Three-dimensional ultrasound and three-dimensional power Doppler improve the preoperative evaluation of complex benign ovarian lesions

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Summary

Purpose of investigation: To evaluate the diagnostic accuracy of three-dimensional ultrasound (3D-US) and three-dimensional power-Doppler (3DPD-US) as adjuncts to conventional B-mode-US in evaluation of complex benign ovarian lesions. *Methods:* Transvaginal B-mode-US, 3D-US and 3DPD-US were performed in 29 patients with unilateral ovarian lesion. Patients were classified as low or high risk for malignancy according to a standardized scoring system composed of ten morphological and vascular parameters. Preoperative scores were matched to the histological results and the diagnostic performance of the scoring system was calculated. *Results:* Seven out of the 16 cases of endometriomas (44%) were graded as low risk masses according to B-mode-US, while the addition of 3D-US and 3DPD-US increased the accuracy to 56% and 94%, respectively. All dermoid cysts were classified as high risk cases by B-mode-US, but 3D-US and 3DPD-US correctly classified 14% and 57% of cases, respectively. The use of B-mode-US, 3D-US and 3DPD-US correctly classified all four cystadenomas. Only the use of 3DPD-US correctly classified one out of two hemorrhagic corpus luteum cases, whereas the other imaging modalities characterized these lesions as high risk. The overall diagnostic accuracy increased from 38%, 48%, and 83% with the application of B-mode-US alone, or combined with 3D-US and 3DPD-US, respectively. *Conclusion:* Conventional ultrasound supplemented with 3D-US and 3DPD-US and the evaluation of findings according to a specific scoring system can facilitate the preoperative classification of complex benign ovarian lesions.

Key words: Benign ovarian lesions; B-mode ultrasound; Dermoid cyst; Endometrioma; Three-dimensional ultrasound; Three-dimensional power Doppler ultrasound.

Introduction

Transvaginal ultrasonography (TVUS) is a well-established imaging modality for the preoperative evaluation of ovarian masses according to visualization of specific structural characteristics and vascular parameters [1]. A reliable preoperative differential diagnosis between benign and malignant lesions can alter the surgical management of adnexal masses and therefore affect the prognosis [2]. Benign masses can be effectively managed with laparoscopy which is associated with lower morbidity and a shorter hospital stay, whereas in case of suspected malignancy, referral to a gynecological oncologist is required [3].

Although the accuracy of the subjective assessment of the ultrasound image of an ovarian mass by an expert is considered to be high, certain cases of complex ovarian lesions are still difficult to correctly classify [4]. The introduction of three-dimensional ultrasound (3D-US) and three-dimensional power Doppler ultrasound (3DPD-US) in the last decade has opened up new possibilities in the evaluation of ovarian masses. Main advantages of 3D-US include: the visualization of three image planes, 3D color display of blood flow, digital volume storage available at any time, and reconstruction of 3D plastic images [5]. Previous studies have demonstrated that 3D imaging techniques can enhance and facilitate the morphologic and functional evaluation of both benign and malignant ovarian lesions [6, 7]. Also, different scoring systems have been proposed for the morphological indexing assessment of an adnexal mass in order to determine the likelihood of malignancy [6, 8]. Current scoring systems proposed include: morphological assessment of ovarian lesions with gray-scale ultrasound, alone or combined with additional Doppler-velocimetric indices, CA125 values, and clinical parameters [4, 9].

The aim of this study was to determine whether the use of 3D-US and 3DPD-US as adjuncts to B-mode sonography and the evaluation of the findings according to a proposed scoring system that incorporates the three imaging modalities could offer any diagnostic yield in cases of questionable benign ovarian lesions.

