ORIGINAL RESEARCH

Utility of ultrasound and magnetic resonance imaging in prenatal diagnosis of placenta accreta: A prospective study

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ABSTRACT

Context: Placenta accreta is the abnormal adherence of the placenta to the uterine wall and the most common cause for emergency postpartum hysterectomy. Accurate prenatal diagnosis of affected pregnancies allows optimal obstetric management. **Aims:** To summarize our experience in the antenatal diagnosis of placenta accreta on imaging in a tertiary care setup. To compare the accuracy of ultrasound (USG) with color Doppler (CDUS) and magnetic resonance imaging (MRI) in prenatal diagnosis of placenta accreta. **Settings and Design:** Prospective study in a tertiary care setup. Materials and Methods: A prospective study was conducted on pregnant females with high clinical risk of placenta accreta. Antenatal diagnosis was established based on CDUS and MRI. The imaging findings were compared with final diagnosis at the time of delivery and/or pathologic examination. **Statistical Analysis Used:** The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for both CDUS and MRI. The sensitivity and specificity values of USG and MRI were compared by the McNemar test. **Results:** Thirty patients at risk of placenta accrete underwent both CDUS and MRI. Eight cases of placenta accreta were identified (3 vera, 4 increta, and 1 percreta). All patients had history of previous cesarean section. Placenta previa was present in seven out of eight patients. USG correctly identified the presence of placenta accreta in seven out of eight patients (87.5% sensitivity) and the absence of placenta accreta in 19 out of 22 patients (86.4% specificity). MRI correctly identified the presence of placenta accreta in 6 out of 8 patients (75.0% sensitivity) and absence of placenta accreta in 17 out of 22 patients (77.3% specificity). There were no statistical differences in sensitivity (P = 1.00) and specificity (P = 0.687) between USG and MRI. **Conclusions:** Both USG and MRI have fairly good sensitivity for prenatal diagnosis of placenta accreta; however, specificity does not appear to be as good as reported in other studies. Both modalities have complimentary role and in cases of inconclusive findings with one imaging modality, the other modality may be useful for obtaining the diagnosis. CDUS remains the first primary modality for antenatal diagnosis of placenta accreta, with MRI reserved forcases where USG is inconclusive.

Keywords: Accreta; color Doppler ultrasound; magnetic resonance imaging, placenta

INTRODUCTION

Placenta accreta refers to abnormal placentation in which chorionic villi attach directly to or invade the myometrium.

It is a significant cause of maternal morbidity and mortality, and is now the most common indication for emergency postpartum hysterectomy.[1] Its prevalence has risen multifold over the past years, primarily due to the increasing percentage of pregnant patients undergoing primary and repeat cesarean sections.

Two studies conducted in the United States suggest a prevalence of 1 in 2500 deliveries, with both studies using clinical as well as pathologic diagnoses.[2] Several studies, both from the United States and abroad, suggest a higher prevalence of about 1 in 500 deliveries[3,4].

Though there is no published data regarding the incidence or prevalence of placenta accreta in the Indian population, retrospective analysis of data from our institute also demonstrated similar rise inits incidence. Therewere 20,735 deliveries from January 2009 to September 2012, with 10 confirmed cases of placenta accreta, making an incidence of 1/2073. The incidence has increased from 1/5647 deliveriesin 2009 to 1/969 deliveries in 2012.

The clinical consequence of placenta accreta is

massive hemorrhage at the time of placental separation. This massive hemorrhage may be associated with serious complications like disseminated intravascular coagulopathy, renal failure, adult respiratory distress syndrome, and may evenresult in patient's death. Emergency hysterectomy is the final resort and may result in associated complications like injury to ureter or urinary bladder and pulmonary embolus[5].

Accurate prenatal diagnosis of placenta accreta is crucial for appropriate patient management. Based on this diagnosis, the patient is planned for delivery at a tertiary care setup with facilities of anesthesia and surgery. The cesarean section is planned electively before 37 weeks of gestation to prevent spontaneous labor.

Identification and management of placenta accreta is a clinical and diagnostic challenge being encountered with increasing frequency. Clinicians should be aware of the clinical issues and risk factors, and radiologists with imaging protocol and findings associated with it to facilitateoptimal case management.

