



Received: 2014.06.23
Accepted: 2014.06.23
Published: 2014.11.12

Authors' Contribution:

- A** Study Design
- B** Data Collection
- C** Statistical Analysis
- D** Data Interpretation
- E** Manuscript Preparation
- F** Literature Search
- G** Funds Collection

The Value of Ultrasound and Magnetic Resonance Imaging in Diagnostics and Prediction of Morbidity in Cases of Placenta Previa with Abnormal Placentation

Ahmed M. Algebally^{1ABCDEF}, Reda Ramadan Hussein Yousef^{1ABCDEF},
Sanaa Sayed Hussein Badr^{2E}, Amal Al Obeidly^{2BCD}, Wojciech Szmięielski^{3EF},
Abdullah A. Al Ibrahim^{4BCD}

¹ Department of Radiology, Hamad General Hospital, Hamad Medical Corporation, Doha, Qatar

² Department of Radiology, Women's Hospital, Hamad Medical Corporation, Doha, Qatar

³ Department of Radiology, National Center for Cancer Care and Research, Hamad Medical Corporation, Doha, Qatar

⁴ Department of Gynecology and Obstetrics, Women's Hospital, Hamad Medical Corporation, Doha, Qatar

Author's address: Wojciech Szmięielski, Department of Radiology, National Center for Cancer Care and Research, Hamad Medical Corporation, P.O. Box 3050, Doha, Qatar, e-mail: w.szmigielski@gmail.com; wszmigielski@hmc.org.qa

Summary

Background:

The purpose of the study was to evaluate the role of ultrasound (US) and magnetic resonance imaging (MRI) in the diagnostics and management of abnormal placentation in women with placenta previa and to compare the morbidity associated with that to placenta previa alone.

Material/Methods:

The study includes 100 pregnant women with placenta previa with and without abnormal placentation. The results of MRI and US in abnormal placentation were compared with post-operative data. The patients' files were reviewed for assessment of operative and post-operative morbidity. The results of our statistical analysis were compared with data from the literature.

Results:

US and MRI showed no significant difference in sensitivity and specificity in diagnosing abnormal placentation (97–100% and 94–100%, respectively). MRI was more sensitive than US for the detection of myometrial invasion and the type of abnormal placentation (73.5% and 47%, respectively). The difference between pre- and post-operative hemoglobin values and estimated blood loss were the most significant risk factors for abnormal placentation, added to risk factors known for placenta previa. Post-partum surgical complications and prolonged hospital stay were more common in the cases of placenta previa with abnormal placentation, however statistically insignificant.

Conclusions:

US and MRI are accurate imaging modalities for diagnosing abnormal placentation. MRI was more sensitive for the detection of the degree of placental invasion. The patient's morbidity increased in cases with abnormal placentation. There was no significant difference in post operative-complications and hospitalization time due to pre-operative planning when the diagnosis was established with US and MRI.

MeSH Keywords:

Magnetic Resonance Imaging • Placenta Accreta • Placenta Diseases • Placenta Previa • Placentation • Ultrasonography, Doppler, Color

PDF file:

<http://www.polradiol.com/abstract/index/idArt/891252>

Background

Placenta previa is an obstetric complication in which the placenta is inserted partially or wholly in the lower

uterine segment and it is a leading cause of antepartum hemorrhage.

