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Role of Early Pregnancy Ultrasound Markers for Predicting Miscarriage: A Systematic Review

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Abstract

Background: Miscarriage is a common complication of early pregnancy, and most losses usually occur during the first trimester. Ultrasound is basically the main imaging technique in the examination of early pregnancy, particularly transvaginal ultrasound (TVUS), and various sonographic markers have been also proposed as predictors of miscarriage as well.

Objective: The present review aimed to systematically summarised the evidence on early pregnancy ultrasound markers that were usually associated with miscarriage.

Methods: The systematic review was based on PRISMA guidelines. Moreover, an electronic databases literature search was conducted using PubMed, Google Scholar, Scopus, Embase and Springer for original studies published between 2016 and 2026. Ten studies met the inclusion criteria and were analysed for study design, population, sonographic findings, estimating ultrasound markers before 12 completed weeks of pregnancy and reporting miscarriage outcomes as well.

Results: Across the included studies, abnormal morphology of the gestational sac, abnormal yolk sac, decreased crown–rump length, fetal bradycardia, and subchorionic hematoma were risk factors that were consistently associated with a higher miscarriage rate.

Conclusion: The study concluded that early pregnancy ultrasound is of value for predicting miscarriage. Standardized criteria and combined use with clinical and biochemical markers might improve predictive accuracy.

Introduction

Early pregnancy loss known as one of the most common complications that obstetricians encounter. It is usually defined as the sudden loss of a pregnancy before 20 weeks of gestation.[1] As miscarriage impacts about 10% to 20% of pregnancies that are clinically recognized.[2] Moreover, a significant number of early pregnancy losses

take place within the first trimester, specifically prior to 12 weeks' gestation.[3] The most common causes that contributes to early pregnancy loss encompasses several attributing factors, such as chromosomal abnormalities, hormonal issues, diseases in the mother, abnormalities within the uterus, infections, and lifestyle conditions. However, in most cases, the exact cause remains unidentified. [4]

The early identification of pregnancies at increased risk of miscarriage is of considerable clinical importance. Hence, with the wide availability of first-trimester ultrasound, multiple sonographic markers have been proposed as predictors of pregnancy viability.[5] So, understanding and integrating such markers into routine clinical practice may also provide improved early diagnosis as well. It also guides decision-making and ultimately enhance maternal care and emotional well-being in early pregnancy as well.[6]

Ultrasound is the one of the most common used modalities in the assessment of early pregnancy. Because it is non-invasive, widely available, repeatable, and does not utilize ionizing radiation. However, among the ultrasound techniques available, transvaginal ultrasound is a very important procedure.[7] It is the usually a modality of choice for evaluating early pregnancy. It basically brings the transducer probe closer to the pelvic organs and allows the utilization of higher-frequency sound waves. Hence, this technique results in significantly sharper, higher-resolution images as compared to transabdominal scans, which is also substantial for early diagnosis and fetal monitoring as well. As it provides good detail and the ability to visualize early gestation structures clearly. These structures basically consist of the gestational sac, yolk sac, early embryo, and the detection of the presence and activity of the heartbeat of the foetus.[8]

While several sonographic features evident during early gestation have been found to have a significant association with an excessive risk of miscarriage. These mostly include some abnormal gestational sac and shape, irregular and either large or absent yolk sac, low crown-rump length for gestation dates, and the absence of heartbeat or presence of slowed heartbeat. Other features generally consist of anechoic fluid collections and discrepancy between last menstrual period and ultrasound dating. [9, 10]

Important ultrasound markers that play an important role in the early prediction of pregnancy viability are discussed in detail as follows. Fetal heart rate usually measured in beats per minute. However, a heart rate of 85-90 or lower for 5 to 8 weeks of gestation, extremely low rate of 80 or lower beats per minute, which strongly suggests a high risk of pregnancy failure. The suspicion of having no fetal heartbeat or absence of embryonic heartbeat, are among the crucial factors for early detection of pregnancy viability. Gestational sac size. In terms of mean sac diameter, or MSD-CRL, or MSD-CRL of 5 mm or less.[11,12]