The present study aims to evaluate the role of color Doppler ultrasonography (CDUS) and magnetic resonance imaging (MRI) in antenatal diagnosis of placenta accreta, to compare the accuracy of the two modalities, and to formulate a protocol for imaging in patients clinically suspected of placenta accreta.

MATERIALS AND METHODS

The present study was designed as a prospective study and carried out in the Department of Radiology in collaboration with the Department of Obstetrics and Gynecology and the Department of Pathology in a tertiary care setup. Approval was obtained from the institutional review board. A written informed consent was obtained from all patientsundergoing MRI.

Thirty pregnant females attending/referred to the obstetrics and gynecologydepartment, fulfilling the inclusion criteria,were included in the study.

INCLUSION CRITERIA

- All pregnant females with high clinical suspicion of placenta accreta based on riskfactors including previous cesarean sections/uterine surgeries and dilatation and curettage, uterine anomalies, submucous leiomyoma, Asherman's syndrome, advanced maternal age, multiparty, hypertension, and smoking
- Pregnant females with previous cesarean sections andUSG diagnosis of placenta previa.

All patients were evaluated along the following lines:

HISTORY

A detailed history regarding age, gravidity, parity, number of previous cesarean sections, previous dilatation and curettage, and uterine surgery was recorded.

IMAGING

All patients underwent CDUS and non-contrast MRI. The USG examination and interpretation of MRI images was done by two separate radiologists, SK with 12 and BS with 9 years of experience in radiology, respectively. The two radiologists were blinded with the results of either modality. Since the patients presented at varied times of gestation, there was no specific gestational age at which imaging was performed. Majority of the patients presented in third trimester, and imaging including CDUS and MRI was performed on the same day as one modality followed by the other. Since the safety of MRI is not proven in earlypregnancy and also the placenta changes its position relative to cervical os with the growth of uterus, imaging was performed at first presentation of patient to the hospital, but not before 20 weeks of gestation.

EXCLUSION CRITERIA

Patients with contraindication to MRI like having pacemaker, cochlear implants, etc., and with claustrophobiawere not included in the study.

USG EVALUATION

All patients underwent USG evaluation, transabdominal or transvaginal, using gray-scale and color/power Doppler settings. The exam was performed on 2-D color Doppler machine "Nemio XG"(Toshiba Medical System, Japan) using 4.0-6.0 MHz curved array transducer or 5.0-7.5 MHz endovaginal probe. The Doppler power settings were at the level approved for fetal use. Gray-scale B mode USG was first used to screen the placental tissue, followed by color Doppler flow.USG findings evaluated were:

- Placenta previa
- Placental lacunae with turbulent flow
- Irregular bladder wall with extensive associated vascularity
- Loss of retroplacental clear spaces
- Myometrial thickness <1 mm or loss of visualization ofthe myometrium
- Gap in the retroplacental blood flow.

MRI EVALUATION

All patients underwent non-contrast MRI evaluation on 1.5 T MRI scanner (Achieva; Philips Medical System, The Netherlands). A phased array surface coil was used. T2-weighted half-Fourier RARE sequence (HASTE or half-Fourier single-shot fast spin-echo)(min/90.0 repetition time, ms/echo time, ms with 256 × 224 matrix, 4mm thickness with no gap, echo train length of 94, receiver bandwidth of 125 kHz) was acquired in the axial, sagittal, and coronal

planes. Balanced steady-state free precession (true FISP) sequence (3.5/1.8 repetition time, ms/echotime, ms with 256 × 224 matrix, one signal acquired, 5mm thickness with no gap, 50° flip angle, receiver bandwidth of 125 kHz) in three orthogonal planes and T1-weighted gradient-echo sequence (repetition/echo times of 162/2.5 ms, 90° flip angle, 384 × 192 data matrix, slice thickness 5.0 mm) in any one plane were also acquired. All these sequences were acquired during maternal breath holding. If placenta accreta was suspected on preliminary survey, additional images in planes perpendicular to the placenta–myometrium or myometrium-bladder interface were obtained. When higher resolution imaging was required to obtain satisfactory signal-to-noise ratio, images in the desired plane were acquired using T2-weighted fast spin-echo sequence (repetition/echo times of 6000/160 ms, 288 × 224 matrix, slice thickness of 5.0 mm).

