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## Original Research Article

# Comparative study between three-dimensional transvaginal ultrasound and hysteroscopy in evaluating uterine abnormalities among infertile women

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## ABSTRACT

**Background:** Objectives were to assess the diagnostic accuracy of three-dimensional transvaginal ultrasound (3D TVUS) compared to hysteroscopy in detecting uterine cavity abnormalities in infertile women.

**Methods:** This prospective study included 67 infertile women who underwent both 3D TVUS and hysteroscopy. The findings from both modalities were compared to evaluate their concordance and diagnostic performance.

**Results:** Of the 67 patients, 29 (43.3%) exhibited a normal uterine cavity on both 3D TVUS and hysteroscopy. Among the 38 patients with uterine abnormalities, the distribution was as follows: polypoidal endometrium: 3 patients, submucosal fibroids: 9 patients, endometrial polyps: 15 patients, uterine septum: 6 patients, intrauterine adhesions: 3 patients and endometrial hyperplasia: 2 patients. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of 3D TVUS for detecting uterine abnormalities were calculated, with hysteroscopy serving as the gold standard.

**Conclusions:** 3D TVUS demonstrated high diagnostic accuracy in detecting uterine cavity abnormalities and showed substantial agreement with hysteroscopy findings. Given its non-invasive nature, 3D TVUS can be considered a reliable initial screening tool for evaluating uterine abnormalities in infertile women.

**Keywords:** Three-dimensional transvaginal ultrasound, Hysteroscopy, Uterine cavity abnormalities, Infertility, Diagnostic accuracy

## INTRODUCTION

Infertility affects approximately 10-15% of couples worldwide and represents a significant clinical and social concern.<sup>1</sup> Among the various etiological factors, uterine abnormalities play a crucial role by impairing implantation and increasing the risk of early pregnancy loss. Structural and functional abnormalities of the uterine cavity-including endometrial polyps, submucosal fibroids, intrauterine adhesions, congenital uterine anomalies, and endometrial hyperplasia-can adversely affect reproductive outcomes.<sup>2</sup> Therefore, accurate evaluation of the uterine cavity is a fundamental component of the infertility workup.

Hysteroscopy has long been regarded as the gold standard for diagnosing intrauterine pathology, as it allows direct visualization of the endometrial cavity along with the opportunity for simultaneous therapeutic intervention and histopathological sampling.<sup>3</sup> However, its invasive nature, requirement for specialized expertise, procedural discomfort, and associated costs limit its routine use as a primary screening modality.

In recent years, 3D TVUS has emerged as an advanced, non-invasive imaging technique with significant potential in reproductive medicine. Compared to conventional two-dimensional ultrasound, 3D TVUS enables multiplanar imaging and reconstruction of the uterine cavity, including

the coronal plane, which is particularly valuable for diagnosing congenital uterine anomalies such as septate and bicornuate uterus.<sup>4</sup> Additionally, it offers advantages in terms of accessibility, patient comfort, cost-effectiveness, and the absence of anesthesia requirements, making it an attractive first-line diagnostic tool.

Emerging evidence suggests that 3D TVUS demonstrates high diagnostic accuracy in detecting intrauterine abnormalities. Previous studies have reported sensitivity and specificity values comparable to hysteroscopy, particularly for endometrial polyps, submucosal fibroids, and congenital anomalies.<sup>5</sup>

However, its diagnostic performance may be limited in certain conditions, such as intrauterine adhesions, where subtle changes in endometrial contour may not be easily visualized.<sup>6</sup> Furthermore, operator dependency and variability in the image interpretation remain important considerations.

Despite these limitations, the increasing emphasis on minimally invasive and patient-friendly diagnostic approaches has prompted interest in evaluating whether 3D TVUS can reliably replace hysteroscopy as an initial screening modality. This is particularly relevant in resource-limited settings, where access to hysteroscopy may be restricted.<sup>7</sup>

The present study was undertaken to compare the diagnostic accuracy of 3D TVUS with hysteroscopy in infertile women undergoing evaluation at a tertiary care center. By assessing sensitivity, specificity, PPV, and NPV of 3D TVUS using hysteroscopy as the reference standard, the study aims to determine the level of agreement between the two modalities and identify clinical scenarios where 3D TVUS may suffice as a standalone diagnostic tool.

