Original Article
The comparison of MRI and Ultrasound in prenatal identification of invasive placentation: a meta-analysis based on 20 parallel control studies

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Abstract: Background: Many previous studies have investigated the Magnetic resonance imaging (MRI) and Ultrasound (US)'s efficiencies in invasive placentation. However, their results were not incomplete agreement. The aim of this research was using meta-analysis method by pooling parallel control studies to compare the MRI and US's efficiencies in invasive placentation. Methods: Sensitivity and 95% confidence interval (CI), specificity and 95% CI, positive likelihood ratios (LR+) and 95% CI, negative Likelihood Ratios (LR-) and 95% CI, diagnostic odds ratio (DOR) and 95% CI, area under curve (AUC) and 95% CI, summary receiver operating characteristic (SROC) of both US and MRI were calculated. Results: This paper found that the sensitivity of MRI for diagnosis of placenta accreta defects was 85%, with a specificity of 88%. The sensitivity and specificity of US were 86% and 92% respectively, while the sensitivity of color Doppler US was 84% with a specificity of 91%. Conventional dichotomous and continuous data meta-analysis methods did not find any evidence that the relevant indexes of MRI and US were significant different. Conclusion: Considering on the economy, safety, non-invasive and time-saving of US, and no different between US and MRI on diagnostic accuracies, this study suggests that US still remains the preferred choice for diagnosis of placenta accreta. Meantime, MRI can be a complementary to US because it can reveal signs which are invisible by US.

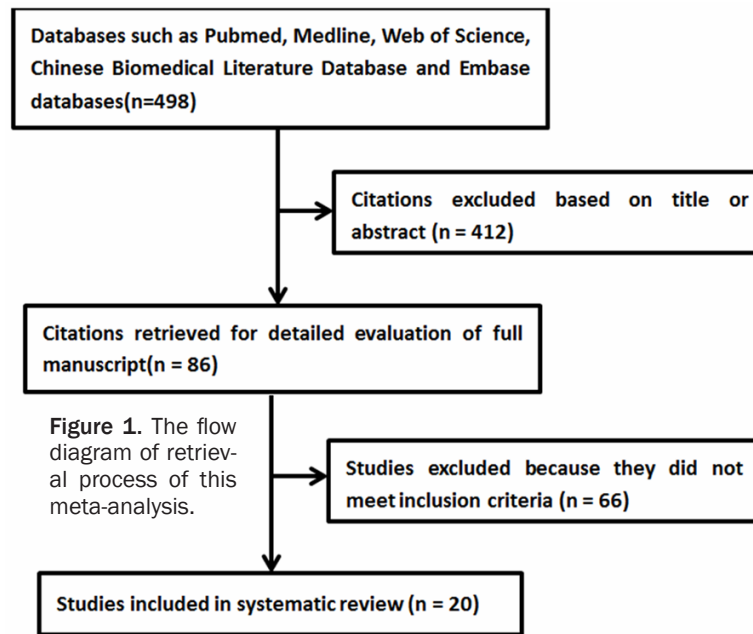Keywords: MRI, US, invasive placentation, prenatal identification

Introduction

Morbidly adherent placenta (MAP) is a rare but serious pregnancy complication in which the placenta grows deeply into the wall of the uterus and is unable to detach after childbirth. MAP can be divided into 3 subtypes depending on the depth of invasion. 1, Placenta accrete: the placenta grows into the uterine lining; 2, Placenta increta: the placenta grows into the muscular wall of the uterus; and 3, Placenta percreta: the placenta grows through the wall of the uterus and in some cases into adjacent organs, such as the bladder, colon, or nearby vessels [1]. Those condition leads to complex pregnancies and deliveries with the potential for life-threatening hemorrhage.

Magnetic resonance imaging (MRI) and Ultrasound (US) are 2 choices used in antepartum diagnosis of placenta accreta. MRI has been reported to be adaptable when US findings are equivocal or in cases with posteriorly located placenta or previous myomectomy [2]. Preoperative recognition of this pathologic condition enables planning for a hysterectomy and postpartum hemorrhage.

Many previous studies have investigated the MRI and US's efficiencies in invasive placentation. However, their results were not incomplete agreement. Some meta-analysis studies have systematically assessed the performance of prenatal MRI and US in the detection of invasive placentation respectively, but those studies did not compare the diagnosis efficiencies between MRI and US [3, 4]. Considering less bias and comparability in same samples (such as diversity of population, patient's individual condition and radiologists reading skill), so this meta-analysis research was performed by pooling parallel control studies only to compare the

Databases such as Pubmed, Medline, Web of Science, Chinese Biomedical Literature Database and Embase databases(n=498)

Citations excluded based on title or abstract (n = 412)

Citations retrieved for detailed evaluation of full manuscript(n = 86)

Studies excluded because they did not meet inclusion criteria (n = 66)

Studies included in systematic review (n = 20)

Figure 1. The flow diagram of retrieval process of this meta-analysis.

MRI and US's efficiencies in invasive placentation.

Materials and methods

Literature search strategy

Without language restriction, this paper searched the databases such as Pubmed, Medline, Web of Science, Chinese Biomedical Literature Database and Embase databases by the terms ("placenta accrete", "placenta increta", "placenta percreta", "ultrasound" or "sonographic" or "US", "magnetic resonance imaging" or "MRI" and 'invasive placenta') to retrieve related studies and the last retrieval time was December, 10, 2015. The flow diagram of retrieval process was shown in **Figure 1**.

