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Role of Placenta Accreta Index in Predicting Conservative Surgery for Placenta Accreta Spectrum

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ABSTRACT

Background & Objective: Because of varying degrees of trophoblastic tissue invasion across the uterine wall, the placenta becomes inseparable from the uterus in cases of morbidly adherent placenta, a kind of placental attachment condition. Finding out how the placenta accreta index score predicts conservative surgery for placenta accreta spectrum.

Materials & Methods: From June 2022 to August 2024, 62 pregnant women over 28 weeks' gestation were the subjects of this diagnostic accuracy study at Ain Shams University Maternity Hospital, a tertiary care facility. The women were diagnosed with placenta previa using 2D ultrasound and Doppler on a placental bed with inclusion and exclusion criteria.

Results: Placenta Accreta Index (PAI) had significant moderate diagnostic performance and characteristics in predicting hysterectomy; was good at excluding hysterectomy but low in confirming it. Placenta Accreta Index (PAI) had significant moderate diagnostic performance and characteristics in predicting conservative surgery; it was good at confirming conservative surgery but low in excluding it. Placenta accreta index (PAI) had significant positive correlations with age, parity, operation duration, and hospital stay duration.

Conclusion: The study effectively illustrates how the Placenta Accreta Index (PAI) may be used to predict hysterectomy and conservative surgery in individuals with Placenta Accreta Spectrum (PAS). The findings indicate that the PAI is a reliable diagnostic tool, with a cut-off value of 6.5 offering strong predictive power for hysterectomy, showing 80% sensitivity and 81% specificity. Additionally, the PAI correlates significantly with clinical factors such as age, parity, operation duration, and hospital stay, enhancing its practical value for surgical decision-making.

Keywords: Morbidly adherent placenta, Pregnancy complications, Hysterectomy, Fertility preservation

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1. Introduction

A kind of placental attachment problem known as morbidly adherent placenta occurs when trophoblastic tissue invades the uterine wall to varying degrees, making the placenta inseparable from the uterus **(1,2)**. A major obstetric issue is the three types of Morbidly Adherent Placentas (MAP): placenta accreta, increta, and percreta **(3,4)**.

The highest risk factor for placenta accreta is placenta previa with a history of Caesarean birth **(5)**. The risk rises significantly with repeated procedures, from 3% to 67% from the first to the fifth procedure. When placenta previa occurs without a Caesarean procedure, the risk of placental invasion varies between 1% and 5% **(6,7)**.

Traditional cesarean-hysterectomy therapy is difficult, with a high maternal morbidity rate from severe bleeding. Surgical complications include damage to the pelvic, bowel, and urinary tract, as well as infertility and the psychological anguish that goes along with it **(8,9)**. In order to retain fertility and maybe lessen bleeding and damage to nearby organs, innovative methods aim to keep the uterus with the attached placenta in situ **(10,11)**.

It is one of the most frequent reasons for Caesarean hysterectomies because of the increased risk of serious obstetric bleeding **(10,12)**. Therefore, preventing maternal morbidity requires early diagnosis and predelivery awareness of adherent placenta, which may also be helpful for multidisciplinary therapy of suspected placental invasion **(13,14)**.

Prenatal diagnosis of morbidly adherent placenta can be made using a variety of modalities, although there are limitations because prenatal diagnosis is not histological **(15)**. However, 2D ultrasound, 3D Doppler, and MRI are important tools for prenatal diagnosis of morbidly adherent placentas **(14,16)**.

The PAI value is determined by combining the number of prior Caesarean sections, placental location, placental morphology (grading of lacunae), the smallest sagittal myometrial thickness, and presence of bridging vessels. The PAI values are then further divided into two major categories, with values <5 being unfavorable for invasion and values ≥5 being favorable for invasion **(1,17)**. Thus, the study's goal is to identify how the placenta accreta index score influences the prediction of conservative surgery for the placenta accreta spectrum.

2. Materials and Methods

Sixty-two pregnant women over 28 weeks' gestation who were diagnosed with placenta previa by 2D ultrasound and Doppler on a placental bed met the following inclusion criteria for this diagnostic accuracy study, which was carried out at the tertiary care hospital at Ain Shams University Maternity Hospital from June 2022 to August 2024 with approval from the ethical committee and written consent from the patients.

The research comprised patients who had undergone one or more cesarean sections, pregnant women who were over 28 weeks along by first trimester U/S, second trimester U/S, or other credible dates, and those who had been identified with placenta previa by 2D ultrasound and Doppler on placental bed. We excluded those who refused to participate.

