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Placental Implantation Sites, Uterine Anatomy, and Uterine Physiology in Relation to Postpartum Hemorrhage: A Systematic Review

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ABSTRACT

Postpartum hemorrhage (PPH) remains a major cause of maternal morbidity and mortality worldwide. Increasing evidence suggests that the placental implantation site and uterine structural characteristics influence the effectiveness of hemostasis after placental separation, particularly in placenta previa and placenta accreta spectrum (PAS). **Objectives:** To systematically review human studies examining the relationship between placental implantation site, uterine anatomy, uterine physiology, and the risk of postpartum hemorrhage. **Methods:** This systematic review followed PRISMA 2020 guidelines. PubMed, Web of Science, and Scopus were searched for studies published between January 2018 and December 2025. Eligible studies included observational human studies and imaging-based diagnostic studies evaluating placental implantation or uterine structural or physiological factors in relation to PPH. Animal studies, case reports, and review articles were excluded. Data were extracted using a standardized form, and methodological quality was assessed using the Newcastle–Ottawa Scale. Due to heterogeneity in study design and outcome definitions, a narrative synthesis was performed. **Results:** Eighteen studies met the inclusion criteria. Abnormal placental implantation, particularly lower uterine segment placentation, placenta previa, pernicious placenta previa, and PAS, was consistently associated with increased PPH risk. Structural factors, including reduced myometrial thickness and disruption of the uteroplacental interface, were frequently reported contributors to excessive bleeding. **Conclusions:** Abnormal placental implantation and associated uterine structural changes are important contributors to postpartum hemorrhage. Antenatal imaging may assist in identifying high-risk pregnancies and guiding delivery planning.

INTRODUCTION

Postpartum hemorrhage (PPH) remains one of the leading causes of preventable maternal morbidity and mortality worldwide. Although uterine atony accounts for a large proportion of cases, anatomical and placental factors also play a critical role in determining the risk and severity of hemorrhage following placental separation [1]. Identifying these factors is essential for improving antenatal risk stratification and guiding delivery planning in high-risk pregnancies [2]. Physiological hemostasis after delivery relies on myometrial contraction and compression of uterine vessels at the placental bed. Normally, myometrial contraction and spiral artery constriction limit postpartum bleeding [3]. This mechanism may be impaired when placental implantation occurs in the lower uterine segment or near cesarean scars, where reduced myometrial thickness and distortion of the uteroplacental interface

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can increase bleeding risk [4]. Placenta previa and placenta accreta spectrum (PAS) are the most recognized forms of abnormal placentation associated with severe obstetric hemorrhage. In PAS, abnormal trophoblastic invasion disrupts the decidual layer, preventing normal placental separation and often leading to significant blood loss, transfusion, and occasionally peripartum hysterectomy [5]. Advances in obstetric imaging, particularly ultrasound and magnetic resonance imaging, have improved antenatal detection of abnormal placental location and invasion, allowing earlier identification of pregnancies at high risk of hemorrhage [6, 7].

Despite increasing research in this area, existing studies vary considerably in design, imaging criteria, and outcome definitions. Moreover, most previous reviews have focused primarily on specific conditions such as placenta previa or placenta accreta spectrum. Less attention has been given to the broader mechanistic relationship between placental implantation site, uterine structural characteristics, and physiological factors that influence hemostatic function after placental separation. As a result, the integrated role of placental location, uterine anatomy, and uterine physiology in the development of postpartum hemorrhage remains insufficiently synthesized. Therefore, this systematic review aims to synthesize human evidence published between 2018 and December 2025, examining how the placental implantation site, uterine anatomical features, and uterine physiological characteristics contribute to postpartum hemorrhage. By integrating findings across these domains, the review seeks to clarify mechanistic pathways linking abnormal placentation to hemorrhage risk and to support improved clinical risk assessment and management strategies.

