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Value of ovarian positional assessment on 4D hysterosalpingo-contrast sonography

Wu-Wu Zheng[1], Li-Xia Chen[1], Shun-Ping Chen[1], Jian Zhu[1], Feng Lin[2], Shi-Hao Xu[1]

[1]Department of Ultrasonography, [2]Department of Gynecology, the First Affiliated Hospital of Wenzhou Medical University, Wenzhou, Zhejiang, China

Abstract

Aims: To investigate the positional relationship between the ovary and Fallopian tube and the relationship between the ovarian position and tubal morphology. **Material and methods:** A total of 195 patients with 338 fallopian tubes were enrolled in this retrospective study. The ovarian and tubal positions were defined relative to the uterus in all directions. Tubal morphology was classified as smooth or tortuous. **Results:** The distribution of the Fallopian tubes corresponded to the positions of the ipsilateral ovaries in the superoinferior direction (χ^2 =197.653, p<0.001), mediolateral direction (χ^2 =237.447, p <0.001) and anteroposterior direction (χ^2 =109.746, p<0.001). Tubal morphology differed according to ovarian position in the superoinferior (χ^2 =21.804, p<0.001), mediolateral directions (χ^2 =4.679, p=0.031) but not in the anteroposterior direction (χ^2 =0.793, p=0.373). **Conclusions:** Evaluating the ovarian position can provide preliminary information on the distribution and shape of the Fallopian tube, helping the operator choose the appropriate initial plane and the necessary approaches for inspection.

Keywords: hysterosalpingo-contrast sonography; ovary; Fallopian tube; position; morphology

Introduction

Infertility is estimated to affect more than 186 million people worldwide and it is a major social burden for women [1-3]. Fallopian tubal factors are responsible for approximately 20% of cases of female infertility [4]. Therefore, accurate evaluation of tubal status is an initial part of infertility diagnosis and can provide important information for clinical treatment. Transvaginal four-dimensional hysterosalpingo-contrast sonography (TVS-4D-HyCoSy) has become a practical screening method for assessing tubal patency due to its lack of radiation exposure, few side effects, good cost-effectiveness and high diagnostic accuracy [5-11].

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Corresponding author: Shihao Xu
Department of Ultrasonography, the First Affiliated Hospital of Wenzhou Medical University, Nanbaixiang Street, Ouhai District, Wenzhou, Zhejiang 325000 China
Phone: +86 13857766918
E-mail: dcxshvip@wmu.edu.cn

However, some false-positive or inconclusive diagnoses can occur due to poor image quality or an inappropriate initial transverse plane on TVS-4D-HyCoSy [8,12], which can lead to a series of unnecessary interventions, such as laparoscopy. The appropriate initial plane is critical to the success of volume imaging. Since the fimbrial end of the tube lies on the ovary, most studies use the method wherein "the region of interest is set to encompass the bilateral cornua of the uterus, possibly with both ovaries" [8,9,13-16] to determine the initial plane of volume imaging. However, it requires the region of interest to encompass the full course of the fallopian tube, not merely the fimbrial end. It has been reported that the position and morphology of the fallopian tube can influence the image quality and that different diagnostic methods should be applied to improve the diagnostic accuracy [8,12]. A few specific cases of the Fallopian tubal position have been reported [12,15]. However, as far as we know, there has been no report on the distribution and morphology of the entire course of the Fallopian tube in different directions.

Therefore, we aimed to investigate the positional relationship between the fallopian tube and the ipsilateral

ovary and the relationship between the position of the ovary and the morphology of the fallopian tube. These findings could help the operator obtain more information about the tube before the contrast agent is injected and improve the accuracy and efficiency of inspection. Additionally, such findings might provide a theoretical foundation for subsequent research on the quality of Fallopian tubes imaging.

Materials and methods

Study participants

A total of 195 patients with 338 fallopian tubes were enrolled in this retrospective study. The inclusion criterion was that patients underwent TVS-4D-HyCoSy in a university hospital between March 2018 and March 2019. The archived images and video were reviewed. The exclusion criteria were as follows: 1. female genital anomalies were present; 2. the tube could not be fully displayed during the examination; 3. the uterus seriously twisted (fig 1). Vaginal secretions were tested before examination to exclude vaginitis. HyCoSy was performed 3-7 days after the last menstrual period. The study was approved by the Ethics Committee of the hospital, and written consent was obtained from each patient.

