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Incremental Value of Residual Myometrial Thickness and CSP Classification for Intraoperative Bleeding Risk Assessment: A Retrospective Cohort Study

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Abstract

Objective: To assess whether residual myometrial thickness (RMT) and conventional cesarean scar pregnancy (CSP) classification add information beyond gestational-sac diameter for intraoperative bleeding risk assessment. **Methods:** This retrospective cohort included 343 surgically treated CSP pregnancies at Shanghai General Hospital from 2016 to 2020. The outcome was intraoperative blood loss >200 mL. Logistic models compared sac diameter alone with the addition of continuous RMT, binary RMT, or CSP classification. Incremental value was assessed using likelihood-ratio tests and paired differences in area under the receiver operating characteristic curve (AUC). Internal validation used 1000 bootstrap samples with model refitting. A sensitivity analysis included 277 pregnancies managed with evacuation without preoperative uterine-artery embolization (UAE). **Results:** The outcome occurred in 23 pregnancies (6.7%). Sac diameter was associated with bleeding after accounting for RMT (OR per 1 mm, 1.080; 95% CI, 1.048–1.114). The sac-only model had an apparent AUC of 0.783 and an optimism-corrected AUC of 0.782. Adding continuous RMT changed apparent AUC by −0.011 (95% CI, −0.031 to 0.040; likelihood-ratio P=0.165), and adding classification changed it by −0.001 (95% CI, −0.017 to 0.050; P=0.114). Corrected Brier scores decreased slightly. The evacuation-without-UAE subgroup showed a similar pattern. **Conclusions:** RMT and conventional CSP classification did not show a clear improvement in discrimination beyond sac diameter for intraoperative blood loss >200 mL. These findings require external evaluation and should be interpreted within the observed treatment pathways.

Keywords: cesarean scar pregnancy; intraoperative bleeding; residual myometrial thickness; gestational-sac diameter; incremental value; ultrasound

Introduction

Cesarean scar pregnancy (CSP) can be complicated by hemorrhage, uterine rupture, and loss of fertility. Ultrasonography is central to diagnosis and pretreatment assessment. [1] Before surgery, clinicians need to describe implantation anatomy and assess the likelihood of procedural bleeding. Whether routinely recorded anatomical features improve bleeding risk assessment beyond gestational-sac size remains a practical question.

International recommendations describe implantation location, sac position relative to the uterine cavity and serosa, and residual myometrial thickness (RMT). [2, 3] However, diagnostic definitions and reporting remain heterogeneous. [4] Ultrasound features associated with bleeding include gestational age and placental lacunae in live CSP undergoing evacuation. [5] Other work has incorporated sac diameter and myometrial thickness into a classification linked to surgical strategy, [6] or developed a

broader multivariable hemorrhage model. [7] These studies establish the relevance of ultrasound assessment but leave uncertainty about the additional information provided by RMT or conventional classification when sac diameter is already available.

Outcome definitions also vary across CSP treatment studies. [8] The COSCAR consensus supports standardized reporting of treatment success, complications, reproductive outcomes, and patient experience. [9] A specified blood-loss threshold therefore needs to be distinguished from transfusion or other manifestations of severe morbidity when evaluating and comparing risk markers.

We evaluated whether RMT and conventional CSP classification added information beyond mean gestational-sac diameter for intraoperative blood loss >200 mL. RMT was examined continuously and at the locally employed 3-mm boundary. A sensitivity analysis restricted the cohort to evacuation without preoperative uterine-artery embolization (UAE) to examine the influence of the treatment mix.

Methods

Study population

We conducted a retrospective cohort study at the north and south campuses of Shanghai General Hospital, treated as one institution. Between January 2016 and December 2020, 414 records of possible CSP were identified. Sixty-seven were excluded: no previous cesarean delivery (n=2), initial treatment elsewhere (n=38), initial nonsurgical treatment (n=5), and incomplete or poor-quality records, including substantial missing data (n=22). Four duplicate records were removed from the remaining 347 records, leaving 343 independent pregnancy events. The pregnancy event was the unit of analysis. Eligibility required previous lower-segment cesarean delivery, serum human chorionic gonadotropin >5 U/L, initial definitive surgical treatment at the institution, clinical and imaging confirmation of CSP supported by operative and pathological findings, and sufficient records for the core analyses. Reporting was informed by STROBE. [10] Cohort selection is shown in **Figure 1.**

This study was conducted in accordance with the Declaration of Helsinki. The study was approved by the Shanghai General Hospital Institutional Review Board on September 30, 2026 (approval No. Yuan Lun Kuai [2026] 699). The requirement for individual informed consent was waived by the institutional review board.