Inclusion and exclusion criteria

Inclusion criteria: (1) study focuses on ultrasound and MRI in prenatal diagnosis of placenta accrete; (2) parallel control study (US and MRI were carried out on the same number of women); (3) data reported was available; (4) published data was fit to this meta-analysis; (5) sample size of study more than 10; (9) Prospective and retrospective cohorts, case-control studies.

The exclusion criteria: (1) animal studies; (2) the reported data was not adaptable; (3) the study only reported the result of MRI or ultrasound; (4) patients were not confirmed by path-

ological examination; (5) review or meta-analysis or comment.

Data extraction

The information about study design, first author's name, published year, endpoint, tools of diagnose, numbers of true-positive, true-negative, false-negative and false-positive in both MRI and US groups were obtained based upon "inclusion and exclusion criteria" mentioned above.

Statistical analysis

Sensitivity and 95% confidence interval (CI), specificity and 95% CI, positive likelihood ratios (LR+) and 95% CI, negative Likelihood Ratios(LR-) and 95% CI, diagnostic odds ratio (DOR) and 95% CI, area under curve (AUC) and 95% CI, summary receiver operating characteristic (SROC) of both US and MRI were calculated by Hierarchical summary receiver-operating characteristics. In order to compare the sensitivity, specificity, DOR, positive predictive value (PPV) and negative predictive value (NPV) between US and MRI, this paper adopted conventional dichotomous and continuous meta-analysis methods. Risk ratio (OR) with a 95% confidence interval (CI) and standardized mean difference (SMD) were conducted to pool the dichotomous and continuous data. Quantitative assessment such as Begg's rank correlation method and Egger's weighted regression method were used to evaluate the potential publication bias of this research. If the *p* value less than 0.05 by Egger's and Begg's test, the potential publication bias was considered to be existed. I^2-statistic and *Q*-statistic was used to represent the statistical heterogeneity. Statistically significant heterogeneity was considered to be existed if P≤0.05 and the random effect model could be used. Otherwise, fixed effects model adopted. Stata 11.0 (StataCorp, College Station, TX) performed all the statistical analysis.

Quality assessment

Quality assessment of diagnostic accuracy studies (QUADAS-2) was used to assess the quality of the studies. A 'yes' or 'no', or 'unclear' scored to each item [5].

Table 1. General characteristics of studies included in systematic review

Name	Year	Country	Sample Size	MRI		US		Conclusion
				Sen	Sep	Sen	Sep	
Bauwens [6]	2014	France	28	0.91	0.76	0.91	0.71	Ultrasonography is a relevant exam for the diagnosis of placenta accreta. Posterior placenta should not be forsaken. Anterior placenta praevia in multiparous patients with a uterine scare should be a warning.
Carri R [7]	2006	USA	453	0.88	1.00	0.77	0.96	A two-stage protocol for evaluating women at high risk for placenta accreta, which uses ultrasonography first, and then MRI for cases with inconclusive ultrasound features, will optimize diagnostic accuracy.
Elhaway [8]	2013	Egypt	39	0.89	0.87	0.80	0.90	US and MRI were useful in the diagnosis of placenta accreta with lacunae and an abnormal color Doppler imaging pattern are the most helpful findings. MRI is most clearly indicated when US findings are ambiguous or there is a posterior placenta.
Shweel [9]	2012	Egypt	28	0.91	0.76	0.91	0.71	Color Doppler and MRI were useful in the diagnosis of placenta accreta with the same sensitivity and positive impact on the peripartum clinical management.
Algebally [10]	2014	Qatar	100	1.00	1.00	0.94	0.97	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.
Yang [11]	2008	China	18	0.83	0.92	0.67	0.92	The diagnose index of MRI (75%) is superior than US (58.4%) with no significant different.
Zhou [12]	2014	China	60	0.64	0.78	0.78	0.88	Color Doppler ultrasound and MRI are 2 suitable methods in diagnosis of IPA. But the combination of ultrasound and MRI has the highest sensitivity and the lowest missed diagnosis rate.
Chen [13]	2010	China	131	0.77	0.93	0.84	0.91	The sensitivity and specificity of color-doppler US are superior than of MRI. The combination of them can improve the sensitivity, but specificity declined.
Li [14]	2015	China	56	0.95	0.97	0.89	0.95	The US and MRI are important means of clinical diagnosis of placenta increta, and those diagnostic value can't be replaced by each other.
Feng [15]	2012	China	95	0.75	0.93	0.81	0.93	The combination of US and MRI can improve the sensitivity.
Ji [16]	2012	China	80	0.81	0.90	0.77	0.90	The combination of US and MRI can improve the sensitivity.
Dwyer [17]	2008	USA	32	0.80	0.65	0.93	0.71	Both sonography 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. In the case of inconclusive findings with one imaging modality, the other modality may be useful for clarifying the diagnosis.
Langen [18]	2011	USA	112	0.68	0.67	0.83	1.00	Although US diagnosis is not definitive, in a small cohort, MRI was not superior to US in detecting invasive placentation among women with placenta previa whose ultrasound findings were concerning for invasive placentation.
Lim [19]	2011	Ireland	13	0.78	0.75	0.67	0.50	The accuracy of MRI may improve if volumes of low-signal-intensity bands are calculated, MRI is performed before 30 weeks' gestation, and risk factors for placental insufficiency are recognized.
Moodley [1]	2004	Africa	30	0.67	0.85	1.00	0.93	Colour flow Doppler was shown to be more specific in the diagnosis of the morbidly adherent placenta praevia than MRI. Doppler had a negative predictive value of 95%.
Marcillac [20]	2015	France	22	0.85	0.78	0.92	0.67	Ultrasonography and RMI represent two interesting and comple-mentary diagnostic tools for antenatal diagnosis of placenta accreta. Because of its cost andaccessibility, ultrasonography remains the first in line to be used for diagnosis. Use of ananalytical grid for diagnosis of placenta accreta could be helpful.
MAHER [21]	2010	Egypt	557	0.86	0.77	0.94	0.98	Placenta accreta can be successfully detected prenatally using ultrasound. MRI can provide additional information in doubtful cases.
Riteau [22]	2014	France	42	0.77	0.50	1.00	0.38	Ultrasound imaging is the mainstay of screening for placenta accreta. MRI appears to be complementary to ultrasonography, especially when there are few ultrasound signs.
Peker [23]	2013	Turkey	40	0.95	0.95	0.65	1.00	Currently, MRI appears to be the gold standard for the diagnosis of placenta accreta. None of the ultrasonographic criteria is solely sufficient to diagnose placental adherence defects, however, they assist in the diagnostic process.
Rezk [24]	2014	Egypt	74	0.96	0.86	0.94	0.90	Placenta accreta can be successfully diagnosed by grey scale and colour Doppler ultrasound. MRI would be more likely suggested for either posteriorly or laterally situated placenta previa in order to exclude placental invasion.