Instruments

The Voluson E8 Expert (GE Healthcare, Milwaukee, WI, USA) ultrasound machine with coded contrast imaging software was used. An RIC5-9-D transvaginal volume probe (5-9 MHz) and a C1-5-D probe (1–5 MHz) were used in the examinations. The equipment settings were as follows: mechanical index, 0.12-0.18; mode: coded pulse inversion with or without simultaneous color-coded imaging; volume box angle, 179°; and volume angle, 120°. The SonoVue contrast agent (Bracco International B.V., Amsterdam, the Netherlands) was used. It was prepared by adding 5 ml of 0.9% saline solution to 59 mg of freeze-dried SonoVue powder and mixing them into a suspension. Then, 2 ml of the SonoVue suspension were added to 13 ml of 0.9% saline solution to prepare 15 ml of diluted contrast agent.

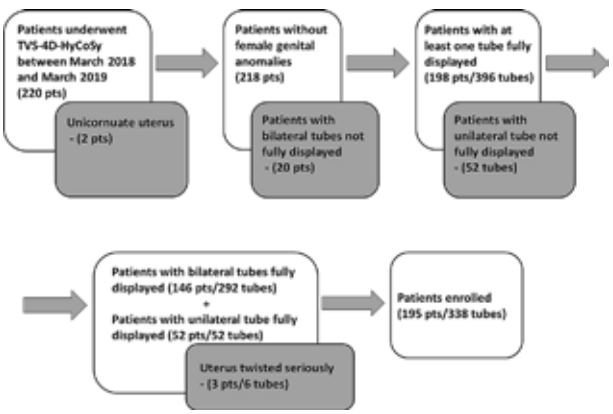


Fig 1. Flow chart of selection of the patients. TVS-4D-HyCoSy, Four-Dimensional Hysterosalpingo-Contrast Sonography. pts, patients.

Examination procedure

The examination time, menstrual and obstetrical history and history of pelvic disease and surgery were recorded. Each patient was placed in the lithotomy position and the cervix was exposed and disinfected. A 12-Fr Foley catheter (Guangzhou Well Lead Medical Co., Ltd., Guangdong, China) was placed into the uterine cavity and the external lumen was inflated with saline to prevent leakage from the cervix. Before the contrast agent was injected, two-dimensional transvaginal sonography (2D-TVS) was conducted to evaluate the uterus and ovaries in the lithotomy position. The uterine position and the relationship between the ovary and uterus were recorded on dynamic and static images. Following identification of the proper initial plane, the TVS-4D-HyCoSy mode was activated and the region of interest was maximized. The contrast agent was injected into the uterine cavity and the images were saved as dynamic and static three-dimensional (3D) and 2D images. The HyCoSy procedure was performed by an ultrasonographer with more than 5 years of experience in HyCoSy.

Image analysis

The uterine position was evaluated according to the preliminary assessment images on 2D-TVS; it was classified as anteversion, horizontal position or retroversion.

The position of the ovary was evaluated according to the preliminary assessment videos on 2D-TVS. It was based on the ovarian relative position to the uterus in the superoinferior, mediolateral and anteroposterior direction. In continuous transverse scanning of the uterus, the relative ovarian position was recorded on its central plane (fig 2). The superoinferior relationship was evaluated according to the part of the uterus that appeared in the ovarian central plane; it was classified as high (corresponding to the ipsilateral uterine horn or above) or low (corresponding to the corpus uteri or below). The mediolateral relationship was evaluated according to the distance from the ovary to the uterus; it was classified as near (the ovary was attached to the uterus) or distant (the ovary kept distance with the uterus). The anteroposterior relationship reflected the position of the ovary relative to the anterior and posterior walls of the uterus; it was classified as parallel (the centre of the ovary was between the anterior and posterior uterine walls) or nonparallel (the centre of the ovary was in front of the anterior uterine wall, or was behind the posterior uterine wall).