Yolk sac or abnormal yolk sac size of excessive size of 6-7 mm or more, or abnormal contour[13], or completely absent yolk sac when an embryo is present [14], these all signs are important predictor of detecting pregnancy viability and indicative of spontaneous miscarriage as well.[15] Crown-rump length, or a small size, or slow rate of growth is also an important factor as it is helpful in detection of expected gestational age. It is basically a standard ultrasound measurement that is taken from the top of an embryo's head (crown) to the bottom of its buttocks (rump) in early pregnancy. Moreover, a slow interval growth rate also shows poor embryonic development.[16]

Other sonographic factors, includes presence of a large subchorionic hematoma, or hematoma associated risk as well.[17] Abnormal gestational sac or abnormal inner contours or crowding of SAC also play a vital role and it is generally low-lying and usually surrounded by a weak echogenic and thin rim of decidual reaction.[18] As the visualization of an empty amnion i.e., without a fetal pole is highly notable during prognosis of a pregnancy. As, empty amnion, or visualization of amnion when heartbeat not visualized, or absent heartbeat is also an important factor. Furthermore,

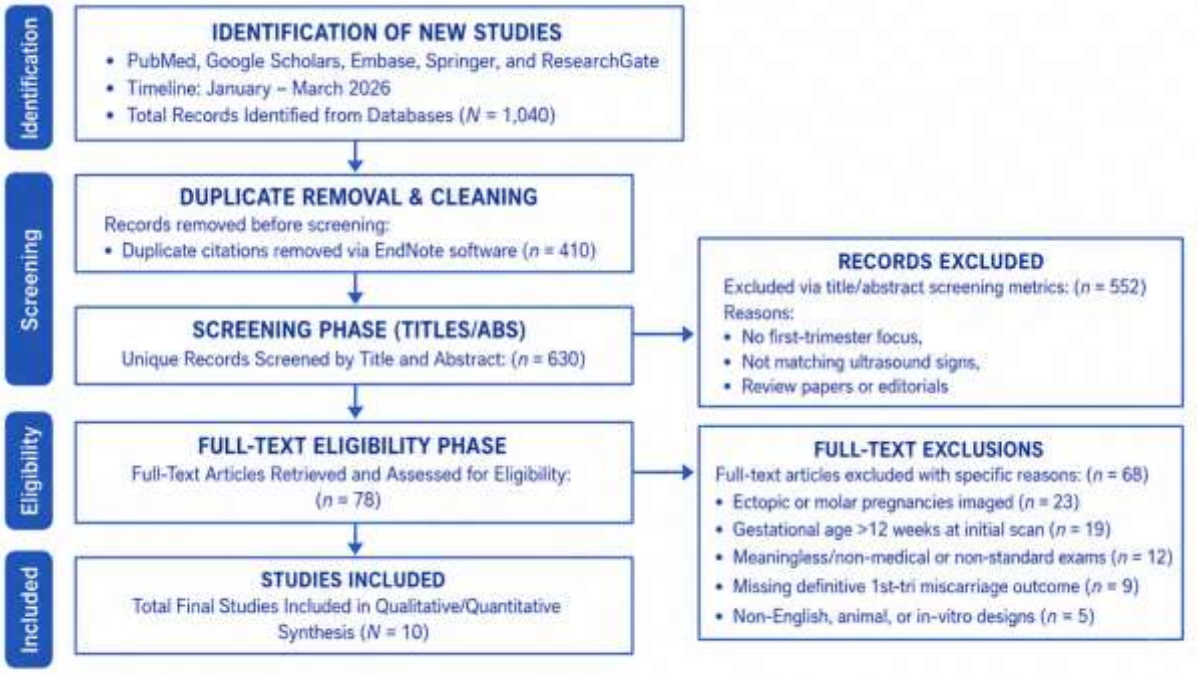
this specific ultrasound marker has extreme specificity for sonographic failure of pregnancy.[19]
Even with the common use of ultrasound in the early stages of gestation, there are still discrepancies in the predictive power of the mentioned markers.[20] Thus, a systematic review perusing the source of the existing literatures on the subject becomes a particularly important step in compiling the evidence on the diagnostic accuracy of the prognostic power of the mentioned markers in the miscarriage of pregnancy.

