RESEARCH ARTICLE

Comparison of differences between three-dimensional ultrasound and magnetic resonance imaging salpingography in false positive cases of proximal fallopian tube obstruction

Fengyun Wang*, Tao Zhang

Henan Technical Institute, Zhengzhou, Henan, China

Received: November 16, 2023; **accepted:** January 24, 2024.

In recent years, female infertility has been increasing year by year, and tubal obstruction infertility is the primary cause, making it a hot topic in clinical research. However, existing technologies have certain diagnostic errors. Therefore, in this study, the differences between three-dimensional ultrasound (3D-HyCoSy) and magnetic resonance imaging (MRI) in salpingography were compared to verify their diagnostic efficacy in infertility patients and provide more options for clinical diagnostic methods. The purpose of this study was to compare the differences between 3D-HyCoSy and MRI techniques with false positive results in proximal fallopian tube obstruction in salpingography, to improve the display rate of the proximal fallopian tube. 167 suspected tubal infertility patients were selected and their differences in 3D-HyCoSy and MRI were observed. The false positive reasons for proximal tubal obstruction caused by different salpingography methods were analyzed. The results demonstrated that the diagnosis of 3D-HyCoSy and MRI techniques showed high consistency ($P > 0.05$). There were three false positive diagnoses in 3D-HyCoSy, which were inferred to be caused by uterine pressure or physiological characteristics of the proximal fallopian tube. There was one false positive diagnosis in MRI, which was inferred to be caused by catheter stimulation. The pain sensation caused to the patient by the two methods was also compared. The results confirmed that 3D-HyCoSy provided patients with less pain and higher tolerance, but the comparison with MRI showed no significant difference ($P > 0.05$). Both 3D-HyCoSy and MRI techniques had high applicability. Patients were relatively more tolerant to 3D-HyCoSy. This study confirmed that both 3D-HyCoSy and MRI could provide clear contrast images for clinical use. However, operational methods, catheter stimulation, and other factors could mislead the diagnosis and result in false positive results. Therefore, in practical applications, the medical staff can choose methods based on the actual situation of patients, which will benefit the individualized operation of patients and improve the effectiveness of their operation.

Keywords: proximal fallopian tube; obstruction; false positive; 3D ultrasound technology; magnetic resonance technology; pain.

***Corresponding author:** Fengyun Wang, Henan Technical Institute, Zhengzhou 450003, Henan, China. Email: wangfy19731103@163.com.

Introduction

Fallopian Tube Obstruction (FTO) or functional disorders is the main factor causing female infertility, with FTO transfusions accounting for up to 40% to 50% [1]. The fallopian tube is a posterior peritoneal organ, and proximal FTO refers to obstruction in the interstitial part of the fallopian tube [2]. If women have endometriosis, pelvic surgery trauma, or post-surgical infection, they are very likely to experience proximal FTO or even blockage [3]. Many women after induced abortion find it difficult to conceive again due to FTO caused by pelvic infection [4]. Therefore, clarifying the patency of the fallopian tubes is beneficial for identifying the causes of infertility

and providing a basis for clinical treatment. Many testing techniques have been applied effectively to the examination of tubal ductal papillomavirus. The combination of hysteroscopy and laparoscopy, hysterosalpingography, magnetic resonance salpingography, and other techniques have been widely applied in clinical practice. The combination of hysteroscopy and laparoscopy is a treatment method with the advantages of small wound size, less bleeding, and short recovery time for patients [5]. Uterine fallopian tube contrast-enhanced ultrasound is the use of a catheter to inject contrast agent into the uterine cavity and inside the fallopian tubes, so as to reveal their morphology and position, to diagnose whether there are lesions or deformities inside them [6]. This technique can be used to assess tubal patency. Magnetic resonance salpingography combined with magnetic resonance and salpingography is a method for diagnosing tubal infertility [7]. It combines clear Magnetic Resonance Imaging (MRI) with the simple operation of fallopian tube imaging and has high clinical application effects. Although these methods have good clinical applications, they still have many shortcomings. For example, the image repeatability of combined hysteroscopy and hysterosalpingography is low, and it is easily influenced by the operational skills of medical staff when diagnosing tubal infertility. In addition, these technologies may cause misdiagnosis due to factors such as operational errors by medical staff and similar clinical symptoms, which can have serious impacts on patients and their families. Also, patients may experience varying degrees of pain during the testing process, reducing their tolerance. To improve the practical application of different techniques, this study analyzed the problems that three-dimensional ultrasound (3D-HyCoSy) and MRI were prone to in diagnosing of FTO by comparing the differences between 3D-HyCoSy and MRI in salpingography with false positive proximal tubal obstruction, and the tolerance of patients in both techniques. The results of this study would present certain reference opinions for timely and early evaluation of tubal patency, which was of great significance for the clinical diagnosis and treatment of tubal infertility.