Various MR findings assessed were:

- Placenta previa
- Uterine bulging
- Heterogeneous signal intensity within placenta
- Dark intraplacental bands on T2-weighted (T2W)images
- Abnormal disorganized placental vascularity
- Focal interruptions in the myometrial wall
- Tenting of the bladder
- Direct visualization of invasion of pelvic structuresby the placental tissue.

The USG and MRI findings were compared with the final diagnosis as determined at delivery and/or by pathologic examination.

STATISTICAL ANALYSIS

The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for both CDUS and MRI. The sensitivity andspecificity values of USG and MRI were compared by the McNemar test.

RESULTS

A total of 30 patients, who were clinically at high risk for placenta accreta, underwent both CDUS and MRI prenatally. Eight out of 30 patients had a diagnosis of placenta accreta clinically at delivery, by pathologic examination, or both. Table 1 shows the baseline characteristics of these patients. The mean age of the patients with confirmed diagnosis of placenta accreta was 25.6 years. Table 2 shows the imaging features of placenta accreta on both CDUS and MRI in these eight patients. Presence of placenta previa, placental lacunae with turbulent flow, loss of retroplacental clear space, and gap in the retroplacental blood flow were the most common findings on CDUS. Heterogeneous signal intensity within placenta, dark intraplacental bands on T2W images, and abnormal disorganized placental vascularity were the most common findings on MRI. In case of placenta percreta, CDUS demonstrated irregular bladder wall with extensive associated vascularity. Tenting of the bladder with direct visualization of invasion by placental tissue was demonstrated on MRI.Table 3 shows the sensitivity, specificity, PPV, and NPV of USG and MRI for their ability to predict placenta accreta within the high-risk cohort. USG had a sensitivity of 87.5% [confidence interval (CI): 47.3-99.6%] and a specificity of 86.4% (CI:65.1-97.1%). MRI had a sensitivity of 75.0% (CI: 34.9-96.8%) and a specificity of 77.3% (CI: 54.6-92.2%). There was no significant difference in the sensitivity andspecificity of USG and MRI (sensitivity: USG vs. MRI: $P = 1.0$; specificity: USG vs. MRI: $P = 0.687$). USG and MRI were discordant in their diagnosis in 7 out of 30 cases. In these, USG was correct in five cases and MRI was correct in two cases. This was not statistically significant. Some of the representative cases from the study are provided [Figures 1-3].

DISCUSSION

Routine evaluation of a normal gestation is incomplete without assessment of placenta. Imaging in the antepartum period is performed using noninvasive techniques which do not use ionizing radiation. USG and MRI form the mainstay for placental imaging.

Figure1 (A-D): A 23-year-old G2P1 womanwithhistoryofone previous cesarean section and myomectomy. Concordant true positive CDUS and MRI. (A and B) T2W MRI images in sagittal and axial planes: The placenta is anterior and previa (arrow in A). Focal uterine bulge is seen along right lateral wall (arrow in B) with dark T2 intraplacental bands (arrowhead in image (C) shows excessive intraplacental lacunae with interrupteBd). CDUS retroplacental blood flow (arrow). Postoperative pathology (D) confirmed presence of placenta increta