Materials and methods

This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) guidelines to ensure methodological transparency and reproducibility. The primary objective was to evaluate the existing literature on the early pregnancy ultrasound signs assessment for the prediction of miscarriages. A comprehensive literature search was performed using three major databases like Scopus, Embase, PubMed, ResearchGate, and Google Scholar—up to March 2026. The search strategy incorporated a combination of relevant keywords and Medical Subject Headings (MeSH) such as 'early pregnancy ultrasound,' 'prediction of miscarriage,' 'yolk sac abnormalities,' 'foetal heart rate,' 'gestational sac,' and 'first-trimester pregnancy loss'. Boolean operators (AND/OR) were applied to optimize sensitivity and precision during retrieval of data.
Studies eligible for inclusion were original peer-reviewed research articles published in English, focusing on pregnant women at risk of miscarriages. Eligible study designs included meta-analyses, prospective and retrospective cohort studies, case control, CNN-based imaging analysis and cross-sectional studies. Basically, the intervention of concern of this systematic review was ultrasound markers employed in early pregnancy, and studies that employed meaningless tests or non-medical tests were also excluded. Inclusion criteria for studies usually regarded the employment of standard ultrasound assessment or biomarkers as a comparison standard or reference. Meanwhile, consecutive patients with confirmed intrauterine pregnancy <12 weeks attending early pregnancy clinics were taken in this study population. Moreover, women aged 18–45 years were particularly recruited in this study group. The study population of this systematic review basically included pregnant female patients. While exclusion criteria generally included studies conducted on healthy participants, ectopic or molar pregnancies, or those involving second- to third-trimester pregnancy complications. Non-English language publications, animal studies or in-vitro research, and unpublished data were also excluded to maintain data quality and applicability to clinical practice as well.
The study selection process was basically executed in two stages by two independent reviewers. Initially, titles and abstracts were usually screened for relevance, followed by full-text review of potentially eligible articles. Disagreements were generally resolved through consensus or consultation with a third reviewer. References of included studies were then manually checked to identify any additional eligible studies that were not captured during the initial database search. Moreover, EndNote reference management software was employed to organize citations and remove duplicates efficiently. Hence, original research articles that basically included prospective cohort studies, retrospective studies, and studies on the accuracy of diagnosis regarding ultrasound findings before the 12th week and the outcome of miscarriage were included.
The data was extracted using a systematic procedure with a pre-existing protocol to maintain consistency throughout each identified study. The data was basically retrieved that was related to the study itself, with details provided in author, study design, setting, and sample size. While population information gathered data related to the mother, which included age range and criteria used for inclusion. Moreover, ultrasound study information was gathered in accordance with gestation age

measurements at time of scanning including gestation sac appearance and measurement, yolk sac detail, crown-rump measurement, fetal heart rate, measurement of subchorionic hematoma, and criteria used to define abnormalities identified. Outcome data basically related to miscarriages was collected. While data related to performance measurements, which included sensitivity, specificity, odds ratio, ratio, curve ratio, and predictive value, was also collected where possible. Due to anticipated heterogeneity in methodology and outcome measures, appropriate quality assessment tools were utilized depending on study type. Cohort studies, either prospective or retrospective, were appraised using the Newcastle–Ottawa Scale. While diagnostic accuracy studies were assessed for risk of bias by employing the QUADAS-2 rules. Each study was particularly assessed independently. The quality was evaluated depending on consistency among ultrasound procedures, outcome definition, follow-up, and level of reporting. Furthermore, a PRISMA flow diagram was generated to visually summarize the study selection process, including the number of records identified, screened, excluded, and finally included in the review.