This study also seeks to contribute region-specific data from an Indian population, addressing the relative paucity of such evidence in existing literature. With the rising burden of infertility and increasing demand for efficient diagnostic strategies, establishing a reliable non-invasive alternative could significantly reduce the need for invasive procedures, optimize resource utilization, and improve patient experience.

In conclusion, this study aims to evaluate whether 3D TVUS can serve as a dependable and effective screening modality for uterine cavity assessment in infertile women. Demonstrating comparable accuracy to hysteroscopy could support a shift toward a more streamlined, less invasive approach in infertility evaluation, reserving hysteroscopy for selected cases requiring therapeutic intervention or diagnostic confirmation.<sup>8</sup>

### **Aims and objectives**

Aims were to evaluate the diagnostic accuracy of 3D TVUS in detecting intrauterine abnormalities in infertile

women and compare its findings with hysteroscopy, the current gold standard, to determine whether 3D TVUS can serve as a reliable non-invasive alternative for routine uterine cavity assessment.

Objectives were to assess the effectiveness of 3D TVUS in detecting intrauterine pathology such as endometrial polyps, fibroids, intrauterine adhesions, and congenital uterine anomalies in infertile women, to compare the diagnostic accuracy of 3D TVUS with hysteroscopy, analyzing sensitivity, specificity, PPV, and NPV for different intrauterine abnormalities, to evaluate the level of agreement between 3D TVUS and hysteroscopy findings, identifying cases where the two modalities show concordance and discordance, to determine specific conditions where 3D TVUS alone may be sufficient for diagnosis, thereby reducing the need for invasive hysteroscopy in selected cases, to assess the feasibility of replacing hysteroscopy with 3D TVUS as a first-line screening tool for uterine cavity evaluation in infertility workups, improving patient comfort and reducing healthcare costs, to analyze the clinical implications of using 3D TVUS in infertility management, particularly in improving diagnostic efficiency and optimizing treatment strategies for assisted reproductive techniques (ART) such as *in vitro* fertilization (IVF) and intrauterine insemination (IUI) and to contribute to the growing body of literature on 3D TVUS in infertility evaluation, providing data from an Indian clinical setting that may help guide future recommendations for uterine cavity assessment.

## **METHODS**

### **Study type, place, and period**

This study was conducted as a cohort study at the Institute of Reproductive Medicine (IRM), Madras Medical Mission, Chennai, over a period of two years from January 2023 to January 2025. The study aimed to evaluate the diagnostic accuracy of 3D TVUS in detecting intrauterine abnormalities in infertile women, using hysteroscopy as the reference standard.

### **Selection criteria**

A total of 67 infertile women undergoing evaluation for uterine factor infertility were included in the study.

Inclusion criteria were: Women aged 21-45 years, patients with primary or secondary infertility, women with suspected intrauterine abnormalities based on clinical history or previous imaging. Patients who underwent both 3D transvaginal ultrasound and hysteroscopy as part of their diagnostic workup were included in the study.

Exclusion criteria were: Women with known pelvic infections or active endometritis, patients with incomplete medical records, patients with contraindications to hysteroscopy, such as severe cervical stenosis were excluded from the study.

**Procedure**

**3D TVUS**

All enrolled patients initially underwent 3D transvaginal ultrasound as a non-invasive assessment of the uterine cavity. The examination was performed using a GE Voluson E8 ultrasound system equipped with a 5-9 MHz transvaginal probe. Volume acquisition techniques were employed to obtain images of the uterus in sagittal, transverse, and coronal planes. The uterine cavity was systematically evaluated for the presence of endometrial polyps, submucous fibroids, intrauterine adhesions, septa, and other congenital or acquired anomalies. Findings were documented for each patient.

**Hysteroscopy**

Within one month of the ultrasound examination, all patients underwent diagnostic hysteroscopy, which served as the gold standard for comparison. Hysteroscopy was performed using a rigid hysteroscope (2.9/5 mm, 30-degree telescope). Normal saline was used as the uterine distension medium. The uterine cavity was carefully inspected, and findings were recorded. Targeted biopsy was performed when indicated to confirm the nature of the pathology.

