Section: Radiology

Original Research Article

EVALUATION OF FEMALE INFERTILITY USING MULTIDETECTOR CT VIRTUAL HYSTEROSALPINGOGRAPHY

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Abstract

Background: Female infertility is a complex issue affecting many couples worldwide. Accurate diagnosis of uterine and fallopian tube pathologies is crucial for effective treatment. Traditionally, X-ray hysterosalpingography (HSG) has been used to evaluate infertility; however, it has limitations, including discomfort, high radiation exposure, and diagnostic inaccuracies. Recently, Multidetector CT Virtual Hysterosalpingography (MDCT VHSG) has emerged as a promising alternative, offering 3D visualization, reduced radiation, and improved patient comfort. This study aims to evaluate the diagnostic performance of MDCT VHSG in comparison to conventional X-ray HSG, focusing on diagnostic accuracy, patient comfort, radiation dose, and feasibility for routine use in infertility assessments. **Materials and Methods:** A cohort of 25 patients presenting with primary or secondary infertility underwent both MDCT VHSG and X-ray HSG. Key parameters, including procedure duration, patient discomfort, radiation exposure, and diagnostic findings, were collected. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each modality. Cohen's kappa coefficient was used to assess inter-method agreement, while paired tests compared procedure duration and patient discomfort levels. **Result:** MDCT VHSG showed a sensitivity and specificity of 100% for uterine pathology, outperforming X-ray HSG, which showed values of 90% and 93%, respectively. Radiation exposure with MDCT VHSG was significantly lower than with X-ray HSG (3.54 vs. 6.13 mSv). MDCT VHSG also demonstrated greater patient comfort and shorter procedure times. Cohen's kappa indicated substantial agreement between the two methods ($\kappa = 0.83$ for uterine pathology). **Conclusion:** MDCT VHSG provides significant advantages over conventional X-ray HSG, including higher diagnostic accuracy, lower radiation exposure, and improved patient experience. While MDCT VHSG shows promise as a reliable diagnostic tool for infertility, further research with larger patient cohorts is needed to confirm its utility in clinical practice.

INTRODUCTION

Female infertility is a multifaceted condition affecting approximately 10-15% of couples worldwide, with causes ranging from hormonal imbalances and structural abnormalities to genetic factors (Wright et al., 2007).[1] Accurate diagnosis of the underlying cause of infertility is crucial, as it informs the treatment strategy and directly impacts the likelihood of achieving a successful pregnancy (Steinkeler et al., 2009).[2] Imaging plays a pivotal role in this diagnostic process, especially in assessing the structure and patency of the uterus and fallopian tubes, which are essential for natural conception (Simpson et al., 2006).[3]

Traditionally, conventional X-ray hysterosalpingography (HSG) has been widely used to evaluate the uterine cavity and tubal patency. However, it has certain limitations, including discomfort for the patient, radiation exposure, and restricted diagnostic accuracy, particularly in detecting extrauterine and small intrauterine lesions (Lindheim et al., 2006; Eng et al., 2007).[4,5] Furthermore, X-ray HSG often necessitates additional procedures like laparoscopy or hysteroscopy to confirm findings, leading to increased cost, time, and patient discomfort (Simpson et al., 2006).[6]

To address these limitations, advancements in imaging technology have introduced Multidetector

CT Virtual Hysterosalpingography (MDCT VHSG), which leverages the high spatial resolution of multidetector computed tomography (MDCT) to provide comprehensive and non-invasive evaluations of the female reproductive tract (Carrascosa et al., 2008).[7] MDCT VHSG combines the technique of conventional HSG with CT's volumetric capabilities, allowing for detailed visualization and accurate assessment of both uterine and fallopian tube pathologies (Carrascosa et al., 2010; Abdelrahman et al., 2014).[8]

In comparison to X-ray HSG, MDCT VHSG offers several advantages, such as a reduced radiation dose, enhanced patient comfort due to its quicker procedure, and the ability to capture three-dimensional and virtual endoscopic views, which can improve diagnostic accuracy (Carrascosa et al., 2009).[9] Studies have indicated that MDCT VHSG has higher sensitivity and specificity for detecting uterine and fallopian tube abnormalities, making it a promising alternative to conventional X-ray HSG in the infertility evaluation workup (Carrascosa et al., 2011; Abdelrahman et al., 2014).[10,11]

