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Systematic Review

Role of ultrasound markers in predicting early pregnancy loss: a systematic review

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ABSTRACT

Early pregnancy loss (EPL), defined as pregnancy loss before 13 weeks' gestation, affects approximately 10–20% of pregnancies and represents a major source of clinical uncertainty within early pregnancy assessment units (EPAUs). Although several ultrasound parameters are routinely measured in early pregnancy, their predictive value for EPL is not consistently applied in clinical practice. A structured review of English-language literature published over the past 10 years was conducted using PubMed, OVID, CINAHL, and Biomed Central databases to evaluate ultrasound markers associated with EPL. Evidence consistently supports predictive value for routinely obtained markers, including crown–rump length (CRL), fetal heart rate (FHR), gestational sac measurements (GSD/MSD), and yolk sac diameter (YSD). Several studies indicate that abnormalities in yolk sac (YS) characteristics and gestational sac (GS) growth may precede changes in FHR or CRL in pregnancies that subsequently miscarry. More recent data refine subchorionic haematoma (SCH) risk stratification, demonstrating a graded association between miscarriage risk and SCH burden expressed as a proportion of GS size, including in assisted reproduction populations. Emerging studies propose gestation-specific predictive thresholds and integrative models using ultrasound indices with or without biochemical markers, while machine-learning and artificial intelligence approaches show high discrimination in selected cohorts. Incorporating routinely measured ultrasound markers into structured early pregnancy assessment may improve counselling and risk stratification, although broader validation is required before advanced predictive models can be adopted routinely.

Keywords: Early pregnancy loss, Early pregnancy ultrasound markers, Ultrasound in predicting early pregnancy outcomes

INTRODUCTION

Early pregnancy loss (EPL), defined as pregnancy loss before 13 weeks' gestation, affects 10 to 20% of clinically recognised pregnancies and is the most common complication of early pregnancy.[1,2] Beyond its physical impact, EPL is associated with significant emotional distress, anxiety, and grief for affected individuals and their partners.[3,4] Recurrent presentations contribute substantially to workload pressures within early pregnancy assessment units (EPAUs).[5]

Women commonly present with vaginal bleeding, abdominal pain, or concerns regarding pregnancy viability.[6] Advances in transvaginal ultrasound allow detailed assessment of early pregnancy from 5–6 weeks' gestation.[7] EPAUs increasingly diagnose non-viable pregnancies and counsel patients during periods of diagnostic uncertainty, often before established criteria for miscarriage are met.[8] Ultrasound is central to this assessment, with routine evaluation of gestational sac (GS), gestational sac diameter (GSD), mean sac diameter (MSD), yolk sac (YS), yolk sac diameter (YSD), crown–rump length (CRL), and fetal heart rate (FHR).[9] Current guidelines employ conservative diagnostic thresholds to avoid false-positive diagnoses; however, these thresholds do not address risk stratification in pregnancies of uncertain viability.[10]

The predictive use of routinely obtained ultrasound markers before meeting diagnostic criteria has the potential to improve counselling, guide follow-up, and reduce patient anxiety.[11] Increasing attention has therefore focused on refining ultrasound-based risk assessment through quantitative evaluation of features such as subchorionic haematoma (SCH) and early placental development.[12] Multiple studies demonstrate that deviations in embryonic growth or extra-embryonic structures may precede sonographic evidence of pregnancy failure by days or weeks.[13,14] In parallel, predictive models incorporating ultrasound, clinical, and biochemical data, including machine-learning (ML) approaches, have been proposed, although their clinical applicability requires further evaluation.[15]

As frontline services, EPAUs must balance high patient volumes with timely reassurance, follow-up planning, and escalation of care when required.[16] Incorporating predictive ultrasound markers into routine assessment may support structured clinical decision-making, optimise resource utilisation, and personalise follow-up pathways. Such approaches should complement, rather than replace, established diagnostic criteria to maintain diagnostic safety.[16]

This review synthesises current evidence on ultrasound markers associated with early pregnancy loss, with particular emphasis on routinely measured parameters. It also examines recent advances in risk stratification and predictive modelling, and discusses their potential application within early pregnancy assessment units.