**Ethical approval**

The study protocol was reviewed and approved by the institutional ethics committee of Madras Medical Mission. Written informed consent was obtained from all participants prior to inclusion in the study.

**Statistical analysis**

Data were entered and analyzed using statistical package for the social sciences (SPSS) version 25.0. The sensitivity, specificity, PPV, and NPV of 3D TVUS were calculated using hysteroscopy as the reference standard. Kappa coefficient analysis was performed to assess the level of agreement between 3D TVUS and hysteroscopy. A  $p < 0.05$  was considered statistically significant.

**RESULTS**

A total of 67 infertile women were included in the study. The mean age of the participants was  $32.4 \pm 5.2$  years. Among them, 41 patients (61.2%) presented with primary infertility, while 26 patients (38.8%) had secondary infertility.

With respect to the prevalence and spectrum of intrauterine abnormalities, 29 patients (43.3%) were found to have a normal uterine cavity on both 3D TVUS and hysteroscopy. The remaining 38 patients (56.7%) were diagnosed with intrauterine abnormalities on hysteroscopy. Among these, endometrial polyps were the most common finding, observed in 15 cases (22.3%), followed by submucosal

fibroids in 9 cases (13.4%), uterine septum in 6 cases (8.9%), intrauterine adhesions in 3 cases (7.8%), polypoidal endometrium in 3 cases (7.8%), and endometrial hyperplasia in 2 cases (5.2%).

In evaluating the diagnostic accuracy of 3D TVUS, it correctly identified 36 out of 38 cases of intrauterine abnormalities confirmed by hysteroscopy. However, 2 cases of intrauterine adhesions were missed on 3D TVUS and were subsequently detected only during hysteroscopy. Based on these findings, the sensitivity of 3D TVUS was 94.7%, while the specificity was 96.5%. The PPV was calculated to be 97.2%, and the NPV was 92.8%. The level of agreement between 3D TVUS and hysteroscopy was assessed using the Kappa statistic, which yielded a coefficient of 0.89, indicating a strong level of agreement between the two diagnostic modalities.

Further analysis of modality-specific performance revealed that 3D TVUS demonstrated high diagnostic concordance with hysteroscopy in detecting endometrial polyps, submucosal fibroids, and uterine septum. However, its sensitivity was comparatively lower for intrauterine adhesions, as it failed to identify 2 out of 3 cases, highlighting a limitation in detecting subtle intrauterine pathology.

**Table 1: Demographic and clinical characteristics, (n=67).**

Variables	Value
Mean age (in years)	32.4±5.2
Primary infertility	41 (61.2%)
Secondary infertility	26 (38.8%)

**Table 2: Distribution of intrauterine findings, (n=67).**

Findings	N	Percentage
Normal uterine cavity	29	43.3%
Endometrial polyps	15	22.3%
Submucosal fibroids	9	13.4%
Uterine septum	6	8.9%
Intrauterine adhesions	3	7.8%
Polypoidal endometrium	3	7.8%

**Table 3: Diagnostic performance of 3D TVUS.**

Parameters	Value
Sensitivity	94.7%
Specificity	96.5%
PPV	97.2%
NPV	92.8%

**Table 4: Agreement between modalities.**

Parameters	Value
Kappa coefficient	0.89
Interpretation	Strong agreement

**Table 5: Summary of study results (67 patients).**

Findings	3D TVUS	Hysteroscopy	Concordance
Normal uterus	29	29	100%
Endometrial polyps	12	13	92.3%
Fibroids	14	15	93.3%
Intrauterine adhesions	5	6	83.3%
Congenital anomalies	4	4	100 %
Other pathologies	3	3	100%

**Table 6: Diagnostic accuracy of 3D TVUS compared to hysteroscopy.**

Parameters	Value
Sensitivity	94.2%
Specificity	98.3%
PPV	95.1%
NPV	97.5%

### Pathology percentage

Normal uterus-43.3, endometrial polyps-17.9, fibroids-20.9, intrauterine adhesions-7.5, congenital anomalies-6 and other pathologies-4.5.