Prisma Flow Chart



Results

A total of 1040 studies were identified through the electronic databases. After removing duplicates, 630 studies were screened based on title and abstract, and 68 studies were selected for full-text review. Of these, 10 studies met the inclusion criteria for the systematic review. The characteristics of the included studies are summarized in Table 1.

Table 1: Characteristics of Included Studies

Author (Year)	Study year	Country	Study Design	Sample Size	Population	Outcome(s) Measured	Major Findings
Kumari et al.[21]	2016	India	Prospective observational study	150	Women in early pregnancy (5–12 weeks' gestation	Early pregnancy failure (miscarriage)	Ultrasound markers such as abnormal MSD, large yolk

					)		sac, reduced CRL, embryonic bradycardia, increased resistive index, and intrauterine hematoma were associated with miscarriage. Overall abortion rate was 16%, with majority occurring between 8–12 weeks. Study confirmed the importance of first-trimester USG in predicting pregnancy failure.
Bamniya et al.[22]	2017	India	Prospective cohort	612	Women with early pregnancy undergoing TVUS	Pregnancy outcome (miscarriage and complications)	Abnormal ultrasound markers significantly predicted pregnancy loss. Large yolk sac showed highest miscarriage rate (78.6%), followed by fetal bradycardia (38%)

							and abnormal gestational sac size (14.3%). Additional complications (IUGR, PIH) were also higher (up to 33%) in abnormal cases. Study highlights strong predictive value of early TVUS markers including yolk sac, FHR, and gestational sac morphology.
Sultana et al.[23]	2018	India	Prospective observational study	365 (335 analyzed)	Women undergoing TVUS at 6–10 weeks gestation	Early pregnancy loss (first trimester miscarriage)	TVUS parameters (GSD, CRL, YSD, fetal heart rate) significantly predicted miscarriage. Low embryonic heart rate (<85 bpm) showed highest predictive accuracy (sensitivity 85%, specificity 99%). GSD <20

							mm and CRL <7.5 mm were also associated with EPL. GSD–CRL difference <8.5 mm had high sensitivity (91%) for predicting miscarriage.
Taylor et al.[24]	2019	Australia	Prospective cohort	Not clearly specified	Women undergoing first-trimester ultrasound	Miscarriage before 12 weeks' gestation	Combined ultrasound parameters (FHR, mean uterine artery PI, trophoblast volume) significantly differed between viable and non-viable pregnancies. Logistic regression model showed good predictive performance (AUC 0.81), with sensitivity 76% at 30% false-positive rate, suggesting multi-parameter models improve prediction accuracy.
Pillai[25]	2021	UK	Prospective cohort	296	Women reported	Miscarriage vs	TVUS (CRL,

					with threatened miscarriage and fetal heartbeat	continued pregnancy	MGSD, FHR) combined with hCG, progesterone, inhibin A; multivariable logistic regression predicted miscarriage with 96% specificity and 57% sensitivity
Wang et al.[26]	2022	China	Retrospective case-control + cohort	1,098	Women having singleton pregnancies	Spontaneous miscarriage	CNN analysis of gestational sac TVUS images; high predictive accuracy (AUC 0.857–0.885), outperforming CRL and FHR alone
Petersen et al.[27]	2023	Denmark	Prospective longitudinal cohort	203	Women with presumed viable pregnancies	First-trimester pregnancy loss	Serial TVUS (CRL, MGSD) and serum markers (hCG, estradiol) used; gestational age–dependent hazard ratios allowed dynamic outcome prediction; miscarriage incidence

