Diagnosis of Ectopic Pregnancy with MRI: Efficacy of \(T_2^*\)-weighted Imaging

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Purpose: To assess MRI in diagnosing ectopic pregnancy (EP), emphasizing \(T_2^*\)-weighted imaging (WI) efficacy.

Methods and Materials: This is a prospective study of 24 female patients (16 to 41 years, average 29.9) clinically suspected of EP from April 1999 to June 2001. Eighteen had minimal vaginal bleeding and slight abdominal pain. All had positive pregnancy tests, and sonography showed no intrauterine pregnancy despite estimated gestational age of embryos and/or high concentrations of human chorionic gonadotrophin. MRI was performed with a 1.5T imager (Siemens, Vision VB33A) with a body-array coil. \(T_2\)-WI (HASTE), \(T_1\)-WI (2D FLASH), and \(T_2^*\)-WI (2D FLASH) were obtained without contrast. \(T_2\)-WI was routinely obtained in 3 directions. \(T_2^*\)-WI orientation was determined based on the \(T_2\)-WI. One of 4 radiologists with experience interpreting abdominal MR images interpreted images based on transvaginal ultrasonography (TVUS) and laboratory results. Abnormal adnexal mass with remarkable low signal area on \(T_2^*\)-WI was diagnosed as EP.

Results: We diagnosed 19 cases as EP. Tubectomy in eighteen and abdominal total hysterectomy in one confirmed diagnosis. In one undergoing diagnostic laparoscopy, EP was denied. In 5 cases diagnosed negative based on the above criterion, no mass was detected in three, and no area of low signal was recognized on \(T_2^*\)-WI in the masses in two.

EP was denied in four of five, and in one of the five, who underwent tubectomy, EP without bleeding was diagnosed. All EP were tubal pregnancies at final diagnosis, 19 were ampullar pregnancies and one, interstitial. Using MRI to diagnose EP, with \(T_2^*\)-WI as a key diagnostic factor, sensitivity was 95\%, specificity 100\%, and accuracy 96\%.

Conclusions: MRI using \(T_2^*\)-WI is a sensitive, specific, and accurate method to evaluate EP. \(T_2^*\)-WI is highly accurate for detecting and diagnosing EP because of its sensitivity to fresh hematoma.

Keywords: ectopic pregnancy, MRI, \(T_2^*\)-weighted imaging

Introduction

Ectopic pregnancy (EP) is becoming more common because of the increase in salpingitis related to sexually transmitted disease (STD), mainly Chlamydia trachomatis infection.\(^1\) Assisted reproductive technologies may also contribute to increased cases of EP.

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Early detection of EP is not uncommon because of the wide availability of qualitative analysis of urinary human chorionic gonadotropin (UCG) and because of the popularity of transvaginal ultrasonography (TVUS). However, though typical cases of EP are not difficult to diagnose, some are difficult to establish by these traditional examinations.\(^4\)\(^-\)\(^7\) Those difficult cases are candidates for diagnostic laparoscopy. Options for treating EP include radical, conservative, and laparoscopic surgery and medical and expectant treatment.\(^3\)
Accurate noninvasive diagnosis is important for adequate therapy. Although diagnostic laparoscopy remains the standard reference in diagnosing EP, high-resolution TVUS, in conjunction with qualitative serum assays of the beta subunit of human chorionic gonadotropin (beta-hCG), allows detection of earlier and smaller EPs. Current therapeutic options for EP include expectant management (i.e., close follow-up), medical treatment (usually injections of methotrexate), and surgery. Accurate diagnosis with TVUS is prerequisite to nonsurgical management, and surgery is the logical treatment with diagnosis by laparoscopy.

Previous reports demonstrated the value of MR imaging in identifying hemorrhagic adnexal mass suggestive of EP. Bradley reported that T2 shortening from magnetic susceptibility effects is enhanced on gradient-echo images (T1*-weighted images [WI]) and reduced with “fast spin-echo” MR techniques (T2-WI). In a fresh hematoma, the short T2 is observed when deoxyhemoglobin, methemoglobin is intracellular. The purpose of this study is to assess the usefulness of MRI, with an emphasis on the efficacy of T2*-WI, in diagnosing EP. To our knowledge, this is the first such English report.

