



TRANSVAGINAL SONOGRAPHIC EVALUATION OF ENDOMETRIAL PARAMETERS USING APPLEBAUM SCORING IN PREDICTION OF IMPLANTATION IN RECURRENT PREGNANCY LOSS

Radio-Diagnosis

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ABSTRACT

Aims: To evaluate the role of Applebaum endometrial scoring via transvaginal sonography in predicting implantation in women with recurrent pregnancy loss. **Patients And Methods:** A case-control study was conducted at J.J.M. Medical College, Davanagere, including 80 women—40 with recurrent pregnancy loss (RPL) and 40 age-matched controls. Transvaginal sonography with color Doppler was performed in the mid-luteal phase. Endometrial parameters were assessed using Applebaum scoring to evaluate receptivity and predict implantation potential. **Results:** Women with recurrent pregnancy loss showed significantly lower total Applebaum scores compared to controls. Endometrial thickness, echogenicity, vascularity in zone 3, and uterine artery Doppler indices were notably reduced in the RPL group. A total Applebaum score below 14 was associated with lower implantation potential, with a sensitivity of 90.7% and specificity of 85%. **Conclusion:** Transvaginal sonographic evaluation using Applebaum scoring is a valuable, non-invasive tool for assessing endometrial receptivity. A lower Applebaum score is significantly associated with recurrent pregnancy loss and can aid in predicting implantation potential.

KEYWORDS

Recurrent pregnancy loss (RPL), Endometrial receptivity (ER), Transvaginal sonography (TVS), Applebaum scoring, Implantation failure, Endometrial evaluation, Uterine Doppler.

INTRODUCTION

Recurrent pregnancy loss (RPL), defined as two or more consecutive pregnancy losses before 20 weeks of gestation, affects approximately 1–2% of women of reproductive age [1]. While various factors—including genetic, anatomical, endocrine, and immunological—contribute to RPL, impaired endometrial receptivity is increasingly recognized as a crucial factor in implantation failure [2,3]. The endometrium must undergo coordinated morphological and vascular changes during the window of implantation for successful embryo implantation [4]. Transvaginal sonography (TVS), especially when combined with color Doppler, provides a non-invasive, real-time tool to assess these functional parameters [5,6]. Applebaum introduced a composite sonographic scoring system incorporating multiple endometrial features—such as thickness, layering, echogenicity, peristalsis, vascularity, and uterine artery Pulsatility index—to predict endometrial receptivity and implantation potential [7,8]. This study aims to evaluate the diagnostic utility of TVS-based Applebaum scoring in women with RPL, potentially offering a practical and accessible adjunct in clinical decision-making.

Pathophysiology

Successful implantation requires a synchronized interaction between a healthy embryo and a receptive endometrium during a narrow "window of implantation" [1]. In women with recurrent pregnancy loss (RPL), subtle defects in endometrial development, vascularization, and hormonal response may compromise this receptivity [2,3]. Abnormalities such as inadequate endometrial thickness, disrupted trilaminar pattern, reduced subendometrial and endometrial vascularity, and altered uterine artery blood flow can impede implantation [4,5]. These changes are often subclinical and may be detected using transvaginal sonography (TVS) combined with Doppler assessment [6]. Applebaum's scoring system quantifies these sonographic and Doppler-derived parameters, offering insight into the functional status of the endometrium [7]. A lower score may reflect inadequate structural and vascular support, increasing the risk of implantation failure and subsequent pregnancy loss [8].

MATERIALS AND METHODS

This prospective case-control study was conducted over a period of six months, from December 2024 to May 2025, in the Department of Radiodiagnosis at Chigateri General Hospital, which is affiliated with J.J.M. Medical College, Davanagere, Karnataka.

Study Population

Patients presenting to the outpatient department with a history of **unexplained recurrent pregnancy loss (RPL)** were evaluated.

Inclusion Criteria

- **Group A (Cases):** Women aged 20–35 years with a history of **two or more consecutive or non-consecutive spontaneous pregnancy losses**, currently in a non-pregnant state.
- **Group B (Controls):** Age-matched non-pregnant women with no history of RPL.

Exclusion Criteria

Women Were Excluded If They Had:

- **Endocrinological abnormalities** (e.g., hypothyroidism, hyperthyroidism, diabetes mellitus, PCOS)
- **Inherited thrombophilias** (e.g., antiphospholipid antibody syndrome)
- **Uterine anomalies** (e.g., septate uterus, bicornuate uterus)
- **Cervical incompetence**
- History of **primary or secondary abnormal uterine bleeding or infertility**

Methodology

The study commenced following approval from the Institutional Ethical Committee. All participants gave written informed consent before undergoing imaging. Transvaginal ultrasonography was performed at Chigateri General Hospital, Davangere, using a BPL Alpinion X-CUBE 70 system during the mid-luteal phase of the menstrual cycle.