METHODS

Search strategy

This study was a structured narrative review of the published literature evaluating ultrasound markers associated with early pregnancy loss (EPL). This systematic review is registered with the International Prospective Register of Systematic Reviews (PROSPERO). A comprehensive literature search was performed using PubMed, OVID, CINAHL, and Biomed Central databases with predefined search terms relating to "early pregnancy loss," "miscarriage," "ultrasound markers," and "risk prediction." Studies published in English within the last 10 years were included to ensure relevance to current clinical practice. Eligible studies consisted of human cohort and observational studies, as well as systematic reviews and meta-analyses. The selection process involved independent screening of titles and abstracts for relevance, followed by full-text review. Any disagreements were resolved through consensus. Reference lists of key articles were also screened to identify additional relevant studies.

Inclusion criteria

All studies in English language, all studies involving ultrasound markers predicting early pregnancy loss and all studies conducted in human beings were included.

Exclusion criteria

Any studies in other language not translated to English, any studies that have other predictors apart from ultrasound markers in predicting early pregnancy loss, any studies conducted in animals, and any studies conducted more than 10 years before (before 2015) were excluded.

Study quality was appraised using the critical appraisal skills programme (CASP) as a qualitative framework (Tables 1 and 2).[17] The CASP tool was used to systematically assess questions such as clarity of study focus, appropriateness of study design, recruitment methods, measurement of exposure and outcomes, identification of confounding factors, and the completeness of follow-up. Both the methodological strengths and limitations of each study were considered.

Table 1: Critical appraisal skills programme - CASP table.

(A) Are results of the review valid?				
Question 1	**Question 2**	**Question 3**	**Question 4**	**Question 5**
Did the review address a clearly focused question?	Did the authors look for the right type of papers?	Do you think all the important relevant studies were included?	Did the review's authors do enough to assess the quality of the included studies?	If the results of the review have been combined, was it reasonable to do so?

Table 2: Critical appraisal skills programme - CASP table.

(B) What are the results		(C) (Will the results help locally?				
Question 6	**Question 7**	**Question 8**	**Question 9**	**Question 10**	**Question 11**	**Question 12**
What are the overall results of the review?	How precise are the results?	Can the results be applied to the local population?	Were all important outcomes considered?	Are the benefits worth the harms and costs?	Do the results of the study fit with other available evidence?	What are the implications of this study for practice?

The PRISMA flowchart visually illustrates the process of selecting suitable studies for this topic review (Figure 1).[18]

Due to significant heterogeneity in study populations, scan timing, ultrasound markers measured, and definitions of pregnancy outcomes, a meta-analysis was not performed. Instead, the findings were synthesised narratively and presented in summary tables where appropriate to highlight key results and areas of agreement or discrepancy across the included literature.

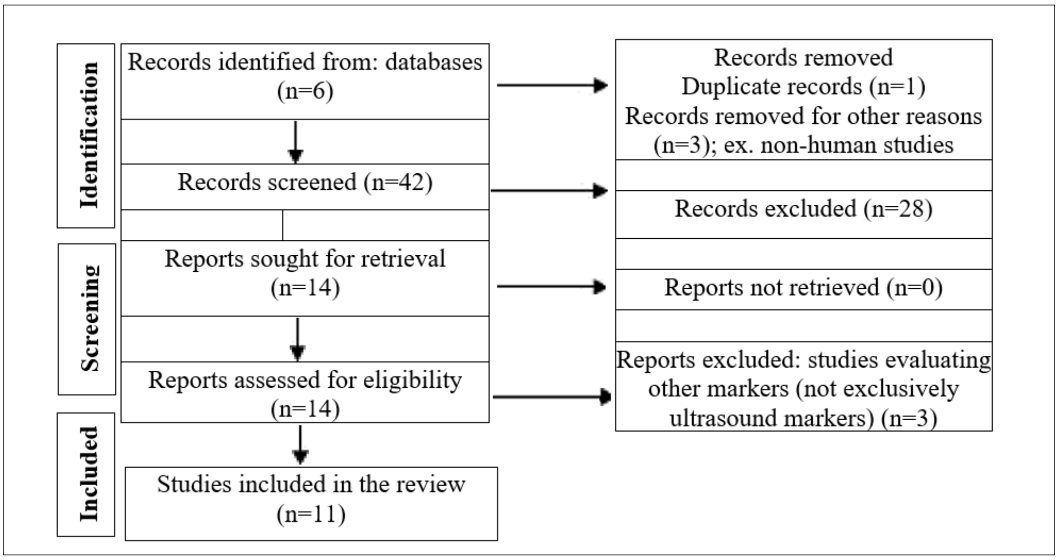

Figure 1: PRISMA flow diagram.