Ultrasound measurements and treatment

Pretreatment transvaginal ultrasound was performed using a Voluson E8 system with an IC5-9-D endocavitary transducer. As part of routine clinical care, examinations and reports were assessed by at least two physicians, with final review by a senior physician. Measurements for this study were extracted

from these clinical records. Mean gestational-sac diameter was the arithmetic mean of three perpendicular diameters. RMT was measured at the thinnest anterior scar myometrium between the endometrial or gestational-sac interface and the uterine serosa adjacent to the bladder. Conventional type I–III classification followed the Chinese expert consensus and incorporated implantation site, growth direction, and RMT. [11] Type I represented partial scar implantation with endogenic growth and RMT >3 mm; type II represented an endogenic pattern with RMT ≤3 mm; type III represented predominant implantation within the scar with outward growth and marked thinning or absence of intervening myometrium. Classification was checked against the source documentation before final analysis.

Treatment was selected by the clinical team. The recorded groups were A, evacuation procedures without preoperative uterine-artery embolization (UAE); B, UAE followed by evacuation; and C, pregnancy removal with scar repair, with or without UAE. These groups were described without causal interpretation because treatment depended on clinical assessment and anatomy.

Outcome ascertainment

The primary outcome was intraoperative blood loss >200 mL, ascertained from operative records and contemporaneous clinical documentation. Operative records took precedence when estimates differed from anesthesia records. For records without a numeric value in the exported dataset, threshold status was established from the source documentation; no numeric loss was imputed and missing values were not assigned zero. Discrepancies were reviewed and corrected before analysis. A recorded loss of exactly 200 mL was classified as a non-event. Pre-existing vaginal bleeding and hemoperitoneum were excluded. This endpoint was distinguished from major hemorrhage or severe maternal morbidity. Alternative 300- and 500-mL endpoints could not be evaluated because exact volumes were unavailable for some records.

Statistical analysis

Continuous variables were summarized as medians and interquartile ranges, and categorical variables as counts and percentages. Sac diameter and RMT were complete. Logistic regression estimated odds ratios and Wald 95% confidence intervals. The available cohort determined the sample size. With 23 outcome events, the principal model was limited to sac diameter and continuous RMT, each entered linearly on the log-odds scale. [12] Estimates were mutually adjusted for these two measurements. Likelihood-ratio tests compared expanded models with the sac-diameter base model, using one additional degree of freedom for RMT and two for classification. Continuous RMT was the principal incremental comparison; binary RMT and classification comparisons were exploratory.

Five models were fitted: sac diameter alone; sac diameter plus binary RMT (≤3 versus >3 mm); sac diameter plus continuous RMT; conventional classification, with type I as the reference; and sac diameter plus classification. The 3-mm boundary came from the local classification and was not optimized in this dataset. Continuous and binary RMT were examined because categorization can discard information. [13] RMT and classification were not entered together because the classification incorporated myometrial thickness. Performance was assessed using AUC for discrimination, Brier score for probability error, and Akaike information criterion (AIC) for fit accounting for complexity. [14]

All five models underwent internal validation using the same 1000 ordinary bootstrap samples. Each model was refitted in every sample and evaluated in that sample and the original cohort. Optimism was the mean difference between bootstrap-sample and original-cohort performance; the corrected estimate was the apparent value minus optimism. [15] Model specifications remained fixed, without variable selection. Percentile 95% confidence intervals for apparent AUC and paired AUC differences were obtained from refitted bootstrap-sample statistics. These intervals were not intervals for optimism-corrected performance. Brier-score changes were descriptive, and no equivalence margin was defined.

Calibration was assessed using calibration-in-the-large, estimated with the model linear predictor as an offset, and calibration slope, estimated with a freely fitted intercept. Ideal values are zero and one, respectively. [14] As apparent values take these values by construction in unpenalized logistic regression, bootstrap-corrected summaries were reported. Apparent calibration plots for sac diameter alone and sac diameter plus continuous RMT grouped predictions into quintiles and displayed observed event proportions with Wilson 95% intervals. Corrected calibration summaries were reported as point estimates.