Materials and Methods

Research objects

237 suspected patients with tubal infertility who visited the Qinglong County Traditional Chinese Medicine Hospital (Qinglong, Hebei, China) from January 2017 to September 2018 were selected for this study. The inclusion criteria were female patients aged between 20 and 45 years who had been infertile for more than one year and had not undergone any other medical examination of the fallopian tubes within six months. All patients had been excluded from the factors that related to male infertility and acute transmission diseases or fever symptoms. An informed consent form was signed by each participant before operation. The procedures of this study were approved by the Ethics Committee of Qinglong County Traditional Chinese Medicine Hospital. The exclusion criteria included allergy to the contrast agents and other reagents used in the procedures, obvious abnormalities of the fallopian tubes such as vaginal bleeding and hydrosalpinx, severe systemic diseases, adverse fertility risk factors such as severe anemia and cardiovascular and cerebrovascular diseases.

Three-dimensional ultrasound salpingography technology

The Voluson E8 BT09 ultrasound diagnostic instrument (GE HealthCare, Chicago, IL, USA) with a RIC5-9-D stereo intracavity probe was employed in this study. 30 mL of physiological saline was prepared prior to operation for intrauterine perfusion, preparation of contrast agents, and dilution of contrast suspensions. SonoVue contrast agent (Shandong Yuanke Biotechnology Co., Ltd., Zaozhuang, Shandong, China) was prepared 30 minutes before operation by adding to 5 mL of physiological saline to prepare a microbubble suspension. Before contrast, 3 mL of suspension was mixed with 20 mL of physiological saline thoroughly. A COVIDien No. 12 double lumen tube (Medtronic,

Minneapolis, MN, USA) was inserted into the cervical opening followed by injection of 1.5 – 2.0 mL of physiological saline into the balloon. The double lumen tube opening was wrapped with disinfectant gauze and attached to the ventral side. 0.5 mg of Atropine was muscular injected to relieve spasms. The patient was then moved to the ultrasound room. The probe was inserted into the transverse section of the uterus followed by a slow injection of 5 mL of physiological saline. The injection speed and dose were adjusted according to the pressure in the uterine cavity. The size of the water sac should be appropriate to allow easy observation of development and to accommodate all developing agents. The 3D key pre-scan of the ultrasound diagnostic instrument was activated to include both uterine horns and ovaries within the image range. The 4D button of the ultrasound diagnostic instrument was activated in the study. When the four grid images appeared on the screen and the computer indicator bar in the lower right corner started timing, contrast agent was injected through the uterine cavity to record the development time of the fallopian tubes. The injection dose and reflux rate were recorded. The patency of the uterus, bilateral fallopian tubes, and the overflow of contrast agent at the fimbria were observed. When the contrast agent overflowed from the fimbria of the fallopian tube, the animation save button should be pressed to save the image and stop the contrast agent injection. The catheter was then removed to perform 3D imaging of the uterine cavity and observe for any lesions. During the operation, the diffusion of contrast agent in the pelvic cavity was also observed.

Magnetic resonance salpingography technology

The magnetic resonance salpingography operation was performed with a Siemens Verio 3.0T superconducting magnetic resonance instrument equipped with six channel torso phased array surface coils (Munich, Germany). Routine examination was performed on the patient in the MR room using the TW1 and TW2 scans. The patient was intubated and given 200 mg of scopolamine orally one hour before operation. After disinfecting the patient's external genitalia, a vaginal speculum was used to expose the cervix, and if necessary, cervical forceps could be used to assist. A fallopian tube imaging catheter was placed in the uterine cavity and 2 mL of 0.9% sodium chloride solution was injected. The tail of the catheter was slowly pulled outwards to reach the cervical area and fixed. The patient returned to the MR room A T2 spin echo sequence was used to scan the field of view in the midsagittal position, ensuring that both uterine horns and ovaries were included in the image collection range as much as possible. The contrast agent, gadolinium gluconate (Bayer AG, Leverkusen, Germany), was then manually injected at the dosage of 0.2 mL/kg. The configuration and operation method of the contrast agent were consistent with the three-dimensional ultrasound salpingography technique, while the contours of the uterus were observed. The 3DT1W gradient echo sequence was used for scanning to obtain continuous images of four phases with each phase lasting for 16 s. Subtraction images and Medical Imaging Physics (MIP) images were generated. Three minutes later, a rapid T1 weighted fat suppression sequence was performed to display the diffusion of pelvic contrast agent. After the examination, the patient should stay in the hospital for observation for half an hour to observe any possible adverse reactions.

The criteria for determining tubal patency and Numerical Rating Scale (NRS) score

Numerical Rating Scale (NRS) was used to evaluate the pain perception of patients during testing and observe their tolerance to different methods. The evaluation criteria for patency were as follows:

(1) Patency: 0.9% sodium chloride solution could pass through the fallopian tubes and enter the pelvic cavity without obstacles when injected into the uterine cavity. At this point, the fallopian tubes could present a continuous strip and be displayed throughout the entire process. There was no visible and continuous fluid flow in the fallopian tube lumen. The 0.9% sodium chloride solution injected overflowed at the fimbria. The

amount of fluid in the uterine and rectal fossa increased, but no contrast agent reflux occurred.

(2) Unconstructed but not smooth: This phenomenon was mild obstruction. When injecting contrast agent, there was a certain resistance, and the patient's fallopian tube development speed was slow and had phenomena such as detour and inversion. The liquid at the fimbria overflowed slowly. After injecting the contrast agent, some patients experienced reflux.