RESULTS

The findings from the included studies demonstrate consistent patterns in the relationship between early pregnancy ultrasound markers and subsequent pregnancy outcomes. Across cohorts and clinical settings, deviations in embryonic growth parameters and extra-embryonic structures were observed before definitive sonographic criteria for non-viability.[19] These results support the concept that EPL is often preceded by measurable abnormalities in growth trajectories rather than the abrupt cessation of viability (Table 3).[20]

Studies evaluating CRL and FHR consistently showed that pregnancies which subsequently miscarried demonstrated smaller-than-expected CRL measurements and lower FHR for gestational age, particularly between 6 and 8 weeks.[21] Combinations of abnormal CRL and FHR were more predictive of loss than isolated abnormalities, highlighting the value of integrated interpretation rather than reliance on single parameters (Table 4).[21]

The GS and YS measurements further refined risk stratification. Several studies reported that abnormal YSD, either enlarged or morphologically atypical, was detectable earlier than changes in fetal heart activity in pregnancies that miscarried.[22] Similarly, reduced growth of the gestational sac relative to gestational age was associated with higher miscarriage rates, particularly beyond 7 weeks' gestation.[22] Week-specific thresholds highlight that the predictive value of ultrasound markers is highly dependent on gestational age. Smaller deviations from expected CRL and mean GSD (mGSD) at earlier gestations carry greater prognostic significance than similar deviations later in the first trimester.[22]

Table 3: Review of key identified studies.

Sr. no.	Study and year	Design/ population	Population size	Ultrasound (US) markers assessed	Main outcome
1	DeVilbiss et al (2020)[3]	Cohort – singleton, VIUP	617 with VIUP – 10.4% subsequent EPL	CRL, FHR	Low CRL + FHR increased EPL risk
2	Detti et al (2020)[4]	Cohort – singleton, VIUP + progressing to EPL	252	GS size, YSD, CRL, FHR	Small GS + large YS predicted loss
3	Liang et al (2024)[5]	Cohort – EPL with SCH	171 singleton VIUP with 72 SCH	SCH grading	Larger SCH associated with miscarriage

Continued.

Sr. no.	Study and year	Design/ population	Population size	Ultrasound (US) markers assessed	Main outcome
4	Yoshihara et al (2024)[6]	Retrospective cohort – EPL with SCH	1305 singleton pregnancies with 80 SCH	Ratio of SCH to GS	Large SCH associated with complications
5	Liu et al (2024)[7]	Cohort- Recurrent pregnancy loss (RPL)	400	CRL, mGSD ± serum markers	Gestational week-specific models predicted EPL risk
6	Hassan et al (2022)[9]	Prospective Cohort – singleton, VIUP	300	CRL, MSD, YSD, FHR	Low FHR, Reduced CRL, MSD, Abnormal YSD predicted EPL
7	Sammut et al (2025)[10]	Cohort - Threatened miscarriage	600	US + biochemical + clinical	Machine learning (ML) algorithms model outperformed traditional regression models
8	Liu et al (2025)[11]	AI model – Early IUP	1619 embryo videos	US video (6–10 weeks)	Feasible automated prediction of EPL
9	Chen et al (2026)[12]	Case control Cohort - IVF/ICSI pregnancies with SCH	275 SCH versus 336 controls	SCH proportion	Higher SCH proportion increased miscarriage risk
10	Petersen et al (2023)[13]	Prospective Cohort – singleton, VIUP	593	CRL, FHR, GSD, YSD+ serum biochemical markers	Series of low CRL + FHR increased EPL risk
11	Taylor et al (2019)[23]	Prospective cohort -singleton, viable early intrauterine pregnancies (VIUP)	606 pregnancies – EPL versus ongoing pregnancies	CRL, FHR, YSD, mGSD, trophoblastic thickness (TT), throphoblastic thickness volume (TTV), mean Umbilical artery doppler index (mUAPI)	Novel predictors of EPL – Reduced TT, TTV, mUAPI, FHR, small GSD and abnormal YSD predicted EPL

Table 4: US predictors of EPL based on Gestational weeks.