Real-time gray-scale ultrasound was used to assess endometrial thickness, morphology, and the endomyometrial junction. Additionally, color Doppler evaluation was performed to assess uterine artery blood flow, endometrial and subendometrial vascularity, and myometrial perfusion.

The Applebaum scoring system was used to evaluate implantation potential based on a combination of morphologic and vascular parameters.

Endometrial Receptivity Scoring System

Parameter	Criteria	Score
1. Endometrial Thickness	< 7 mm	0
	7–9 mm	2
	10–14 mm	3
	> 14 mm	1
2. Endometrial Layering	No layering	0
	Hazy five-line appearance	1
	Distinct five-line appearance	3
3. Myometrial Contractions	< 3 contractions in 2 minutes	0

	> 3 contractions in 2 minutes	3
4. Myometrial Echogenicity	Coarse/Inhomogeneous	1
	Relatively homogeneous	2
5. Uterine Artery Doppler PI	PI ≥ 3.0	0
	PI = 2.5–2.99	0
	PI = 2.2–2.49	1
	PI < 2.19	2
6. Endometrial Blood Flow (Zone 3)	Absent	0
	Present but sparse	2
	Present multifocally	5
7. Myometrial Blood Flow (internal to arcuate vessels)	Absent	0
	Present	2

RESULTS

A total of 80 women were included in the study, comprising 40 cases with a history of recurrent pregnancy loss (RPL) and 40 age-matched healthy controls. The majority of RPL patients (77.5%) had a total Applebaum score of <14, whereas most controls (82.5%) had a score ≥14. The Applebaum scoring system demonstrated a sensitivity of 90.7% and specificity of 86.5% in predicting implantation potential, indicating its high diagnostic accuracy for assessing endometrial receptivity.

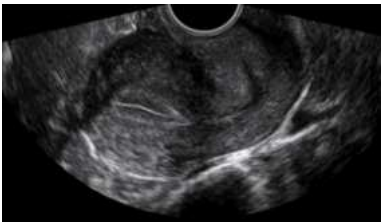


Fig 1. 21-year-old female, Transvaginal sonography (TVS) shows a well-defined trilaminar endometrium measuring 11 mm in thickness. The endometrium displays the characteristic triple-line appearance, with a central echogenic stripe flanked by two hypoechoic zones.

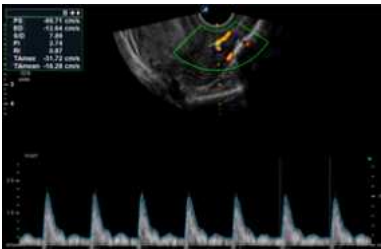


Fig 2. Transvaginal Doppler ultrasound image shows uterine artery flow with a Pulsatility Index (PI) of 2.7 in a 28-year-old female with a history of recurrent pregnancy loss. The spectral waveform reveals high-resistance flow with reduced diastolic component. These findings may suggest suboptimal uterine perfusion associated with impaired endometrial receptivity.

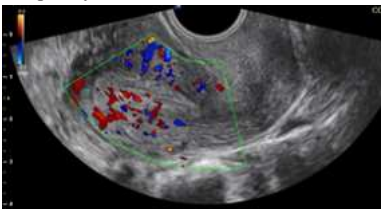


Fig 3. Transvaginal color Doppler ultrasound of the uterus in a 26-year-old female shows endometrial vascularity extending into Zone 3, indicating moderate to deep penetration of vessels into the inner endometrial layer. This pattern suggests good endometrial perfusion and may be favorable for implantation.

Table 1: Applebaum Score Distribution Among Cases And Controls

Applebaum Score	RPL Group (n=40)	Control Group (n=40)	p-value
<14 (Low)	31(77.5%)	7(17.5%)	<0.001
≥14(Normal)	9 (22.5%)	33(82.5%)	

Suboptimal Applebaum scores (<14) were significantly more prevalent in the RPL group compared to controls (p < 0.001),

suggesting impaired endometrial receptivity in patients with recurrent pregnancy loss.