Placenta accreta is a pathological condition in which the placental trophoblast invades the endometrium beyond the Nitabuch's layer due to a defect in the decidua basalis [1]. In more severe cases, the trophoblast invades the myometrium (placenta increta) or the serosa and beyond (placenta percreta). In a series of studies by Miller et al. including 62 pathologically confirmed cases of abnormal placentation, 76% were accreta, 18% were increta, and 6% were percreta [2]. The major morbidity associated with such an abnormal placentation primarily arises from a significant blood loss that occurs at the time of delivery, requiring longer maternal hospital stay and blood transfusion [3]. In addition, pregnancies complicated by placenta accreta are thought to be associated with increased incidence of cystotomy, ureteral injury, pulmonary embolism, need for ventilator use, reoperation, and intensive care unit (ICU) admission [4]. Risk factors for placenta accreta include prior cesarean section (CS) delivery, uterine instrumentation and intrauterine scarring, all of which may be associated with damage to or absence of the decidua basalis. Another important factors are placenta previa, smoking, maternal age over 35 years, grand multiparity and recurrent miscarriage [1,5,6]. Given the continual increase in CS deliveries worldwide, the relationship between prior uterine surgery and the risk of placenta previa and accreta is gaining on importance. It has been noted that one prior CS delivery doubles the risk of placenta previa in a subsequent pregnancy and those women are particularly at risk for placenta accreta [7]. Abnormal placental adherence to/or invasion into the myometrium prevents normal separation of the placenta at the time of delivery, potentially resulting in life-threatening uterine hemorrhage or retained products of conception. Given the significant morbidity associated with this diagnosis, the ability to accurately diagnose placenta accreta is essential as it allows both the patient and the obstetrician to be prepared for potential complications of delivery and to proceed with antenatal care to minimize blood loss during and after delivery [8]. Because ultrasonography (US) is relatively inexpensive and widely available, it remains the primary diagnostic tool for abnormal placentation, together with fetal screening examinations. Gray-scale and color Doppler ultrasound findings of placenta accreta include blood vessels or placental tissue bridging the placenta-myometrium or myometrium-bladder interface or crossing the uterine serosa, loss of the normal placental myometrial interface, presence of lacunae with a turbulent flow, interruption of the echogenic line at the myometrial-bladder interface, and retroplacental myometrial thickness of less than 1 mm; however, US findings may not reliably differentiate between degrees of myometrial invasion [9-13]. Magnetic resonance imaging (MRI) is more costly than US and requires both experience and expertise in the evaluation of abnormal placental invasion. Although most studies have suggested comparable diagnostic accuracy of MRI and US for placenta accrete, MRI is considered an adjunctive modality and adds little to the diagnostic accuracy of US. However, MRI is important when there are ambiguous US findings or suspicion of posterior placenta accreta, with or without placenta previa. A prospective series of 300 cases published in 2005 showed that MRI was able to outline the anatomy of the invasion and relate it to the regional anastomotic vascular system [14]. Some investigators have advocated the use of gadolinium-based contrast

agents to improve the specificity of MRI in diagnosing placenta accreta by better defining the outer placental surface and myometrium and distinguishing placenta accreta from percreta [15-18]. Although no detrimental effects of gadolinium-based contrast agents on the human fetus have been convincingly shown, these agents do cross the placenta. The American College of Radiology guidance document for safe MRI practice recommends that intravenous gadolinium should be avoided during pregnancy and should be used only if absolutely essential [19].

The aim of the study

The purpose of the study was to assess the value of US and MRI in diagnostics and management of abnormal placentation in women with placenta previa and to compare the morbidity associated with that to placenta previa alone, assessment of US and MRI findings as well as risk factors in patients with placenta previa and abnormal placentation.

Material and Methods

This prospective study included one hundred pregnant women presenting with placenta previa who were examined in the Department of Radiology, Hamad Medical Corporation in Doha, Qatar between January 1, 2011 and March 31, 2014.

All those patients were at a high risk of abnormal placentation (placenta accrete, increta and percreta) regarding their clinical history of either one or all of the following: placenta previa, previous uterine interventional procedures (e.g. cesarean sections, dilation & curettage and myomectomy, maternal age of 35 years or more and grand multiparity [7,15,17].

The age of the patients ranged from 20 to 42 years (mean age: 33 years). The patients without prepartum US and MRI examinations and a full post-partum record were not included.

US followed by MRI studies were performed on one hundred patients with elective delivery at 36 weeks gestation. All US gray-scale and Doppler studies were performed by registered sonographers and interpreted by an accompanied radiologist.

The US equipment included Siemens Sonoline Elegra (Siemens, Issaquah, WA) and GE Voluson 730 (GE Electric Medical Systems, Milwaukee, WI) machines with 3.5- or 5.0-MHz curvilinear, sector and endovaginal transducers.