Analyses used Python and maximum-likelihood logistic regression. Implementation details and complete model coefficients are provided in the supplementary material and Table S1. Two-sided $P<0.05$ was used for association tests. Prediction reporting was informed by TRIPOD+AI. [16] No clinical operating cutoff or final model was selected, and external validation and clinical-utility analysis were not undertaken.

A post hoc sensitivity analysis restricted the cohort to group A, evacuation without preoperative UAE. Sac diameter alone and sac diameter plus continuous RMT were refitted and internally validated using 1000 bootstrap samples. This restriction examined sensitivity to the treatment mix. Further subgroup interactions were not fitted because event counts were limited.

Results

Cohort characteristics

The cohort comprised 343 pregnancy events, including 23 (6.7%) with intraoperative blood loss >200 mL **(Figure 1).** CSP types I, II, and III accounted for 193 (56.3%), 110 (32.1%), and 40 (11.7%) pregnancies, respectively. Treatment groups A, B, and C included 277, 15, and 51 pregnancies. Characteristics by bleeding status and variable-specific missingness are reported in Table 1.

Associations with bleeding

In the model containing both measurements, larger sac diameter was associated with bleeding (OR per 1 mm, 1.080; 95% CI, 1.048–1.114; P<0.001). RMT had an inverse estimated association, but its confidence interval included no association (OR per 1 mm, 0.867; 95% CI, 0.699–1.075; P=0.193). **(Table 2)** . The likelihood-ratio test comparing this model with sac diameter alone was not significant (P=0.165).

Incremental model comparisons

The sac-diameter model had an apparent AUC of 0.783 (95% CI, 0.671–0.881). Adding binary RMT, continuous RMT, or classification yielded apparent AUCs of 0.777, 0.773, and 0.782, respectively **(Table 3; Figure 2).** Paired AUC differences were −0.007 (95% CI, −0.020 to 0.030), −0.011 (95% CI, −0.031 to 0.040), and −0.001 (95% CI, −0.017 to 0.050); corresponding likelihood-ratio P values were 0.198, 0.165, and 0.114 **(Table 4).** Optimism-corrected AUCs were 0.782 for sac diameter alone and 0.766, 0.762, and 0.765 for the expanded models **(Table 5).** Corrected Brier scores decreased from 0.0557 to 0.0546, 0.0542, and 0.0536, indicating modest reductions in probability error without improved discrimination. Classification alone had apparent and corrected AUCs of 0.666 and 0.640.

Bootstrap-corrected calibration-in-the-large ranged from 0.007 to 0.011, and corrected slopes ranged from 0.945 to 1.016 across full-cohort models **(Table 5).** The apparent calibration plots showed wide uncertainty in observed event proportions **(Figure 3).**

Sensitivity analysis by treatment pathway

Group A included 277 pregnancies and 15 bleeding events (5.4%); groups B and C included 15 pregnancies with no events and 51 pregnancies with eight events (15.7%), respectively. In group A, the two-measurement model yielded an OR of 1.061 per 1-mm increase in sac diameter (95% CI, 1.020–1.105; P=0.003) and 0.907 per 1-mm increase in RMT (95% CI, 0.718–1.145; P=0.411). Adding RMT did not provide clear evidence of improved fit (P=0.391). Apparent AUC was 0.725 for sac diameter alone and 0.705 after adding RMT (**Table 6**). These descriptive treatment-group event rates do not

estimate treatment effects. After internal validation, subgroup AUCs were 0.721 for sac diameter alone and 0.678 after adding RMT; corrected Brier scores were 0.0510 and 0.0506. Corrected calibration slopes were 1.196 and 0.954, respectively (**Table 5**).

Discussion

Principal findings

Larger gestational-sac diameter was associated with intraoperative blood loss >200 mL. Adding RMT or conventional classification did not clearly improve discrimination, although probability error decreased slightly. The evacuation-without-UAE subgroup showed the same general pattern. By comparing each expanded model with a common base model, the study addresses the additional information provided by routinely available ultrasound features rather than their association with bleeding in isolation.