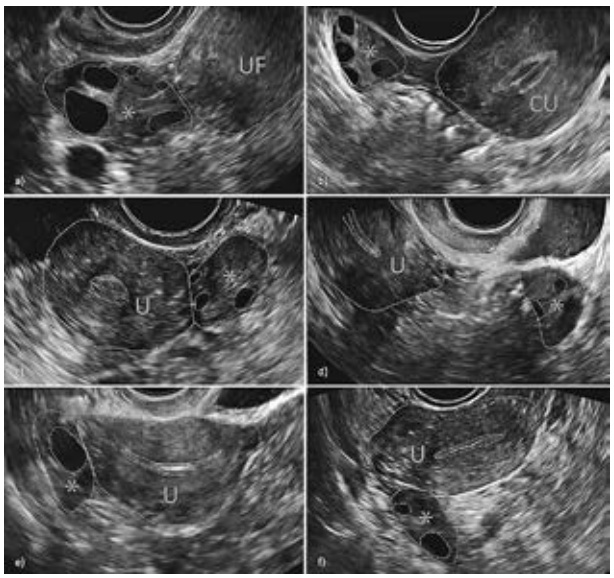


Fig 2. Positions of ovaries (star) in different directions. In the superoinferior direction, an ovary at the high level (a) or low level (b), corresponded to the uterine fundus (UF) or corpus uteri (CU), respectively. In the mediolateral direction, an ovary in the near position (c) was attached to the uterus. An ovary in the distant position (d) was far from the uterus. In the anteroposterior direction, an ovary in the parallel position (e) located between the anterior and posterior uterine walls. An ovary in the nonparallel position (f) located behind the posterior uterine wall, or was in front of the anterior uterine wall. U: uterus; dotted line: outline of the structure.

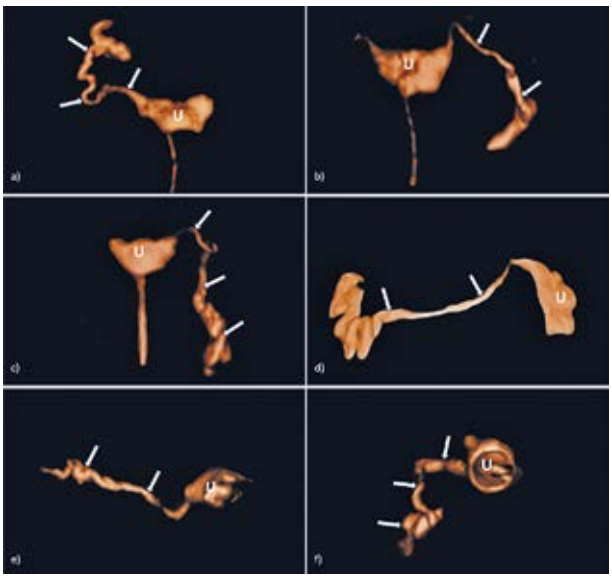


Fig 3. Positions of fallopian tubes (arrows) in different directions. In the superoinferior direction, the tubal position was classified as high (a), or low (b). In the mediolateral direction, the tubal position was classified as near (c), or distant (d). In the anteroposterior direction, the tubal position was classified as parallel (e), or nonparallel (f). U: uterus.

The distribution of the fallopian tube was evaluated according to its distribution on real-time 3D images. It was classified by the tubal relative position to the uterus in the superoinferior direction, mediolateral direction and anteroposterior direction (fig 3). The superoinferior relationship was classified as high (more than half of the tube was above the ipsilateral uterine horn) or low (more than half of the tube was below the ipsilateral uterine horn) on the coronal view. The mediolateral relationship was classified as near (the tube was beside the uterus) or distant (the tube was far away from the uterus) on the coronal view. The anteroposterior relationship was classified as parallel (more than half of the tube was between the anterior and posterior uterine walls) or nonparallel (more than half of the tube was in front of the anterior uterine wall, or was behind the posterior uterine wall) on transverse view.

The morphology of the fallopian tube was observed on real-time 3D images and classified as smooth or tortuous. A smooth fallopian tube was defined as one without obvious turns, and a tortuous fallopian tube was defined as one with obvious turns.

The image analysis was performed independently by two ultrasonographers, each with more than 3 years of experience with HyCoSy. When there was a disagreement, a third ultrasonographer, with more than 5 years of experience with HyCoSy, was consulted. All three ultrasonographers reached a consensus on the positional and morphological evaluation criteria in advance.

Statistical analysis

All of the statistical analyses were performed with IBM SPSS Statistics software version 26.0 for Macintosh (IBM Corporation, Armonk, NY, USA). Chi-Square test (χ^2) were used for categorical variables. Interobserver agreement for positional and morphological evaluations was assessed with the kappa statistic. A p-value less than 0.05 was considered statistically significant.

Results

A total of 195 patients with 338 fallopian tubes were enrolled in the study. The patients were 20 to 46 years old (median age 31 years). The percentage of primary infertility was 35.4% (69/195) and the percentage of secondary infertility was 64.6% (126/195).