Table 2. Summary of main diagnostic test indexes for different identification methods in the prenatal diagnosis of invasive placentation

Methods	Subgroups	Studies (n)	Sensitivity (95% CI)	Specificity (95% CI)	LR+ (95% CI)	LR- (95% CI)	DOR (95% CI)	AUC area (95% CI)	Publication bias (*P* value)
US	Overall	22	0.86 (0.82-0.90)	0.92 (0.86-0.95)	10.4 (6.1-17.8)	0.15 (0.11-0.20)	70 (38-129)	0.93 (0.90-0.95)	0.234
	GADU	9	0.88 (0.81-0.93)	0.92 (0.83-0.97)	11.4 (4.9-26.7)	0.13 (0.08-0.21)	90 (29-283)	0.94 (0.92-0.96)	0.182
	DU	13	0.84 (0.77-0.89)	0.91 (0.82-0.96)	9.4 (4.9-18.4)	0.18 (0.13-0.25)	52 (27-100)	0.91 (0.89-0.94)	0.116
MRI	Overall	20	0.85 (0.78-0.90)	0.88 (0.81-0.92)	6.9 (4.2-11.3)	0.17 (0.11-0.26)	40 (18-91)	0.92 (0.90-0.94)	0.281

GADU: Gray Scale And Color Doppler Ultrasonography Combined; DU: Color Doppler Ultrasonography Only; LR+ and LR-: Positive and Negative Likelihood Ratios; DOR: Diagnostic Odds Ratio; AUC: Area Under Curve.
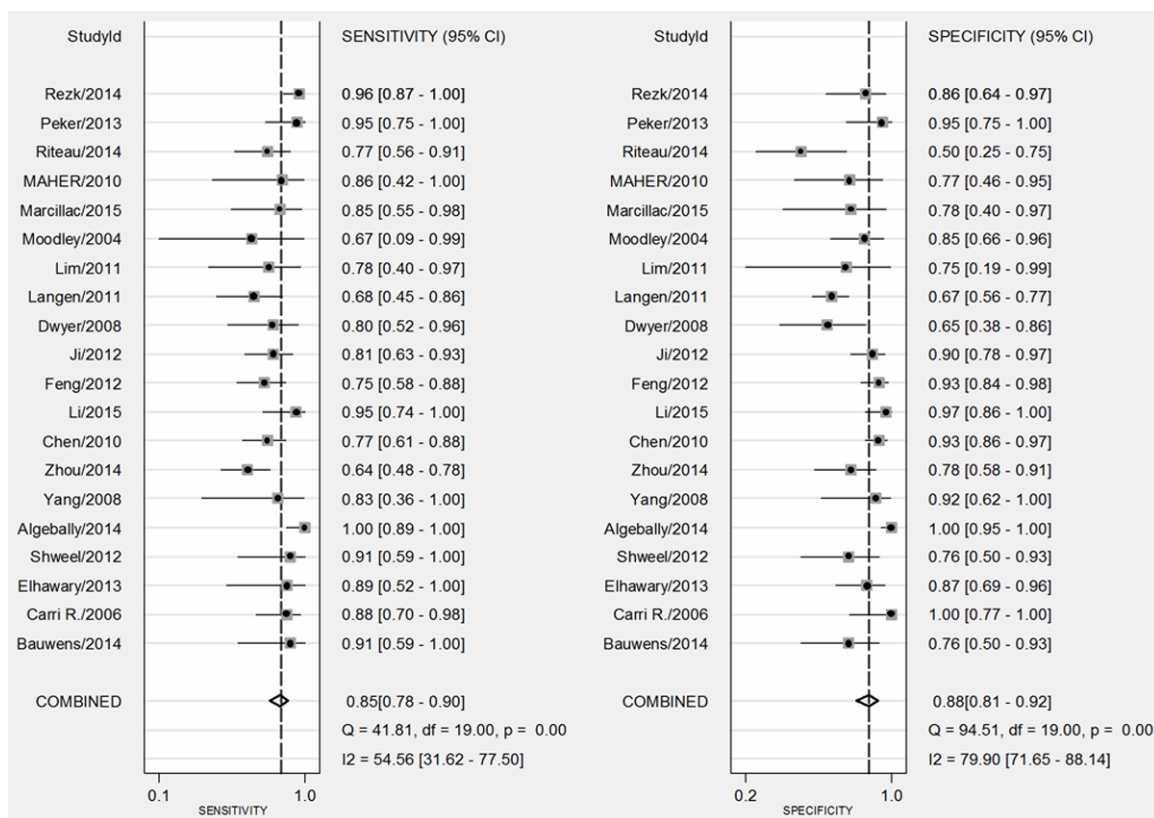
Figure 2. The forest figure of sensitivity and specificity of MRI in the prenatal diagnosis of invasive placentation.
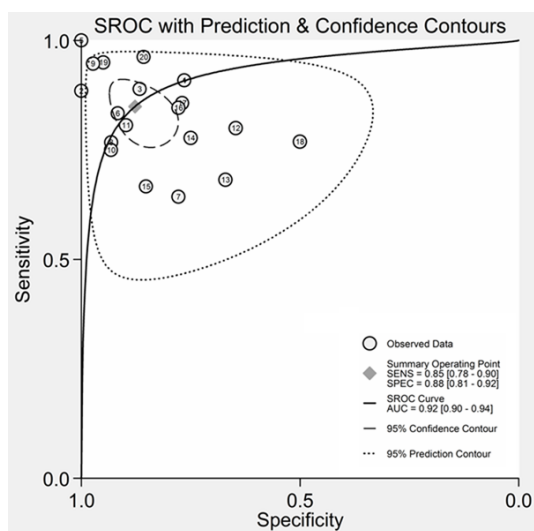