MRI of the pelvis was performed for all patients using a 1.5-T (Avanto, Siemens, Erlangen, Germany) MRI machine with a phased-array coil. MRI evaluation of the placenta was done for placental location, type of previa and to check for the signs of abnormal placentation, even if preliminary US was negative. The examinations were performed in supine position for patients who could tolerate it, for patients who could not tolerate the supine position; left lateral decubitus positioning was used. The following sequences were applied:

1. After a localizer scan, sagittal and coronal scan series were acquired using the half-Fourier acquisition with single-shot turbo spin-echo (HASTE) with an effective echo time of 90 ms in continuous 8-mm slices covering the entire abdomen and pelvis.
2. Additional HASTE sequences were acquired subsequently to cover the entire placenta in three orthogonal planes, followed by selected oblique planes that are perpendicular to the placenta-uterine interface. The HASTE sequence acquires sequential single slices rather than the full volume, with each image being acquired in a subsecond to freeze fetal motion.
3. T1-weighted spin echo sequence (SE): TE 15 ms, TR 535 ms in the axial and sagittal plane.
4. T2-weighted pulse sequence – fast spin echo (FSE): TE 90 ms, TR 5.0 ms in the axial, sagittal and coronal plane using matrix 256×192.

For sequences (3 and 4), slice thickness of 5-6 mm with 1-mm gap, flip angle of 90° and FVO of 370–400 mm.

Ultrasound and MRI image analyses were carried out separately by three qualified radiologists who did not have knowledge on the findings of earlier performed US examinations.

Placenta previa was subdivided according to the position of the placenta in relation to the internal cervical os (according to Elsayes et al.) into: low-lying, marginal, complete, and central [20]. US findings regarded as consistent with placenta accreta included the following: loss of the retroplacental hypoechoic clear zone, loss of the bladder wall-uterine interface, presence of placental lacunae (vascular spaces), abnormal color Doppler imaging pattern as the presence of hypervascularity of the interface between the uterine serosa and the bladder wall, turbulent flow within placental lacunae and reduced myometrial thickness [21,22].

In our study we used MRI criteria established by Lax et al. [23]. The most useful findings on placenta accreta/percreta in MRI included: uterine bulging, heterogeneous signal intensity within the placenta, dark intraplacental bands on T2-WI, focal defects in the myometrial wall, tenting of the bladder, direct visualization of invasion of pelvic structures by placental tissue.

The delivery plan was made according to the suggested degree of placenta previa on imaging and presence/absence of abnormal placentation. The ability of US and MRI to properly detect and assess placenta accreta was correlated with findings at CS, which were considered the gold standard of reference.

Electronic medical records were used to determine estimated blood loss (EBL), the pre- and post-operative hemoglobin level difference (HB-dC), the need for transfusion of packed red blood cells (PRBC), coagulation factors and platelets, as well as the amount of blood products transfused in each case, presence or absence of CS hysterectomy, SICU admission and the length of hospital stay. Statistical analysis was performed using IBM SPSS statistics (V. 22.0, IBM Corp., USA, 2013).