The positional and morphological evaluations of the two sonographers were consistent (Table I). There was no significant difference in the ovarian position or the tubal position among different uterine positions (Table II). There was a positive correlation between the position of the fallopian tube and the corresponding ovary (Table III). In the inconsistent cases, most of the fimbrial end of the fallopian tubes travelled along the wall of the ipsilat-

Table I. Positional and morphological evaluation by the two sonographers

	Kappa	p-value	95% CI
Position of uterus	0.941	<0.001	0.908-0.974
Position of ovary in the superoinferior direction	0.925	<0.001	0.866-0.984
Position of Fallopian tube in the superoinferior direction	0.899	<0.001	0.830-0.968
Position of ovary in the anteroposterior direction	0.825	<0.001	0.758-0.892
Position of Fallopian tube in the anteroposterior direction	0.838	<0.001	0.771-0.905
Position of ovary in the mediolateral direction	0.672	<0.001	0.596-0.748
Position of Fallopian tube in the mediolateral direction	0.721	<0.001	0.648-0.794
Morphology of Fallopian tube	0.874	<0.001	0.821-0.927

Table II. Correlation between the position of the uterus and the positions of the ovary and Fallopian tube

Positions of ovary and Fallopian tube		Position of uterus			χ^2	p-value
		Anteversion	Horizontal	Retroversion		
Position of ovary in the superoinferior direction						
	High	25	7	17	1.247	0.536
	Low	170	40	79		
Position of ovary in the mediolateral direction						
	Near	128	36	74	5.044	0.080
	Distant	67	11	22		
Position of ovary in the anteroposterior direction						
	Parallel	150	32	68	2.219	0.330
	Nonparallel	45	15	28		
Position of Fallopian tube in the superoinferior direction						
	High	18	8	18	5.921	0.052
	Low	177	39	78		
Position of Fallopian tube in the mediolateral direction						
	Near	120	35	71	5.903	0.052
	Distant	75	12	25		
Position of Fallopian tube in the anteroposterior direction						
	Parallel	149	34	67	1.538	0.463
	Nonparallel	46	13	29		

Table III. Positional correlation between the ovary and the Fallopian tube in different directions

Position of ovary		Distribution of Fallopian tube		χ^2	p-value
		High	Low		
Superoinferior direction	High	37	12	197.653	<0.001
	Low	7	282		
		Near	Distant		
Mediolateral direction	Near	220	18	237.447	<0.001
	Distant	6	94		
		Parallel	Nonparallel		
Anteroposterior direction	Parallel	222	28	109.746	<0.001
	Nonparallel	28	60		

eral ovary in any direction on transvaginal 2D hysterosalpingo-contrast sonography (TVS-2D-HyCoSy).

As shown in Table IV, there were significant differences in tubal morphology among different ovarian positions in the superoinferior direction (χ^2=21.804, p<0.001) and in the mediolateral direction (χ^2=4.679, p=0.031) but not in the anteroposterior direction (χ^2=0.793, p=0.373). For the ovary located above the uterine horn or attached to the uterus, the corresponding tube was more likely to be tortuous.

Discussions

TVS-4D-HyCoSy is a noninvasive examination method for evaluating the patency of Fallopian tubes. By tracking the flow of the contrast agent, TVS-4D-Hy-

Table IV. Correlation between Fallopian tubal morphology and ovarian position in different directions

Position of ovary		Morphology of Fallopian tube		χ^2	p-value
		Smooth	Tortuous		
Superoinferior direction					
	High	7	42	21.804	<0.001
	Low	145	144		
Mediolateral direction					
	Near	98	140	4.679	0.031
	Distant	54	46		
Anteroposterior direction					
	Parallel	116	134	0.793	0.373
	Nonparallel	36	52		

CoSy provides a view of the fallopian tubes in real time [8,9,12,15,16]. Preassessment of the ovaries is advisable to avoid unnecessary prolongation of the procedure [17]. However, there have been few studies of the value of ovarian positional assessment on TVS-4D-HyCoSy.

In this study, we found that the distribution of the Fallopian tube in all directions is closely related to the position of the ovary on the same side. In the superoinferior direction, for ovaries that were positioned high, most of the corresponding fallopian tubes were positioned high as well; for this type of situation, the distribution of many of these tubes exceeded the space between the ovary and the cornu. In order to include the tube in the scope of scanning completely, we should keep the ovary and cornu at a safe distance from the edge of the scope when possible.