Materials and Methods

We studied 25 consecutive women clinically suspected of having EP who underwent MR image evaluation at the Kameda Medical Center (Kamagawa, Japan) between April 1999 and June 2001. We excluded one because the strong influence of intestinal tract gas precluded T2*-WI evaluation and examined the 24 remaining cases. Pregnancy tests were positive in all patients. Vaginal bleeding was observed in 13 and slight abdominal pain in 18. Six patients had or 18 were scheduled to undergo dilatation and curettage (D & C).

Sonographic studies preceded MR imaging in all patients. Intrauterine pregnancies were denied with TVUS in all patients except one case in which intrauterine pregnancy was difficult to distinguish from interstitial pregnancy. Mean gestational age at diagnosis was 7 weeks (range 5 to 10). Exact hCG value (last measurement before MR examination) was obtained in 21 cases (128 to 25800 mIU/mL, mean 6150 mIU/mL), of which 17 (81%) showed hCG concentrations 1000 mIU/mL. The gold standard for final diagnosis of EP was a consensus among laparoscopy, surgery, serial hCG concentration, D & C, and sonographic findings. Among the 24 patients, 22 underwent laparoscopy, which confirmed 18 EP in 18 cases. Of the 18, 17 underwent tubectomy, and one underwent abdominal total hysterectomy (ATH).

Pelvic MR imaging was performed using a 1.5T superconducting system (Magnetom Vision VB33A, Siemens, Erlangen, Germany) with a torso phased-array coil. We performed the following pulse sequences: axial T1-weighted gradient echo imaging (2D fast low angle shot [FLASH]: repetition time/echo time/flip angle/number of excitations [TR/TE/FA/NEX] = 157 ms/4.1 ms/80/1; acquisition time = 20 s; slice thickness = 5 mm; field of view [FOV] = 250 to 300 mm; matrix 128 × 256), axial, coronal, and sagittal T2-WI (half-Fourier single shot turbo spin-echo [HASTE]; TR/TE/NEX = ∞/64 ms/1; acquisition time = 23 to 27 s; slice thickness = 6 mm; FOV = 300 to 350 cm; matrix = 160 to 240 × 256). Orientation of T2*-WI (2D FLASH: TR/TE/FA/NEX = 748 ms/18 ms/15/1; acquisition time = 215 s; slice thickness = 6 mm; FOV = 250 to 300 mm; matrix = 192 × 256) was determined referring to the 3 directional T2-WIs. Contrast-enhanced T1-WI with gadolinium (Gd) were not obtained. No drugs were used to reduce peristaltic artifacts. Total examination time was about 20 min. Informed consent was obtained from all patients prior to MRI. With knowledge of the TVUS and laboratory results, one of 4 radiologists on duty with experience in interpreting abdominal MR images interpreted the images. The criteria for EP on MRI were detection of (1) no intrauterine gestation sac (GS) on T1-WI and detection of (2) abnormal adnexal mass on T1 and/or T2-WI, with remarkable low signal area on T2*-WI. EP was diagnosed when both (1) and (2) were satisfied. Mass and other structures were distinguished by observing 3-directional T2-WI.

Results

Based on the gold standard consensus above, EP was the final diagnosis in 19 cases. All were tubal pregnancies: 18 ampullar and one interstitial. Figure 1 summarizes MR findings and treatment results of all cases. Based on the stated diagnostic criteria, there were 18 true positive cases, 5 true negative cases, and 1 false negative case. Signal intensity of tubal hematomas was predominantly intermediate to high on T1-WI and mixed on T2-WI with areas of remarkable low intensity characteristic on T2*-WI in all true-positive patients (Figs. 2–4). Areas of remarkable low signal intensity in hematomas were clearly recognized only on T2*-WI (Fig. 3). One false negative patient was early-stage EP without hematoma (Fig. 5). In the 18 true positive cases, 17 with ampullar pregnancies under-
Fig. 1. Diagram shows results of 24 patients who underwent MRI for suspicion of ectopic pregnancy (EP).