(3) Obstruction: The fallopian tubes could not be fully developed or presented as a "string of beads". The liquid at the fimbria had not overflowed or was relatively small. The injection resistance of liquid was relatively high, and only a small amount of liquid could be injected. The patient exhibited symptoms of maladaptation.

The NRS score uses numbers from 0 to 10 to indicate how much the patient is suffering. 0 indicates that the patient is not experiencing pain, while 10 indicates that the patient is experiencing indescribably intense pain. According to He *et al*., 0 - 10 was divided into painless (0), mild pain (1 - 4), moderate pain (5 - 7), and severe pain (8 - 10) [8].

Evaluation of contrast image quality

The excellent images were determined as that the images of the fallopian tubes, pelvic cavity, and other detection areas were clear, continuous, and free from artifacts, while the good images were defined as that the clarity of the test images for the fallopian tubes and ovaries were poor, but it could meet the diagnostic needs, and the bad quality images were that the images of the fallopian tubes, pelvic cavity, and ovaries were not clear and could not meet the diagnostic requirements.

Statistical analysis

SPSS 20.0 (IBM, Armonk, New York, USA) was employed in this study. The data were presented in the form of mean ± standard deviation. The comparison results of two techniques were tested for sensitivity, accuracy, and specificity using the Kappa test. The differences were tested using McNemar's test, with $P < 0.05$ indicating significant difference and $P < 0.01$ indicating very significant difference.

Results

Comparison of patient general information under three-dimensional ultrasound and magnetic resonance salpingography techniques

A total of 167 female patients were examined, with an average age of 26.8 ± 4.3 years old and an average duration of infertility of 3.6 ± 2.95 years. Among them, 82 people (49%) were primary infertility patients and 85 people (51%) were secondary infertility patients. A total of 167 three-dimensional ultrasound fallopian tube images and magnetic resonance salpingography images were collected in this study with a total of 668 pieces. The general information comparison of patients under two detection techniques was shown in Table 1, confirming that the patient conditions under the two detection techniques were similar and could be used for subsequent experimental comparisons ($P > 0.05$).

Comparison of NRS scores under three-dimensional ultrasound and magnetic resonance salpingography techniques

NRS score could be used to reflect the patient's pain perception, indirectly reflecting the patient's tolerance and safety of use. In the NRS scores of patients under different detection techniques, the pain experienced by patients under 3D-HyCoSy and MRI was mainly mild and moderate. There was a slight difference in the NRS score of patients under the two techniques. The NRS score of patients under MRI was high, but the comparison between 3D-HyCoSy and MRI showed that there was no statistical difference ($P > 0.05$).

Analysis of clarity of three-dimensional ultrasound and magnetic resonance salpingography

Table 1. Comparison of general information.

Item	3D-HyCoSy	MRI	*t*	*P*
Age (years old)	25.70 ± 4.20	27.90 ± 4.40	0.23	0.79
Infertility time (year)	3.50 ± 3.11	3.60 ± 2.79	0.26	0.77
BMI (kg/m^2)	22.39 ± 2.51	22.62 ± 2.04	0.33	0.75
The number of pregnancies	0.62 ± 0.76	0.57 ± 0.53	0.69	0.46
The number of parturitions	0.07 ± 0.16	0.07 ± 0.13	0.32	0.75
Tubal patency		**piece (%)**		
Patency (piece %)	36 (43.37)	37 (44.05)		
Unobstructed but not smooth	24 (28.92)	23 (27.38)	0.84	0.21
Obstructed	23 (27.717)	24 (28.57)		

Table 2. Quality comparison of developing image.

Quality	3D-HyCoSy (n = 83)	MRI (n = 84)	*t*	*P*
Excellent	27 (32.53)	23 (27.38)		
Good	49 (59.04)	52 (61.90)	1.127	0.058
Bad	7 (8.43)	9 (10.71)		

The statistical results obtained by comparing the clarity of various parts of the fallopian tube images obtained using two techniques were shown in Figure 1. The clarity of the interstitial, isthmus, and umbellar of fallopian tube developed by 3D-HyCoSy was higher than that of MRI ($P < 0.05$), while the clarity of them in ampulla was consistent ($P > 0.05$). A visual analysis of the patient's fallopian tube imaging situation showed that two techniques had good consistency in diagnosing "bilateral blockage" and "hydrosalpinx" of the fallopian tubes (Figure 2). A total of 47 patients, accounting for 28.14%, had a bilateral obstruction of the oviduct during this procedure. A total of nine patients were treated with hydrosalpinx, accounting for 5.39% of the total. By comparing the fallopian tube imaging obtained by two methods and reviewing the imaging of the contrast agent entering the fallopian tube during the operation, it was determined that 14 cases of 3D-HyCoSy were misdiagnosed, while 9 cases were misdiagnosed on MRI. The patient's diagnosis of the fallopian tubes using two operation methods showed that there was no statistical difference ($P > 0.05$). The quality comparison of developing images of the patient's fallopian tubes under 3D-HyCoSy and MRI experiments demonstrated no statistical difference ($P > 0.05$) (Table 2). Based on the results in Figure 2 and Table 2, the development effects of two techniques were relatively consistent.