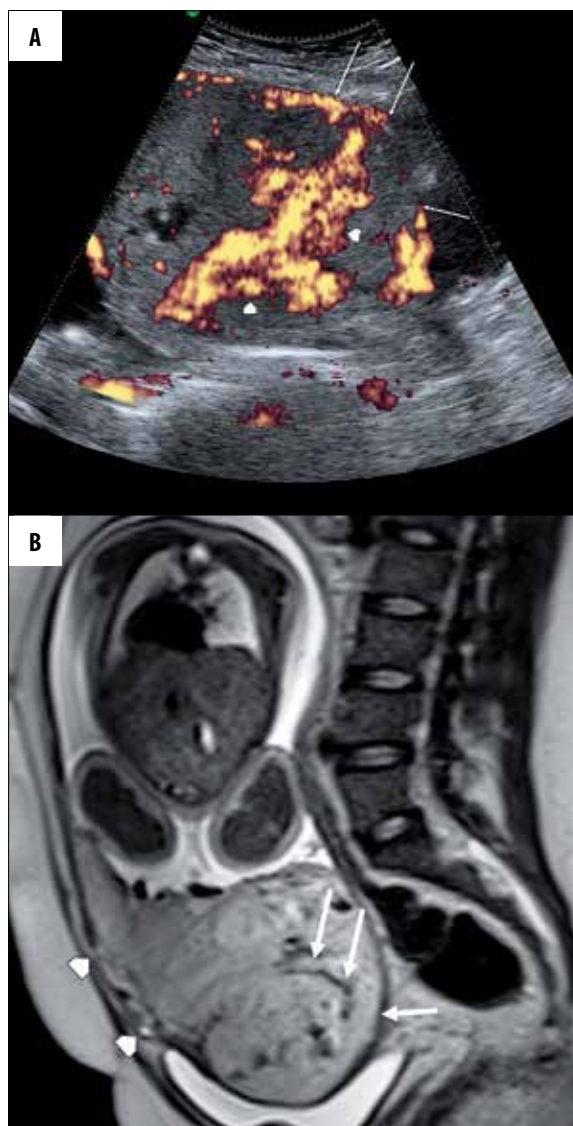


Figure 1. Female, 25 years old, pregnant at 32 weeks, placenta previa grade IV. (A) Color Doppler ultrasound: Placental lacunae with turbulent flow (arrowheads), abnormal vascularity of the interface between the placenta and the myometrium with loss of retroplacental clear space (arrows); (B) MRI: Heterogeneous placental signal, placental bulge (arrow), thinning of the myometrium (arrowheads) and dark placental bands (arrows).

Results

Out of 100 pregnant women diagnosed with placenta previa, 66 were diagnosed as having placenta previa with no abnormal placentation, 34 were diagnosed with US as having associated abnormal placentation. MRI, on the other hand, diagnosed 32 patients as having abnormal placentation.

The examples of US and MRI findings are shown in Figures 1–3.

The incidence of true negative, true positive, false positive and false negative cases in US, MRI and surgical assessment are shown in the Table 1.



Figure 2. Female, 28 years old, pregnant at 33 weeks, placenta previa grade IV. (A) Color Doppler ultrasound: turbulent placental lacunae flow (arrows) and abnormal vascularity at the placenta/myometrial interface (arrowheads); (B) MRI: Myometrial invasion (arrow), placental bulge and dark placental bands (arrowheads).

The sensitivity of US and MRI was 94% and 100%, and the specificity 97% and 100%, respectively (Table 2). Positive predictive value (PPV) of US and MRI was 94% and 100% and negative predictive value (NPV) of US and MRI was 97% and 100%, respectively (Table 2).

The frequency of demonstration of the type of abnormal placentation by US, MRI and surgery is shown in Table 3.

The frequency of US and MRI signs of abnormal placentation in cases with placenta previa is shown in Tables 4 and 5.

In our study HB-difference (HB-dC) between pre- and post-operative values and estimated blood loss were the most significant risks factors for abnormal placentation added to risk factors known for placenta previa (Table 6).

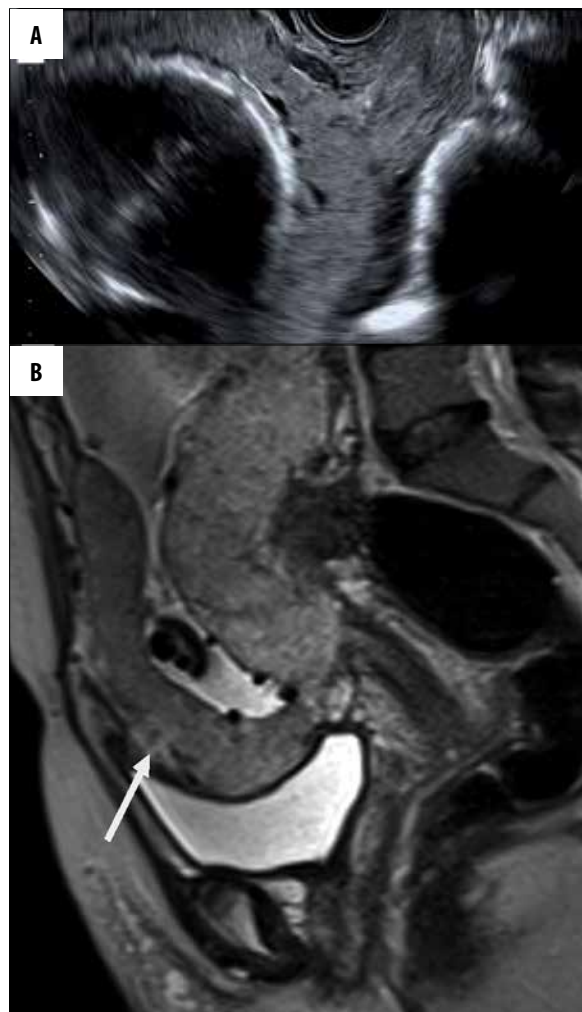


Figure 3. Female, 30 years old, pregnant at 30 weeks, placenta previa grade IV. (A) Ultrasound: placenta previa type 4; (B) MRI: Focal myometrial infiltration of CS scar site (arrow).