Every participant had their medical history taken, a general examination, an abdominal examination, and investigations conducted, with a focus on lab work, including CBC, blood type, liver and kidney functions, coagulation profile, and imaging, including 2D ultrasound and 3D Doppler on the placental bed.

For each patient, the whole placenta was scanned at the Ultrasound and Fetal Care Unit, Ain Shams University Maternity Hospital, by the same senior consultant sonographer systematically using 2D-grayscale and 3D power Doppler and 3D color Doppler ultrasound for criteria of morbidly adherent:

- Placental location.
- Abnormal placental lacunae.
- Reduced myometrial thickness.
- Bridging vessels

Patients were taken up for elective CS by consultant between 34 and 36 weeks if suspected to be having PAS as per our hospital protocol, or earlier in case the patient started bleeding. The intraoperative findings were noted to make a clinical diagnosis and compared with the PAS index score of the patient.

To rule out postpartum endometritis following conservative surgery, follow-up postpartum visits were conducted in the second week following the procedure. These visits included evaluating vital signs (blood pressure, temperature, and pulse), checking the pelvis for pain or offensive purulent discharge, and performing pelvic ultrasounds or vault hematomas following cesarean hysterectomy.

Elimination of detection bias:

Detection bias was avoided by the blinding method. Radiologists who assessed the ultrasound images were unaware of patient histories, and the treating physicians were unaware of PAI scores before making the surgical decisions.

Sample Size: Bansal et al., reported the incidence of Placenta Accreta (PAS) in the high-risk group to be (30/71) 42% and the AUC of the ROC curve to be 0.87. Based on this information, a sample size of at least 60 cases with an expected 25 cases of PAS produces a two-sided 95% confidence interval with a width of 0.20 when the estimated AUC under the ROC curve is 0.87. The sample is inflated by 20% to compensate for the dropouts. The sample is satisfactory to estimate a sensitivity of 73% and a specificity of 95% with a 95% confidence interval width of 20% (17).

Outcome measures:

The primary outcome:

Accuracy of PAS index score in prediction of conservative surgery

Secondary outcomes:

1- Intraoperative blood loss

2- Amount and need of blood transfusion

3- Operative duration on time

4- Postoperative hemoglobin

5- Hospital stay

6- Postpartum endometritis

The patient information was anonymous. Patient confidentiality was maintained, and data presentation was done by diagnosis rather than by patient name. Every participant gave their informed permission, which was verified by date and time and was in Arabic. By giving the patient's initials a number that only the researcher knew, confidentiality was maintained.

Statistical analysis: SPSS version 20.0 was utilized. For numerical parametric variables, the data was displayed as range, mean, and standard deviation; for numerical non-parametric variables, it was displayed as range, median, and interquartile range, and for categorical variables, it was displayed as number and %. After that, appropriate statistical analyses were

used. The results' significance was assessed at the 0.05 level.

3. Results

Table 1 shows that age and Placenta Accreta Index (PAI) were significantly higher in cases that underwent hysterectomy.

Table 2 shows that the Placenta Accreta Index (PAI) had significant moderate diagnostic performance and characteristics in predicting hysterectomy; it was good at excluding hysterectomy but low in confirming it.

Table 3 shows that the Placenta Accreta Index (PAI) had significant moderate diagnostic performance and characteristics in predicting conservative surgery, it was good at confirming conservative surgery but low in excluding it.

Table 4 shows that age and Placenta Accreta Index (PAI) were significantly higher in cases that needed blood transfusion.

Table 5 shows that Placenta Accreta Index (PAI) had significant moderate diagnostic performance and characteristics in predicting need for blood transfusion; was good at confirming need for blood transfusion but poor in excluding it.

Table 6 shows that Placenta Accreta Index (PAI) had significant positive correlations with age, parity, operation duration, and hospital stay duration.