Accuracy analysis of three-dimensional ultrasound and magnetic resonance salpingography

Regarding the accuracy, sensitivity, and specificity of 3D-HyCoSy and MRI for detecting tubal patency, there were 11 false negative cases and 3 false positive cases of unilateral FTO diagnosed with 3D-HyCoSy, and 8 false negative cases and 1 false positive case of unilateral FTO diagnosed by MRI. The areas of the subject's work characteristic curves were 0.911 and 0.935, respectively. The two technologies had good consistency in various indicators (the average kappa value between these three was 0.835).

Regression analysis of related factors

The relevant factors affecting the patency of the patient's fallopian tubes were analyzed, and a logistic regression analysis was obtained for factors such as age, contrast agent injection dose, and fallopian tube injection time. The regression analysis results of both techniques showed a close relationship between the contrast agent

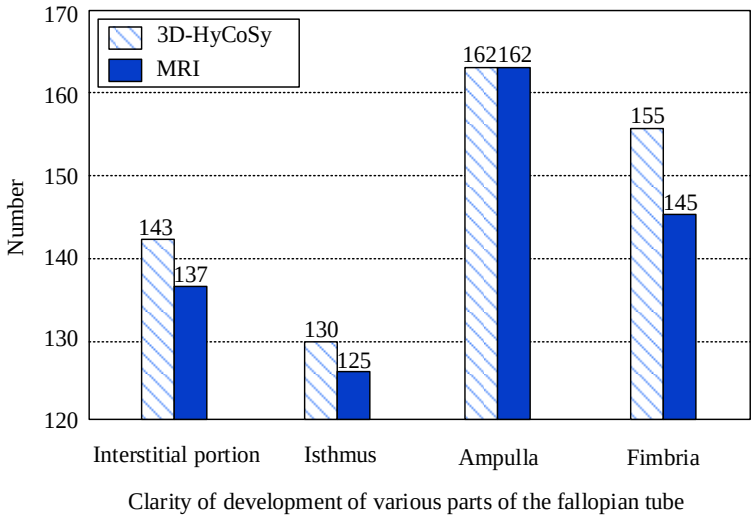


Figure 1. Clarity of 3D-HyCoSy and MRI.

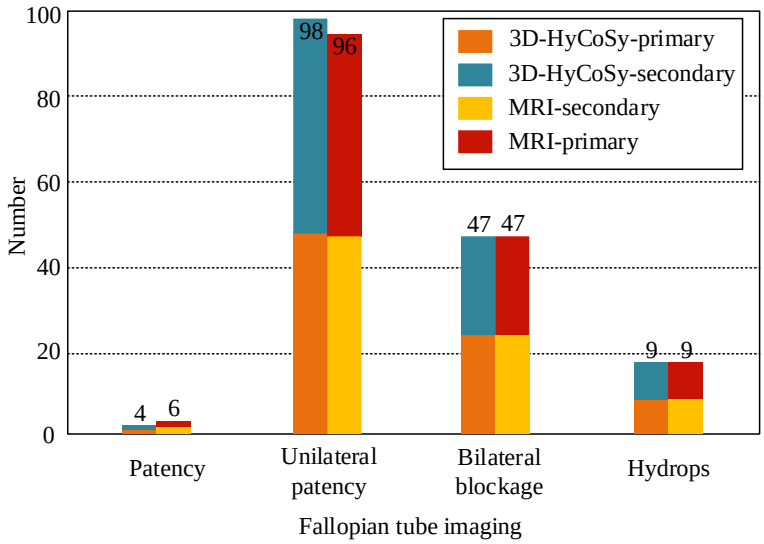
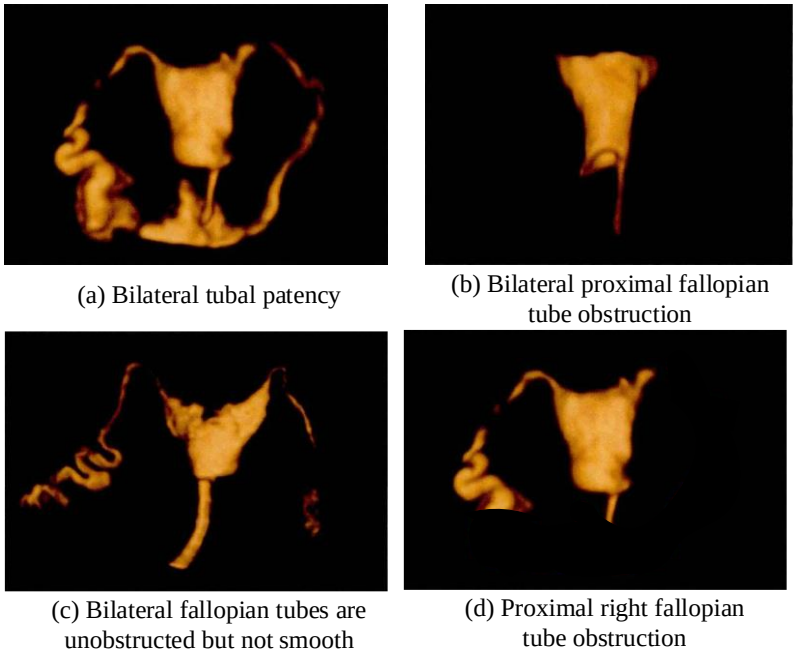