METHODS

This systematic review was conducted to evaluate the relationship between placental implantation sites, uterine anatomy, uterine physiology, and the risk of postpartum hemorrhage (PPH). The review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. Due to substantial heterogeneity in study design, imaging modalities, populations, and outcome definitions, a qualitative narrative synthesis was performed, and meta-analysis was not undertaken. A comprehensive literature search was conducted in three electronic databases: PubMed, Web of Science, and Scopus. Studies published between January 2018 and December 2025 were considered eligible. The search strategy incorporated combinations of Medical Subject Headings (MeSH) and free-text terms related to placental implantation and postpartum hemorrhage. The primary Boolean search strategy used in PubMed was: ("postpartum hemorrhage" OR "postpartum hemorrhage" OR PPH) AND ("placenta previa" OR "placenta accreta spectrum" OR PAS OR "placental implantation" OR "placental location") AND ("uterine anatomy" OR "uterine physiology" OR "myometrial thickness" OR "uteroplacental interface" OR "lower uterine segment" OR "uterine vascularity"). Similar search combinations were adapted for Web of Science and Scopus using database-specific syntax. Reference lists of all eligible studies were also manually screened to identify additional relevant publications. Original human studies using observational designs, including prospective cohort, retrospective cohort, case-control, cross-sectional, and imaging-based diagnostic studies, were eligible for inclusion. Studies were included if they evaluated the placental implantation site, uterine anatomical features, or uterine physiological parameters in relation to postpartum hemorrhage or objectively measured obstetric blood loss. Studies involving animal experiments, case reports, case series, narrative reviews, systematic reviews, meta-analyses, editorials, conference abstracts, or studies not reporting postpartum hemorrhage outcomes were excluded. Only studies published in the English language were included due to feasibility and resource limitations. This restriction may introduce language bias and has been acknowledged as a limitation of the review. All identified records were imported into a reference management software, and duplicate records were removed before screening. Title and abstract screening as well as full-text eligibility assessment were performed independently by two reviewers to minimize selection bias. Disagreements between reviewers were resolved through discussion and consensus. The database search initially identified 835 records. After the removal of 112 duplicates, 723 articles underwent title and abstract screening. A total of 642 records were excluded during the initial screening stage due to a lack of relevance. Eighty-one full-text articles were assessed for eligibility, of which 63 were excluded for reasons including absence of postpartum hemorrhage outcomes, non-human studies, or review articles. Finally, 18 studies met the inclusion criteria and were included in the qualitative synthesis. The study selection process is illustrated using the PRISMA 2020 flow diagram. Data were extracted using a standardized data extraction form to ensure consistency and accuracy. Extracted information included author name, year of publication, country, study design, study population, sample size, placental or uterine characteristics assessed, assessment methods, delivery mode where reported, and outcomes related to postpartum hemorrhage. Extracted data were cross-checked to minimize extraction errors. The methodological quality of included studies was assessed using the Newcastle–Ottawa Scale (NOS) for observational studies. The scale evaluates three domains: selection of

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study groups (maximum 4 stars), comparability of groups (maximum 2 stars), and outcome assessment (maximum 3 stars), giving a maximum score of 9 stars. Studies scoring 7–9 stars were classified as low risk of bias, 5–6 stars as moderate risk of bias, and ≤4 stars as high risk of bias. Quality assessment results were used to interpret study reliability, but no studies were excluded solely based on quality score. Because of substantial heterogeneity in study design, imaging criteria, measurement of placental invasion, and definitions of postpartum hemorrhage, statistical pooling of results was not feasible. Therefore, heterogeneity indices such as I^2 could not be calculated, and findings were synthesized using a structured narrative approach.

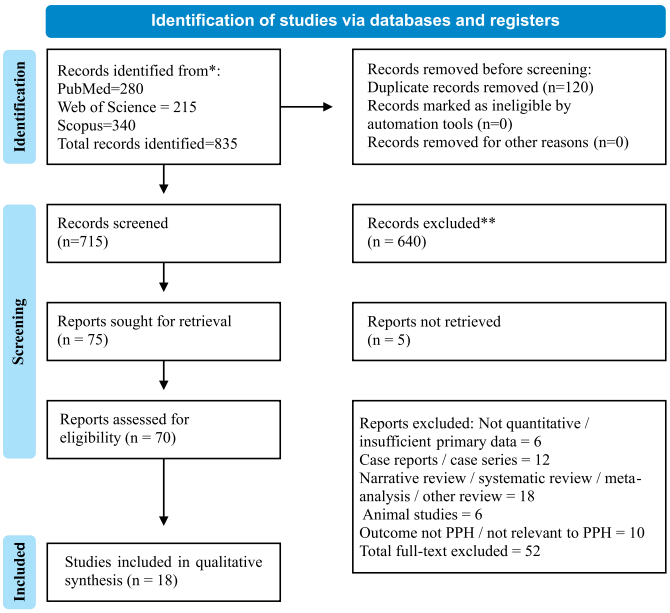

Figure 1: PRISMA 2020 flow diagram illustrating the study selection process for the systematic review on placental implantation sites, uterine anatomy, and uterine physiology in relation to postpartum hemorrhage. A total of 835 records were identified through database searches, and after screening and eligibility assessment, 18 studies met the inclusion criteria and were included in the qualitative synthesis