Figure 3. Receiver-operating characteristics curve for MRI in the prenatal diagnosis of invasive placentation.

Diagnose criteria

The ultrasound criteria: 1) placental lacunae with turbulent blood flow; 2) hypervascular serosa-bladder interface; 3) gap in the myometrial blood flow; 4) dilated vessels over peripheral sub-placental zone.

The MRI criteria: 1) placental heterogeneous signal; 2) dark intraplacental bands on T2WI, uterine wall bulging; 3) focal interruptions in myometrial; 4) wall, tenting of the bladder and direct visualization of the invasion of pelvic structures by placental tissue.

Main results

Characteristics of studies

20 relevant parallel control studies with 2080 individuals and 3 different types of diagnose methods ("Gray Scale and Color Doppler Ultrasonography combined", "Color Doppler Ultrasonography alone" and "MRI") were employed for this meta-analysis. The characteristics of each study were presented in **Table 1**.

Quantitative data synthesis

Diagnostic accuracy: As **Table 2**; **Figures 2** and **3** shown, the sensitivity, specificity, LR+, LR-,
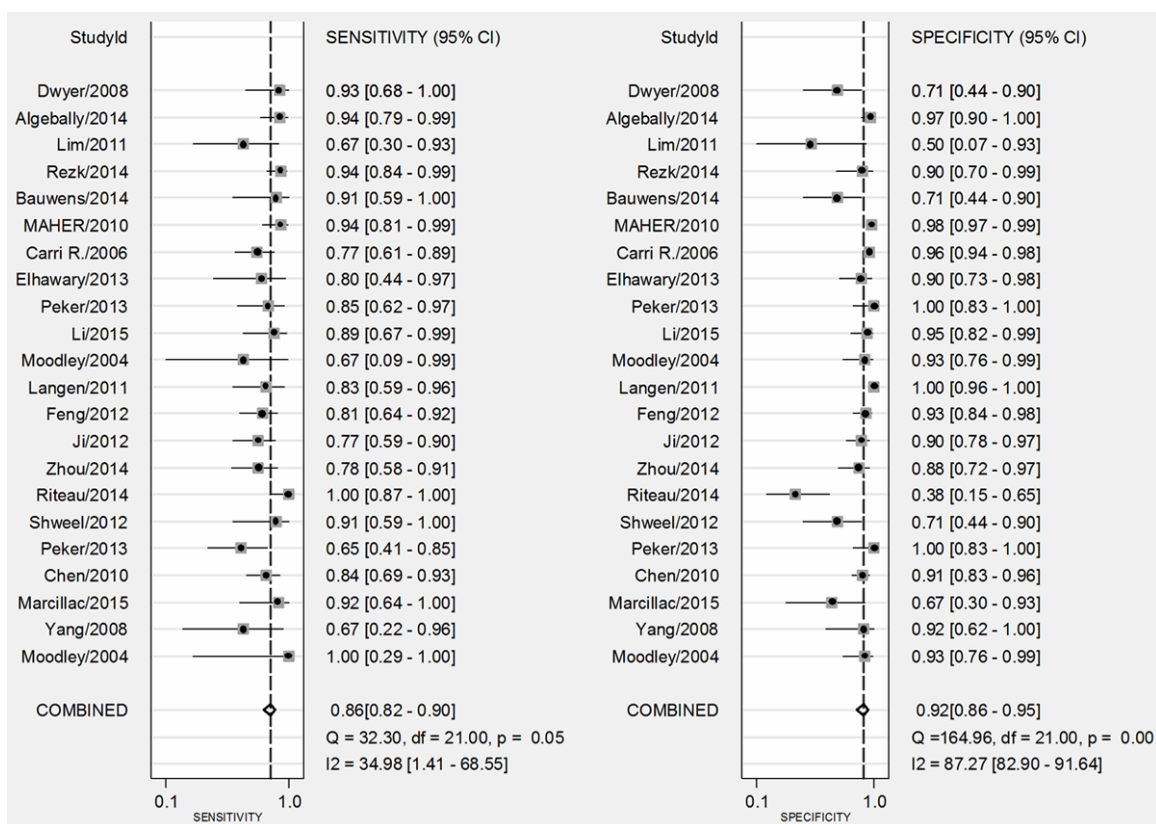
Figure 4. The forest figure of sensitivity and specificity of US in the prenatal diagnosis of invasive placentation.
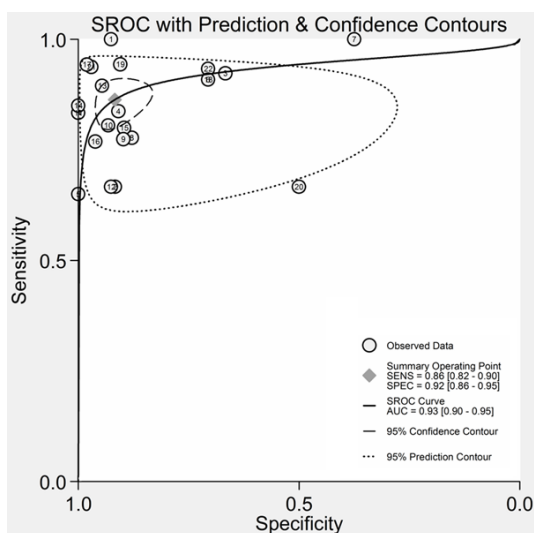