Table 1. Comparison to operative technique regarding baseline characteristics

Variables	Hysterectomy (Total=20)	Conservative (Total=42)	P-value
Age (years)	32.4±4.6	29.5±5.2	0.041*
BMI (kg/m^2)	27.8±2.3	28.4±3.6	0.390
Parity	3.0±1.0	2.3±1.3	0.053
Placenta Accreta Index (PAI)	7.3±1.5	4.8±2.1	<0.001*

Table 2. Diagnostic performance and characteristics of Placenta Accreta Index (PAI) in predicting hysterectomy

Factors	Value	95% CI
AUC	0.818	0.708-0.928
P-value		<0.001*
Cut point		≥6.5
Sensitivity	80.0%	56.3%-94.3%
Specificity	81.0%	65.9%-91.4%
Diagnostic accuracy	80.6%	68.6%-89.6%
Youden's index	61.0%	39.8%-82.1%
Positive predictive value	66.7%	44.7%-84.4%
Negative predictive value	89.5%	75.2%-97.1%

Table 3. Diagnostic performance and characteristics of Placenta Accreta Index (PAI) in predicting conservative surgery

Factors	Value	95% CI
AUC	0.818	0.708-0.928
P-value		<0.001*
Cut point		<6.5
Sensitivity	81.0%	65.9%-91.4%
Specificity	80.0%	56.3%-94.3%
Diagnostic accuracy	80.6%	68.6%-89.6%
Youden's index	61.0%	39.8%-82.1%
Positive predictive value	89.5%	75.2%-97.1%
Negative predictive value	66.7%	44.7%-84.4%

Table 4. Comparison according to need to blood transfusion regarding baseline characteristics

Variables	Blood transfusion (Total=49)	No transfusion (Total=13)	P-value
Age (years)	31.3±4.8	26.9±5.0	0.005*
BMI (kg/m^2)	28.2±3.2	28.4±3.4	0.816
Parity	2.6±1.2	2.1±1.2	0.147
Placenta Accreta Index (PAI)	6.1±2.0	3.8±2.3	<0.001*

Table 5. Diagnostic performance and characteristics of Placenta Accreta Index (PAI) in predicting need to blood transfusion

Factors	Value	95% CI
AUC	0.796	0.651-0.941
p-value	0.001*	
Cut point	≥5.3	
Sensitivity	71.4%	56.7%-83.4%
Specificity	84.6%	54.6%-98.1%
Diagnostic accuracy	74.2%	61.5%-84.5%
Youden's index	56.0%	32.7%-79.4%
Positive predictive value	94.6%	81.8%-99.3%
Negative predictive value	44.0%	24.4%-65.1%

Table 6. Correlations of Placenta Accreta Index (PAI) among the studied cases

Characteristics	Placenta accreta index (PAI)	
	r	P-value
Age (years)	0.424	0.001*
BMI (kg/m2)	-0.003	0.984
Parity	0.642	<0.001*
Operation duration (minutes)	0.472	<0.001*
Blood loss (mL)	-0.170	0.186
Preoperative hemoglobin (gm/dL)	-0.066	0.611
Postoperative hemoglobin (gm/dL)	0.106	0.412
Hemoglobin drop (gm/dL)	-0.155	0.228
Packed RBC units	0.221	0.126
Fresh frozen plasma units	-0.102	0.766
Hospital stay duration (days)	0.330	0.009*

4. Discussion

The risk assessment of morbidly adherent placentas has become a major challenge in modern obstetrics with the increasing number of Caesarean sections **(18,19)**.

To prevent life-threatening hemorrhage and maternal mortality, imaging specialists need detailed knowledge of the ultrasound features of a morbidly adherent placenta and its associated risk factors **(20,21)**. As a standard criterion for stratifying the probability of placental invasion, an easy and reproducible diagnostic tool is needed **(1,22)**.

Because surgical management of morbidly adherent placentas poses a significant conflict and may cause maternal morbidity and mortality **(23,24)**, it has been suggested that evaluating the diagnostic performance of the PAI in the prediction of PAS for reducing intra- and postoperative complications has been of great interest **(24)**.

Rac et al., **(25)** used a regression model to create the Placenta Accreta Index (PAI) to maximize the diagnosis. Three sonographic parameters-abnormal placental lacunae decreased myometrial thickness, and bridging vessels-are combined to provide a nine-point score for a high-risk group of third-trimester pregnant women (i.e., women with prior CS and anterior low-lying placenta, or PP). The likelihood of histopathologic invasion increases with the PAI score. Nonetheless, the authors acknowledged that their findings were retrospective in nature and requested a prospective evaluation.

This study was thus carried out with the intention of identifying the function of the placenta accreta index score in forecasting conservative surgery for the placenta accreta spectrum.

From June 2022 to August 2024, 62 pregnant women over 28 weeks' gestation were the subjects of this diagnostic accuracy research at Ain Shams University Maternity Hospital, a tertiary care facility. The women were diagnosed with placenta previa using 2D ultrasound and Doppler on the placental bed.