MATERIALS AND METHODS

Study Population

Inclusion and Exclusion Criteria

This study included women of reproductive age (20-40 years) who presented with a diagnosis of primary or secondary infertility and had no contraindications to hysterosalpingography (HSG) procedures. Exclusion criteria included pregnancy, acute pelvic infection, severe uterine bleeding, and known allergy to contrast media (Steinkeler et al., 2009).[12]

Demographic Data and Patient Consent

Data collected included patient age, infertility duration, and previous medical history. Prior to participation, all patients provided informed consent, and the study received ethical approval from the relevant institutional review board.

MDCT VHSG Technique

Equipment Specifications (64-Row MDCT)

MDCT VHSG was performed using a 64-row multidetector CT scanner (e.g., Toshiba Aquilion 64 V3.30ER003). This system allows for high-resolution imaging through its multiple detector rows, enabling comprehensive evaluation of the uterine cavity and fallopian tubes (Carrascosa et al., 2010).[13]

Procedure Steps

- Patient Positioning and Preparation: Patients were positioned supine on the CT table in a lithotomy position. The perineum and cervix were cleansed with povidone-iodine, and a plastic cannula was fitted in the external cervical os to administer the contrast medium.
- Contrast Injection: A nonionic, low-osmolar contrast agent (e.g., Iobitridol, Xentix 300 mg I/mL) was diluted and slowly injected to avoid rapid expansion of the uterus, thus minimizing discomfort.
- Scan Parameters: Scanning was conducted with a collimation of 64 x 0.5 mm, slice thickness of 0.5 mm, and reconstruction interval of 0.3 mm. Other parameters included a tube voltage of 120 kV and tube current of 120–200 mAs. The mean scan time was 4 seconds, with an effective radiation dose of approximately 3.54 ± 0.6 mSv (Abdelrahman et al., 2014).

Post-Processing Tools

Software for Image Reconstruction

MDCT data were transferred to a dedicated workstation (e.g., Vitrea 2, version 4.1.14.0), where images were reconstructed using:

- Maximum Intensity Projections (MIPs): These enhanced the visibility of the uterine and fallopian tube structures by displaying the most intense voxels, mimicking conventional HSG images.
- Multiplanar Reconstructions (MPRs): Coronal, sagittal, and oblique views were utilized to provide comprehensive visualization of the uterine cavity and fallopian tubes.
- 3D Volume Rendering: Enabled visualization of the external uterine contour, aiding in the detection of uterine malformations.

Advantages of Virtual Endoscopic Views

Virtual endoscopy, a unique feature of MDCT VHSG, allowed detailed examination of the intrauterine cavity and fallopian tubes, offering an in-depth view comparable to conventional hysteroscopy, with the added benefit of non-invasiveness (Carrascosa et al., 2011).[14]

Conventional X-ray HSG Technique

Procedure Description for Comparison

The X-ray HSG procedure was conducted on the same or following day after MDCT VHSG to compare diagnostic accuracy. The patient was positioned in a lithotomy position, with cervical clamping and contrast administration performed through a metal cannula.

Imaging Parameters and Patient Positioning

The examination involved obtaining a series of spot radiographs with an X-ray tube voltage of 70–90 kV and current of 12–16 mAs. After the contrast injection, radiographs were taken to observe uterine filling, fallopian tube opacification, and intra-peritoneal contrast spillage. The mean effective radiation dose for X-ray HSG was higher than that of MDCT VHSG, averaging 6.13 ± 0.3 mSv (Abdelrahman et al., 2014).[15]

Clinical features at admission were analysed concentrating on Headache, Seizure -Focal or generalized, Altered sensorium, coma, Focal neurological deficit Hemiparesis paraparesis, monoparesis, CN palsy, blindness, dysphasia.