Figure 2. Images of the patient's fallopian tubes under 3D-HyCoSy and MRI.

injection dose, contrast agent injection pressure, and contrast agent backflow after injection with fallopian tube patency. For 3D-HyCoSy, the *P* value was 0.032 between the contrast agent injection dose and the fallopian tube patency, 0.000 between the contrast agent injection pressure and the fallopian tube patency, and 0.005 between the contrast agent backflow after injection and the fallopian tube patency. For MRI, the *P* value was 0.035 between the contrast agent injection dose and the fallopian tube patency, 0.000 between the contrast agent injection pressure and the fallopian tube patency, and 0.003 between the contrast agent backflow after injection and the fallopian tube patency. These results indicated that the injection dose, injection pressure, and backflow after injection of contrast agents affected the patency of the fallopian tubes. Therefore, it is necessary to pay attention to the use of contrast agents during operation.



(a) Bilateral tubal patency

(b) Bilateral proximal fallopian tube obstruction

(c) Bilateral fallopian tubes are unobstructed but not smooth

(d) Proximal right fallopian tube obstruction

Figure 3. Fallopian tube imaging results under 3D-HyCoSy.

Analysis of the causes of false positive proximal FTO

The imaging results of the fallopian tubes obtained in this study using 3D-HyCoSy under different typical conditions were shown in Figure 3. Figure 3 (a) showed that the contrast inside of fallopian tube moved naturally and smoothly with both sides unobstructed. Figure 3 (b) demonstrated that the proximal ends of the fallopian tubes were blocked on both sides, and the contrast agent couldn't enter the fallopian tubes on both sides. The fallopian tube in Figure 3 (c) was unobstructed but not smooth, showing a convoluted and stiff shape with the fimbria raised. Figure 3 (d) showed that the contrast agent only developed in the left fallopian tube with obstruction in the proximal end of the right fallopian tube. The 3D-HyCoSy technique had three false positive misdiagnosis results. Two of them showed unobstructed bilateral fallopian tubes but were not smooth (condition c). However, based on MRI analysis, these two cases belonged to the bilateral tubular pathology (condition a). There was one case that was detected by 3D-HyCoSy and identified as the proximal right fallopian tube obstruction (condition d). However, the final diagnostic result was unobstructed biliary fallopian tubes but were not smooth (condition c), which might be due to factors such as the characteristics of the proximal fallopian tube itself, uterine cavity pressure, and the amount of contrast agent used. The imaging results of fallopian tube of different typical conditions under MRI were shown in Figure 4. From conditions a to f, they were unilateral proximal FTO infusion (a), bilateral tubal unobstructed but not smooth (b), right tubal proximal obstruction, one side unobstructed but not smooth, the other side distal obstruction with hydrosalpinx (c), left distal obstruction with hydrosalpinx (d), right proximal obstruction (e), and bilateral proximal obstruction (f). There was a false positive misdiagnosis result in MRI technology, that was, bilateral fallopian tubes with patency in (b) were diagnosed as unilateral patency with patency in (d).

Discussion

Fallopian tube diseases are relatively common in the female reproductive system [9]. FTO or