Interpretation in relation to previous evidence

The sac-diameter association is consistent with its inclusion in previous CSP risk-assessment studies. [6] Sac size may reflect pregnancy advancement or the volume of tissue requiring removal, although these mechanisms were not tested. Outcomes vary with gestational age at diagnosis, [17] and gestational age and placental lacunae have been associated with major bleeding during evacuation of live CSP. [5] Diameter therefore needs to be interpreted alongside gestational age, viability, vascularity, and implantation anatomy; our analysis adjusted only for RMT.

RMT remains important for describing scar implantation and has been linked to CSP outcomes. [18] Its confidence interval in this cohort was compatible with an inverse association as well as little or no association. Limited events, measurement variation, and treatment selected in response to anatomy may explain the uncertain additional contribution. An association with bleeding during early surgical treatment may also differ from its relationship with rupture or progression of a continuing pregnancy.

The continuous and binary RMT analyses examined whether the representation of the same measurement affected performance. Although categorization can lose information, [13] continuous RMT did not improve discrimination here. Paired intervals included both deterioration and improvement, so the results do not establish model equivalence or exclude additional value in a larger cohort. The small Brier-score reductions reflect probability error and do not establish clinical benefit. [14]

Published hemorrhage models address different populations and outcomes. Ban et al. used a different bleeding threshold and linked classification to surgical strategy, whereas Chen et al. examined

a broader predictor set with a separate validation framework. [6, 7] Differences in eligibility, outcome severity, treatment, and validation preclude ranking their AUCs directly against ours.

Outcome definition and treatment context

The >200-mL endpoint describes intraoperative blood-loss volume and should not be interpreted as severe hemorrhage. Standardized CSP outcomes distinguish blood loss from transfusion and other serious complications. [8, 9] Incomplete numeric volumes prevented analysis of higher thresholds or a dose–response relationship. Future studies should record exact loss, its timing and ascertainment method, and clinically consequential outcomes.

Treatment context is important. National cohort data illustrate the diversity of CSP management, [19] while comparative evidence includes a network meta-analysis and a randomized trial of hysteroscopic resection versus ultrasound-guided evacuation after methotrexate preparation. [20, 21] Bleeding associations must therefore be interpreted in relation to the procedure and preparation used.

Anatomical findings may influence prophylactic UAE or scar repair, which can in turn alter observed bleeding. This interaction between treatment and prediction is recognized in methodological literature. [22] Our estimates describe risk under the local treatment pathways and cannot establish untreated risk or comparative treatment effects. Adjustment for treatment alone would not necessarily resolve this issue.

Restricting analysis to evacuation without UAE reduced variation from embolization and planned scar repair. The similar associations support the consistency of the findings within that pathway. Nevertheless, the subgroup included different evacuation procedures, treatment selection remained nonrandom, and only 15 events occurred; it provides a sensitivity check rather than independent validation.

Strengths, limitations, and implications

Strengths include a defined five-year cohort, complete recording of the principal ultrasound measurements, and source review of discrepant outcome and classification records. A common base model, paired AUC comparisons, uniform bootstrap validation, and a clinically defined sensitivity analysis allowed focused assessment of incremental information.

Limitations include the retrospective single-institution design, heterogeneous procedures, and possible selection bias from excluding incomplete records. Clinically estimated blood loss and reconstruction of threshold status may introduce ascertainment error. Interobserver reproducibility was not quantified. Linear terms may miss nonlinear associations, and 23 events limited precision and

evaluation of additional predictors. Estimates were adjusted only for the other ultrasound measurement. Secondary comparisons and the post hoc subgroup analysis were exploratory, without multiplicity adjustment.

The clinical implication is to distinguish anatomical characterization from demonstrated improvement in bleeding prediction. RMT and classification remain relevant to procedural planning even when their additional discrimination for this endpoint is uncertain. Bootstrap-corrected performance and calibration were point estimates with unquantified uncertainty, and subgroup calibration was less stable. Independent evaluation of discrimination, calibration, and benefit for a specified clinical decision is needed before implementation. [14, 16] Consistent ultrasound definitions and standardized outcomes would strengthen that evaluation. [3, 9]

Conclusion

In this retrospective cohort, RMT and conventional CSP classification did not clearly improve discrimination beyond gestational-sac diameter for intraoperative blood loss >200 mL, despite small reductions in probability error. A sensitivity analysis restricted to evacuation without UAE showed a similar pattern. These findings inform the assessment of additional ultrasound information within the observed treatment pathways and require external evaluation before clinical use.