Fallopian tubes with high positions are located in the far field on the TVS-4D-HyCoSy sonogram and interference from intestinal gas readily forms artifacts, making it difficult to display the shape and patency of the fallopian tubes [12,17]. At this time, other diagnostic methods, such as transabdominal hysterosalpingo-contrast sonography (TAS-HyCoSy), should be considered as improving image quality [8]. On the TAS-HyCoSy sonogram, this type of Fallopian tube may be located in the near field and interference from intestinal gas can be eliminated by compressing the abdomen. In the mediolateral direction, regarding ovaries far from the uterus, most of the corresponding fallopian tubes travelled far away from the uterus (94/100), traversing a wide range. This type of fallopian tube can easily lead to a misdiagnosis [8,12] since its distal part might not be included in the scope of the scan. Therefore, for ovaries far from the uterus, if the corresponding fallopian tube is not visualized completely on the TVS-4D-HyCoSy sonogram, one should merely adjust the orientation of the probe more laterally. Additionally, further detection, such as TVS-2D-HyCoSy, should be performed to track the microbubble to the end of the tube.

In conclusion, the distribution of most fallopian tubes corresponded to the positions of the ipsilateral ovaries. The method wherein "the region of interest is set to encompass the bilateral cornua of the uterus, possibly with both ovaries" [8,9,13-16] is useful for determining the initial plane of volume imaging in most cases. Additionally, in the following situations, these issues should be considered further: 1) if the bilateral ovaries are both attached to the cornua of the uterus, the probe should be adjusted to set the bilateral ovaries and cornua in the centre of the initial plane as much as possible; 2) if the bilateral ovaries are both far from the cornua of the uterus and cannot feasibly be included in the scope of scanning at the same time, the tubes should be scanned separately to ensure that the full course of each tube is displayed. This suggestion is consistent with previous studies [9,15]; 3) if one ovary is far from the uterine horn and the other ovary is attached to the uterine horn, the probe should be adjusted to ensure that the former ovary and the corresponding cornu are fully included within the scope of scanning. At the same time, the ovary and cornu on the other side should be included in the scope of scanning but kept at a safe distance from the edge of the scope when possible, as the range covered by the corresponding fallopian tube could exceed the space between the ovary and the cornu. Furthermore, if a Fallopian tube in this situation is not visible on the TVS-4D-HyCoSy sonogram, an improper initial plane, poor image quality or interference from intestinal gas should be considered as a possible cause, and further detection of the unilateral tube should be applied. At the same time, other diagnostic methods, such as TVS-3D-HyCoSy (for better image quality), TVS-2D-HyCoSy (allowing real-time tracking of the microbubbles) and TAS-HyCoSy, should be considered for this situation.

However, the ovarian and tubal positions do not match in some cases, which could be related to factors that change the distribution of the Fallopian tube, such as pelvic space-occupying masses, pelvic inflammatory

disease, endometriosis, or history of surgery. These conditions can cause some fallopian tubes to be excluded from the region of interest [12]. Further imaging of the Fallopian tube should be performed in 2D contrast mode because it allows real-time tracking of the microbubbles from the cavity to the fimbrial end of the tube. At the same time, in addition to the patency assessment, the association of the tubal distribution and the ovarian position should be noticed, which is directly related to the tubal function of receiving the egg.

We found also that the morphology of the Fallopian tube was related to the position of the ovary. For ovaries located closer to the uterine fundus in the superoinferior and mediolateral directions, the corresponding tube was more likely to appear as a tortuous line. This is related to its anatomy. The tube is an elongated tubular structure that connects the ovary and the uterus. Therefore, when the ovary and the uterine horn are close together, the curvature of the line between the two points is especially obvious, and the fallopian tube appears as a tortuous line. This condition may cause technical difficulty in the assessment of tubal patency because of the abnormal tubal shape and interference by intestinal gas [10,17], and the experience of the sonographer may be crucial. However, in the anteroposterior direction, the relationship between them was not statistically significant. The reason for this finding might be that the different positions in the anteroposterior direction result in little change in the distance between these two points. Additionally, a study has shown that an abnormally shaped fallopian tube is associated with obstruction [8], further reflecting the pathological status of the fallopian tube and pelvis. Therefore, in routine 2D ultrasound examinations on infertile women, Fallopian tube obstruction should be suspected as one cause of infertility when the ovary is found close to the uterine horn.

There are some limitations of our study. First, it was a retrospective, single-centre study that obtained limited information. Besides, a comparison between experienced and less experienced sonographers was not analysed. And the intraobserver agreement was not assessed. In the future, we will also study the factors affecting ovarian and tubal position.

Conclusions

In conclusion, the distribution and morphology of the Fallopian tube are related to the position of the ipsilateral ovary. Evaluating the ovarian position can provide preliminary information on the distribution and shape of the fallopian tube, helping the operator choose the appropriate initial plane and the necessary approaches for inspection.

Conflict of interest: none

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