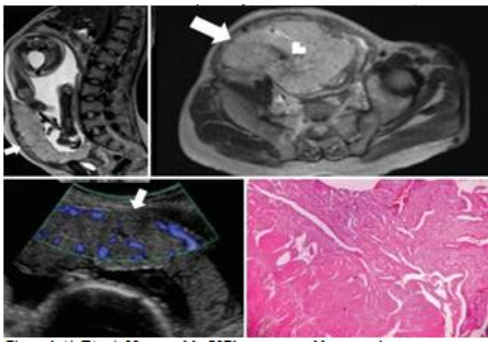


Table 1: Characteristics of patients with placenta accreta

Age (years)	Gravidity	Parity	Gestation age at delivery	Previous CS	Other maternal history	Presenting complaints	Placental location	USG	MRI	Delivery findings	Pathologic finding	Outcome
31	4	2	26	1	One previous dilatation and curettage	Fever, dysuria, hematuria	Anterior, previa	Positive	Positive	Emergency cesarean hysterectomy	Percreta	Expired D1
33	5	2	36	1	Two previous dilatation and curettage	Bleeding per vaginum	Posterior, previa	Positive	Positive	Emergency cesarean hysterectomy	Vera	Uneventful
32	3	2	42	2	-	Bleeding per vaginum	Anterior, previa	Positive	Positive	Emergencycaesarean hysterectomy	Increta	Uneventful
32	2	1	37	1	-	Pain abdomen scartenderness	Posterior, left lateral wall	Positive	Positive	Emergency caesarean hysterectomy	Vera	Uneventful
28	3	2	34	2	-	Bleeding per vaginum	Anterior, previa	Positive	Positive	Elective caesarean hysterectomy	Increta	Uneventful
23	2	1	35	1	Myomectomy	Anemia	Anterior, previa	Positive	Positive	Elective caesarean hysterectomy	Increta	Uneventful
23	2	1	37	1		Bleeding per vaginum	Anterior, previa	Negative	Negative	Elective caesarean with small adherent placenta left *in situ*	Vera	Uneventful
35	3	2	33	2		Pain abdomen	Anterior, previa	Positive	Negative	Elective caesarean hysterectomy	Increta	Uneventful

Table 2: Imaging features of patients withconfirmed placenta accrete

Patient no.	1	2	3	4	5	6	7	8
ColorDoppler ultrasound								
Placenta previa	+	+	+	_	+	+	+	+
Placental lacunae with turbulent flow	+	+	+	+	_	+	_	_
Irregular bladder wall with extensive associated vascularity	+	_	_	_	_	_	_	_
Myometrial thickness <1 mmorlossof visualization of the myometrium	+	_	_	+	_	_	_	+
Loss of retroplacental clear spaces	+	_	+	+	+	+	_	+
Gap in the retroplacental blood flow	+	+	+	+	+	+	_	+
MRI								
Uterine bulging	+	_	+	_	_	+	_	_
Heterogeneous signal intensity within placenta	+	+	+	+	+	+	_	_
Dark intraplacental bands on T2-weighted images	+	+	+	+	+	+	_	_
Abnormal disorganized placental vascularity	+	+	+	+	_	+	_	_
Focal interruptions in the myometrial wall	+	_	_	+	_	_	_	_
Tentinenting obf ththe bladdeb ladder	+	_	_	_	_	_	_	_
Direct visualization of invasion of pelvic structures byplacentaltissue	+							

At MRI, the placenta appears as soft-tissue structure of intermediate signal intensity along the margin of the uterus. The myometrial-decidual interface has a low signal intensity line deep to the placenta. Initially, the placenta appears homogeneous, with the degree of placental lobulation and heterogeneity increasing with gestational age. Thin septa can be routinely seen coursing through the normal placenta between lobules. The subjacent uterine wall has atrilayered appearance on T2W (sandwich appearance) image, consisting of a vascular layer of high signal intensity between two thinner layers of low signal intensity. In unenhanced T1-weighted images, the placenta and the myometrium both demonstrate homogeneous intermediate signal intensity.

Dynamic contrast-enhanced imaging of the placenta shows early intense lobular enhancement of the placental tissue that precedes enhancement of the myometrium.[7]

During normal placentation, the decidua basalis separates placental chorionic villiform the myometrium. In case of placenta accreta vera, the mildest form, there is direct The myometrium is seen as a thin, well-demarcated rim of hypoechoic tissue. The placenta is homogenous and granular in the second trimester, and becomes heterogeneous in the third trimester, secondary to calcifications and vascular lakes. A thin, subplacental clear space is seen adjacent to the myometrial side of the placenta. Normal placental blood flow forms a regular continuous pattern, with occasional vessel dipping into the placental parenchyma[6].

In cases of placenta percreta, chorionic villi invade through the myometrium to reach or extend beyond the serosa into the surrounding tissues or organs[8].

Placenta previa refers to abnormal implantation of the placenta in the lower uterine segment, overlying or near the internal cervical os. Normally, the lower placental edge should be at least 2 cm from the margin of the internal cervical os. Placenta previa can be subdivided according to the position of the placenta relative to the internal cervical os into low-lying placenta (lower placental margin within 2 cm of the internal cervical os), marginal previa (placenta extends to the edge of the internal os but does not cover it), complete previa (placenta covers the internal os), and central previa (placenta is implanted directly over the internal os).