Figure 5. Receiver-operating characteristics curve for US in the prenatal diagnosis of invasive placentation.

DOR and AUC for MRI in prenatal diagnosis of placenta accrete was 0.85 (0.78-0.90), 0.88 (0.81-0.92), 6.9 (4.2-11.3), 0.17 (0.11-0.26), 40 (18-91) and 0.92 (0.90-0.94) respectively.

The diagnostic accuracy of overall US was little better than MRI in prenatal diagnosis of placenta accrete, with the sensitivity of 0.86 (0.82-0.90), specificity of 0.92 (0.86-0.95), LR+ of 10.4 (6.1-17.8), LR- of 0.15 (0.11-0.20), DOR of 70 (38-129) and AUC of 0.93 (0.90-0.95) respectively (**Table 2**; **Figures 4** and **5**). The sensitivity, specificity, LR+, LR-, DOR and AUC for two subgroups, "gray scale and color Doppler ultrasonography combined" and "color Doppler ultrasonography only", were 0.88 (0.81-0.93), 0.92 (0.83-0.97), 11.4 (4.9-26.7), 0.13 (0.08-0.21), 90 (29-283), 0.94 (0.92-0.96) and 0.84 (0.77-0.89), 0.91 (0.82-0.96), 9.4 (4.9-18.4), 0.18 (0.13-0.25), 52 (27-100), 0.91 (0.89-0.94) respectively (**Table 2**).

Comparison of MRI and US on the sensitivity, specificity, DOR, PPV and NPV: Considering potential biases caused by diversity of population, patient's individual condition and radiologists reading skill, so this paper only admitted the parallel control studies (US and MRI were carried out on the same number of women) into this meta-analysis. Conventional dichotomous

Table 3. Comparison of different screening methods in main diagnostic test indexes for the prenatal diagnosis of invasive placentation

Indexes	Subgroups	Studies (n)	OR/SMD (95% CI)			Homogeneity			Publication Bias	
			OR/SMD	CI	P value	Q	Ph	I^2 (%)	P_B	P_E
Sensitivity	Us vs. MRI	22	OR=1.012	0.835-1.226	0.766	2.20	1.000	0.0	0.473	0.136
	GADU vs. MRI	9	OR=0.957	0.716-1.280	0.766	0.32	1.000	0.0	0.268	0.579
	CDU vs. MRI	13	OR=1.056	0.818-1.365	0.675	1.62	1.000	0.0	0.377	0.298
Specificity	Us vs. MRI	22	OR=1.058	0.909-1.232	0.468	3.81	1.000	0.0		
	GADU vs. MRI	9	OR=1.019	0.780-1.332	0.888	0.54	0.994	0.0		
	CDU vs. MRI	13	OR=1.077	0.895-1.297	0.432	3.16	1.000	0.0		
PPV	Us vs. MRI	22	OR=1.026	0.848-1.242	0.791	7.34	0.997	0.0		
	GADU vs. MRI	9	OR=0.947	0.710-1.263	0.371	1.37	0.995	0.0		
	CDU vs. MRI	13	OR =1.093	0.847-1.411	0.682	5.44	0.941	0.0		
NPV	Us vs. MRI	22	OR =1.032	0.885-1.202	0.690	2.40	1.000	0.0		
	GADU vs. MRI	9	OR=1.009	0.772-1.320	0.946	0.54	1.000	0.0		
	CDU vs. MRI	13	OR=1.043	0.865-1.256	0.660	1.82	1.000	0.0		
DOR	Us vs. MRI	22	SMD=0.093	-0.066-0.252	0.253	24.37	0.000	67.2		
	GADU vs. MRI	9	SMD=0.016	-0.226-0.259	0.895	45.38	0.002	73.6		
	CDU vs. MRI	13	SMD=0.143	-0.065-0.352	0.178	74.75	0.000	71.9		