Sixty-two participants were enrolled in the trial after 80 patients had their eligibility evaluated. Seven patients declined to participate in the trial, while eleven of the eligible patients were disqualified from it due to inclusion rules.

The data from 62 pregnant women who were over 28 weeks along and had been identified with placenta previa by 2D ultrasound and Doppler on the placental bed ultimately served as the basis for the analysis.

The current study highlights that a higher PAI score is significantly associated with the need for more invasive surgical procedures, such as hysterectomy. Specifically, a PAI cut-off value of ≥6.5 demonstrated strong diagnostic accuracy, making it a valuable tool in preoperative planning.

Moreover, the study results showed that the PAI has significant correlations with various clinical factors such as patient age, parity, operation duration, and hospital stay duration. These correlations suggest that higher PAI scores indicate more complex and severe cases, which often require longer surgeries and extended recovery times. The study also found that cases requiring blood transfusions had significantly higher PAI scores, further supporting its predictive value.

The study also highlighted the strengths and limitations of using the PAI as a predictive tool. While the index showed good diagnostic accuracy for predicting the need for conservative surgery, however, the PAI's diagnostic performance was moderate, being better at confirming the need for conservative surgery than excluding it. This suggests that while the PAI can be a helpful guide in surgical decision-making, it should not be the sole factor considered. Clinical judgment, along with other diagnostic tools and patient-specific factors, should be integrated into the decision-making process to ensure the best outcomes.

These results are consistent with earlier research. In a prospective trial, Bansal et al., **(17)** used the PAI to identify PAS prior to surgery in 71 pregnant women with placenta previa and a history of cesarean sections. According to this study, all the placenta accreta index's ultrasound characteristics were statistically significant for predicting PAS (P-value<0.001) when compared to clinical and histological diagnosis at cesarean delivery. The optimum cutoff value to diagnose PAS, according to the ROC curve, was 4.75 with an AUC of 0.87 and 95% CI of 0.77-0.94. The sensitivity and specificity were 73.3% and 95.1%, respectively, for diagnosing PAS. These values indicate that while the PAI is highly specific in identifying true cases of PAS, it may miss some cases due to its lower sensitivity.

However, our study demonstrated similarly high diagnostic performance for predicting hysterectomy, with a sensitivity of 80% and specificity of 81%. This balance indicates the PAI's effectiveness in predicting which patients may require more aggressive surgical management.

Both studies emphasize the utility of the Placenta Accreta Index (PAI) as a predictive tool, but they target different outcomes: our study focuses on the need for surgical intervention, while Bansal et al., **(17)** aim at diagnosing PAS in high-risk patients.

Purnama et al., **(18)** conducted a diagnostic test study that enrolled 177 placenta previa cases to evaluate the value of PAI score and PAS stage in diagnosing Placenta Accreta Spectrum Disorders (PASD) and revealed that the cut-off was set at 4.6, yielding 75% sensitivity and 83% specificity and reporting diagnostic accuracy of 75-90% for both the PAI and PAS stage, making both tools reliable for PASD diagnosis. The sensitivity was slightly lower compared to our study, but the specificity was comparable. The study focused on PAS stages alongside the PAI, showing that the combination of the two can improve diagnostic outcomes.

The Placenta Accreta Index (PAI) can be used as a sensitive and specific marker for predicting the probability of an invasive placenta. Agarwal et al., **(1)** conducted a prospective study that included 45 pregnant women in order to estimate the level of interobserver agreement in the calculation of PAI and to evaluate the accuracy of PAI in predicting a morbidly adherent placenta. They also introduced a simplified scoring system, the Morbid Adherent Placenta Score, which is easy to use while maintaining high accuracy. These criteria also demonstrate a high level of consistency and reliability in its computation, since the PAI better known as the MAP score can be used to create a rough estimate of the likelihood of placental invasion, whether it be high or low. Sending the ultrasound data to the referring obstetrician for decision-making and suitable treatment planning might be helpful.

While no specific cut-off was given, Agarwal et al., **(1)** highlighted the high accuracy and reliability of PAI with 90% accuracy in detecting morbidly adherent placenta, suggesting that the cut-off might be comparable to that in other studies, which is consistent with Bansal et al., **(17)**. Both studies report slightly higher accuracy than our study, which may suggest that the PAI performs better in diagnosing severe PAS (as in Agarwal et al.,) or in high-risk populations (as in Bansal et al.,).