Patients underwent MRI (n = 24)

MRI diagnosis of EP (n = 18)
- Tubectomy (n = 17)
- Final diagnosis of EP
- ATH because of interstitial pregnancy (n = 1)

MRI diagnosis of Not EP (n = 6)
- No mass (n = 4)
- No low signal area on T2*-WI (n = 2)
- Conservative follow up (n = 2)
- Diagnosis of pregnancy in the septate uterus on MRI (n = 1)
- Diagnostic laparoscopy (n = 1)
- Diagnostic laparoscopy (n = 1)
- Tubectomy (n = 1)

Final diagnosis of Not EP
Final diagnosis of EP

Fig. 2. A 26-year-old woman with ectopic pregnancy (EP). This is a typical case. An abnormal mass (arrow) with remarkable low signal area with T2*-WI was diagnosed as EP.
went tubectomy and the one case with interstitial pregnancy underwent ATH. One true negative case was pregnancy with septate uterus. GS was demonstrated in the uterus with MR imaging (Fig. 6). We detected no mass in three of 5 true negative patients. In two of 5 cases, we recognized adnexal masses, but no area of remarkable low signal intensity was noted in the masses with \text{T}_2^*-\text{WI} (Fig. 7). Therefore, the sensitivity was 95\% (18/19), the specificity 100\% (5/5), and the accuracy 96\% (23/24) for the diagnosis of EP (Table).

**Discussion**

An EP is a clinical condition in which a fertilized ovum implants and grows at a site other than the uterine cavity. More than 95\% of EPs occur in the Fallopian tubes. Within the tube, most EPs are found in the ampulla (75 to 80\%), with about 10 to 15\% isthmic and 5\% at the fimbriae. Epidemiologic studies note an increased incidence of EP of 1\% to 2\% over the past 25 years because of the prevalence of risk factors, including pelvic inflammatory disease (PID), assisted fertilization, in-dwelling intrauterine device, and prior EPs. Although the prevalence of EP has increased, most cases are diagnosed unruptured at the early stage of pregnancy owing to the recent progress in diagnostic tests and ultrasonography. Surgery is still the standard treatment for EP; however, there is a recent trend towards treating EP either medically or not at all. These medical regimens most often use methotrexate (MTX) administered systemically or locally into the ectopic sac or hematosalpinx. Early institution of medical therapy with MTX diminishes the risk of rupture, decreases patient morbidity and health care costs, and avoids surgery and hospitalization. This approach requires a highly accurate noninvasive test to evaluate patients with EP. Accurate determination of size of the extrauterine gestation is important because early EP measuring less than 4 cm can be treated medically with MTX.\textsuperscript{16} Trophoblastic vascular invasion in tubal pregnancy is a common pathologic finding.\textsuperscript{17} It is important that the maternal vessels rupture into the GS that cause the hematosalpinx.\textsuperscript{17} TVUS
is highly accurate in the diagnosis of EPs and is, of course, the first modality of choice. The most highly specific finding is an extrauterine GS containing a yolk sac or embryo. However, the most adnexal finding is an echogenic homogeneous or heterogeneous, rounded or elongated solid structure, located outside, but in proximity to the ovary, indicating hematosalpinx. In tubal pregnancy, the Fallopian tube is enlarged by products of conception, blood, and blood clots. Sonography enables identification of this hematosalpinx based on echogenic and morphological characteristics. Unfortunately, this diagnosis is not specific because sonography cannot characterize blood. Ultrasound also has some weak points: intestinal gases cause some blind areas; obese patients are difficult to examine; and ultrasonography is insufficient to characterize the abnormality.

MR imaging is useful in diagnosing EP because it is superior in both positional information and tissue characterization. MR findings include hematosalpinx, bloody ascites, and a heterogeneous adnexal mass composed of a hematoma and GS. The hematosalpinx and bloody ascites are of intermediate signal intensity on T1-WI. The heterogeneous mass has mixed signal intensity on T2-WI. It was reported that identification of fresh blood seems highly important in diagnosing early tubal pregnancy. According to the authors, MR imaging is unique as the only modality capable of allowing identification of the stage of a hematoma. Our MR criteria for diagnosis for tubal pregnancy