GADU: Gray Scale And Color Doppler Ultrasonography Combined; CDU: Color Doppler Ultrasonography Only; DOR: Diagnostic Odds Ratio; SMD: Standardized Mean Difference; OR: Odds Ratio; PPV: Positive Predictive Value; NPV: Negative Predictive Value.

and continuous data meta-analysis methods were adopted to analyze the different of the relevant indexes between MRI and US. As **Table 3**; **Figures 6** and **7** shown, there were no significant different between overall US and MRI on the sensitivity, specificity, DOR, PPV and NPV. No evidence was found that the relevant indexes between MRI and "gray scale and color Doppler ultrasonography combined" subgroup, or MRI and "color Doppler ultrasonography only" subgroup was significant different.

Quality assessment

According to QUADAS-2 guidelines, all the 20 studies included for this meta-analysis were assessed. As **Figure 8** shown, most of the studies with high quality, indicating that there was a low risk bias exist.

Heterogeneity

Statistically significant heterogeneities were found in some sub-analysis and the random effect model had been used. And the heterogeneity might be derived from the study of the design type, racial differences in the study population, gestational age, location of placenta and the type of probe and frequency, differ of diagnostic experience.

Publication bias

Neither the Egger's nor the Begg's test found significant publication bias in analysis of this meta-analysis.

Discussion

Placenta accreta is a potentially life-threatening complication of pregnancy and has been a major health problem in the world [25]. It is a major cause of obstetric hemorrhage and is thus associated with increased maternal morbidity and mortality. Over the last three decades, as cesarean delivery rate increasing, both the incidences of placenta accrete and placenta previa is increasing dramatically [7]. One study carried out in 1997 has reported that 62 cases were confirmed placenta accrete among 155,670 deliveries. Moreover, the incidence of placenta accrete has reached up to approximately 10% among women with placenta previa [26]. Epidemiology studies find that the incidence was 1 in 4,027 pregnancies in the 1970s, 1 in 2,510 in the 1980s, and 1 in
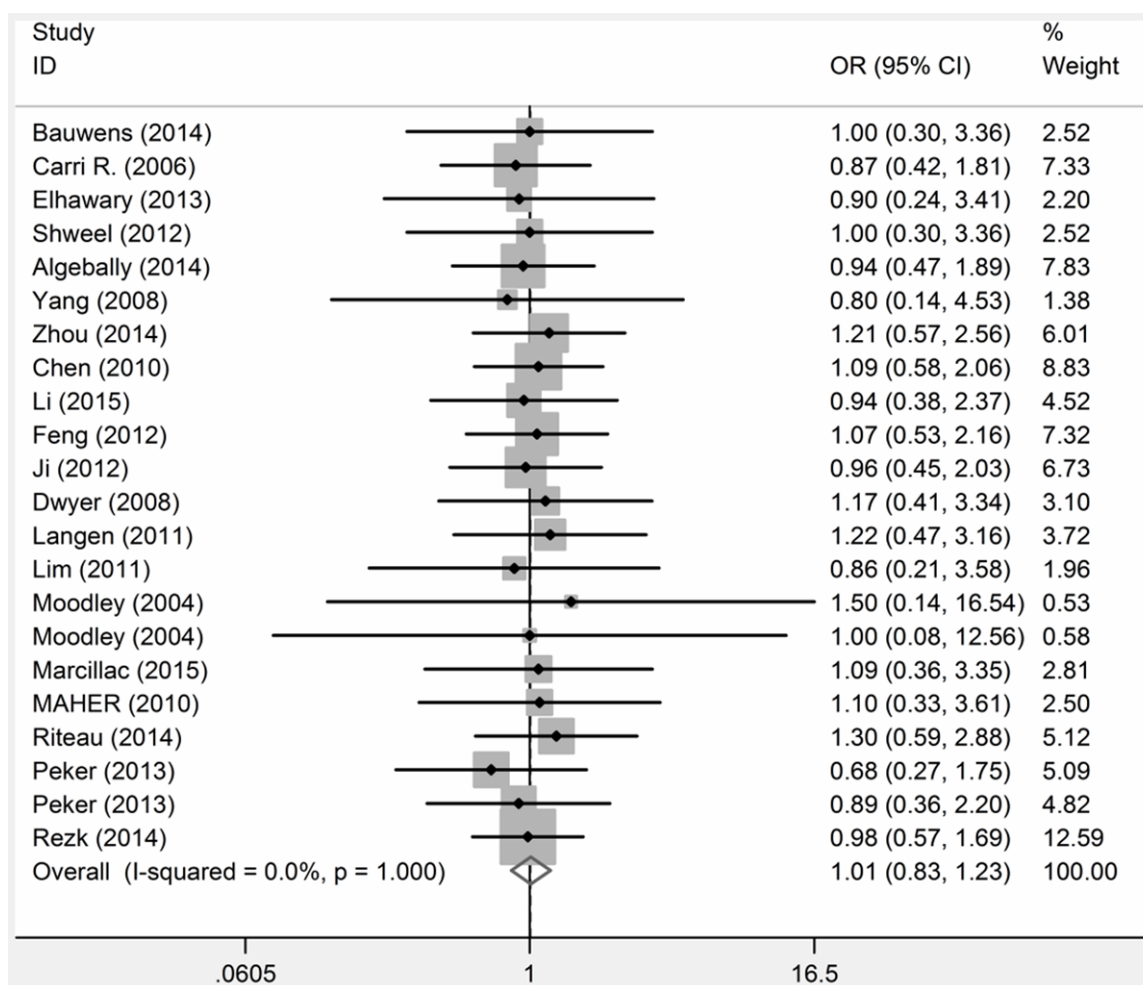
Study ID		OR (95% CI)	% Weight
Bauwens (2014)		1.00 (0.30, 3.36)	2.52
Carri R. (2006)		0.87 (0.42, 1.81)	7.33
Elhawary (2013)		0.90 (0.24, 3.41)	2.20
Shweel (2012)		1.00 (0.30, 3.36)	2.52
Algebally (2014)		0.94 (0.47, 1.89)	7.83
Yang (2008)		0.80 (0.14, 4.53)	1.38
Zhou (2014)		1.21 (0.57, 2.56)	6.01
Chen (2010)		1.09 (0.58, 2.06)	8.83
Li (2015)		0.94 (0.38, 2.37)	4.52
Feng (2012)		1.07 (0.53, 2.16)	7.32
Ji (2012)		0.96 (0.45, 2.03)	6.73
Dwyer (2008)		1.17 (0.41, 3.34)	3.10
Langen (2011)		1.22 (0.47, 3.16)	3.72
Lim (2011)		0.86 (0.21, 3.58)	1.96
Moodley (2004)		1.50 (0.14, 16.54)	0.53
Moodley (2004)		1.00 (0.08, 12.56)	0.58
Marcillac (2015)		1.09 (0.36, 3.35)	2.81
MAHER (2010)		1.10 (0.33, 3.61)	2.50
Riteau (2014)		1.30 (0.59, 2.88)	5.12
Peker (2013)		0.68 (0.27, 1.75)	5.09
Peker (2013)		0.89 (0.36, 2.20)	4.82
Rezk (2014)		0.98 (0.57, 1.69)	12.59
Overall (I-squared = 0.0%, p = 1.000)		1.01 (0.83, 1.23)	100.00