RESULTS

The characteristics of the 18 observational studies included in the qualitative synthesis were published between 2018 and 2025 across multiple geographic regions. Most studies employed retrospective cohort or imaging-based observational designs and predominantly investigated pregnancies complicated by placenta previa or placenta accreta spectrum disorders. The majority of studies evaluated structural placental or uterine factors using ultrasound or magnetic resonance imaging, while several studies also incorporated intraoperative findings or clinical outcomes. Overall, the included studies consistently explored the relationship between placental implantation characteristics and the occurrence of postpartum hemorrhage (Table 1).

Table 1: Characteristics of Included Studies (2018–2025)

S. No.	References	Country	Study Design	Study Population	Sample Size	Placental/Uterine Factor Studied	Outcome Related to PPH
1	[8]	China	Observational diagnostic	Placenta previa/ accreta undergoing cesarean	122	Ultrasound predictors of placental invasion	Severe hemorrhage >1500 mL
2	[9]	China	Retrospective cohort	Placenta previa	246	Placental implantation depth	Severe PPH
3	[10]	China	Retrospective cohort	Suspected PAS	40	MRI placental features	Massive intraoperative hemorrhage
4	[11]	Japan	Imaging observational	Placenta previa	94	Anterior vs posterior placental location	Surgical blood loss
5	[12]	USA	Retrospective observational	Placenta accreta spectrum	88	MRI placental invasion parameters	Intraoperative blood loss
6	[13]	USA	Retrospective cohort	Placental adhesion disorder	131	MRI placental bed abnormalities	Massive PPH
7	[14]	Italy	Observationalcohort	Placenta previa	156	Combined ultrasound/MRI markers	Hemorrhagic morbidity
8	[15]	Japan	Retrospective cohort	Total vs partial placenta previa	183	Placental type and implantation site	PPH and transfusion
9	[16]	USA	Cohort study	Resolved low-lying placenta	628	Prior LUS placentation	Postpartum hemorrhage
10	[17]	China	Retrospective modelling	Pernicious placenta previa	212	Placental implantation pattern	PPH prediction
11	[18]	China	Imaging cohort	Placenta accreta spectrum	101	Myometrial thickness	Severe blood loss
12	[19]	Slovakia	Prospective observational	Vaginal and cesarean deliveries	92	LUS vascularity	Postpartum uterine perfusion
13	[20]	China	Retrospective validation	Pernicious placenta previa	268	Imaging-clinical model	PPH risk

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14	[21]	China	Observational cohort	Placenta accreta spectrum	146	PAS subtype and placental invasion	Hemorrhage severity
15	[22]	South Korea	Multicenter cohort	Placenta previa	1248	Anterior vs non-anterior placentation	Transfusion and PPH
16	[23]	USA	Retrospective cohort	Resolved low-lying placenta	512	Previous LUS implantation	PPH
17	[24]	Japan	Imaging predictive study	Placenta previa	85	MRI radiomics placental bed	Massive hemorrhage >2000 mL
18	[25]	Australia	Observational cohort	Singleton pregnancies	3214	Placental implantation mapping	Postpartum hemorrhage

The association between placental implantation site and postpartum hemorrhage. Abnormal placental implantation, particularly involving the lower uterine segment, placenta accreta spectrum, and anterior placenta previa, was frequently associated with increased bleeding risk. Where reported, effect estimates such as odds ratios or relative risks indicated higher odds of postpartum hemorrhage in pregnancies with abnormal placental implantation. Among the seventeen studies that directly evaluated this association, fifteen reported an increased risk of postpartum hemorrhage, while two studies reported comparable bleeding risks between specific placental subtypes. These findings support the consistent role of placental location as an important determinant of postpartum bleeding. Most studies reporting severe hemorrhage outcomes involved cesarean delivery or cesarean hysterectomy, particularly in cases of placenta accreta spectrum, whereas a smaller number of studies included mixed delivery modes (vaginal and cesarean deliveries) (Table 2).