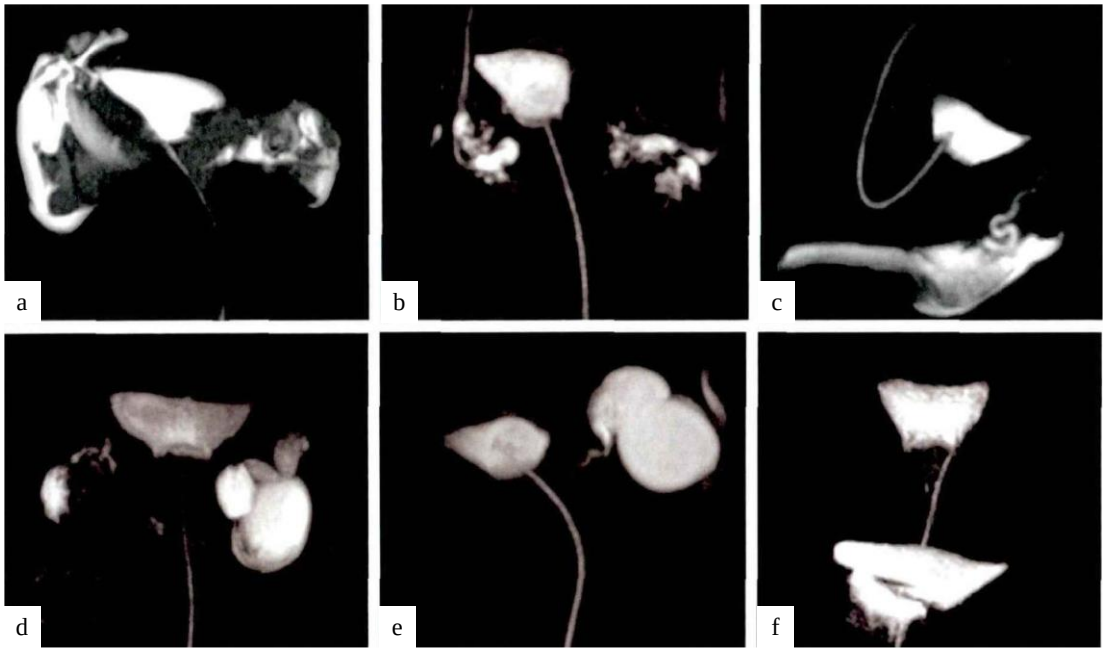


Figure 4. Fallopian tube imaging results under MRI.

functional disorders are a major factor contributing to female infertility. Accurate and effective examination of the patency of the patient's fallopian tubes is crucial for the diagnosis and treatment of infertility. In practical clinical testing, imaging technology has been effectively applied [10]. It can better reflect the patency of the uterine cavity and fallopian tube cavity, effectively improving the FTO detection accuracy. However, according to the investigation results of the World Health Organization, approximately 42% to 95% of near-end FTO detected during imaging are falsely positive, which will directly affect clinical diagnostic accuracy and treatment effectiveness [11]. In view of this, this study explored the accuracy of 3D-HyCoSy and MRI, and deeply analyzed the causes for false positive imaging, with the aim of improving the display rate of proximal fallopian tubes and thereby improving the proximal FTO accuracy.

3D-HyCoSy and MRI have demonstrated excellent performance in the diagnosis of fallopian tube patency, achieving over 90% accuracy, sensitivity, and specificity. Compared to the 83.56% accuracy of conventional fallopian tube contrast-enhanced ultrasound technology, the accuracy has been greatly improved [12]. The fallopian tube images developed by 3D-HyCoSy had high clarity, which was beneficial for diagnosing the type of disease. Through regression analysis, there was a significant correlation between the contrast agent injection dose, contrast agent injection pressure, and contrast agent backflow after injection with fallopian tube patency. It has been reported that, when evaluating the patency of the fallopian tubes, it is necessary to combine the imaging with factors such as contrast agent dosage and injection pressure recorded during operation, which can effectively reduce the probability of false positive diagnosis [13, 14]. Several false-positive misdiagnosis cases occurred in the trial, which were mainly caused by improper operation, external stimulation of the uterus or the characteristics of the fallopian tubes. Previous studies have shown that factors such as the tip of the catheter leaning towards one side of the uterine horn, tubal spasm, and lesions around the fallopian tubes can all lead to the occurrence of proximal FTO infusion [15-17]. In

addition, clinical experiments have shown that improper manipulation during intrauterine intubation may lead to the opening of endometrial blood vessels, allowing contrast media to enter the lower pressure area, while the fallopian tubes on the higher pressure side cannot be visualized. When patients experience uterine spasms, this phenomenon becomes more pronounced [18, 19], which is similar to a false-positive symptom in magnetic resonance salpingography. During this trial, many patients experienced abdominal pain, but the proximal fallopian tube on the spasmodic side was not shown in the imaging. Scholars recommend using lidocaine suspension for injection into the uterine cavity. Most cases showed ipsilateral fallopian tubes (60% in this case), indicating that tubal spasm was an important factor affecting false positives [20, 21]. In addition, instrumental operational errors are also a significant cause of artifacts. If the correction accuracy is insufficient or not corrected, the 3D image is prone to deformation or positioning abnormalities [22]. The temperature of physiological saline and contrast agent is also a cause of detection errors [23]. When the temperature of physiological saline and contrast agents used in the test is consistent with body temperature, they can reduce spasticity of the fallopian tubes and abdominal pain in patients, which may be due to the fact that the proper temperature reduces the irritation of the fluid on the oviduct, thereby reducing spasms and pain in the patient. An increase in the temperature of physiological saline and contrast agents may effectively dilate the fallopian tubes, further avoiding blockage caused by spasms. This may affect the quality of the developed image, further affecting the accuracy of monitoring. In MRI detection, the signal of magnetic resonance is related to the concentration of contrast agent used [24]. The detection signal will increase with the concentration of the contrast agents. When the signal reaches its peak, an increase in the concentration of the contrast agent will lead to a weakening of the detected signal. Therefore, in practical MRI detection, it is necessary to set appropriate contrast agent concentrations to enhance the detected signal and improve the detection accuracy.