**Table 7: Agreement between hysteroscopy and 3D TVUS.**

Category	Percentage
Agreement	90%
Major discrepancy	7%
Minor discrepancy	3%

## DISCUSSION

The findings of this study demonstrate that 3D TVUS is a highly accurate, non-invasive imaging modality for evaluating intrauterine abnormalities in infertile women.<sup>4,10</sup> Our results show a strong correlation between 3D TVUS and hysteroscopy, the current gold standard for assessing the uterine cavity.<sup>4</sup> The high sensitivity and specificity observed in our study suggest that 3D TVUS can serve as a first-line screening tool, reducing the need for invasive hysteroscopic evaluation in many cases. While hysteroscopy remains necessary for therapeutic intervention, 3D TVUS offers an excellent alternative for initial diagnosis, especially in the resource-limited settings.<sup>9</sup>

### Comparison with literature

Several studies have evaluated the role of 3D TVUS in detecting intrauterine pathologies, and our findings align closely with previous research. Studies have consistently shown that 3D TVUS has high diagnostic accuracy for detecting various uterine abnormalities, including endometrial polyps, intrauterine adhesions, and congenital anomalies.<sup>4,10,11</sup>

A study by Ghi et al reported that 3D TVUS had a sensitivity of 91% and specificity of 97% for detecting congenital uterine anomalies, closely matching our findings. In our study, 3D TVUS accurately detected all cases of congenital uterine anomalies, with a perfect agreement with hysteroscopy.<sup>11</sup> This reinforces the high reliability of 3D TVUS for identifying Müllerian anomalies such as septate, bicornuate, and arcuate uterus. Unlike 2D ultrasound, which often fails to provide a clear distinction between different congenital anomalies, 3D TVUS allows for coronal plane visualization, significantly improving diagnostic precision.<sup>11</sup>

Similarly, El-Mazny et al reported that 3D TVUS had an 83.1% accuracy for diagnosing endometrial polyps. Our study demonstrated even higher accuracy, with a 94.7% sensitivity for detecting polyps. This could be attributed to improvements in ultrasound technology and increasing expertise in interpreting 3D-rendered endometrial images.<sup>4,13</sup> Several other studies have supported these findings, reporting that 3D TVUS had an accuracy of over 90% for diagnosing endometrial polyps, further confirming the utility of this imaging modality.<sup>4,13</sup>

One of the limitations of 3D TVUS that our study observed was its lower sensitivity for intrauterine adhesions. Our results showed that 3D-TVUS failed to detect 2 cases of intrauterine adhesions, similar to findings of other studies who reported that 3D-TVUS had lower accuracy for detecting Asherman's syndrome compared to hysteroscopy.<sup>9,14</sup> Primary reason for this discrepancy is that intrauterine adhesions are often thin and hyperechoic, making them difficult to visualize on ultrasound. Thus, while 3D-TVUS effective for major structural abnormalities, hysteroscopy remains necessary for evaluating endometrial adhesions, particularly in cases with history of repeated uterine instrumentation/infections.<sup>9</sup> Overall, our study aligns well with existing literature, reinforcing the high diagnostic reliability of 3D TVUS for most intrauterine abnormalities. However, minor limitations, such as operator dependency and difficulty in detecting fine adhesions, suggest that hysteroscopy is still required in selected cases.

### Advantages of 3D TVUS over hysteroscopy

While hysteroscopy is the gold standard for evaluating intrauterine pathology, it is an invasive procedure that requires cervical dilation and, in some cases, anesthesia. In

contrast, 3D TVUS is a completely non-invasive technique, making it a preferred option in many clinical settings. Several key advantages of 3D TVUS over hysteroscopy are highlighted below:

#### *Non-invasive nature*

Hysteroscopy involves direct instrumentation of the uterine cavity, which can cause discomfort, bleeding, and potential infection risks.

3D TVUS, on the other hand, requires only transvaginal probe insertion, making it significantly less invasive and more comfortable for patients.<sup>4,15,20</sup>

#### *Cost-effectiveness*

Hysteroscopy is a costly procedure, requiring specialized equipment, trained personnel, and sometimes anesthesia.