Postpartum SICU admission, prolonged hospital stay and CS hysterectomy were more common in the cases of placenta previa associated with abnormal placentation. However, they were statistically insignificant (P value was 0.831 and 0.365, respectively).

Discussion

US is an established technique of choice of placenta evaluation and screening with both trans-abdominal and trans-vaginal examinations for placenta invasion [24]. US is always the first imaging modality used to evaluate suspected abnormal placentation. It is widely available, patient-friendly, and relatively inexpensive. However, US is operator-dependent and limited by large body habitus and posterior placenta [25]. Although US remains the primary modality in the evaluation of placental implantation, in recent years there has been interest in the use of MR imaging. A few authors have suggested that MR imaging due to its multiplanar imaging abilities and excellent soft tissue resolution can better define areas of abnormal placentation, identify levels of invasion, and ultimately change surgical management, and thus should be routinely used [26,27].

Table 1. Statistical evaluation of US, MRI and surgical assessment.

	US		MRI		Post surgical	
True negative	66	(66%)	68	(68%)	68	(68%)
True positive	30	(30%)	32	(32%)	32	(32%)
False positive	2	(2%)	0	(0%)	0	(0%)
False negative	2	(2%)	0	(0%)	0	(0%)
Total	100	(100%)	100	(100%)	100	(100%)

Table 2. Statistical evaluation of US and MRI in diagnosis of abnormal placentation.

Imaging modality	Sensitivity %	Specificity	PPV	NPV
Ultrasonography	94	97	94	97
MRI	100	100	100	100

Table 3. Abnormal placentation type demonstrated by US, MRI and verified by intra-operative findings.

Abnormal placentation type	Intra-operative diagnosis		Imaging studies diagnosis			
	Number	%	US number	%	MRI number	%
Accreta	12	35%	16	47%	8	24%
Increta	8	24%	12	35%	12	35%
Percreta	12	35%	4	12%	12	35%
Normal	2	6%	2	6%	2	6%
Total	34	100%	34	100%	34	100%

Table 4. Ultrasound signs of abnormal placentation in patients with placenta previa (34 cases).

Ultrasound signs of abnormal placentation	Number of positive cases	% from positive cases	Number of negative cases	% from negative cases
1 – Placental lacunae with turbulent flow	28/34	82%	16/66	24%
2 – Thinned myometrial zone below 1 mm or loss of visualization	32/34	94%	33/66	50%
3 – Loss of retroplacental clear space	20/34	58%	30/66	45%
4 – Gap in the retroplacental blood flow	16/34	47%	12/66	18%
5 – Abnormal Color Doppler Imaging patterns in the form of disruption and increased color Doppler flow at placenta myometrium interface	30/34	88%	10/66	15%

Others have suggested that MR imaging is most clearly indicated when there is a posterior placenta or when the US findings are ambiguous. MRI has been shown beneficial in some cases when ultrasound findings are equivocal or non-diagnostic [28,29]. Our current work is a prospective study to determine the true need for MR imaging in radiological diagnostics of patients with abnormal placentation. The sensitivity and specificity of US in diagnosing abnormal placentation was 94% and 97%, while of MRI 100% and 100%, respectively, showing no statistically significant difference. Masselli et al. confirmed that pelvic US using color

Doppler is highly reliable to diagnose or exclude the presence of placental adhesive disorders (PAD) and found MRI to be an excellent tool for staging and topographic evaluation of PAD [30]. They had stated that MR and US Doppler showed no statistical difference in identifying patients with PAD, while MRI was statistically better than US Doppler in characterizing the topography of invasion. MRI showed accuracy of 100% in assessing the depth of placental infiltration versus 75% for US. Another study by Warshak et al., comparing US and post-contrast MR imaging performance in the diagnostics and evaluation of placenta

Table 5. MRI signs of abnormal placentation in patients with placenta previa (32 cases).