Figure 2 (A-C): Discordant true-positive CDUS and false-negative MRI findings for diagnosis of placenta accreta in 35-year-old G3P2 woman with history of two previous cesarean sections. (A) T2W MRI in axial plane: The placenta is homogenous and placental–uterine interface maintained (B and C) Gray-scale and color Doppler sonogram: Placenta previa is present. There is poor definition of the placental-uterine interface (arrow) with multiple placental lacunae

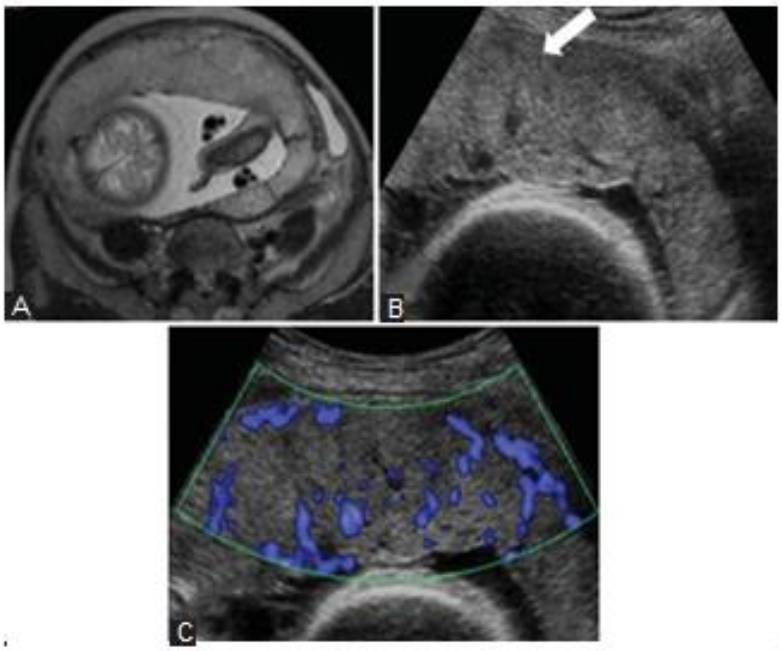


Table 3: Accuracy of CDUS versus MRI in antenatal diagnosis of placenta accrete

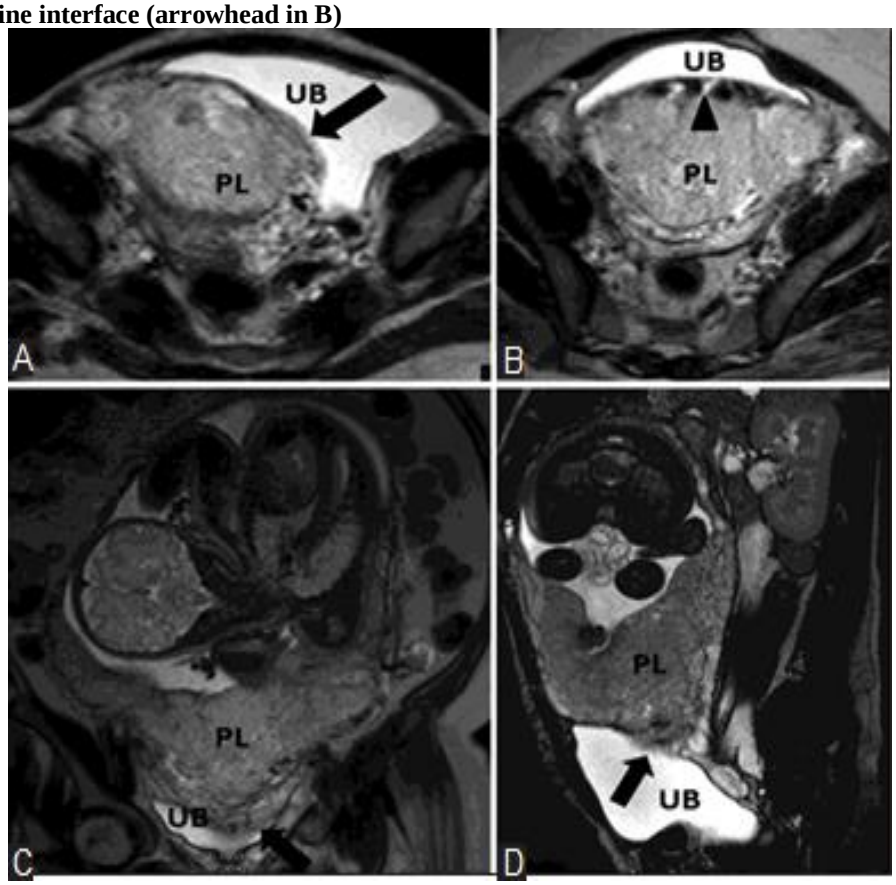
	USG				**MRI**			**P^a**
	TP	**FP**	**FN**	**TN**	**TP**	**FP**	**FN**	**TN**
Numbers	7	1	3	19	6	2	5	17