.0605   1   16.5

Figure 6. The forest figure of sensitivity comparison between US and MRI in the prenatal diagnosis of invasive placentation.

533 for 1982-2002. In 2002, ACOG estimated that incidence has increased 10-fold over the past 50 years [27]. Among pregnancies with placenta previa, previous cesarean delivery years is an independent risk factor for placenta accrete, with rates of 3%, 11%, 40%, 61%, and 67% for the first, second, third, fourth, and fifth or greater number of Caesarean sections [28]. Timely diagnosis of placenta accreta during the antenatal period can enable preparations for a possible obstetric emergency, so that could avoid obstetric complications such as Cesarean hysterectomy and massive transfusion and improve the perinatal prognosis [29]. Prenatal percreta diagnosis using US and MRI are the two important techniques for obstetrician to identify and manage.

The conventional sonographic criteria for adherent placenta include absence of normal hypoechoic placental myometrium zone, thinning or disruption of the hyperechoic uterine serosa-bladder interface, presence of focal exophytic masses, and the presence of lacunae in the placenta [30]. Because Color Doppler imaging can more accurately determine the depth of invasion of the placenta into the uterine myometrium or serosa and improve the accuracy, so it has been widely used in diagnosis of adherent placenta, especially in cases with anterior placenta [31]. MRI may be the better choice for accreta in posterior placenta, or to confirm equivocal US findings, because it can create a niche in the areas where US can't provide completely during the second and the third trimester [32].