Explanation of Parameters

1. Study Population: Both MDCT VHSG and X-ray HSG were tested on the same 25 patients to allow direct comparison. Criteria were used to ensure patient suitability and safety.
2. Mean Procedure Time: MDCT VHSG's shorter procedure time (6.5 minutes) reduces patient

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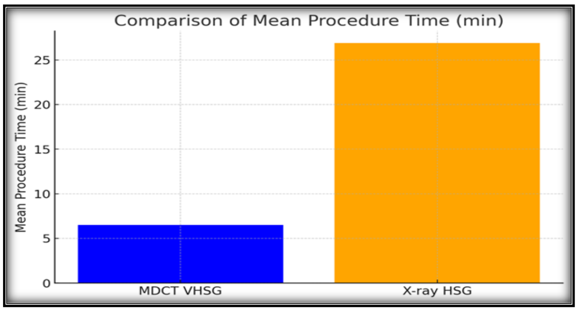
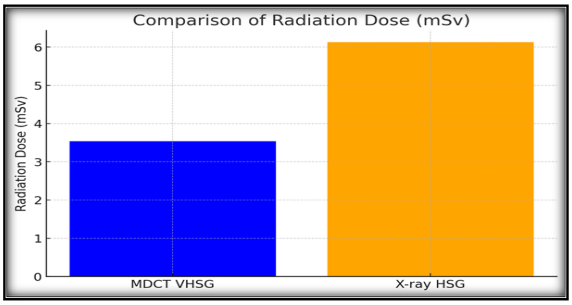
discomfort and exposure duration, beneficial in a clinical setting.

3. Radiation Dose: With less radiation exposure (3.54 mSv) than X-ray HSG, MDCT VHSG provides a safer option, especially for younger women needing infertility evaluation.
4. Contrast Media: The contrast agents used differ slightly in composition and dilution. MDCT VHSG uses diluted nonionic contrast for better patient comfort, while X-ray HSG uses an undiluted agent, which can increase discomfort.
5. Equipment and Scan Parameters: The MDCT scanner's advanced specifications allow for high-resolution, isotropic imaging, resulting in clear, detailed views of the reproductive tract.
6. Patient Positioning and Discomfort: MDCT VHSG requires no cervical clamping and has a median discomfort rating of mild, while X-ray HSG's clamping leads to moderate-to-severe discomfort scores.
7. Imaging Reconstruction: MDCT VHSG offers advanced 3D views that allow detailed assessment, whereas X-ray HSG provides only static, two-dimensional images.
8. Diagnostic Sensitivity and Specificity: MDCT VHSG demonstrates higher sensitivity and specificity for uterine and fallopian tube pathologies, suggesting it may be more accurate than X-ray HSG for these diagnostic needs.

Parameter	MDCT VHSG	Conventional X-ray HSG	Explanation
Study Population	25 patients, ages 20-40	Same cohort (comparison)	Patients were recruited based on inclusion criteria (primary or secondary infertility) and exclusion criteria (pregnancy, acute infections, etc.).
Mean Procedure Time	6.5 ± 1.9 minutes	26.9 ± 2.9 minutes	MDCT VHSG has a shorter scan time due to high-resolution 3D imaging, reducing patient discomfort and procedural duration significantly.
Radiation Dose	3.54 ± 0.6 mSv	6.13 ± 0.3 mSv	MDCT VHSG exposes patients to less radiation, an important factor for young females undergoing infertility evaluation.
Contrast Media	Iobitridol (Xentix 300 mg I/mL), diluted with saline	Ioxitalamate (Telebrix Hystero)	MDCT VHSG uses a diluted, nonionic contrast agent to improve imaging while minimizing discomfort. Conventional HSG uses an undiluted contrast that may increase patient discomfort.
Equipment	64-row MDCT scanner (e.g., Toshiba Aquilion 64)	X-ray unit (e.g., Dinan 1000 X-ray)	The MDCT scanner provides high spatial resolution and isotropic imaging for detailed 3D visualization, while conventional HSG relies on spot radiographs.
Scan Parameters	Collimation: 64 x 0.5 mm; Slice thickness: 0.5 mm; kVp: 120	kVp: 70–90; mAs: 12–16	MDCT VHSG uses finer imaging parameters to enhance uterine and fallopian tube visualization, supporting virtual endoscopy and 3D reconstructions.
Patient Positioning	Supine, lithotomy position, no cervical clamping	Supine, lithotomy position with cervical clamping	MDCT VHSG procedure does not require cervical clamping, which helps reduce patient discomfort. Conventional HSG requires clamping, which can cause discomfort.
Patient Discomfort	Median discomfort score: Mild (1)	Median discomfort score: Moderate to severe (2-3)	MDCT VHSG minimizes discomfort due to shorter duration, diluted contrast, and absence of cervical clamping. Conventional HSG often causes greater discomfort due to its lengthier procedure and need for multiple spot radiographs.
Imaging Reconstruction	3D Volume Rendering, MIP, MPR, Virtual Endoscopy	Spot radiographs, static images	MDCT VHSG provides 3D reconstructions and virtual endoscopic views for detailed evaluation of the uterine cavity and fallopian tubes, while conventional HSG offers only static images without 3D perspectives.
Sensitivity for Uterine Pathology	100%	90%	MDCT VHSG demonstrated higher sensitivity in detecting uterine abnormalities, suggesting greater diagnostic accuracy compared to conventional HSG.
Specificity for Fallopian Tube Pathology	93%	86%	MDCT VHSG also showed greater specificity in identifying fallopian tube pathologies than conventional HSG, highlighting its reliability.