Materials and Methods

The authors prospectively analyzed the preoperative sonographic reports of 29 patients aged 16 - 56 years (mean age 33 years) who presented complex adnexal ovarian masses. Patients presenting a unilateral complex ovarian mass who were examined by an experienced sonographer and underwent elective surgical treatment (laparoscopy or laparotomy) were eligible for

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Table 1. — *Sonographic scoring criteria for the assessment of an ovarian lesion.*

	Sonographic criteria		Score
B-MODE-US	Wall structure	Smooth	0
		Low level irregularities	1
		Papillarities	2
	Shadowing	Present	0
		Absent	1
	Septa	None or thin = 3 mm or less	0
		Thick > 3 mm	1
	Solid parts	Absent	0
		Low solid pattern	1
		High solid pattern	2
	Echogenicity	Sonolucent	0
		Mid level echo	1
		High level echo	2
	Peritoneal fluid	Absent	0
		Present	1
3D-US	Surface	Regular	0
		Low level irregularity	1
		High level irregularity	2
	Relationship with the surrounding structures	Normal	0
		Low level disturbance	1
		High level disturbance	2
3DPD-US	Vessel's architecture	Linear vessel arrangement	0
		Disturbed vessel arrangement	1
		Chaotic vessel arrangement	2
	Branching pattern	Simple	0
		Moderate	1
		Complex	2

inclusion. The exclusion criteria were as follows: pregnancy, inability to tolerate transvaginal sonography, surgery 120 days after sonographic assessment and incomplete submission of data. All the examinations in premenopausal women were performed during the early proliferative phase of the menstrual cycle to avoid increased vascularity of corpus luteum and / or follicular structure. In all cases, the ovarian lesions were assessed by B-mode ultrasound (B-mode-US), 3D-US and 3DPD-US, and the histopathological diagnosis was made by an expert pathologist after the surgical excision. Research and Ethics Committee of the Hospital approved the study, and all women gave an informed consent.

Sonographic examinations were performed using a Voluson 730 Expert ultrasound system (GE Healthcare, Zipf, Austria). A transvaginal scan of the pelvic organs was performed using a multifrequency endovaginal probe. In the color, spectral and power modes, the Doppler ultrasound had a frequency of 5 MHz. Three-dimensional studies were performed using a B-mode scanner which monitors spatial orientation of the images and stores them as a volume set in the memory of the computer. After completing each examination, images were evaluated according to the following parameters: structure of the mass wall, shadowing, presence of septa and solid tissue, echogenicity of the cystic content, and presence of ascites defined as fluid collection (> 50 ml) in the pouch of Douglas. Surface irregularity and relationships with the surrounding tissues were assessed by 3D-US. Vessel architecture and branching pattern in the papillary projections and solid tissue, other than papillary projections, were evaluated with the use of 3DPD-US. Standardized definitions of ultrasound terms to describe sonographic features according to the International Ovarian Tumor Analysis (IOTA) group were used [10]. A papillary projection was defined as any solid protrusion into a cyst cavity from the cyst wall with a height greater than or equal to three mm. The authors did not use 2D color or 2D power Doppler, as it is not possible to describe the morphology of the vessel tree with these modalities; moreover, previous studies have indicated that the pattern of vascularization is a more specific criterion compared to the quantitative analysis of blood flow waveform with the use of 2D power Doppler [11, 12].

Finally, on the basis of assessment of gray-scale and 3D-US findings, a score was assigned to each lesion (Table 1) and the examiner classified each mass as low or high risk for ovarian malignancy according to the following cut-off scores: B-mode-US score less than three, B-mode-US and 3D-US score less than six, and combined 3D (3D-US and 3DPD-US) and B-mode-US less than eight. The results of pathological examination were obtained for each surgically removed adnexal mass and were compared to the preoperative scores of the respective specimen. The diagnostic accuracy of each sonographic method was evaluated according to the cut-off scores proposed.

Table 2. — *Correlation between histopathologic and 2D sonographic findings.*

Histopathological diagnosis (cases)	Cystic	Mixed	Septations	Papillarities
Endometrioma (16)	9	7	2	8
Dermoid cyst (7)	1	6	1	6
Cystadenoma (4)				
serous (2)	2	0	0	1
mucinous (2)	2	0	0	1
Hemorrhagic corpus luteum (2)	2	0	1	2

Table 3. — *Scores obtained after the evaluation of the sonographic characteristics of each ovarian lesion according to the proposed scoring system.*