Declarations

Ethics approval and consent to participate: This study was conducted in accordance with the Declaration of Helsinki. The study was approved by the Shanghai General Hospital Institutional Review Board on September 30, 2026 (approval No. Yuan Lun Kuai [2026] 699). The requirement for individual informed consent was waived by the institutional review board. **Clinical trial number:** not applicable.

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Author contributions: Xuexin Zhou: Conceptualization, Writing – review & editing. Decui Cheng: Conceptualization, Writing – review & editing. Wengong Wei: Data curation, Writing – review & editing. Wei Zhang: Formal analysis, Validation, Writing – review & editing. Min Min: Validation, Writing – review & editing. Yanjun Zhang: Validation, Formal analysis, Writing – review & editing. Hailin Chen: Writing – review & editing. Ru Zhang: Writing – original draft, Writing – review & editing.

All authors contributed to the interpretation of the data, critically revised the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

Data availability: Deidentified participant-level data and the data dictionary may be made available after publication on reasonable request to the corresponding author, subject to approval by the institutional ethics committee and a data-use agreement.

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Tables and figures

Table 1. Characteristics by intraoperative bleeding status

Characteristic	All 343	Absent 320	Present 23
Age, years	33.0 (29.0–36.0)	33.0 (29.0–36.0)	34.0 (30.5–38.0)
Gestational age, days	45.0 (40.5–52.5)	44.5 (40.0–52.0)	50.0 (43.0–61.5)
Recorded hemoglobin, g/L	126.0 (118.3–133.0)	125.6 (118.0–133.0)	130.0 (123.0–134.0)
Sac diameter, mm	17.7 (12.7–26.3)	17.3 (12.3–26.0)	32.7 (22.5–43.2)
RMT, mm	4.0 (2.5–5.0)	4.0 (2.6–5.1)	3.0 (2.0–4.0)
One prior cesarean delivery	198 (57.9%)	185 (58.0%)	13 (56.5%)
Two prior cesarean deliveries	134 (39.2%)	126 (39.5%)	8 (34.8%)
Three prior cesarean deliveries	10 (2.9%)	8 (2.5%)	2 (8.7%)
Fetal cardiac activity present	114 (33.2%)	108 (33.8%)	6 (26.1%)
Doppler flow absent	258 (75.2%)	247 (77.2%)	11 (47.8%)
Doppler flow sparse	49 (14.3%)	45 (14.1%)	4 (17.4%)
Doppler flow abundant	36 (10.5%)	28 (8.8%)	8 (34.8%)
Type I	193 (56.3%)	185 (57.8%)	8 (34.8%)
Type II	110 (32.1%)	104 (32.5%)	6 (26.1%)
Type III	40 (11.7%)	31 (9.7%)	9 (39.1%)
Group A evacuation without UAE	277 (80.8%)	262 (81.9%)	15 (65.2%)
Group B UAE and evacuation	15 (4.4%)	15 (4.7%)	0 (0.0%)
Group C removal and scar repair	51 (14.9%)	43 (13.4%)	8 (34.8%)

Values are median (interquartile range) or number (%). Bleeding was defined as intraoperative blood loss >200 mL. Percentages use available records. Hemoglobin was missing in four pregnancies (two in each outcome group); prior cesarean count was missing in one non-event pregnancy. Available denominators for these variables were 339 and 342, respectively. Other displayed variables were complete. Doppler categories reproduce the recorded grades. UAE, uterine-artery embolization.

Table 2. Regression estimates for ultrasound measurements

Model and predictor	OR	95% CI	P value
Sac diameter alone per 1 mm	1.081	1.049–1.114	<0.001
Two-variable model sac diameter per 1 mm	1.080	1.048–1.114	<0.001
Two-variable model RMT per 1 mm	0.867	0.699–1.075	0.193

Table 3. Apparent model performance

Model	AUC (95% CI)	Brier	AIC
Sac diameter	0.783 (0.671–0.881)	0.0548	145.5
Sac diameter and binary RMT	0.777 (0.671–0.881)	0.0532	145.8
Sac diameter and continuous RMT	0.773 (0.672–0.885)	0.0529	145.6
Conventional classification	0.666 (0.571–0.786)	0.0592	161.8
Sac diameter and classification	0.782 (0.680–0.890)	0.0518	145.1