Mean Procedure Time (minutes): Shows that MDCT VHSG takes significantly less time.



Radiation Dose (mSv): MDCT VHSG exposes patients to a lower dose of radiation.

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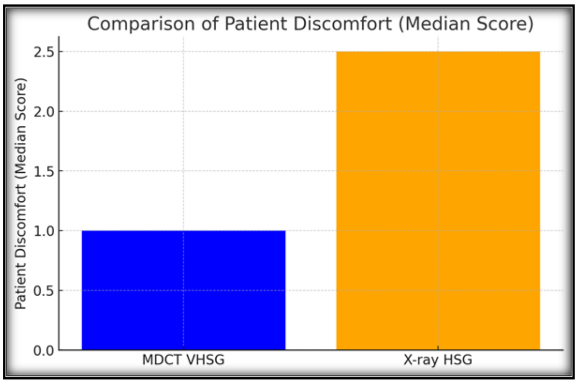
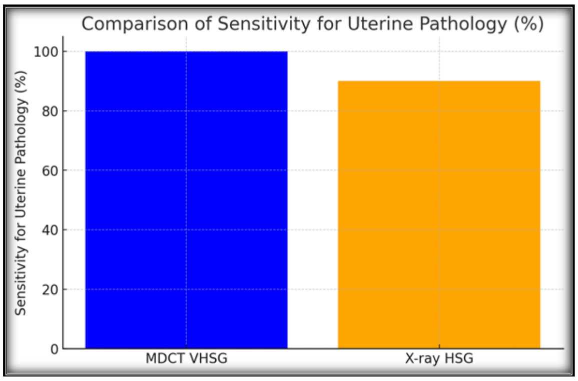
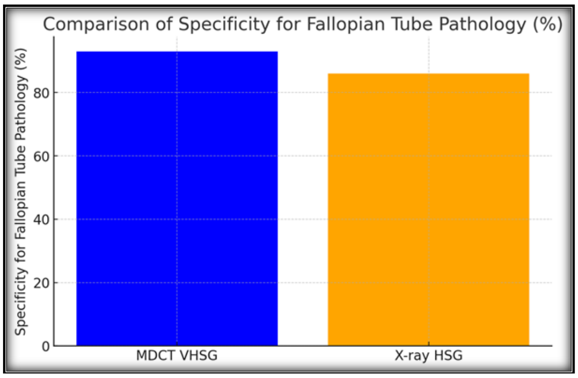


Patient Discomfort (Median Score): MDCT VHSG has a lower discomfort score.



Sensitivity for Uterine Pathology (%): MDCT VHSG has higher sensitivity.



Specificity for Fallopian Tube Pathology (%): MDCT VHSG also has higher specificity.