In addition, the pain perception of patients was analyzed under 3D-HyCoSy and MRI. In both detection techniques, patients' pain perception was a common adverse reaction, thereby reducing their tolerance. This might affect the accuracy of fallopian tube examination. The reasons for patient pain during 3D-HyCoSy and MRI examinations may be due to the following factors. Firstly, it may be the pain caused by doctors using medical devices such as a vaginal speculum. Secondly, the use of contrast agents may cause irritation to the uterine cavity and peritoneum. The overflow or reflux of contrast agent can cause pain in the muscle layer. The release of prostaglandins during the examination may also cause delayed post-operative pain in patients. 3D-HyCoSy and MRI can cause patients to experience pain, which has a certain adverse effect on fallopian tube detection. If a patient experiences pain during the test, poor imaging may occur due to muscle contraction, spasms, and other causes. Therefore, in practical testing, it is necessary to further reduce the pain perception of the patient. Through continuous practice, medical staff need to stabilize the patient's psychological state and provide preoperative counseling. Then they need to inject the contrast agent as gently as possible. Research has confirmed that injecting contrast agents after preheating to 37°C can reduce discomfort in the body to a certain extent [25]. In this case, the dose of the contrast agent should be reduced as much as possible, and the contrast time should be reduced. In addition, research has confirmed that anesthesia such as lidocaine can be used to reduce patients' vagal response [26]. Therefore, in practical testing, proper consideration can be given to the use of anesthetics to reduce patient pain. Because a certain amount of physiological saline is injected during the detection, it will increase the required space for the balloon in the uterine cavity. Patients may experience varying degrees of pain due to the squeezing of space. The balloon continues to grow and tightly adhere to the

uterine horns on both sides, which can cause the contrast agent to not pass through properly, resulting in poor quality of fallopian tube imaging [27]. In response to the effect of the balloon, non-balloon catheters can be used in practical oophorectomy tests to alleviate the patient's discomfort. However, it may lead to insufficient contrast agent, which may reduce the development effect. Therefore, in practical applications, multiple considerations are required to improve the detection effect of fallopian tube abnormalities. Through these studies, simply adjusting the operating techniques can reduce patients' pain perception and improve their tolerance. This has important practical significance for the detection of fallopian tubes in infertile patients. There were three false positive misdiagnosis results in 3D-HyCoSy, which might be due to the characteristics of the proximal fallopian tubes themselves or uterine pressure factors. The proximal end of the fallopian tube was two narrowest parts of fallopian tube with the interstitial part continuing at the uterine horn and therefore relatively fixed, while the isthmus was freer and more active. Twisting of the bottom of the uterus or the proximal end of fallopian tube could cause the contrast agent to be unable to circulate or move smoothly inside the fallopian tube. In addition, the excessive injection of physiological saline into the balloon during the operation might cause excessive pressure in the uterine cavity, leading to pain and even spasms in the patient, which could affect the imaging results. There was a false-positive misdiagnosis result in the MRI, which might be caused by catheter factors. On the one hand, mechanical obstructions at the tip of catheter may cause difficulty in the flow of contrast media. On the other hand, the top of catheter may stimulate the fallopian tubes, leading to uterine spasms and presenting false positive diagnostic results.

Based on the literature review and experimental summary, the following operational precautions for 3D-HyCoSy and MRI are proposed. (1) Before operation, the contrast agent should be appropriately heated together with the operation instrument to close to body temperature to avoid uterine spasms caused by operative techniques and instrument stimulation. (2) Before the operation, patients should be given spasmolytic and pain-relieving drugs and appropriate emotional comfort. (3) If there are signs of patency or infarction during the operation, it is necessary to extend the observation time or perform repeated imaging tests to improve the accuracy of judgment. (4) In actual MRI testing, it is necessary to set an appropriate concentration of contrast agents to enhance the detection signal and improve the accuracy of the detection. In summary, 3D-HyCoSy and MRI have promising clinical applications in diagnosing symptoms of fallopian tube obstruction with high accuracy and good positive predictive rate. However, due to factors such as operation and structure, false positive diagnostic results may occur. By analyzing and discussing the experimental results, these factors can essentially be eliminated by external conditions. A large amount of experimental data is needed to supplement and improve the causes and preventive measures of false positive FTO in 3D-HyCoSy and MRI in proximal.

References

1. Abega CL, Ndoua CCN, Tsala INK, Fonkou A, Ateba GN, Ntsobe TE, *et al*. 2023. The interest of endoscopy in the diagnosis of fallopian tubes diseases at the Yaoundé Gyneco-Obstetric and Pediatric hospital (Ygoph). Open J Obstet Gynecol. 13(4):767-774.
2. Javed AT, Abbas A. 2023. EUS-guided gastroenterostomy for proximal jejunal obstruction: technique modification for more distal upper GI tract obstruction. VideoGIE. 8(1):35-37.
3. Fataftah J, Tayyem R, Al Rshoud F, Al-Omari M. 2022. Spontaneous pregnancy rate after fallopian tube recanalization for unilateral obstruction with a patent contralateral tube. Egypt J Radiol Nuc M. 53(1):1-7.
4. Howard C, Rice PFS, Keenan M, Dominguez-Cooks J, Heusinkveld J, Hsu C, Barton J. 2022. Study of fallopian tube anatomy and mechanical properties to determine pressure limits for endoscopic exploration. J Histotechnol. 45(1):10-20.
5. Zhu C, Fang J, Yang J, Geng Q, Li Q, Zhang H, et al. 2023. The role of ultrasound-guided multipoint fascial plane block in elderlypatients undergoing combined thoracoscopic -