							18%
Liu et al.[28]	2024	China	Retrospective cohort	603 RPL patients	Women showing recurrent pregnancy loss (RPL)	Miscarriage in RPL patients	Week-specific TVUS markers (CRL, mGSD) with hCG and progesterone; ROC analysis showed moderate-high predictive performance (AUC 0.671–0.872)
Saucedo et al.[29]	2025	Multicenter (not specified)	Prospective cross-sectional study	258	Viable singleton first-trimester pregnancies (5+4 to 10+6 weeks)	Spontaneous miscarriage	Fetal heart rate (<5th percentile) and MSD–CRL difference were the only significant predictors of miscarriage. MSD–CRL ≤5 mm increased risk 21.3-fold, while low FHR increased risk 2.8-fold. Model showed good fit (Hosmer–Lemeshow p=0.804), confirming strong predictive value of combined

							ultrasound markers.
Mani et al.[30]	2026	India	Prospective cohort	319	Antenatal women (6–10 weeks gestation)	First-trimester pregnancy outcome (miscarriage vs ongoing pregnancy)	TVUS parameters (CRL, MSD, YSD) significantly associated with pregnancy outcome. ROC analysis showed optimal cut-offs: CRL ≈15.3 mm, MSD ≈27.9 mm, YSD ≈4.15 mm. MSD demonstrated highest diagnostic performance (sensitivity 70.3%, specificity 69.2%, accuracy 69.5%). Demographic risk factors (age 26–30 years, infertility history, prior miscarriages) further improved prediction.

Abbreviations: **MSD** (mean gestational sac diameter), **GSD** (gestational sac diameter), **CRL** (crown–rump length), **YSD** (yolk sac diameter), **FHR** (fetal heart rate), **TVUS** (transvaginal ultrasound), **RPL** (recurrent pregnancy loss), **EPL** (early pregnancy loss), **PIH** (pregnancy-induced hypertension), **IUGR** (intrauterine growth

restriction), **hCG** (human chorionic gonadotropin), **ROC** (receiver operating characteristic), **AUC** (area under the curve), **CNN** (convolutional neural network), **PI** (pulsatility index), **MGSD** (mean gestational sac diameter), **USG** (ultrasonography)

Discussion

The current systematic review comprised of findings reported by the published studies between 2016 and 2026, focusing on the important role played by ultrasonography performed during the first trimester in predicting early pregnancy loss (EPL). Regardless of different populations and research designs, important ultrasound markers such as mean gestational sac diameter (MSD), crown rump length (CRL), yolk sac diameter (YSD), and fetal heart rate (FHR) have been shown to be of considerable significance in predicting pregnancy complications. The evidence clearly showed that designated ultrasound anomalies detected before 12 weeks' gestation had a significant association with increased risk of pregnancy loss. These observations tended to affirm the practical utility of early ultrasound as a predictive method rather than a diagnostic procedure.

Furthermore, traditional grayscale ultrasonography parameters like mean gestational sac diameter **(MSD)**, crown rump length (**CRL)**, and yolk sac diameter (**YSD)** remained basic in early pregnancy evaluation. Numerous studies included in this review, constantly demonstrated that abnormal sac morphology, reduced CRL growth, enlarged yolk sac, and embryonic bradycardia were strongly correlated with miscarriage (Kumari et al., 2016); Bamniya et al., 2017); Sultana et al., 2018). Notably, fetal heart rate (FHR) became one of the major predictors of miscarriage, being characterized by high specificity level (up to 99%) as reported by Sultana et al. (2018).

Moreover, the inclusion of quantitative cutoffs models further increased the predictive accuracy. In this regard, research conducted by Shah et al. (2019) and Saucedo et al. (2025) revealed that combined values, especially MSD–CRL variances, played a very important role in determining the risk classification of miscarriages. The study findings by Saucedo et al. (2025) further showed that an MSD-CRL differential of ≤5mm was strongly indicative of pregnancy complications. This finding helped to focus on the need for assessing growth proportionality instead of singular measurements.