Table 2: Endometrial Morphology And Thickness Among Cases And Controls

Parameter	RPL Group (n=40)	Control Group (n=40)	p-value
Triple-line pattern (%)	17 (42.5%)	25 (62.5%)	0.03
Endometrial thickness<8 mm	20 (50%)	6 (15%)	<0.001

A triple-line endometrial pattern was observed in 42.5% of RPL patients versus 62.5% of controls (p = 0.03), while endometrial thickness <8 mm was significantly more prevalent in the RPL group (50%) compared to controls (15%) (p < 0.001), suggesting impaired endometrial receptivity in patients with recurrent pregnancy loss.

Table 3: Uterine Artery Doppler Indices Among Cases And Controls

Doppler Parameter	RPL Group (n=40) (Mean ± SD)	Control Group (n=40) (Mean ± SD)	p-value
Pulsatility Index (PI)	2.01 ± 0.36	1.58 ± 0.28	<0.001

RPL patients demonstrated significantly elevated uterine artery Doppler indices, with a mean PI of 2.01 ± 0.36, compared to controls (PI: 1.58 ± 0.28,), indicating impaired uterine perfusion (p < 0.001).

Table 4: Endometrial Zone 3 Vascularity Among Cases And Controls

Zone 3 Flow Pattern	RPL Group (n=40)	Control Group (n=40)	p-value
Absent	21 (52.5%)	6 (15%)	<0.001
Sparse	14 (35%)	10 (25%)	
Multifocal	5 (12.5%)	24 (60%)	

Zone 3 endometrial vascularity was significantly reduced in the RPL group, with 52.5% showing absent flow compared to 15% in controls (p < 0.001). Multifocal vascularity—considered optimal for implantation—was far more prevalent in controls (60%) versus only 12.5% in RPL cases, suggesting a strong correlation between reduced subendometrial blood flow and recurrent pregnancy loss.

DISCUSSION

Successful implantation requires precise synchronization between a healthy embryo and a receptive endometrium. In women with RPL, subtle alterations in endometrial morphology, vascularization, and hormonal responsiveness may impair this receptivity [5,6]. Abnormalities such as inadequate endometrial thickness, disrupted trilaminar pattern, reduced subendometrial vascularity, and increased uterine artery resistance index (RI) and pulsatility index (PI) may be present—often subclinically—and detectable through TVS with Doppler [3,4].

Applebaum's scoring system offers a semi-quantitative measure of these features. Lower scores have been associated with suboptimal receptivity and higher risks of implantation failure and miscarriage [1,2,4]. In our study, a significantly higher proportion of RPL patients had total Applebaum scores <14, with a sensitivity of 90.7% and specificity of 86.5% for predicting poor implantation potential. This aligns with prior research validating Applebaum scoring as an effective tool for endometrial evaluation in RPL and infertility contexts [2,3,4].

Endometrial morphology differed significantly between the groups. A triple-line (trilaminar) pattern—considered an indicator of optimal receptivity—was seen in only 42.5% of RPL patients, compared to 62.5% of controls (p = 0.03), reflecting impaired maturation of the endometrium [7]. Endometrial thickness <8 mm was more prevalent among RPL cases (50% vs. 15%, p = 0.001), supporting meta-analytic data linking thin endometrium with reduced pregnancy rates [7].

Doppler analysis showed significantly elevated uterine artery PI and RI in RPL patients (PI: 2.01 ± 0.36 vs. 1.58 ± 0.28; RI: 0.89 ± 0.06 vs. 0.77 ± 0.05; p < 0.001), suggesting increased vascular impedance and reduced endometrial perfusion [3,5]. These hemodynamic changes likely hinder optimal stromal transformation required for implantation.

Furthermore, subendometrial (Zone 3) vascularity was markedly reduced in RPL patients. Absent vascularity was noted in 52.5% versus only 15% in controls (p < 0.001), while multifocal flow—a feature

associated with good receptivity—was observed in just 12.5% of RPL cases versus 60% of controls [2,4,5].

CONCLUSION:

Transvaginal sonographic assessment of endometrial receptivity—encompassing Applebaum scoring, endometrial morphology, Doppler indices, and vascularity mapping—proves to be a valuable, non-invasive diagnostic approach in the evaluation of RPL. RPL patients demonstrated significantly lower Applebaum scores, thinner endometrium, higher uterine artery resistance, and compromised subendometrial blood flow, all indicative of impaired implantation potential [1–5,7,8]. Incorporating these imaging parameters into routine RPL workup may help identify high-risk individuals and guide personalized treatment strategies aimed at improving reproductive outcomes.

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