	2D score		2D + 3D score		2D+3D+3DPD score	
	Range	Mean	Range	Mean	Range	Mean
Endometrioma	0 - 6	3.19	0 - 9	4.25	0 - 9	4.38
Dermoid cyst	5 - 8	6.71	5 - 10	7.86	7 - 11	9.29
Cystadenoma	0 - 3	2	0 - 4	2.25	3 - 6	4.50
Hemorrhagic corpus luteum	5 - 6	5.5	7 - 9	8	7 - 9	8

Results

A total of 29 women presenting a unilateral ovarian mass were recruited for the study and underwent transvaginal gray-scale, 3D and 3DPD ultrasound examination. Histological analysis of ovarian lesions identified 16 endometriomas, seven teratomas, four cystadenomas and two hemorrhagic corpus luteum cysts. Table 2 presents the correlation of the histological diagnosis with the presence of septa or papillary projections and the cystic or solid appearance of the lesion. Dermoid cysts and hemorrhagic corpus luteum cysts presented more complex features and thus more conspicuous morphology. None of the cases in this study were characterized by chaotic vessel arrangement or complex branching patterns which are associated with malignancy.

At the end of the scanning session, the scores obtained by different types of ovarian masses according to B-mode or 3D/3DPD ultrasound modalities applied were evaluated and are shown in Table 3. According to B-mode-US findings, only seven endometriomas had a score less or

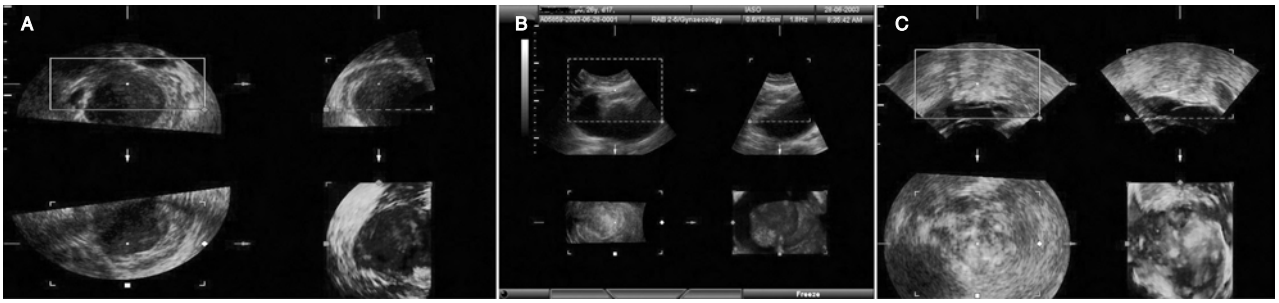

Figure 1. — 3D-US acquisitions of endometrioma (A), dermoid cyst (B), and haemmorhagic cyst of corpus luteum (C), that were allocated a high score by using sonographic criteria. B-mode-US, 3D-US, 3DPD-US scores were 5, 9, and 9 for A 8, 10, and 10 for B, and 6, 9, and 9 for C.

equal to three (44%), and were preoperatively classified as low risk for malignancy. The addition of 3D-US and 3DPD-US increased the accuracy to 56% (nine cases) and 94% (15 cases), respectively (Figure 1A). All cases of dermoid cysts included in the study were misinterpreted as high risk lesions according to B-mode scoring. Subsequent examination with 3D-US reduced the risk in one case, and the addition of 3DPD-US correctly classified another three cases (Figure 1B). All four cystadenomas were accurately graded as low risk masses with B-mode-US, 3D-US and 3DPD-US examinations. Both hemorrhagic corpus luteum cysts were initially misinterpreted by B-mode-US as high risk ovarian lesions due to rather high scores indicating ovarian malignancy, but the addition of 3D-US and 3DPD-US findings provided the correct diagnosis in one case (Figure 1C).

The overall diagnostic accuracy of sonographic examination of ovarian lesions with the aid of B-mode was 38% and increased to 48% and 83% with the addition of 3D-US and 3DPD-US, respectively. Other parameters of diagnostic performance, such as specificity and false positive rate, could not be estimated because the study group included only benign cases.