MRI signs of abnormal placentation	Number of positive cases	% from positive cases	Number of negative cases	% from negative cases
Thinned myometrial zone	16/32	50%	20/68	30%
Absent myometrial zone	22/32	68%	5/68	7.3%
Focal interruption of myometrial zone	20/32	60%	0/68	0%
Uterine bulge	28/32	87%	20/68	30%
Heterogeneity of placenta	28/32	87%	18/68	26%
Dark placental band in T2WI	24/32	75%	5/68	7.3%
Signs of invasion	18/32	56%	0/68	0%
Tenting of UB	1/32	3%	0/68	0%

Table 6. Risk factors for patients with placenta previa and abnormal placentation.

Risk factor		n	Mean	SD	t	p	Sig.
HB_Pre_op	Abnormal	10	11.39	0.8185			
	Normal	32	11.434	0.679	-0.156	0.879	NS
HB_Post_op	Abnormal	10	7.64	1.3451			
	Normal	32	8.934	1.759	-2.457	0.024	S
HB_dC	Abnormal	10	-0.3319	0.09216			
	Normal	32	-0.2182	0.14904	-2.895	0.008	HS
Est_BI_loss	Abnormal	10	4050	895.9787			
	Normal	32	3150	1642.971	2.218	0.035	S
BI_Tx	Abnormal	10	4.8	1.8738			
	Normal	31	4.903	2.6753	-0.135	0.894	NS

accrete, reported that ultrasound had a sensitivity of 77% and specificity of 96%, while MRI with gadolinium had a sensitivity of 88% and specificity of 100% [31]. Statistically high values in that study could be a result of routine trans-vaginal ultrasound examinations performed in addition to trans-abdominal US, as well as of using gadolinium in MRI examinations, since, according to them, it delineated more clearly the outer placental surface relative to the myometrium. Teo et al. described only MRI features of suspected placental invasion in a limited retrospective review, which included seven patients with US findings indicative of placental invasion [32]. They reported that the described MRI features were useful in establishing the presence and depth of placental invasion. In previously mentioned studies, the differences in the sensitivity and specificity between sonography and MRI were not statistically significant. Similarly, in our study, the difference between US and MRI was not found to be statistically significant for diagnosing abnormal placentation. However, when comparing the ability to evaluate the degree of placental invasion, we found a statistically significant difference, with MRI sensitivity of 73.5% and US sensitivity of 47%. The specificity of US in our study was higher, which may be due to the fact

that we used trans-vaginal ultrasound. The trans-vaginal approach improved the diagnostics of abnormal placentation and determination of the degree of myometrial invasion due to near-field resolution of the interface between the placenta and the lower uterine segment. Moreover, US in which an abdominal probe is used, is affected by obesity of the patient and degree of bladder filling. Placenta percreta was more frequent in our study than in the literature [9], which is mostly due to the presence of multipara patients with repeated CS. In our study, the most frequent ultrasound findings for abnormal placentation were: thinned myometrial zone below 1 mm or loss of its visualization (94%), abnormal color Doppler imaging pattern at placenta-myometrium interface (88%) and placental lacunae with turbulent flow (82%). The first finding was frequently seen in cases of placenta previa without abnormal placentation. However, the other two signs were significantly less common in cases without abnormal placentation, making it a more important diagnostic finding, which is consistent with the literature [21,33]. In our study, the most common MRI signs of abnormal placentation were uterine bulge (87%), heterogeneity of placenta (87%) and dark intraplacental bands (75%). Lax et al. showed similar results and

described uterine bulge as a focal outward contour bulge and disruption of the normal pear shape of the uterus [23]. Marked heterogeneous signal intensity in the placenta with increased vascularity is associated with placental invasion and may represent either areas of hemorrhage in the placenta or the lacunae. Dark intraplacental bands can also be seen in patients with PA, appearing as nodular or linear areas of low signal intensity on T2-weighted images.