S. no.	Gestational week	US predictors of EPL	Parameter threshold
1	6	mGSD, CRL	mGSD <18.3 mm; CRL <2.4 mm
2	7	CRL	CRL <9.9 mm
3	8	CRL	CRL <16.9 mm
4	9	mGSD, CRL	mGSD <33.3 mm; CRL <18.6 mm

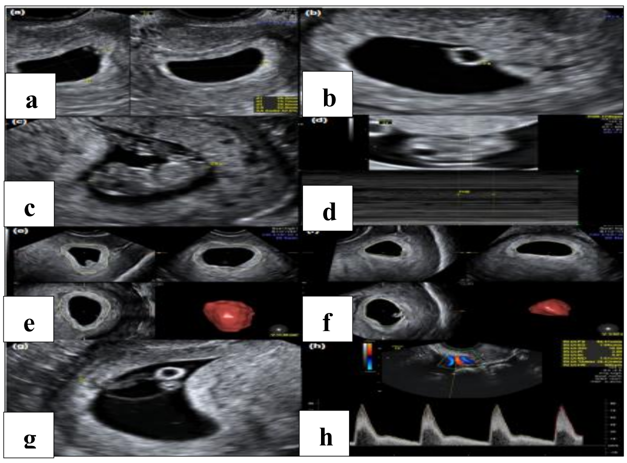

Figure 2: Novel USS markers – (a) MSD, (b) YSD, (c) CRL, (d) FHR, (e) TTV larger, (f) TTV smaller, (g) TT, and (h) UAPI.

These findings support the use of gestation-adjusted risk interpretation rather than fixed universal cut-offs when counselling patients with pregnancies of uncertain viability. Predictive performance of US markers can be substantially improved using repeated, longitudinal ultrasound assessment, particularly when CRL and FHR trajectories are interpreted together rather than in isolation.[22]

Taylor et al in 2019 provided detailed prospective data demonstrating that pregnancies which subsequently miscarried exhibited early deviations across multiple routinely and non-routinely measured ultrasound parameters.[23] In addition to reduced CRL and FHR, the study identified reduced trophoblastic thickness (TT), trophoblastic thickness volume (TTV), and mean umbilical artery pulsatility index (mUAPI) as novel early predictors of early pregnancy loss. Importantly, abnormalities in GS size and YSD were detectable before definitive loss, supporting the concept that early placental and extra-embryonic development play a central role in pregnancy viability rather than embryonic growth alone (Figure 2).[23]

These parameters reflect embryonic growth, extra-embryonic development, and early placental vascularisation, all of which have been associated with early pregnancy loss risk. These findings reinforce the value of integrated ultrasound assessment beyond isolated CRL or FHR measurements (Figure 3).[23]

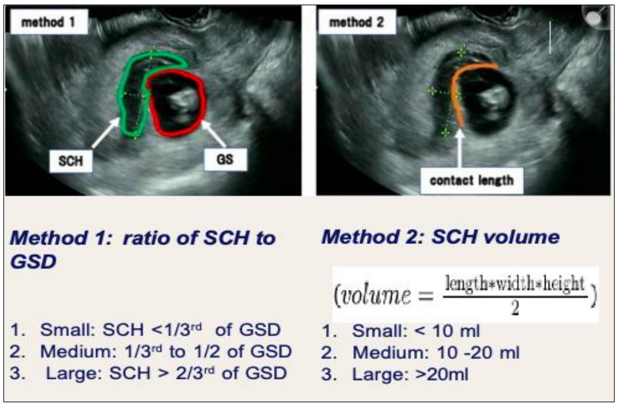

Figure 3: SCH quantification in comparison to GSD.