laparoscopic esophagectomy: A prospective randomized study. Pain Ther. 12(3):841-852.
6. Burak KW, Douglas L, Congly SE. 2023. Comparing magnetic resonance imaging and Contrast - Enhanced Ultrasound (CEUS) for the characterization of nodules found on hepatocellular carcinoma surveillance. J Ultras Med. 42(6):1175-1180.
7. Davies R, Parker M, Basu A, Alleemudder D. 2023. The clinical applications of interventional radiological techniques in obstetrics and gynaecology. Obstet Gynaecol. 25(2):131-139.
8. He S, Renne A, Argandykov D, Convissar D, Lee J. 2022. Comparison of an emoji-based visual analog scale with a numeric rating scale for pain assessment. Jama. 328(2):208-209.
9. Maria Lúcia,Moleiro, Alfredo Barroco G. 2022. Extra-abdominal lymph node metastases as the first presentation in ovarian and fallopian tube carcinomas. Reprod Sci. 30(4):1017-1032.
10. Bordalo M, Arnaiz J, Yamashiro E, Al-Naimi MR. 2023. Imaging of muscle injuries: MR imaging - ultrasound correlation. Magn Reson Imaging C. 31(2):163-179.
11. Rupa R, Prema R, Popat PB, Manchanda S, Venkatesh K, Chandramohan A, *et al*. 2023. Imaging recommendations for diagnosis, staging, and management of ovarian and fallopian tube cancers. Indian J Med Paediat. 44(1):100-109.
12. Aljassim F, Georgopoulou N, Rigby CH, Powell SG, Wyatt JNR, Hapangama DK, *et al*. 2023. Exploring the presence of markers of decidualization in the fallopian tubes: a systematic review. Biol Reprod. 109(2):125-136.
13. Anshuman A, Panigrahi BK, Jena MK. 2023. Enhanced visualization and characterization of low frequency oscillations in power system. IEEE Syst J. 17(1):828-839.
14. Giampaolino P, Zizolfi B, Corte LD, Serafino P, Angelis MCD, Carugno J, *et al*. 2022. Unicornuate uterus with noncommunicating rudimentary horn (class U4aC0V0/ESHRE/ESGE classification) and a communicating bladder endometriotic nodule. J Minim Invas Gyn. 29(7):816-817.
15. Adjénou KEV, Couscous HS, Saha N, Kafupi K, Wallace E, Lantam S, *et al*. 2023. Place of selective tubal catheterization in the management of female infertility in Togo. Open J Radiol. 13(1):77-85.
16. Kauffman RP, Alfaro AG. 2023. Nodular adenomyosis of the fallopian tube. J Gynecol Surg, 39(3):147-148.
17. Stevens K, Wasfie T, Haus C. 2023. Endometrioma causing near-complete obstruction of the sigmoid colon. Am Surgeon. 89(4):1264-1266.
18. Kurz C, Ott J, Parry JP, Janji N, Hager M, Mauer-Gesek B, *et al*. 2023. Is there a fallopian tube sphincter that causes tubal spasm? An anatomic pilot study in transmen. Fertil Steril. 119(5):883-885.
19. Auerbach M. 2023. Optimizing diagnosis and treatment of iron deficiency and iron deficiency anemia in women and girls of reproductive age: Clinical opinion. Int J Gynaecol Obstet. 162(S2):68-77.
20. Tamblyn J, Jeve Y. 2022. Surgical management of tubal disease and infertility. Obstet Gynaecol Reprod Med. 32(2):7-13.
21. Sharaf MF, Fawzy I, Elkhateb IT, Edrees O. 2020. Diagnostic accuracy of hysterosalpingo-lidocaine-foam sonography combined with power Doppler (HyLiFoSy-PD) compared to laparoscopy and dye testing in tubal patency assessment in cases of infertility. Middle East Fertil S. 27(1):1-9.
22. Ramos J, Pellicer N, Fernandez-Sanchez M. 2022. Hysterosalpingography is obsolete: hysterosalpingo-contrast foam sonography should be the alternative. Reprod Biomed Online. 45(5):839-842.
23. Sezer NY, Aker MN, Gnen I, Topuz, Ükür YE. 2023. The effect of virtual reality on women's perceived pain, fear, anxiety, and views about the procedure during hysterosalpingography: A randomized controlled trial. Eur J Obstet Gynecol Reprod Biol. 286:5-9.
24. Kalor A, Girometti R, Maheshwari E, Kierans AS, Puglies RAi, Buros C, *et al*. 2022. Update on MR contrast agents for liver imaging: What to use and when. Radiol Clin. 60(5):679-694.
25. Arefeen Y, Xu J, Zhang M, Dong Z, Wang F, White J, *et al*. 2023. Latent signal models: Learning compact representations of signal evolution for improved time-resolved, multi-contrast MRI. Magn Reson Med. 90(2):483-501.
26. Malave B, Vrooman B. 2022. Vasovagal reactions during interventional pain management procedures—a review of pathophysiology, incidence, risk factors, prevention, and management. Med Sci. 10(3):39-50.
27. Phillips K, Olanrewaju RA, Omole F. 2023. Infertility: Evaluation and management. AM Fam Physician. 107(6):623-630.