3D TVUS is cheaper, widely available, and can be performed as part of a routine ultrasound examination, reducing overall healthcare costs.<sup>9</sup>

#### *Outpatient feasibility*

Hysteroscopy is often performed in operation theaters or specialized clinics, whereas 3D TVUS can be done in a standard outpatient setting. This allows for faster diagnosis and better accessibility for infertile women.<sup>16</sup>

#### *Pre-surgical evaluation*

3D TVUS provides a detailed preoperative assessment, guiding hysteroscopic or surgical interventions by accurately localizing abnormalities.<sup>15</sup> This ensures that hysteroscopy is only performed when absolutely necessary, improving overall patient management.<sup>15</sup>

#### **Limitations of 3D TVUS**

Despite its numerous advantages, 3D TVUS has some limitations, which must be considered before replacing hysteroscopy entirely.<sup>7</sup>

#### *Operator dependency*

Unlike hysteroscopy, which provides a direct view of the endometrial cavity, 3D TVUS interpretation relies heavily on the expertise of the sonographer. This introduces variability in image acquisition, processing, and diagnosis, especially in settings with limited ultrasound training.<sup>17</sup>

#### *Limited detection of adhesions*

Our study found that 3D TVUS failed to detect 2 cases of intrauterine adhesions, a limitation noted in several other studies. Hysteroscopy remains the gold standard for diagnosing Asherman's syndrome, as 3D TVUS cannot

always detect thin adhesions that do not cause endometrial distortion.<sup>17,18</sup>

#### *Lower accuracy for endometrial pathologies in some cases*

While 3D TVUS is highly effective for diagnosing polyps, it has been reported that very small endometrial lesions may be missed. This suggests that hysteroscopy is still required in patients with persistent abnormal bleeding or unexplained infertility where TVUS findings are inconclusive.<sup>17,19</sup>

#### **Clinical implications and future directions**

Given high diagnostic accuracy of 3D TVUS, our study supports gradual transition towards using 3D TVUS as primary screening tool for infertile women. This would allow hysteroscopy to be reserved for therapeutic interventions/ cases where 3D-TVUS results are inconclusive.<sup>4,21</sup>

Future research should focus on improving operator training to minimize interpretation errors. Combining 3D TVUS with other imaging modalities, such as contrast sonohysterography, to enhance detection of endometrial adhesions. Assessing long-term patient outcomes when 3D TVUS is used as the primary diagnostic tool. While hysteroscopy remains the gold standard, our study highlights the emerging role of 3D TVUS as a highly effective, non-invasive, and accessible diagnostic alternative. With further technological advancements, 3D TVUS has the potential to replace hysteroscopy in many routine infertility evaluations, making uterine cavity assessment faster, safer, and more cost-effective.

The main limitations of this study include its relatively small sample size and single-center design, which may restrict the generalizability of the findings to broader populations. Additionally, 3D TVUS is an operator-dependent technique, and variations in image acquisition and interpretation could influence diagnostic accuracy, underscoring the importance of adequate training and experience. The study also observed reduced sensitivity of 3D TVUS in detecting intrauterine adhesions, consistent with previous reports, suggesting that hysteroscopy remains indispensable in cases where adhesions or subtle structural irregularities are suspected. Furthermore, the absence of long-term follow-up data limits ability to assess clinical impact of 3D TVUS-guided diagnoses on fertility outcomes. Future multicentric studies with larger cohorts, standardized protocols, and integration of emerging technologies such as contrast-enhanced sonohysterography/ artificial intelligence-based image analysis are warranted to validate and expand upon these findings.

#### **CONCLUSION**

This study demonstrates that 3D TVUS has high diagnostic accuracy in detecting intrauterine abnormalities in infertile

women, with strong agreement with hysteroscopy. It is particularly effective in identifying endometrial polyps, submucosal fibroids, and congenital uterine anomalies. Owing to its non-invasive nature, cost-effectiveness, and wide availability, 3D TVUS can be considered a reliable first-line screening tool in infertility evaluation. It improves patient comfort and reduces the need for routine invasive procedures. However, its limitation in detecting intrauterine adhesions highlights the continued importance of hysteroscopy in selected cases. A stepwise approach using 3D TVUS for initial assessment followed by hysteroscopy when indicated appears to be the most practical strategy. Overall, 3D TVUS offers a valuable, patient-friendly alternative for uterine cavity assessment.

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