Table 2: Association Between Placental Implantation Site and Postpartum Hemorrhage

S. No.	References	Implantation / Placental Location	Comparator	Mode of Delivery	Effect Estimate (OR/RR, 95% CI)	Association With PPH	Key Findings
1	[8]	Placenta previa with invasive implantation	Non-invasive previa	Cesarean section	NR	Increased risk	Deep placental invasion associated with severe hemorrhage (>1500 mL)
2	[9]	Lower uterine segment implantation	Upper uterine segment	Cesarean section	OR 2.84 (1.45–5.23)	Increased risk	Lower implantation depth predicted severe PPH
3	[10]	Placenta accreta spectrum	Non-PAS placenta	Cesarean section	NR	Markedly increased risk	Massive intraoperative bleeding
4	[11]	Anterior placenta previa	Posterior placenta previa	Cesarean section	NR	Increased risk	Higher surgical blood loss
5	[12]	Deep placental invasion	Superficial invasion	Cesarean hysterectomy	NR	Increased risk	Greater invasion depth correlated with bleeding
6	[13]	Placental adhesion disorder	Normal placentation	Cesarean section	NR	Increased risk	MRI markers predicted massive PPH
7	[14]	Placenta previa with PAS	Placenta previa without PAS	Cesarean section	OR 3.10 (1.70–5.60)	Increased risk	Combined imaging markers predicted hemorrhage
8	[15]	Total placenta previa	Partial/marginal previa	Cesarean section	RR 1.05 (0.78–1.42)	Comparable risk	No significant bleeding difference
9	[16]	Resolved low-lying placenta	Normal placenta	Mixed delivery	OR 2.30 (1.25–4.10)	Increased risk	Persistent PPH risk despite migration
10	[17]	Pernicious placenta previa	Non-pernicious previa	Cesarean section	OR 3.45 (1.90–6.30)	Increased risk	Implantation over cesarean scar increased bleeding
11	[18]	Placenta accreta	Non-accreta placenta	Cesarean section	NR	Increased risk	Myometrial thinning predicted severe blood loss
12	[20]	Abnormal lower-segment placentation	Normal implantation	Cesarean section	OR 2.90 (1.60–5.10)	Increased risk	Imaging model predicted hemorrhage
13	[21]	PAS involving LUS	Upper-segment PAS	Cesarean hysterectomy	NR	Increased risk	Greater hemorrhage severity
14	[22]	Anterior placenta previa	Non-anterior placenta previa	Cesarean section	OR 1.88 (1.32–2.68)	Increased risk	Higher transfusion requirement
15	[23]	Resolved low-lying placenta	Normal placental location	Mixed delivery	OR 2.10 (1.20–3.70)	Increased risk	History of LUS implantation increased PPH
16	[24]	Placental bed involvement	Limited involvement	Cesarean section	NR	Increased risk	Radiomics predicted massive hemorrhage
17	[25]	Lower uterine segment placentation	Fundal/ lateral placentation	Mixed delivery	RR 1.92 (1.30–2.84)	Increased risk	LUS implantation is independently associated with PPH

Summary: 15 increased risks; 2 comparable risks. The majority of studies demonstrated elevated PPH risk with abnormal placental implantation

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Uterine anatomical and physiological factors associated with postpartum hemorrhage. The most frequently reported structural contributors included reduced myometrial thickness at the placental implantation site, abnormalities of the uteroplacental interface, and impaired contractility of the lower uterine segment. Imaging findings obtained from ultrasound and magnetic resonance imaging demonstrated that disruption of the placental bed or thinning of the myometrium may compromise effective physiological hemostasis following placental separation. In addition, altered vascular indices in the lower uterine segment were suggested as potential physiological contributors to excessive postpartum bleeding (Table 3).