In order to avoid clinically and methodologically varied, this study took 20 parallel control studies (US and MRI were applied to the same pop-
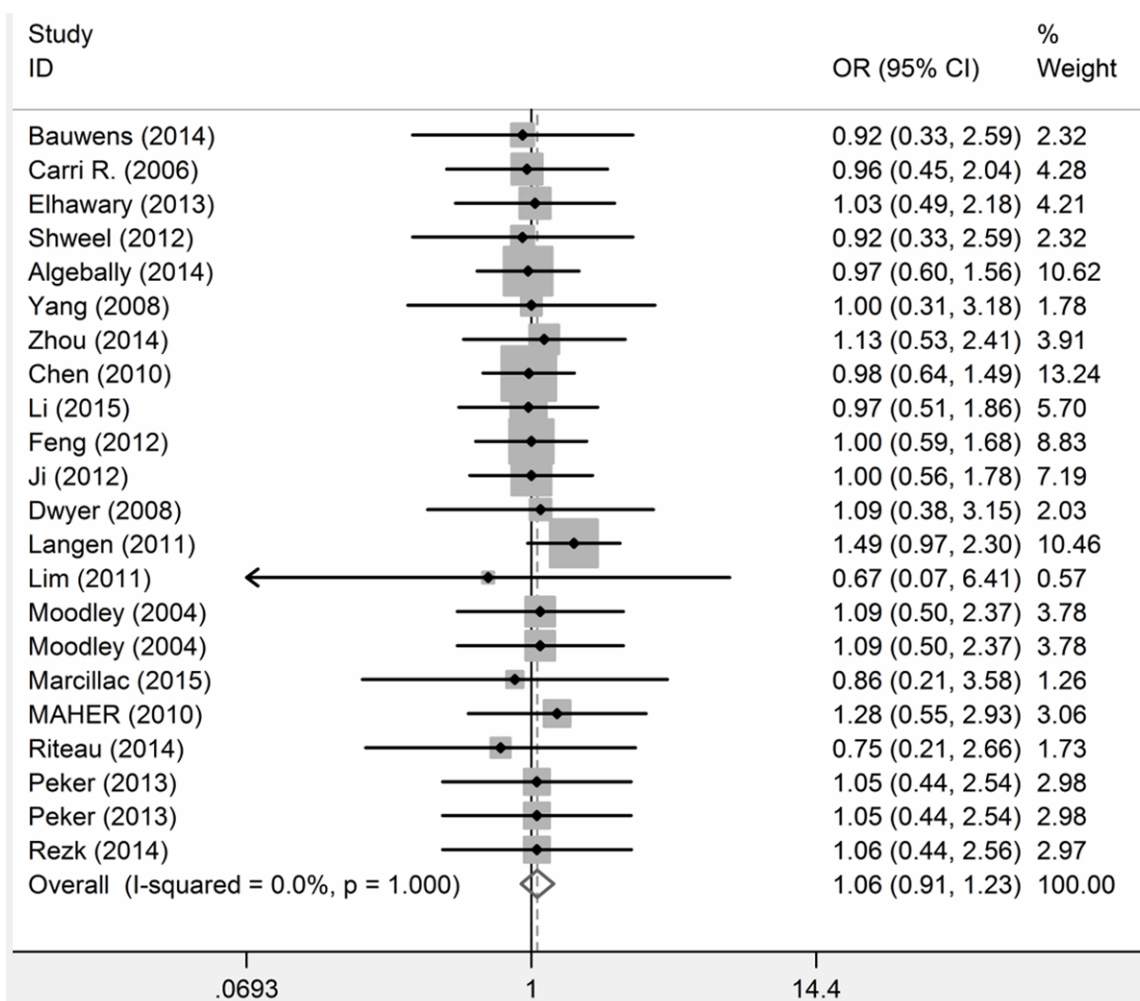
Figure 7. The forest figure of specificity comparison between US and MRI in the prenatal diagnosis of invasive placentation.
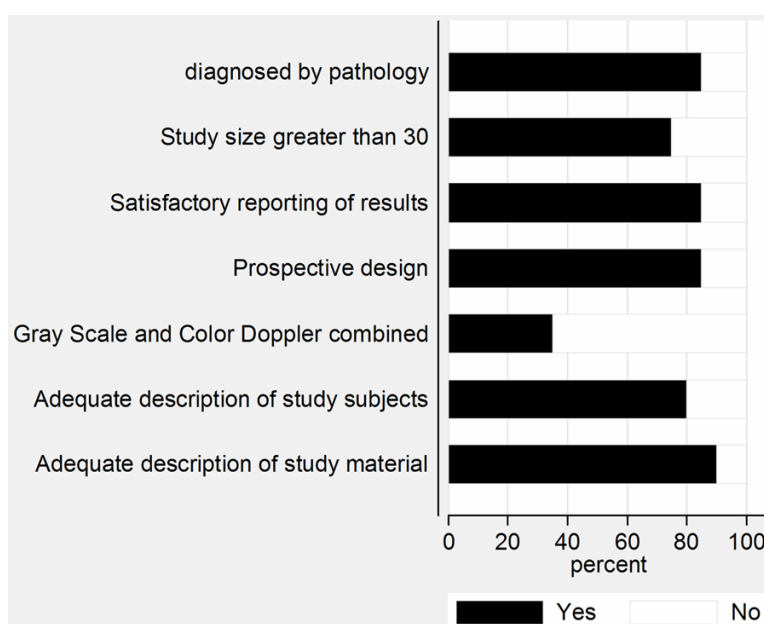

Figure 8. Quality assessment of 20 studies included in this meta-analysis.

ulation) into this meta-analysis. This paper found that the sensitivity of MRI for diagnosis of placenta accreta defects was 85%, with a specificity of 88%. The sensitivity and sp-ecificity of US were 86% and 92% respectively, while the sensitivity of color Doppler US was 84% with a specificity of 91%. Conventional dichotomous and continuous data meta-analysis methods did not find any evidence that the relevant indexes of MRI and

US were significant different. Interpretation of those results maybe as follows: 1, for cases with typical placenta accreta, the diagnostic efficiencies of US and MRI were similar, and untypical cases accounted for very low proportion. So the different of diagnostic efficacies of US and MRI could not be significant distinguished. 2, trimesters, diagnostic experience and location of placenta could affect the diagnostic efficacies of US and MRI. But because of limitation of the original data, this study could not do detailed subgroup analysis to distinguish the different of efficacies between US and MRI.

Conclusion

Considering on the economy, safety, non-invasive and time-saving of US, and no different between US and MRI on diagnostic accuracy, this study suggests that US still remains the preferred choice for diagnosis of placenta accreta. Meantime, MRI can be a complementary to US because that it can reveal signs which are invisible by US (eg. intraplacental bands).

Disclosure of conflict of interest

None.

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