagnostic quality.

In bilateral normal kidneys MRI and US gave equal results in all fetuses except in one case. US diagnosis was not so clear due to the reverberation artifacts of the fetal bones and the morbid maternal obesity, they obscure the normal kidney and MRI picked them. In the 14 cases with normal kidneys and oligohydramnios the explanation was as follows; one case received prostaglandin synthetase inhibitor (indomethacin) for 2 weeks to suppress preterm labor and this case later delivered by Caesarian section due to fetal distress and postnatal evaluation revealed normal renal function. Four cases had growth restriction with abnormal fetal weight at the time of diagnosis and abnormal or even no weight gain over the next 2 weeks following the diagnosis, all these babies were admitted to neonatal intensive care unit (NICU) and post-natal evaluations revealed normal renal functions, one died later due to severe respiratory distress syndrome (RDS). Rest of the cases, were idiopathic with no possible cause that could be detected pre-natally. All these fetuses when evaluated post-natally, normal renal function was detected and although eight were discharged later from NICU, one died due to sepsis.

In APCKD fetuses, our study showed equal results for both imaging modalities and this was in agreement with Poutamo et al. (12), who did not support the role of MRI in PCKD and concluded that fetal MRI did not provide more information than US. Also Cassart et al. (13) found similar findings.

In bilateral MCDK fetuses, US and MRI results were concordant except in one fetus in which US diagnosis was difficult because the kidneys were small and MRI easily detected small kidneys with bright signals. MRI diagnosed unilateral renal agenesis with the other kidney small MCDK in five cases, while US diagnosed them falsely as bilateral renal agenesis and the findings were confirmed in the post-natal evaluation except in one case that died before evaluation. So in unilateral and bilateral MCDK MRI was superior to US and modified the diagnosis in 16.6% of the cases and changed the diagnosis in 3.3% of the cases. These findings were different from Barsegghyan et al. (14) and mostly because they evaluated only seven cases while we evaluated 30 cases.

In bilateral renal agenesis cases MRI and US were concordant in 73.5% of the cases. MRI modified the diagnosis in 17.6% of the cases. The diagnosis of one case was modified from bilateral renal agenesis to unilateral renal agenesis with the other kidney normal, and the diagnosis of five cases was modified from bilateral renal agenesis to unilateral renal agenesis with the other kidney small MCDK, also MRI changed the diagnosis in 8.8% of cases from inconclusive to bilateral renal agenesis in two cases and unilateral agenesis with the other kidney normal in one case.

Urinary bladder evaluation was nearly equal by both techniques except in one fetus, where the urinary bladder was seen only by US, mostly because the bladder was empty at the time when MRI was performed.

Six (6.7%) fetuses had controversy in the results between US and MRI. Although all these fetuses labeled by US as having bilateral renal agenesis, MRI modified the diagnosis as five with unilateral agenesis while the other kidney was MCDK and the remaining case was with unilateral agenesis while the other kidney was structurally normal. The MCDK in these five fetuses although small, MRI detected all of them by the T2 bright signals.

Five (5.6%) fetuses had inconclusive findings by US and the acoustic window limitations was due to maternal obesity, oligohydramnios, and the fetal position which did not allow proper evaluation of the kidneys, MRI was the only available diagnoses and these findings were confirmed post-natally. Out of these, three fetuses (two with bilateral renal agenesis and one with bilateral MCDK) had poor prognosis while in the other two (one with structurally normal kidneys and one with unilateral structurally normal kidney) the findings were very important for the managing doctor.

According to the above data, MRI assisted the diagnosis in 11 (12.2%) fetuses (five cases with inconclusive results by US and six cases with controversy between US and MRI) 10 fetuses out of them had diagnosis of either renal agenesis or MCDK. Barsegghyan et al. (14) found that MRI modified the diagnosis in 36% of the cases and changed the diagnosis in 3% of the cases and similar findings were found by Gupta et al. (15). The differences between their studies and the current study mainly are due to the smaller number in their study and also because they evaluated all renal anomalies whereas we only evaluated renal anomalies associated with oligohydramnios.

Legal issues limit the practical relevance of our results, because termination of pregnancy is prohibited by the country law even with the presence of documented prenatal lethal anomalies, however, the provided findings by using both imaging modalities allowed the counseling doctor for preparing parents for poor neonatal outcome.

Our study had the following points of strength, (A) large number of the study population, (B) women were examined prospectively, (C) both imaging modalities were performed in all patients, and (D) prenatal evaluation was documented by postnatal examination in most cases. Main limitation of our
study was the non-availability of post-mortem evaluation in 13 fetuses due to parents’ refusal, which prevented the confirmation of the findings.

In conclusion, MRI is of value in cases of oligohydramnios in limited circumstance when US findings were inconclusive.

References