Table 3: Uterine Anatomical and Physiological Factors Associated with PPH

S. No.	References	Factor	Method	Timing	Association	Mechanistic Insight
1	[8]	Placental invasion depth	Ultrasound + surgery	Antepartum/Intrapartum	Increased	Disrupts myometrial contraction
2	[9]	Reduced myometrial thickness	Ultrasound	Antepartum	Increased	Reduced contractile capacity
3	[10]	Placental bed disruption	MRI	Antepartum	Increased	Loss of muscle architecture
4	[11]	Anterior LUS implantation	MRI	Antepartum	Increased	Reduced contractility
5	[12]	Uteroplacental interface distortion	MRI	Antepartum	Increased	Impaired vessel occlusion
6	[13]	Placental bed abnormalities	MRI	Antepartum	Increased	Failed placental separation
7	[14]	Decidual disruption	Ultrasound/MRI	Antepartum	Increased	Spiral artery closure impaired
8	[15]	Placental extension across LUS	Surgical findings	Intrapartum	Variable	Larger bleeding surface
9	[16]	Persistent LUS remodeling	Ultrasound	Antepartum/Postpartum	Increased	Structural changes persist
10	[17]	Placenta over cesarean scar	Ultrasound	Antepartum	Increased	Scar reduces contractility
11	[18]	Myometrial thickness <2 mm	MRI	Antepartum	Increased	Severe contractile deficit
12	[19]	Altered vascular indices	3D Doppler	Early puerperium	Physiological	Higher vascular flow
13	[20]	Combined impairment	MRI + ultrasound	Antepartum	Increased	Amplified bleeding risk
14	[21]	PAS subtype involving LUS	MRI	Antepartum	Increased	Higher hemorrhage severity
15	[22]	Anterior placenta previa	Clinical/imaging	Intrapartum	Increased	Reduced uterine compression
16	[23]	Residual LUS remodeling	Ultrasound	Postpartum	Increased	Predisposes to atony
17	[24]	Placental bed radiomics	MRI	Antepartum	Increased	Large dysfunctional bed
18	[25]	LUS vs fundal implantation	Clinical mapping	Antepartum	Increased	Fundal uterus provides better hemostasis

The methodological quality assessment of the included studies using the Newcastle–Ottawa Scale. Most studies demonstrated adequate selection of study populations and objective assessment of outcomes. Based on the predefined scoring criteria, fourteen studies were classified as having low risk of bias, while four studies were categorized as having moderate risk of bias. The most common limitation identified across studies was incomplete adjustment for potential confounding factors such as maternal characteristics or previous obstetric history (Table 4).

Table 4: Risk of Bias Assessment (Newcastle–Ottawa Scale)

References	Selection	Comparability	Outcome	Total	Risk
[8]	★★★★	★★	★★★	9	Low
[9]	★★★	★★	★★★	8	Low
[10]	★★★	★★	★★	7	Low
[11]	★★★	★★	★★	7	Low
[12]	★★★	★★	★★	7	Low
[13]	★★★	★★	★★	7	Low
[14]	★★★	★★	★★	7	Low
[15]	★★★	★	★★	6	Moderate
[16]	★★★★	★★	★★★	9	Low
[17]	★★★	★	★★	6	Moderate
[18]	★★★	★★	★★	7	Low
[19]	★★★	★	★★	6	Moderate
[20]	★★★	★★	★★	7	Low
[21]	★★★	★★	★★	7	Low
[22]	★★★★	★★	★★★	9	Low
[23]	★★★	★★	★★	7	Low
[24]	★★★	★	★★	6	Moderate
[25]	★★★★	★★	★★★	9	Low

Low risk = 7-9 stars
Moderate risk – 5-6 stars

DISCUSSION

This systematic review synthesizes available evidence on the relationship between placental implantation sites, uterine anatomy, uterine physiology, and the risk of postpartum hemorrhage (PPH). The findings indicate that abnormal placental implantation, particularly placenta previa, low-lying placenta, and placenta accreta spectrum (PAS), is consistently associated with an increased risk of postpartum bleeding due to structural and physiological alterations in the uteroplacental interface and impaired uterine hemostasis. A number of systematic reviews conducted in recent years confirm that abnormal placental implantation is a major determinant of PPH. Bonanni *et al.* 2025 reported in the systematic review and meta-analysis