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**Fig. 4.** A 33-year-old woman with multiple adnexal abnormal masses. This case was equivocal on transvaginal ultrasonography (TVUS) because of multiple adnexal masses. Though it is diagnosed obviously as left tubal pregnancy (arrow) with ovarian cysts on MRI. Remarkable low signal area with T2*-WI is seen.
are based on hematoma. In a fresh hematoma, the short is $T_2$ observed when deoxyhemoglobin, methemoglobin is intracellular.$^{15}$ Fast spin-echo images are not sensitive to magnetic susceptibility effects as a result of the rephasing effect of multiple 180° pulses. However, gradient echo sequences with low flip angle yield $T_2^*$-WI, which are very sensitive to differences in magnetic susceptibility. $T_2^*$-weighted images are useful for identification of hemorrhage by demonstrating deoxyhemoglobin and hemosiderin contents. In our study, MR gave 18 true positive, 5 true negative, one false negative, and no false positive results for the diagnosis of tubal pregnancy. The predominant signal intensity of tubal hematomas was intermediate to high on $T_1$-WI, mixed signal intensity on $T_2$-WI, and remarkable area of low signal intensity in hematoma on $T_2^*$-WI in all true positive patients. We detected no mass in three of 5 true negative patients. In two of 5 cases, we recognized adnexal mass, but no area of low signal in the masses on $T_2^*$-WI, so EP could be correctly denied. In only one false negative case, we recognized adnexal mass, but no area of low signal in the mass on $T_2^*$-WI. This patient was at an early stage of EP without hematoma as a result of operation. Such a case is rare, and our method is not useful in such patients. So, comprehensive diagnosis with other clinical information and close follow-up are important and help accurate diagnosis.

Identification of blood seems highly important in diagnosing tubal pregnancy. Our results show the superiority of $T_2^*$-WI in detecting and characterizing EP because of its sensitivity to fresh hematoma. $T_2^*$-WI could recognize fresh hematoma in all true positive cases and its absence in all true negative cases.

Fig. 5. A 16-year-old woman with ectopic pregnancy (EP). This is a false negative case. Right abnormal mass (arrow) was recognized on MRI, but there was no low signal area with $T_2^*$-WI in the mass.
Fig. 6. A 19-year-old woman with pregnancy in septate uterus. This case suspected of being interstitial pregnancy on transvaginal ultrasonography (TVUS) is diagnosed obviously as normotopic pregnancy in the right side of septate uterus on MRI.

Fig. 7. A 19-year-old woman with a right adnexal mass. This is a true negative case. Right abnormal mass (arrow) is recognized on MRI, but there is no low signal area with T2*-WI in the mass.

cases with adnexal mass. However, T1- and T2-WI could not diagnose fresh hematoma clearly in all true positive and negative cases because signal intensity of tubal hematomas on T1- and T2-WI were not specific. T2*-WI has some drawbacks: intestinal gases and/or motion artifact. However, in our study, only one in 25 cases could not be evaluated. Some author reported the sensitivity of echo planar imaging (EPI) for the detection of acute and chronic blood products.18 Though we did
Table. The overall result of MRI in the diagnosis of EP

<table>
<thead>
<tr>
<th>MRI Diagnosis</th>
<th>Final Diagnosis</th>
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<tbody>
<tr>
<td></td>
<td>EP</td>
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<td>Total</td>
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<tr>
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<td>18</td>
<td></td>
</tr>
<tr>
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<td>6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>5</td>
<td>23</td>
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sensitivity: 95%, specificity: 100%, accuracy: 96%.
Note.-Numbers are numbers of cases. EP = ectopic pregnancy.

not investigate EPI in this study, it is worth considering its usefulness diagnosing EP.

Some authors have reported that Gd-enhanced T1-WI is useful in diagnosing EP because increased vascularity of the tubal wall following implantation enhances the wall. In this study, we made our diagnoses without Gd-enhanced T1-WI. Although we used Gd-enhanced T1-WI initially, we found that detection of the Fallopian tubes was not always easy. Furthermore, the side effects of Gd, additional cost, and examination time became subjects of discussion. Although our cases were evaluated without contrast enhancement, hematoma and/or a GS-like structure was identifiable and correctly diagnosed in 18 of 19 cases.

In conclusion, non-contrast MR imaging using T2*-WI is a sensitive, specific, and accurate method for evaluating EP. We would like to emphasize that the efficacy of T2*-WI contributes to the high accuracy in detection and diagnosis of EP because of its sensitivity to fresh hematomas.

References