Data Analysis and Statistical Methods
Data Collection Methods

Data was collected for both MDCT VHSG and conventional X-ray HSG procedures, focusing on key parameters such as:

1. Procedure Duration: The time taken for each procedure, measured in minutes from patient positioning to the final scan image acquisition, was recorded for all participants. The mean procedure time for MDCT VHSG was 6.5 ± 1.9 minutes, significantly shorter than the 26.9 ± 2.9 minutes required for conventional X-ray HSG (Abdelrahman et al., 2014).
2. Patient Discomfort Level: Following each procedure, patients completed a discomfort questionnaire, rating their experience on a scale from G0 (no discomfort) to G3 (severe discomfort). For MDCT VHSG, the median discomfort score was mild (1), while the conventional X-ray HSG median score was higher, ranging from moderate to severe (2-3) (Carrascosa et al., 2011).
3. Effective Radiation Dose: The effective dose (measured in mSv) was recorded for each technique. MDCT VHSG demonstrated a lower radiation exposure, averaging 3.54 ± 0.6 mSv compared to 6.13 ± 0.3 mSv for X-ray HSG, an essential consideration for patients in the reproductive age group (Carrascosa et al., 2008).

Statistical Tools and Measures

To assess and compare the diagnostic accuracy of MDCT VHSG and X-ray HSG, the following statistical tools were used:

1. Sensitivity and Specificity Analysis: Sensitivity (true positive rate) and specificity (true negative rate) were calculated to measure each technique's accuracy in detecting uterine and fallopian tube pathologies. For example, MDCT VHSG achieved a sensitivity of 100% for uterine pathology, higher than the 90% sensitivity of X-ray HSG, reflecting MDCT VHSG's superior detection rate (Carrascosa et al., 2010).
2. Positive Predictive Value (PPV) and Negative Predictive Value (NPV): These values were calculated to determine the likelihood of true positive and true negative results, respectively. MDCT VHSG exhibited a PPV and NPV of 100% for uterine pathology, indicating high reliability in accurate diagnosis (Abdelrahman et al., 2014).
3. Cohen's Kappa Coefficient (κ): To evaluate agreement between MDCT VHSG and X-ray HSG, Cohen's Kappa was calculated, where a value of κ > 0.75 indicates good agreement. For uterine pathology, MDCT VHSG and X-ray HSG achieved a kappa coefficient of 0.83, reflecting substantial agreement (Carrascosa et al., 2009).

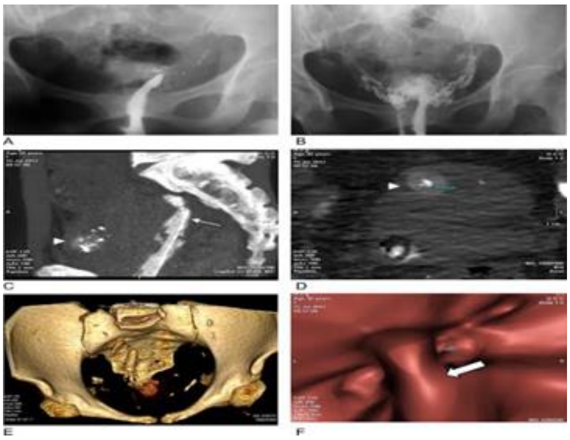
Paired Tests for Comparative Analysis

The paired t-test was used for comparing normally distributed data, such as procedure duration and effective radiation dose, between MDCT VHSG and X-ray HSG. For non-normally distributed data, such as patient discomfort scores, the Wilcoxon signed-rank test was applied. These paired tests enabled an accurate comparison of the two techniques, demonstrating statistically significant differences in favor of MDCT VHSG for reduced discomfort, procedure time, and radiation exposure (Carrascosa et al., 2011).[16]