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reported that low-lying placenta or placenta previa diagnosed during pregnancy increases the risk of postpartum hemorrhage approximately twofold compared with normal placental location [26]. Our findings are consistent with these reports and further suggest that even a resolved low-lying placenta may still carry a persistent risk of hemorrhage, possibly due to structural remodeling and altered lower uterine segment physiology. Placenta previa is widely recognized as one of the most important obstetric risk factors for PPH because implantation within the lower uterine segment limits effective myometrial contraction after placental separation. Epidemiological studies indicate that placenta previa complicates approximately 1–2% of pregnancies and is strongly associated with maternal morbidity due to severe bleeding [27]. In addition, placenta previa frequently coexists with placenta accreta spectrum disorders, in which abnormal trophoblastic invasion penetrates the myometrium and disrupts the normal decidual interface. Such pathological implantation prevents controlled placental separation and substantially increases the likelihood of massive hemorrhage, transfusion requirement, and cesarean hysterectomy [28]. The importance of PAS in severe obstetric hemorrhage is further supported by recent systematic evidence demonstrating that increasing depth of trophoblastic invasion is associated with higher surgical complexity and greater blood loss [29]. International consensus classifications such as the FIGO grading system also recognize that the extent of placental invasion correlates with hemorrhage severity and surgical management complexity. Imaging studies increasingly support the use of magnetic resonance imaging as a complementary modality to ultrasound for identifying myometrial invasion and placental bed abnormalities that may predispose to PPH [30, 31]. Placental location within the lower uterine segment and anterior uterine wall may further influence hemorrhage risk. Emerging cohort evidence suggests that anatomical differences in placental position may affect imaging characteristics and bleeding severity, highlighting the potential role of placental mapping in antenatal risk stratification [32, 33]. Another key observation of this review relates to the contribution of uterine structural and physiological characteristics to postpartum bleeding. Implantation in the lower uterine segment may lead to reduced myometrial thickness and impaired contractile capacity, limiting the ability of the uterus to achieve physiological hemostasis following placental separation. Disruption of the uteroplacental interface caused by abnormal placentation or underlying uterine structural abnormalities has also been associated with retained placenta and failed uterine contraction [34]. Altered vascularity within the lower uterine segment may represent another important contributor to PPH pathophysiology. Doppler imaging studies have demonstrated abnormal vascular indices and altered uterine perfusion patterns in pregnancies complicated by abnormal placentation. However, it should be noted that several studies included in this review inferred hemorrhage risk primarily from imaging findings rather than direct quantitative measurement of postpartum blood loss. Therefore, mechanistic interpretations derived from imaging observations should be interpreted cautiously. The findings of this review have important clinical implications for antenatal risk assessment and delivery planning. Routine ultrasound evaluation of placental location, particularly in women with previous cesarean delivery or uterine surgery, allows early identification of pregnancies at risk of severe hemorrhage. Early recognition of PAS or abnormal placental implantation enables referral to tertiary care centers where multidisciplinary teams, interventional radiology, and adequate blood product availability can improve maternal outcomes. Conservative surgical approaches and placenta-preserving strategies have also shown promising results in selected PAS cases, although standardized clinical protocols are still evolving [35].

Risk stratification models such as the Placenta Accreta Index and FIGO classification have been proposed to guide clinical decision-making; however, their predictive performance varies across populations and healthcare settings. In addition, this review did not quantitatively evaluate diagnostic accuracy measures such as sensitivity, specificity, or predictive values of antenatal imaging modalities, and therefore imaging findings should be interpreted primarily as indicators of hemorrhage risk rather than definitive predictors. Several limitations should be acknowledged. Most included studies were observational and heterogeneous in design, imaging criteria, and outcome definitions. Definitions of PPH varied between studies (≥500 mL vs ≥1000 mL blood loss or transfusion-based outcomes), limiting comparability. Some studies relied on imaging-based inference rather than direct hemorrhage measurement, and only English-language publications were included. Future research should focus on large prospective multicenter studies using standardized hemorrhage definitions and integrated imaging-clinical prediction models.

CONCLUSIONS

This systematic review synthesizes available evidence on the relationship between placental implantation sites, uterine anatomy, uterine physiology, and the risk of postpartum hemorrhage (PPH). The findings indicate that abnormal placental implantation, particularly placenta previa, low-lying placenta, and placenta accreta spectrum (PAS), is consistently associated with an increased risk of postpartum bleeding due to structural and physiological

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alterations in the uteroplacental interface and impaired uterine hemostasis.

Authors' Contribution

Conceptualization: DESA, SA
Methodology: AM, MA, SF, RUJ
Formal analysis: AM, SF
Writing and Drafting: DESA, SA, MA, RUJ
Review and Editing: DESA, AM, SA, MA, SF, RUJ, NNC

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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