Similar findings were made by Rac et al., **(25)**, who discovered that a PAI score greater than 5 indicates high specificity between 92 and 100% and high Positive Predictive Value (PPV) between 75 and 100. They also discovered that the PPV ranged from 82% to 93% and the specificity between 90% and 97%. In the

same way, the lower PAI values demonstrated sensitivity between 86% and 93%, compared to 72% to 100% in reference research.

Abu Hashim et al., **(26)** conducted a prospective study that enrolled 100 third-trimester pregnant women and evaluated PAI in predicting PAS in high-risk pregnancies with a specific focus on third-trimester pregnant women with placenta previa or low-lying placentas and prior cesarean deliveries and revealed a cut-off value of 5.37, with 83.9% sensitivity, 76.3% specificity, and 81% diagnostic accuracy. This is in line with the findings of our study in terms of diagnostic accuracy, although the cut-off value is slightly lower.

Furthermore, Abu Hashim et al., **(26)** provided more specific odds ratios (ORs) for individual parameters of PAI, such as lacunae grades (OR 9.22) and sagittal smallest myometrial thickness (SSMT)<1.5 mm (OR 3.78), showing that lacunae grades were the strongest predictor of PAS. This approach offers a more detailed understanding of which PAI parameters contribute most significantly to PAS prediction, adding depth to the analysis that wasn't covered in other studies.

The cut-off values vary slightly between studies, which could be due to differences in patient populations, methodologies, or the severity of PAS cases studied. Bansal et al., **(17)** and Purnama et al., **(18)**, which focused on high-risk populations (e.g., placenta previa with previous cesarean sections), had lower cut-off points (around 4.6-4.75), indicating that these populations may develop PAS at lower PAI scores.

The significance of the different cut-off values in these studies is closely tied to the clinical context and the priorities of the study: higher cut-off values (e.g., 6.5 in our study) are better suited for predicting severe outcomes like hysterectomy, ensuring that only the most critical cases are flagged. Lower cut-off values (4.6-4.75 in Bansal et al., **(17)** and Purnama et al., **(18)**) are more useful for screening and early diagnosis, particularly in high-risk populations. While intermediate cut-off values (5.37 in Abu Hashim et al., **(26)**) provide a middle ground, effectively capturing both moderate and severe cases without over-diagnosing or under-diagnosing PAS.

The integration of these findings highlights the PAI's versatility as a diagnostic and predictive tool in managing placenta accreta spectrum **(27,28)**. The ability to use the PAI both for early diagnosis and for guiding surgical decision-making demonstrates its broad applicability in obstetric care. The different cut-off values identified in these studies underscore the importance of context-specific thresholds: lower values may be more suitable for screening and diagnosis, while higher values are crucial for predicting surgical outcomes **(29,30)**.

One important confounding factor in this study is the experience and skill level of the surgeons performing the procedures, which can significantly influence surgical outcomes, complication rates, and even the decision to perform hysterectomy versus conservative surgery. Since this was a single-center study, all procedures were conducted at Ain Shams University Maternity Hospital, where surgical expertise may be higher compared to smaller or non-specialized centers. Surgeons with extensive experience in PAS cases may be more confident in attempting conservative approaches, potentially lowering the hysterectomy rate, whereas less experienced surgeons might opt for hysterectomy more frequently as a safer alternative to prevent severe hemorrhage or other complications. This variability in surgical skill and decision-making could have influenced the outcomes independently of the Placenta Accreta Index (PAI) score.

Highly experienced surgeons may be more skilled in uterine-preserving techniques, managing hemorrhage, and minimizing complications, leading to lower hysterectomy rates. In contrast, less experienced surgeons may opt for hysterectomy more frequently as a safer alternative. This variability can bias the study's conclusions about PAI's predictive power.

Clinical implications in practice:

The clinical implications of this study highlight the importance of integrating the Placenta Accreta Index (PAI) into preoperative assessments to improve decision-making in patients with Placenta Accreta Spectrum (PAS). The findings suggest that a PAI cut-off of 6.5 is a useful predictor for hysterectomy, allowing obstetricians to better anticipate the need for extensive surgical intervention. By identifying high-risk cases earlier, clinicians can optimize surgical planning, resource allocation, and patient counseling, ensuring that multidisciplinary teams, including maternal-fetal medicine specialists, anesthesiologists, and blood bank services, are well-prepared for potential complications. This approach may help reduce maternal morbidity associated with massive hemorrhage and emergent surgical procedures.