Although there is evidence of morbidity related to placenta previa, the presence of abnormal placentation was a significant factor for adding more morbidity risk [34]. Blood loss is considered the most significant morbidity factor [34]. In our study, we found that the estimated blood loss and hemoglobin differences between pre and post-operative values were the most significant morbidity risk factors for abnormal placentation with placenta previa, added to risk factors known for placenta previa alone. Postpartum SICU admission, prolonged hospital stay and CS hysterectomy were more common in the cases of placenta previa associated with abnormal placentation. However, they were statistically insignificant in the current study. This can be attributed to the fact that treatment plans were changed owing to accurate diagnosis of abnormal placentation, rendering less complication and morbidity, which is consistent with a study by Eller et al. [35].

Conclusions

We concluded that early and systematic detection of abnormal placentation is a crucial step in planning delivery and subsequent management to overcome the morbidity associated with abnormal placentation. The strength of our study is that: 1) both US and MRI were used for primary scanning of cases of placenta previa eliminating the possibilities of missed cases, 2) it evaluated the ability of MR imaging and US to detect the most common signs of maternal mortality and morbidity, 3) sensitivity and specificity of MR was estimated without the use of gadolinium, which is the approach most suitable for gravid patients, 4) in spite of blood loss and hemoglobin drop, surgical morbidity and hospitalization time were significantly reduced due to accurate diagnosis of abnormal placentation. Finally, we concluded that ultrasound in expert hands should be used as a primary imaging modality in diagnosing abnormal placentation. However, due to the technical abilities of MRI, it can be used in doubtful cases for evaluation of the posteriorly located placenta or for evaluation of the degree of invasion of the myometrium, if US is unsatisfactory. These imaging modalities are excellent methods for the prediction of maternal morbidity and planning as pre-delivery precaution.

References:

1. ACOG Committee Opinion. Placenta accreta. No. 266. January 2002. American College of Obstetricians and Gynecologists. *Obstet Gynecol*, 2002; 99: 169–70
2. Miller DA, Chollet JA, Goodwin TM: Clinical risk factors for placenta previa-placenta accreta. *Am J Obstet Gynecol*, 1997; 177: 210–14
3. Usta IM, Hobeika EM, AbuMusa AA et al: Placenta previa-accreta: risk factors and complications. *Am J Obstet Gynecol*, 2005; 193: 1045–49
4. Silver RM: The MFMU cesarean section registry: maternal morbidity associated with multiple repeat cesarean deliveries. *Obstet Gynecol*, 2006; 107: 1226–32
5. Clark SL, Koonings PP, Phelan JP: Placenta previa/accreta and prior cesarean section. *Obstet Gynecol* 1985; 66: 89–92
6. Gielchinsky Y, Rojansky N, Fasouliotis SJ et al: Placenta accreta: summary of 10 years: a survey of 310 cases. *Placenta*, 2002; 23: 210–14
7. Silver RM: The MFMU cesarean section registry: maternal morbidity associated with multiple repeat cesarean deliveries. *Obstet Gynecol*, 2006; 107: 1226–32
8. Warshak CR, Ramos GA, Eskander R et al: Effect of predelivery diagnosis in 99 consecutive cases of placenta accreta. *Obstet Gynecol*, 2010; 115: 65–69
9. Comstock CH, Love JJ, Bronsteen RA et al: Sonographic detection of placenta accreta in the second and third trimesters of pregnancy. *Am J Obstet Gynecol*, 2004; 190: 1135–40
10. Finberg HJ, Williams JW: Placenta accreta: prospective sonographic diagnosis in patients with placenta previa and prior cesarean section. *J Ultrasound Med*, 1992; 11: 333–43
11. McGahan JP, Phillips HE, Reid MH: The anechoic retroplacental area: a pitfall in diagnosis of placental – endometrial abnormalities during pregnancy. *Radiology*, 1980; 134: 475–78
12. Wong HS, Cheung YK, Zuccollo J et al: Evaluation of sonographic diagnostic criteria for placenta accreta. *J Clin Ultrasound*, 2008; 36: 551–59
13. Belfort MA; Publications Committee, Society for Maternal-Fetal Medicine. Placenta accreta. *Am J Obstet Gynecol*, 2010; 203: 430–39
14. Palacios Jaraquemada JM, Bruno CH: Magnetic resonance imaging in 300 cases of placenta accreta: surgical correlation of new findings. *Acta Obstet Gynecol Scand*, 2005; 84: 716–24
15. Warshak CR, Eskander R, Hull AD et al: Accuracy of ultrasonography and magnetic resonance imaging in the diagnosis of placenta accreta. *Obstet Gynecol*, 2006; 108: 573–81
16. Lam G, Kuller J, McMahon M: Use of magnetic resonance imaging and ultrasound in the antenatal diagnosis of placenta accreta. *J Soc Gynecol Investig*, 2002; 9: 37–40
17. Dwyer BK, Belogolovkin V, Tran L et al: Prenatal diagnosis of placenta accreta: sonography or magnetic resonance imaging? *J Ultrasound Med*, 2008; 27: 1275–81
18. Masselli G, Brunelli R, Casciani E et al: Magnetic resonance imaging in the evaluation of placental adhesive disorders: correlation with color Doppler ultrasound. *Eur Radiol*, 2008; 18: 1292–99
19. Kkanal E, Barkoich AJ, Bell C et al: ACR guidance document for safe MR practices: 2007 ACR blue ribbon panel on MR Safety. *Am J Roentgenol*, 2007; 188: 1447–74
20. Elsaves KM, Trout AT, Friedkin AM et al: Imaging of the placenta: a multimodality pictorial review. *Radiographics*, 2009; 29: 1371–91
21. Baughman WC, Corteville JE, Shah RR: Placenta Accreta: Spectrum of US and MR Imaging Findings. *Radiographics*, 2008; 28: 1905–16
22. Comstock CH, Lee W, Vettraino IM et al: The Early Sonographic Appearance of Placenta Accreta. *J Ultrasound Med*, 2003; 22: 19–23
23. Lax A, Prince MR, Mennitt KW et al: The value of specific MRI features in the evaluation of suspected placental invasion. *Magn Reson Imaging*, 2007; 25: 87–93
24. Esakoff TF, Sparks TN, Kaimal AJ et al: Diagnosis and morbidity of placenta accreta. *Ultrasound Obstet Gynecol*, 2011; 37(3): 324–27
25. Jauniaux E, Jurkovic D: Placenta accreta: pathogenesis of a 20th century iatrogenic uterine disease. *Placenta*, 2012; 33: 244–51
26. Palacios Jaraquemada JM, Bruno CH: Magnetic resonance imaging in 300 cases of placenta accreta: surgical correlation of new findings. *Acta Obstet Gynecol Scand*, 2005; 84: 716–24
27. Seet EL, Kay HH, Wu S, Terplan M: Placenta accreta: depth of invasion and neonatal outcomes. *J Matern Fetal Neonatal Med*, 2012; 25:2042–45
28. Levine D, Hulka CA, Ludmir J et al: Placenta accreta: evaluation with color Doppler US, power Doppler US, and MR imaging. *Radiology*, 1997; 205: 773–76
29. Derman AY, Nikac V, Haberman S et al: MRI of placenta accreta: a new imaging perspective. *AJR Am J Roentgenol*, 2011; 197:1514–21

-
30. Masselli G, Brunelli R, Casciani E et al: Magnetic resonance imaging in the evaluation of placental adhesive disorders: correlation with color Doppler ultrasound. *Eur Radiol*, 2008; 18(6): 1292–99
 31. Warshak C, Eskander R, Hull A et al: Accuracy of ultrasonography and magnetic resonance imaging in the diagnosis of placenta accreta. *Obstet Gynecol*, 2006; 108: 573–81
 32. Teo TH, Law YM, Tay KH et al: Use of magnetic resonance imaging in evaluation of placental invasion. *Clinical Radiol*, 2009; 64(5): 511–16
 33. Twickler DM, Lucas MJ, Balis AB et al: Color flow mapping for myometrial invasion in women with a prior cesarean delivery. *J Matern Fetal Med*, 2000; 9: 330–35
 34. Tikkanen M, Paavonen J, Loukovaara M et al: Antenatal diagnosis of placenta accreta leads to reduced blood loss. *Acta Obstet Gynecol Scand*, 2011; 90: 1140–46
 35. Eller AG, Bennett MA, Sharshiner M et al: Maternal morbidity in cases of placenta accreta managed by a multidisciplinary care team compared with standard obstetric care. *Obstet Gynecol*, 2011; 117: 331–37