Beyond the traditional measures, there have been multiple investigations that had used multivariable analysis and sophisticated prediction methods. For example, the combination of FHR with doppler ultrasound findings of trophoblastic and uterine arteries in Taylor et al.'s study (2019) had shown a high accuracy rate of prediction (AUC 0.81) and implied that the outcome of early pregnancy should be evaluated by comprehensive methods rather than a single ultrasound finding. Likewise, Pillai's study (2021) and Petersen et al. (2023) had combined both biochemical and ultrasound markers, for enhanced predictive performance and dynamic risk evaluation across gestational age.

Most recent research work is now leaning towards the use of computational and artificial intelligence techniques. According to Wang et al. (2022) CNN analysis of images taken from gestational sacs proved more accurate compared to conventional measures like CRL and FHR, resulting in excellent predictive values (AUC up to 0.885). Similarly, Yland et al., (2024)[31] also emphasized the importance of using integrated approaches involving ultrasonography, hormones, demographics, and other clinical parameters as well. In addition, the combination of ultrasound information with biochemistry, such as β-hCG and progesterone levels, is also now increasingly being researched (Liu *et al.*, 2024).

More importantly, current research findings indicated a paradigm change from one-parameter measurement to multifactorial predictive models, which combined the ultrasound markers with biochemical and demographic variables. Mani et al. (2026)

work provided even more justification for this trend by identifying particular cutoff points for CRL, MSD, and YSD as well as highlighting the role of maternal risk factors, including age and previous pregnancy losses.

Overall, this review had found that individual ultrasound predictions were not precise enough to be used to definitively determine an impending miscarriage. But rather a combination of features including sac morphology, yolk sac morphology, crown-rump length, and foetal heart rate was most informative and useful. Additionally, follow-up and standardized criteria could be of even further benefit. Although the conventional parameters like CRL, MSD, YSD, and FHR continue to be important clinically, the trend towards using combined prediction models, along with artificial intelligence in diagnosis leads to greater accuracy and improved diagnosis as well.

Hence, the predictive power of the markers in early pregnancy ultrasound basically depends on some limitations. As ultrasound scanning is operator-dependent, and there might also be discrepancies in the accuracy of the results among different operators. It might also be liable to false negatives in cases of delayed embryo development due to the gestational age of the pregnancy at the time of scanning. While some of the markers, like subchorionic hematoma, are unreliable in predicting miscarriage. These markers perform inconsistently in different studies.

Recently, improved technology particularly in the use of ultrasound, such as the use of high-resolution transvaginal probes and doppler studies of uteroplacental blood flow, has also been used to assess early pregnancy. Three-dimensional (3D) ultrasound and quantitative analysis for trends in fetal growth rates are also being investigated as possible methods for improved risk assessment as well.

Conclusion

Early pregnancy ultrasound scanning especially trans vaginal ultrasound (TVUS) technique has been critical in the development of models that can predict miscarriage, as certain sonographic signs have been found to be associated with adverse outcomes in pregnancies. Suggestive gestational sac abnormalities, yolk sac abnormalities, low crown-rump length, fetal heart rate slowing, and significant subchorionic hematomas had also been found to be critical predictors of early pregnancy loss across studies. Even as ultrasound scanning continues to prove valuable as a non-invasive, accessible, and promising predictive modality, the greatest predictive accuracy could be achieved when these parameters would be combined with clinical, biochemical, and advanced computational models. Future studies must address setting standardized cutoff values and developing and validating artificial intelligence–based predictive models for optimizing early pregnancy risk assessment.

Recommendations

Further research should concentrate on multicentric prospective studies where first trimester ultrasonographic examinations would be performed under uniform protocols to increase predictability of early pregnancy losses. Moreover, standardized cut-off points for CRL, MSD, YSD, and FHR measurements need to be defined as well. Sonographer training should be intensified to avoid any inter-operator variance. The possibility of combining ultrasonography data with biochemical and clinical indicators for development of an even more sophisticated prediction tool needs to be examined. Artificial intelligence-based devices could contribute to the process; however, they should first be tested and validated in terms of their diagnostic performance.

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