Discussion

Conventional B-mode TVS is usually considered the first-line imaging technique for the accurate characterization of ovarian lesions according to the subjective evaluation of ultrasound findings. However, this approach may fail to distinguish complex benign ovarian lesions and also to detect malignancy in lesions without conventional "malignant" morphology [13]. The findings in this study indicate that assessment of morphological characteristics and vascularization of ovarian lesions using 3D-US and 3DPD-US as adjuncts to B-mode-US, and evaluation according to a standardized scoring system, seem to improve the diagnostic accuracy in cases of complex benign adnexal mass.

Complex adnexal masses, such as endometriomas, can present diverse sonographic features which may resemble those of an ovarian carcinoma [14]. In this study, according to B-mode-US and 3D-US findings, just seven endometriomas had a score less than three and nine endometriomas less than six, respectively, which suggested low risk for malignancy. After the 3DPD-US examination, 15 out of 16 endometriomas included in the study were correctly visualized as benign. Qualitive analysis of tumor vascularity by 3DPD-US examination in these cases can be proven valuable, since it can distinguish the linear vessel pattern of a benign tumor and correctly guide diagnosis [15]. Similarly, dermoid cysts typically appear as heterogeneous masses with irregular hypoechoic and hyperechoic areas with posterior shadowing not separated by septa or homogeneous hyperechoic masses with regular capsule and posterior shadowing [2]. However, these masses are characterized by a great variability in sonographic appearance rerders their correct interpretation as low risk lesions more challenging [14]. All the presented cases were initially considered suspicious for malignancy according to the B-mode score, mainly due to the presence of solid irregular inner contents. Additional examination with 3D-US changed the risk in one case, whereas the use of 3DPD-US changed the preliminary diagnosis in another three cases and assigned them as low risk category. Absence of vascularity within the solid part of the mass, linear appearance, and regular branching of the peripheral vessels demonstrated with the 3DPD-US, assisted in the correct classification of dermoid cysts.

A recent multicenter study included cystadenomas, either serous or mucinous, in the adnexal masses that present diagnostic difficulties on the basis of sonographic findings [4]. No ovarian cystadenoma in this study gave the wrong impression of malignant lesion by its B-mode scores due to its solid component. Three-dimensional visualization of the regular surface of solid components protruding into the cystic cavity and linear vessel architecture in the periphery of the lesion (3DPD-US criterion) correctly indicated a benign lesion. Furthermore, both hemorrhagic corpus luteum cysts were misinterpreted by B-mode-US and 3D-US examinations, as the morphologic scores obtained were high that may be associated to the presence of papillary projections, indicating ovarian malignancy; however, the addition of 3DPD-US imaging modality classified one case as low risk. The age of hematoma within a corpus luteum cyst affects the sonographic appearance of a hemorrhagic corpus luteum

cyst, and if acutely imaged may simulate a solid mass due to the presence of heterogeneous echoes.

Multicenter studies have demonstrated that experienced ultrasound examiners using high-end ultrasound systems are able to correctly discriminate between benign and malignant adnexal masses in > 90% cases based on morphological and Doppler assessment [4]. However, in a small proportion of cases even an experienced ultrasound examiner will find it difficult to determine whether the mass is most likely to be benign or malignant and the false positive rate is about 25% [4, 16]. In particular, a mass with papillary projections, multilocularity, low-level echogenicity of cystic fluid, and moderate vascularization with color Doppler ultrasound examination seem to be the most difficult to classify. There is ample evidence that both 3D-US and 3DPD-US are reproducible techniques among examiners and could be useful in selected cases in which conventional B-mode-US cannot confidently lead to a definite diagnosis [5]. Three-dimensional ultrasound images facilitate the recognition of the ovarian lesion anatomy and relationship with other pelvic structures, the accurate visualization of the surface features, the evaluation of the intracystic morphology, and the analysis of the tumor vasculature. In addition, the 3D-US mode allows the exploration of the outlet wall surface with the surface rendering an increasingly precise description of lesion anatomy via the acquisition of multiple sections, rotation, and reconstruction of the plastic image of the mass without increasing the scanning time. In this study, the addition of 3D-US appeared to improve the evaluation of the lesion's architecture and was associated with a significant decrease in false-positive findings. Moreover, morphological assessment of mass vascularity as depicted by 3DPD-US seems to further add positively in gray-scale ultrasound imaging in ovarian lesions, confirmed by previous studies [7, 17].