Table 4. Incremental performance relative to sac diameter alone

Added information	ΔAUC (95% CI)	ΔBrier	LR P
Add binary RMT	-0.007 (-0.020 to 0.030)	-0.0015	0.198
Add continuous RMT	-0.011 (-0.031 to 0.040)	-0.0019	0.165
Add CSP classification	-0.001 (-0.017 to 0.050)	-0.0030	0.114

Negative ΔAUC indicates lower apparent discrimination; negative ΔBrier indicates lower apparent probability error. Intervals are percentile intervals for apparent AUC differences from 1000 paired ordinary bootstrap samples with refitting, not intervals for corrected performance. LR, likelihood-ratio test; RMT, residual myometrial thickness. Comparisons do not establish equivalence.

Table 5. Bootstrap optimism-corrected model performance

Model	AUC	Brier	Calibration intercept	Calibration slope
Sac diameter	0.782	0.0557	0.010	1.016
Sac diameter and binary RMT	0.766	0.0546	0.009	0.977
Sac diameter and continuous RMT	0.762	0.0542	0.007	0.976
Conventional classification	0.640	0.0600	0.009	1.000
Sac diameter and classification	0.765	0.0536	0.011	0.945
Group A sac diameter	0.721	0.0510	0.026	1.196
Group A sac diameter and RMT	0.678	0.0506	0.027	0.954

All values are optimism-corrected point estimates from 1000 bootstrap samples with refitting. Calibration intercept denotes calibration-in-the-large with slope fixed at one; ideal intercept and slope are zero and one. Full-cohort n=343, events=23; group A n=277, events=15. Confidence intervals for these corrected summaries were not estimated. Group A models are subgroup refits, not external validation.

Table 6. Sensitivity analysis in evacuation without preoperative UAE

Predictor	OR (95% CI)	P value
Sac diameter per 1 mm	1.061 (1.020–1.105)	0.003
RMT per 1 mm	0.907 (0.718–1.145)	0.411

Subgroup n=277, with 15 events. Estimates are from the model containing both measurements. Adding RMT to sac diameter: likelihood-ratio P=0.391. Apparent AUC: 0.725 for sac diameter alone and 0.705 with RMT. UAE, uterine-artery embolization.