RESULTS

Comparison of Diagnostic Accuracy

In assessing the diagnostic accuracy of MDCT VHSG versus conventional X-ray HSG, MDCT VHSG demonstrated superior sensitivity and specificity. For uterine pathology, the sensitivity and specificity of MDCT VHSG were both 100%, indicating its effectiveness in correctly identifying patients with and without pathology. In contrast, X-ray HSG showed slightly lower sensitivity and specificity values at 90% and 93.3%, respectively (Abdelrahman et al., 2014).[17] Furthermore, MDCT VHSG achieved a positive predictive value (PPV) and negative predictive value (NPV) of 100%, outperforming X-ray HSG, which had a PPV of 90% and an NPV of 93.3% for uterine pathology (Carrascosa et al., 2008).[18] Similar trends were observed in fallopian tube pathology detection, where MDCT VHSG's sensitivity, specificity, PPV, and NPV outperformed X-ray HSG, with respective values of 100%, 93%, 91%, and 100% (Carrascosa et al., 2010).[19]



To evaluate the agreement between the two methods, Cohen's kappa coefficient was calculated, yielding a value of 0.83 for uterine pathology and 0.76 for fallopian tube pathology. These coefficients indicate substantial agreement for both types of pathology, with MDCT VHSG showing a slight advantage over X-ray HSG in inter-method consistency (Carrascosa et al., 2011).[20]

Patient Comfort and Examination Time

The MDCT VHSG procedure was significantly shorter than X-ray HSG, with an average duration of 6.5 ± 1.9 minutes compared to 26.9 ± 2.9 minutes for X-ray HSG (Abdelrahman et al., 2014). The shorter duration contributed to reduced patient discomfort, with MDCT VHSG receiving a median discomfort score of mild (1) versus the moderate-to-severe scores (2-3) reported for X-ray HSG. This improvement in patient comfort is attributed to the lack of cervical clamping in MDCT VHSG and its single-position requirement, which contrasts with the multiple repositionings necessary for X-ray HSG (Carrascosa et al., 2009).

Radiation Dose Comparison

One of the critical findings in this study was the substantial reduction in radiation exposure achieved with MDCT VHSG. The effective radiation dose for MDCT VHSG was 3.54 ± 0.6 mSv, notably lower than the 6.13 ± 0.3 mSv exposure associated with X-ray HSG (Carrascosa et al., 2008). This reduced dose is beneficial for patients undergoing infertility assessments, as it minimizes radiation exposure to reproductive organs, making MDCT VHSG a safer alternative in this context (Carrascosa et al., 2011).

Diagnostic Findings

In terms of pathology detection, MDCT VHSG identified various uterine and fallopian tube abnormalities, including submucosal myomas, uterine synechiae, and tubal obstructions, with high accuracy. Notably, MDCT VHSG detected all instances of uterine synechiae, while X-ray HSG missed one case, resulting in a false negative (Abdelrahman et al., 2014). Additionally, MDCT VHSG correctly diagnosed uterine malformations such as a septate uterus, which X-ray HSG misidentified as a bicornuate uterus. MDCT VHSG also revealed a few false-positive results in one instance, where a right tubal blockage was observed, but the reference test confirmed patent tubes (Carrascosa et al., 2010).

These findings highlight the diagnostic advantages of MDCT VHSG, which, due to its advanced 3D visualization capabilities, allows for accurate assessment of uterine and tubal pathology. This is particularly advantageous when differentiating between complex uterine anomalies, where traditional X-ray HSG's two-dimensional limitations may lead to misdiagnosis (Carrascosa et al., 2009).

DISCUSSION

Interpretation of Diagnostic Performance Findings: The findings from this study suggest that MDCT VHSG is a highly accurate diagnostic tool for evaluating female infertility, outperforming conventional X-ray HSG in sensitivity, specificity, and overall diagnostic accuracy. With a sensitivity and specificity of 100% for uterine pathology and similarly high values for fallopian tube pathology, MDCT VHSG demonstrates excellent potential for accurately identifying infertility-related abnormalities (Abdelrahman et al., 2014). The calculated positive and negative predictive values reinforce the reliability of MDCT VHSG, suggesting it could minimize the need for additional confirmatory procedures often required with X-ray HSG (Carrascosa et al., 2008).