The SCH emerged as an important modifier of risk.[24] While earlier studies reported SCH as a binary finding, more recent evidence demonstrated a graded relationship between SCH burden and miscarriage risk.[24] Expressing SCH size as a proportion of gestational sac area or volume was associated with progressively increasing risk, supporting proportion-based reporting as a clinically meaningful approach (Table 5).[24]

Model-based approaches represent an evolution from single-parameter prediction toward integrative risk assessment.[25] Week-specific predictive models and machine learning approaches consistently outperform traditional regression in selected cohorts by incorporating multiple ultrasound, biochemical, and clinical variables. However, limited external validation and workflow integration currently restrict their routine clinical use (Table 6).[25]

Emerging algorithmic approaches further enhanced predictive performance in selected populations.[24,25] Although promising, these approaches remain investigational and require external validation before routine clinical adoption.[24,25] Across the literature, routinely measured markers (CRL, FHR, GSD/MSD, YSD) demonstrate consistent predictive value, while SCH and newer models refine risk estimation (Table 7).[3,7,23]

Table 5: SCH and association with EPL.

Sr. no.	SCH category	Suggested method	Prediction of EPL
1	Small	Small fraction of GS area/volume	Lower observed risk
2	Medium	Meaningful fraction of GS area/volume (>1/3rd of GSD)	Intermediate risk
3	Large	High fraction of GS area/volume (>½ of GSD)	High risk

Table 6: Newer model-based predictive approaches.

Sr. no.	Approach	Data utilised	Clinical value	Limitation
1	Gestation week specific models	US markers + patient demographics + serum markers	Derived gestational specific thresholds	Needs validation
2	ML models	Clinical + US markers+ biochemical	Higher statistical significance (AUC) in some cohorts	Small cohort studies
3	AI from US videos	US markers	Automated feature extraction	Workflow integration; greater AI technical knowledge and skill

Table 7: Strengths and limitations of the selected studies.

Sr. no.	Study and year	Bias addressed	Applicability	Overall quality	Limitation
1	DeVilbiss et al (2020)[3]	Yes	High	High	Single- centre cohort; limited ethnic diversity
2	Detti et al (2020)[4]	Moderate	High	High	Single time-point measurements; lacks longitudinal assessment
3	Liang et al (2024)[5]	Moderate	Moderate	Moderate–high	SCH specific cohort; variability in SCH definition and quantification

Continued.

Sr. no.	Study and year	Bias addressed	Applicability	Overall quality	Limitation
4	Yoshihara et al (2024)[6]	Moderate	Moderate	Moderate	SCH estimations – measurement bias
5	Liu et al (2024)[7]	Moderate	High	High	RPL cohort; limits generalisability to low-risk populations
6	Hassan et al (2022)[9]	Moderate	Moderate–high	Moderate–high	Single- centre cohort; lacks external validation; limited generalisability
7	Sammut et al (2025)[10]	Moderate	High	High	Machine learning (ML) approach; limited validation and interpretability
8	Liu et al (2025)[11]	Moderate	High	High	AI model – requires validation and integration into EPAUs
9	Chen et al (2026)[12]	Moderate	High	High	Findings may not extrapolate to spontaneous conceptions
10	Petersen et al (2023)[13]	Moderate	High	High	Requires repeated scans and serum sampling; increased workload
11	Taylor et al (2019)[23]	Moderate	Moderate to high	High	Novel predictors – operator dependent; requires validation

The included studies demonstrate broad consistency across populations and study designs in identifying early ultrasound markers associated with subsequent pregnancy loss.[25] Despite heterogeneity in gestational age at scanning and outcome definitions, reduced CRL, lower FHR, abnormal YSD characteristics, and increasing SCH burden were repeatedly associated with early pregnancy loss.[25] More recent studies extend earlier findings by quantifying risk using proportional and gestation-specific approaches, improving clinical applicability.[25]

DISCUSSION

The findings of this review have important implications for how care is organised and delivered within early pregnancy assessment units (EPAUs).[26] These units face considerable clinical and operational pressures, including high patient volumes, limited appointment availability, and a continuous need for timely reassurance or escalation of care. Incorporating predictive ultrasound markers into standard EPAU workflows can promote more structured and consistent clinical decision-making, potentially enhancing both patient outcomes and workflow efficiency.[26]

Implications for EPAU clinical practice

At the service level, implementing evidence-based predictive frameworks can improve appointment utilisation, minimise unscheduled re-attendance, and help prioritise clinical resources.[21,23,25] While algorithmic and machine learning models may further advance risk prediction, their successful integration into EPAU workflows will depend on thorough validation, appropriate governance, and alignment with established diagnostic safety standards.[18,20,26]