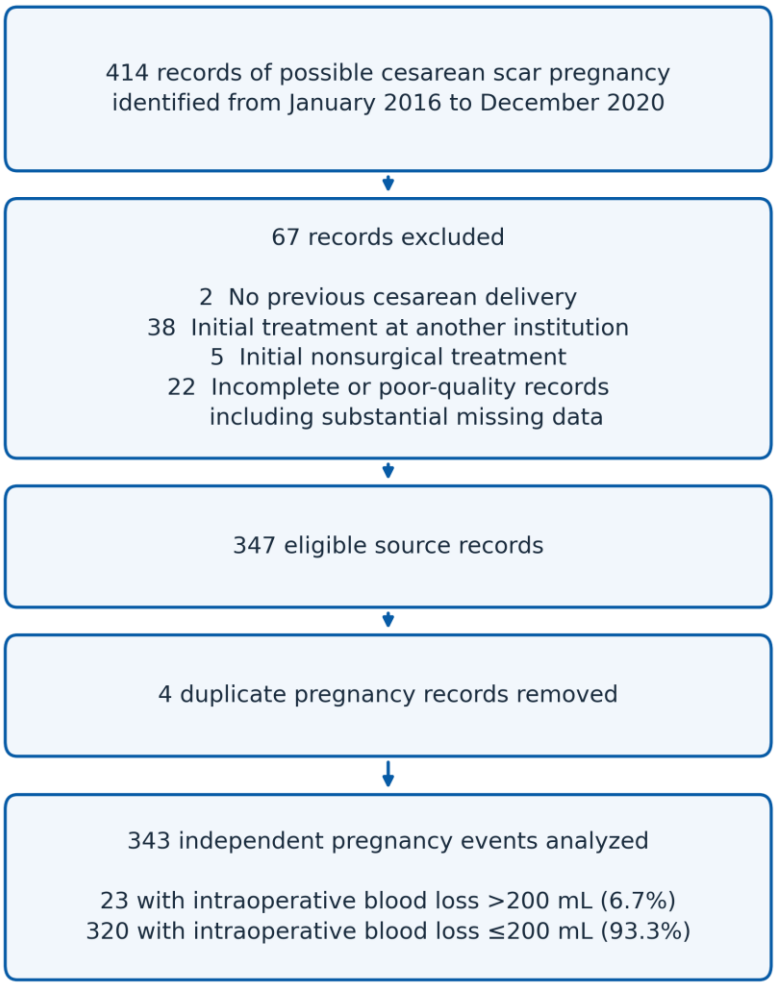


Figure 1. Cohort selection from January 2016 to December 2020. After eligibility assessment and removal of duplicate records, 343 independent pregnancy events were analyzed. Intraoperative blood loss >200 mL occurred in 23 pregnancies (6.7%); the remaining 320 pregnancies (93.3%) were classified as non-events.

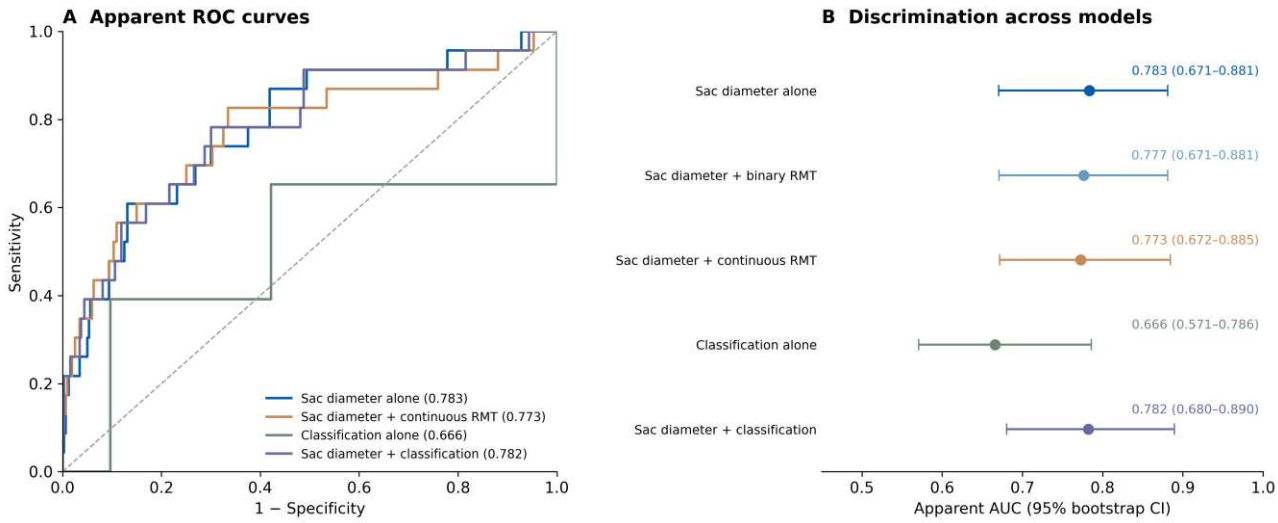


Figure 2. Apparent discrimination for intraoperative blood loss >200 mL. (A) ROC curves for sac diameter alone, sac diameter plus continuous RMT, classification alone, and sac diameter plus classification. (B) Apparent AUCs and percentile 95% confidence intervals for all five models, estimated from 1000 ordinary bootstrap samples with refitting. Binary RMT was coded as ≤3 versus >3 mm. Intervals describe apparent AUC uncertainty and are not intervals for optimism-corrected performance. Bootstrap-corrected estimates are reported in Table 6. RMT, residual myometrial thickness; AUC, area under the ROC curve.