Sensitivity (%)	87.5 (47.3-99.6)	75.0 (34.9-96.8)	1.000
Specificity (%)	86.4 (65.1-97.1)	77.3 (54.6-92.2)	0.687
PPV(%)	70.0 (34.8-93.3)	54.5 (23.4-83.3)	
NPV(%)	95.0 (75.1-99.9)	89.5 (66.9-98.7)	
LR+	6.42 (2.14-18.97)	3.3 (1.39-7.86)	
LR−	0.14 (0.02-0.918)	0.32 (0.94-1.10)	

TP=True positive, FP=False positive, FN=False negative, TN=True negative, PPV=Positive predictive value, NPV=Negative predictive value, LR=Likelihood ratio aMcNemar test

Imaging plays a crucial role in the prenatal diagnosis of placenta accreta. CDUS has been the primary diagnostic tool for placental evaluation. The anomaly scan done at 18-20 weeks of gestation provides an ideal opportunity to screen for the disorder. Placenta previa, placental lacunae, abnormal color Doppler imaging patterns, loss of the retroplacental clear space, and reduced myometrial thicknesshave been described in the diagnosis of placenta accreta. An irregular bladder wall suggests the possibility of placenta percreta. The presence of lacunae has the highest sensitivity allowing identification ofaccreta in 78-93% of cases.[9,10].

Figure 3 (A-D): Placenta percreta in a 31-year-old woman with G4P2 and one previous cesarean section. T2W MRI images in different planes: (A and B) Axial (C) coronal (D) sagittal. The lower uterine segment is widened with focal uterine bulge along the inferior and right lateral wall. The placenta is seen to extend into the serosa and urinary bladder (UB) wall (arrows). Prominent tortuous vessels are seen at the bladder–uterine interface (arrowhead in B)



Although CDUS remains the primary modality in the evaluation of placental implantation, there has been interest in the use of MRI in recent years. Early MR criteria for the diagnosis of placenta accreta primarily focussed on demonstrating direct invasion of the placenta into the uterus, including thinning and indistinctness of the myometrium, loss of thin T2 dark uteroplacental interface, and direct visualization of placental tissue within or outside the myometrium. These MR criteria are, however, nonspecific.Indistinct interface between myometrium and placenta may not be useful, as this finding may also be seen in normal pregnancy. This is especially true in late trimester when the myometrium is

stretched significantly.In 2007, Lax *et al*[11]. Described three new secondary signs of abnormal placentation, including irregular thick intraplacental T2 darkbands, marked placental heterogeneity, and bulging of the lower uterine segment. Teo *et al*[12]. also observed all three MRI criteria described by Lax and colleagues in all patients with placenta accreta. In 2011, Derman *et al*[13]. postulated that the most sensitive MR criteria for the diagnosis of invasive placentation are abnormal placental vascularity andintraplacental T2 dark bands.

Some authors have reported MRI to be better than CDUS in posteriorly located placenta and useful in patients with ambiguous USG findings[14]. Others have suggested that MRI can better define areas of abnormal placentation,determine the levels of invasion, and ultimately change the surgical management. The reported sensitivity, specificity, and PPV of MRI indiagnosing placenta accreta are variable.

Table 4 provides the sensitivity, specificity, PPV, and NPV of CDUS and MRI for diagnosing placenta accreta in someof the previous studies.

Name of study	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Present study				
Ultrasound	87.5	86.4	70.0	95.0
MRI	75.0	77.3	54.0	89.0
Dwyer *et al*.[8]				
Sonography	93.0	71.0	74.0	92.0
MRI	80.0	65.0	67.0	79.0
Warshak *et al*.[14]				
Ultrasound	76.92	96.13	65.21	97.78
MRI	88.46	100.0	100.0	82.35
Masselli *et al*.[13]				
Ultrasound	91.0	100.0	100.0	100.0
MRI	100.0	100.0	100.0	100.0

PPV=Positive predictive value, NPV=Negative predictive value, MRI=Magnetic resonance imaging

The present study showed that USG and MRI without the use of gadolinium demonstrate similar accuracy for correctlydiagnosing placenta accreta prenatally. When either USG or MRI is inconclusive, the other modality provides the correct diagnosis. This suggests that USG and MRI have complementary role in diagnosis of placenta accreta.