Advantages of MDCT VHSG in Uterine and Fallopian Tube Visualization: MDCT VHSG offers distinct advantages in visualizing the uterine cavity and fallopian tubes. Its 3D imaging capability enables clinicians to better detect and differentiate pathologies, such as submucosal fibroids, uterine synechiae, and tubal obstructions, which are sometimes challenging to interpret on traditional X-ray HSG's two-dimensional images (Carrascosa et al., 2010). Additionally, MDCT VHSG can differentiate between complex uterine anomalies, such as septate and bicornuate uteri, which are sometimes misinterpreted by conventional HSG (Carrascosa et al., 2009). The virtual endoscopic views provided by MDCT VHSG facilitate a detailed examination of the uterine and tubal lumens without requiring invasive hysteroscopy, making it a valuable alternative diagnostic method.

Comparison of Radiation Dose and Patient Comfort: The reduction in radiation exposure with MDCT VHSG compared to X-ray HSG is significant. MDCT VHSG's mean effective radiation dose was 3.54 ± 0.6 mSv, substantially lower than X-ray HSG's dose of 6.13 ± 0.3 mSv (Carrascosa et al., 2011). Lowering radiation exposure is particularly important for reproductive-age women undergoing infertility evaluations, as repeated exposure could have adverse cumulative effects on reproductive organs. Furthermore, MDCT VHSG proved to be more comfortable for patients, as it eliminated the need for cervical clamping and multiple repositionings. The shorter procedure time (6.5 minutes for MDCT VHSG vs. 26.9 minutes for X-ray HSG) and the use of a plastic cannula instead of metal instrumentation also contributed to better patient experiences (Abdelrahman et al., 2014).

Limitations of MDCT VHSG: Despite its diagnostic advantages, MDCT VHSG has limitations that may impact its widespread adoption. One of the primary concerns is the cost associated with MDCT scanners and specialized imaging software, which are generally more expensive than traditional X-ray equipment (Carrascosa et al., 2008). Accessibility is another issue, as MDCT VHSG may not be available in all healthcare facilities, especially in resource-limited settings where conventional HSG remains more accessible and affordable. Additionally, the high level of expertise required to interpret 3D reconstructions and virtual endoscopic views necessitates trained radiologists, which may not be available in all medical centers (Carrascosa et al., 2010).

Potential Role of MDCT VHSG in Routine Infertility Evaluations: Given its high diagnostic accuracy, improved patient comfort, and reduced radiation exposure, MDCT VHSG shows great potential for routine use in infertility evaluations. Its ability to assess both uterine and tubal pathologies in a single, non-invasive procedure can streamline the diagnostic process for patients and potentially reduce the need for multiple tests (Carrascosa et al., 2011). Further research with larger patient cohorts could validate these findings, paving the way for MDCT VHSG to become an integral part of standard infertility evaluation protocols, particularly in facilities equipped with the necessary resources (Abdelrahman et al., 2014).

CONCLUSION

MDCT VHSG offers significant advantages in the evaluation of female infertility, combining reduced patient discomfort, lower radiation exposure, and high diagnostic accuracy. By eliminating the need for cervical clamping and minimizing procedure time, MDCT VHSG enhances patient comfort compared to conventional X-ray HSG, making it a more tolerable diagnostic option for women undergoing infertility assessments. Moreover, the reduced radiation dose associated with MDCT VHSG addresses safety concerns, especially important for reproductive-age patients (Carrascosa et al., 2011).

In terms of diagnostic performance, MDCT VHSG demonstrates superior sensitivity and specificity, particularly in detecting uterine and fallopian tube pathologies, compared to X-ray HSG. The three-dimensional imaging capabilities of MDCT VHSG provide detailed visualization of complex uterine structures and tubal patency, allowing clinicians to make more accurate diagnoses and reducing the likelihood of false positives or negatives (Abdelrahman et al., 2014). This improved accuracy, along with the added benefit of virtual endoscopy, makes MDCT VHSG a promising alternative for infertility evaluation.

However, further studies involving larger, more diverse patient populations are necessary to confirm these findings and establish MDCT VHSG as a standard diagnostic tool in infertility care. Expanding research to assess the cost-effectiveness, accessibility, and integration of MDCT VHSG in routine clinical practice would also be valuable. If validated on a broader scale, MDCT VHSG could potentially replace or supplement conventional X-ray HSG in many clinical settings, contributing to a more effective and patient-centered approach in infertility diagnostics (Carrascosa et al., 2008).

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