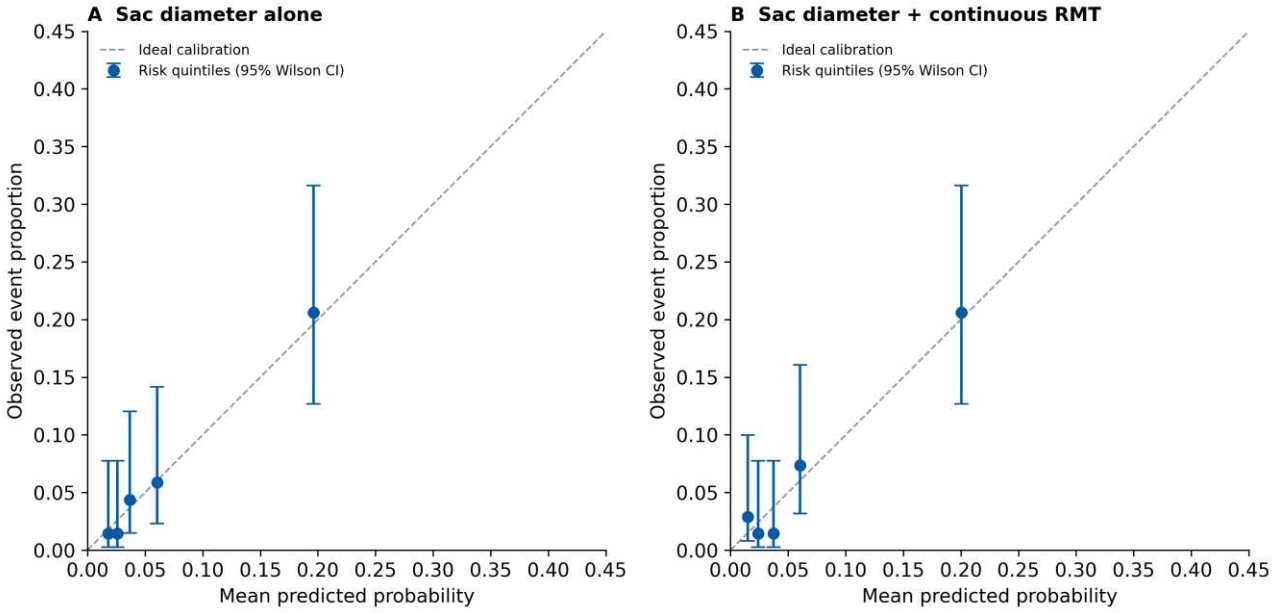


Figure 3. Apparent calibration for sac diameter alone and sac diameter plus continuous RMT. Panels A and B show the sac-only and sac-plus-continuous-RMT models, respectively. Each point represents one quintile of predicted risk; bars show Wilson 95% intervals for the observed proportion. The dashed line denotes equality between predicted and observed risk. These plots use fitted predictions in the development cohort and are not optimism-corrected or independently validated. Bootstrap-corrected calibration summaries are in Table 6.

Supplementary model specification

Computational details: Analyses used Python 3.12.14, NumPy 2.3.5, SciPy 1.17.0, and pandas 2.2.3. Maximum-likelihood logistic regression used a BFGS optimizer; convergence required a maximum absolute likelihood gradient below 0.0001. Bootstrap random seeds were 20261004 for the full cohort and 20261005 for group A. All 1000 resamples yielded usable fits for each full-cohort and subgroup model.

The model probability is $p = 1 / [1 + \exp(-\eta)]$, where η is the intercept plus the sum of each coefficient multiplied by its predictor. Sac diameter and continuous RMT are measured in millimeters. Binary RMT equals one when RMT $\leq$3 mm and zero otherwise. Type II and III are indicator variables, with type I as the reference. A dash indicates that a term was absent from the model. Coefficients are unpenalized development estimates; no shrinkage or clinical decision threshold was applied.

Table S1. Complete logistic regression coefficients

Model	Intercept	Sac diameter	Binary RMT	Continuous RMT	Type II	Type III
M1	-4.709554	0.078262	–	–	–	–
M2	-4.968036	0.075528	0.610791	–	–	–
M3	-4.125318	0.077139	–	-0.142852	–	–
M4	-3.140914	–	–	–	0.288283	1.904152
M5	-4.773971	0.068891	–	–	0.199046	1.222346
A1	-4.216790	0.057576	–	–	–	–
A2	-3.833693	0.059607	–	-0.097905	–	–

M1, sac diameter; M2, sac diameter and binary RMT; M3, sac diameter and continuous RMT; M4, classification; M5, sac diameter and classification. A1 and A2 are the subgroup A sac-only and sac-plus-continuous-RMT models. These exploratory equations are supplied for reproducibility and require independent evaluation before clinical use.