The results of the present study are similar to those of Dwyer *et al*[15]. This was a historical cohort study undertaken at three institutions. It identified 15 cases of confirmed placenta accreta in a high-risk group of 32 patients who underwent both MRI and CDUS evaluation antenatally. The sensitivity of both modalities in both these studies was fairly good, whereas the specificity was low as compared to other similar studies. One of these studies comparing CDUS and MRI with gadolinium for prenatal diagnosis of placenta accreta was conducted by Warshak *et al*[16]. In an unpaired study design of 39 cases of confirmed placenta accreta, USG had a sensitivity of 77% and a specificity of 96%. MRI with gadolinium had a sensitivity of 88% and a specificity of 100%. Another prospective study by Masselli *et al[17].* identified 12 cases with final diagnosis of placenta accreta in a group of 50 high-risk patients. They reported a sensitivity of 100% and91% for MRI and CDUS, respectively, and a specificity of 100% for both modalities. They reported that MRI was statistically better than USG in evaluation of depth of placental infiltration and more accurate in characterizing the topography of invasion.

The differences in sensitivity and specificity between USGand MRI were not statistically significant in all studies, similar to our study. In these studies, the specificity was better for both USG and MRI as compared to our study and the study of Dwyer *et al*. These differences could be due toascertainment/referral bias (i.e. patient population studied) and differences in random sampling. The difference in the specificity of USG between studies could also be due to the fact that transvaginal USG was always used in their study but not used routinely in our study. The difference in the specificity of MRI could be due to the use of gadolinium. Another important factor could be due to late presentation of patients, generally in late third trimester, in our setup. At this time, there is significant

distension of the myometrium, large baby parts, and relatively less amount of liquor, making imaging technically more difficult and resulting in less accurate findings.

The use of gadolinium in pregnancy is still controversial, as it crosses placenta, enters the fetal circulation, and is excreted by the fetal kidney. Its fetal effects are unknown. Since the kidney is considered immature in children younger than 1 year, the European Medicines Agency warns that gadolinium should be used with caution in this age group. Applying the same rationale, the use of gadolinium in pregnancy is questionable[18].

No similar prospective study comparing the accuracy of USG and MRI for prenatal diagnosis of placenta accreta has been previously reported in an Indian population. The strength of our study is that it is a prospective study, directly comparing the accuracy of USG and MRI in the same group of patients. Two separate radiologists performed USG and interpreted MRI and were blind to the results of other modality. In addition, MRI contrast was not used. Therefore, this study provides more realistic information about the diagnostic accuracy of these imaging modalities in a group of patients who were at high risk for placenta accreta. Themajor limitation of our study was its small sample size. All the diagnostic indices have large CIs and on the basis of our data, it is difficult to determine the superiority of either modality.

Pregnant females with clinical suspicion of placenta accrete Based on this study, a protocol for imaging in suspected cases of placenta accretacan be formulated [Figure 4].

Although many studies have been done in the past and enough literature is already present related to this topic, not a single study on the Indian population has been reported. Even today, screening for placenta accreta is not done routinely, though the literature says anomaly scan carried out at 18-20 weeks provides an ideal opportunity to screen for accretion. A myth regarding MRI being the modality of choice for diagnosis of placenta accreta is quite prevalent. This study was conducted to address these lacunae. It intended to make screening for possible accretion a routine, understand when and where MRI can help over USG, and familiarize the radiologists with the different imaging criteria of placenta accreta.

CONCLUSION

Toconclude, both USG and MRI havefairly good sensitivity for prenatal diagnosis of placenta accreta; however, specificity does not appear to be as good as reported in other studies. Both modalities have complimentary role and in cases of inconclusive findings with one imaging modality, the other modality may be useful for obtaining the diagnosis. CDUS remains the first primary modality for antenatal diagnosis of placenta accreta, with MRI reserved for cases where USG is inconclusive.

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