Several scoring systems have been proposed for the preoperative assessment of adnexal masses based on morphological and / or Doppler characteristics in order to determine the likelihood of malignancy [18, 19]. In this study, a scoring system that relies on ten parameters describing the structure and vessels' architecture of the ovarian lesions was utilized to rule out malignant cases. Six morphological criteria (wall structure, shadowing, septa, solid parts, echogenicity, and peritoneal fluid) were assessed by 2D ultrasound, whereas wall surface and relationships with surrounding tissues were evaluated with the aid of 3D ultrasonography. Vessel architecture and branching pattern were scored with the application of 3DPD-US. Characteristics suggestive of malignancy included irregular wall structure, presence of gross papillary projections, solid areas, septa, and solid echogenicity. Moreover, irregular and randomly dispersed vessels with complex branching that do not follow the geometry of the pre-existing vasculature could substantially increase the risk [6]. Another research group used a similar scoring system to demonstrate that the 3D imaging modality predominated over the B-mode-US in the classification of ovarian lesions and exhibited an excellent diagnostic performance (100% sensitivity and 99.08% specificity); however, the sample size of that study composed of 109 benign and 11 malignant cases is still inadequate to draw definite conclusions [20]. The same researchers conducted a second study based on the same scoring system to confirm that 3D-US and 3DPD-US offer a clear advantage over conventional TVUS combined with color Doppler to analyze the flow velocity waveform, in the correct classification of ovarian lesions [21]. The aim in the present study was to determine the diagnostic accuracy of a similar scoring system that would offer a detailed evaluation of each ovarian lesion based only on the analysis of qualitive characteristics, with the combined application of B-mode and 3D ultrasound imaging rather than to compare them.

Review of these features in comparison with the confirmed histological diagnosis following the surgical excision of these masses enabled the present authors to establish the cut-off values of each modality to predict benignity: a cut-off value less than three for B-mode-US, less than six for the combined use of 2D and 3D-US, and less than eight for the addition of 3DPD-US. Published scoring systems provided good results giving an accuracy of about 93% - 96% confirming that ultrasound-based triage is an excellent method of selecting the surgical approach for adnexal masses. However, some benign lesions are still very difficult to discriminate from malignant lesions and a false-positive rate of at least 5% - 10% has to be assumed when ultrasound scoring systems are applied, even in experienced hands [5, 22]. In fact, the largest multicenter study applying an ultrasound-based triage system reported a false-positive rate of 24% [23]; moreover, when the scorings systems were validated prospectively in different centers, their diagnostic performance was less pronounced [24, 25]. On the other hand, previous studies have shown that the use of pattern recognition for a conclusive diagnosis by a non-expert ultrasound operator reaches a sensitivity and specificity of 86% and 80%, respectively, whereas the evaluation of ultrasound findings by a very experienced examiner has a sensitivity of 90% and a specificity of 93% [26]. A valid scoring system will overcome this gap posed by the subjective evaluation of ultrasound findings (pattern recognition) and will facilitate the routine clinical practice.

The findings in the present study demonstrate that the addition of 3D-US and 3DPD-US in the conventional ultrasound evaluation of adnexal masses and the evaluation of the findings according to the proposed scoring system could improve the identification of complex benign complex ovarian lesions. A more accurate classification of ovarian lesions could be explained by the meticulous investigation of the lesion anatomy and the qualitive analysis of the vascularity architecture with the aid of 3D imaging. However, possible advantages of this approach demonstrated in our preliminary study should be validated in randomized clinical trials that will recruit a large sample size and include malignant cases as well. Moreover, it should be noted that the 3D power Doppler criteria were descriptive and may be replaced by quanti-

tive criteria of vascularization, such as flow index and vascularization index, resulting in a less subjective evaluation system. A reliable preoperative classification of complex ovarian lesions will establish the optimal surgical management affecting positively the prognosis in each case.

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