Future perspectives:

A critical recommendation emerging from this study is the need for long-term follow-up of PAS patients, particularly those managed conservatively. Future research should focus on tracking fertility outcomes, PAS recurrence rates, and pregnancy complications in subsequent pregnancies. Understanding how conservative treatment affects future pregnancies is essential for refining patient selection criteria for uterus-preserving approaches. This information would allow clinicians to better counsel patients on their reproductive options and provide individualized recommendations based on long-term maternal and neonatal health risks.

Study strength points:

This research's strengths include its diagnostic accuracy study design. The study focuses on the Placenta Accreta Index (PAI) to predict both conservative surgery and hysterectomy outcomes,

providing clinicians with valuable guidance on surgical decisions related to Placenta Accreta Spectrum (PAS) and demonstrating strong diagnostic accuracy (80.6%), along with high sensitivity (80%) and specificity (81%), providing reliable predictions for both conservative management and hysterectomy. Moreover, a unique strength of this study is the exploration of correlations between PAI and other clinical factors such as age, parity, operation duration, and hospital stay. This provides a broader understanding of the clinical utility of PAI beyond just predicting the need for surgery.

The limitations of the study:

It is important to consider the limitations of this study, such as the comparatively lower sample size compared to earlier research, when interpreting the results. A single institution performed the study, which limited the findings' generalizability and prevented it from being a multicentric investigation. The study focuses solely on the PAI without comparing its performance with other diagnostic methods such as Doppler ultrasound, MRI, or other imaging techniques. Such comparisons could enhance the understanding of PAI's relative strengths and weaknesses. Another limitation is the relatively short-term follow-up of patients postoperatively and the lack of follow-up on long-term outcomes such as fertility preservation, recurrence of PAS, and long-term maternal health, which provide a more comprehensive evaluation of conservative surgery versus hysterectomy.

5. Conclusion

The study successfully demonstrates the utility of the Placenta Accreta Index (PAI) in predicting both conservative surgery and hysterectomy in patients with Placenta Accreta Spectrum (PAS). The findings indicate that the PAI is a reliable diagnostic tool, with a cut-off value of 6.5 offering strong predictive power for hysterectomy, showing 80% sensitivity and 81% specificity. Additionally, the PAI correlates significantly with clinical factors such as age, parity, operation duration, and hospital stay, enhancing its practical value for surgical decision-making.

The PAI appears to be a promising predictive tool for managing placenta accreta spectrum cases, particularly in helping clinicians prepare for potential complications and make informed decisions about surgical interventions. However, its use should be part of a comprehensive clinical evaluation to ensure the best possible outcomes for patients.

6. Declarations

Acknowledgments

None.

Ethical Considerations

This study was conducted in compliance with the Declaration of Helsinki and approved by the Research Ethics Committee of Ain Shams University Maternity Hospital. Written informed consent was obtained from all participants prior to inclusion in the study. Confidentiality of patient data was strictly maintained through anonymization and secure storage. All participants had the right to withdraw from the study at any time without any impact on their clinical care.

Conflict of interest: The contender stated that they had no conflicts of interest and that they had covered the study's expenses.

Confidentiality of Data: The authors affirm that they have complied with their work center's guidelines on the publishing of patient data.

Protection of Human and Animal Subjects: The authors affirm that the methods used were compliant with the World Medical Association's Code of Ethics (Declaration of Helsinki) and the rules of the applicable clinical research ethics committee.

Authors' Contributions

Each author contributed significantly to the work reported, approved the final version for publication, agreed on the journal to which the paper was submitted, and agreed to take responsibility for all elements of the work. Walid Hitler Ahmed Eltantawy: Principal investigator. Supervised the entire project, coordinated between departments, contributed to data analysis, and critically revised the manuscript for intellectual content. Sahar Mohamed Abd Elmaksoud: Contributed to the study design, patient recruitment, and manuscript drafting. Oversaw clinical data collection and interpretation. Ahmed Mohamed Mamdouh: Participated in ultrasound evaluations, managed data processing, and contributed to writing and reviewing results. Amr Saad Mahmoud Ahmed: Performed surgical interventions, contributed to the outcome assessment, and co-wrote the discussion and clinical implications.

Conflict of Interest

The contender stated that they had no conflicts of interest and that they had covered the study's expenses.

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