Standardised reporting is crucial for seamless workflow integration and continuity of care, especially in EPAUs where patients may be seen by different providers at each visit. Consistent documentation of growth trends, YS characteristics, and SCH burden, preferably as a proportion of GS size, facilitates information transfer among clinicians.[6,7,15] From a patient-centred perspective, using predictive markers in a structured way allows clinicians to communicate risk in probabilistic terms, improving counselling quality. Clear communication of risk trajectories can help manage patient expectations, reduce anxiety during uncertainty, and support shared decision-making about follow-up care.[12,13]

Risk stratification using routinely measured ultrasound parameters such as CRL, FHR, YSD, and mGSD growth enables more personalised follow-up pathways.[3,6,7,12] Pregnancies showing reassuring growth and normal ancillary markers can be scheduled for standard follow-up, while those with high-risk features may require earlier repeat scans, senior clinician review, or targeted counselling. This approach optimises resource use and reduces unnecessary repeat visits without compromising patient safety.[18,22]

This review confirms that routinely measured ultrasound markers, especially CRL, FHR, GSD and YSD, provide clinically meaningful predictive value for early pregnancy loss (EPL).[3,6,7,12] Advances such as proportion-based SCH reporting and emerging predictive models are promising, though external validation remains essential before widespread adoption.[4,5,10] The widespread use of high-resolution transvaginal ultrasound has transformed early pregnancy assessment, enabling the detection of subtle developmental deviations at very early gestations.[4,5,10]

This review demonstrates that parameters already embedded in routine scanning protocols offer valuable prognostic information, particularly when interpreted longitudinally and in combination. Notably, the interplay between gestational age, CRL, and FHR provides insight into embryonic growth dynamics beyond simple viability assessment.[11,12,23] YSD warrants special attention. Recent evidence indicates that abnormal YS size or morphology can precede detectable changes in embryonic heart activity, making it a critical parameter in pregnancies of uncertain viability where counselling is complex.[3,6,24] Including YS assessment in structured reports may help reduce diagnostic uncertainty and alleviate patient anxiety.[3,12,22]

SCH assessment has advanced significantly over the past decade.[10,23,24] The shift from binary reporting to proportion-based quantification aligns better with biological plausibility and clinical risk. Expressing SCH size relative to gestational sac area or volume enhances reproducibility and offers a nuanced risk framework, which is especially relevant in assisted reproduction, where baseline miscarriage risk differs from spontaneous conception.[4,5,10,25]

Novel predictors such as TT, TTV, mUAPI, along with YSD predict EPL more robustly than embryonic size parameters such as GSD, CRL and FHR alone.[12,26] Algorithmic prediction models are a promising adjunct to clinical interpretation, with machine learning approaches showing improved risk discrimination, especially when ultrasound parameters are combined with biochemical markers.[24] However, their implementation requires caution and attention to external validation, and integration into clinical workflows is essential. Importantly, such tools should support, not replace, clinical judgement.[8,9]

Key messages for clinicians

Early pregnancy loss is frequently preceded by measurable abnormalities in embryonic and extra-embryonic growth trajectories before diagnostic criteria are met. Routinely measured ultrasound parameters particularly crown–rump length, fetal heart rate, yolk sac diameter, and gestational sac growth can be combined to support early risk stratification. Ultrasound findings should be interpreted longitudinally and, in a gestation, specific manner rather than as isolated measurements. Subchorionic haematoma assessment is most clinically informative when reported as a proportion of gestational sac area or volume rather than as a binary finding. Predictive use of ultrasound markers can enhance counselling and follow-up planning in pregnancies of uncertain viability but must complement established diagnostic safety thresholds. Machine learning and AI-based prediction models show promise but require further validation before routine implementation in early pregnancy assessment units.

CONCLUSION

Ultrasound markers routinely assessed in early pregnancy have significant value in predicting early pregnancy loss. Quantification of SCH burden improves risk stratification, while algorithmic approaches show promise but require further validation before routine clinical use. Future research should focus on multicentre prospective validation of proportion-based SCH thresholds, longitudinal ultrasound trajectories, and explainable AI models that allow clinicians to understand decision pathways. Establishing consensus on reporting standards will be critical to translating predictive ultrasound research into routine EPAU practice.

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