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CLINICAL ARTICLE

Conventional and color Doppler sonography in preoperative assessment of ovarian tumors

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Abstract

Objective: To study the vascular patterns of ovarian tumors by color Doppler imaging (CDI) and compare the findings of conventional sonographic studies and CDI with histopathologic findings for the same tumors. *Methods:* Fifty nonpregnant women scheduled for elective surgery for ovarian tumors were examined by sonographic scanning and CDI by the same physician. Sonographic morphology scores [SMSs] were used, and the pulsatility index (PI) and resistance index (RI) were calculated after locating vessels in and around the tumors by CDI. *Results:* It was possible to obtain CDI results in 26 of the 50 women. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were 100%, 71.43%, 73.33%, and 100%, respectively, for SMS. With CDI, the sensitivity, specificity, PPV, and NPV were 100%, 85.72%, 95%, and 100% for PI and 100%, 71.43%, 90.48%, and 100% for RI. RI sensitivity and specificity were identical to those of SMS, i.e., 100% and 71.43%, respectively, but PI specificity was better (85.72%). *Conclusion:* In this study, CDI was definitely better than SMS when color flow could be obtained through the tumors. The overall efficiency in diagnosing the nature of tumors is very high if SMS and CDI are both used in patients having ovarian tumors.

1. Introduction

Ovarian cancer, which occurs predominantly in postmenopausal women, accounts for about 25% of all malignancies of the female genital tract in

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the United States [1], and it is the most common cause of death from gynecological disease. In more than two-thirds of cases, disease is advanced at the time of diagnosis, and overall 5-year survival rates range between 15% and 20% [2,3]. If ovarian cancer is detected at an early stage, survival dramatically increases.

It is important to know the nature of the tumor before surgery, especially when the patient is young, wishes to have children, and conservative treatment could be possible. In 1991, Sassone and colleagues [4] devised a scoring system to characterize ovarian lesions using traditional grey-scale transvaginal ultrasonography. A sonographic morphology score (SMS), based on 4 morphologic characteristics of the mass (wall thickness, inner wall structure, characteristics of septae, and echogenicity), allowed to differentiate benign from malignant ovarian masses with reasonable accuracy. The positive predictive value (PPV) of this system, however, was lowered by obviously benign but nonetheless high-scoring masses such as benign cystic teratomas, fibroma-thecoma, and, less frequently, endometriomas. Recently, the evaluation of uterine and ovarian diseases has been made easier by the introduction of transvaginal color Doppler imaging (CDI), and several studies [5—9] have assessed blood flow in ovarian and uterine lesions using this technique. Moreover, Alcazar and colleagues [10] have used 3-dimensional power Doppler sonography to assess vascularization in highly suggestive areas (gross papillary projections, solid areas, and thick septations). The purpose of this study was to determine whether blood flow characteristics determined by CDI could be used to distinguish benign from malignant ovarian masses, and, more specifically, to determine whether low impedance, manifested as a low pulsatility index (PI) or a low resistance index (RI), correlates with neovascularity, a feature specific to malignant neoplasm.

2. Materials and methods

Between March 2003 and February 2004, 50 women admitted to this institution with a suspected primary ovarian tumor were examined using both the SMS devised by Sassone and colleagues [4] and CDI prior to laparoscopy or laparotomy. The inclusion criterion was a primary ovarian mass greater than 5 cm. The ultrasonographic and CDI examinations were performed and evaluated by the same physician. Tumors were characterized as benign or suspicious of being malignant by both ultrasonography and CDI before surgery. The sonographic and CDI results were compared with the histopathologic diagnosis of the ovarian tumors. Patients who did not undergo surgery and those who had an adnexal mass of nonovarian origin were excluded from the study.

All patients were scanned transabdominally and transvaginally with a digital channel ATL Philips device (model HDI 512). A 2- to 5-MHz transducer was used for the transabdominal scan and a 5- to 9-MHz transducer was used for the transvaginal scan. An SMS greater than 9 was considered to indicate a malignant tumor and an SMS of 9 or less was considered to indicate a benign tumor [11].

After evaluating the SMS, CDI was performed and a minimum of 3 waveforms were obtained from any areas of flow within or around the tumor. The PI (peak systolic velocity minus end diastolic velocity divided by mean velocity) and RI (peak systolic velocity minus end diastolic velocity divided by peak systolic velocity) were calculated, and the lowest value was taken as representative of the most suspicious pathologic characteristics.

A PI of 1.0 or less was considered to indicate a malignant tumor and a PI of 1.0 or higher was considered to indicate a benign tumor [12]. A RI of 0.6 or less was considered to indicate a malignant tumor and a RI of 0.6 or higher was considered to indicate a benign tumor [13].

Statistical analysis was done by using χ^2 test and Fisher's Exact Test for significance in the distribution of ultrasonographic and CDI findings of benign and malignant tumors. The validity of different indices was verified using tests for sensitivity, specificity, PPV, and negative predictive value (NPV).

3. Results

In 24 of 50 patients, no color flow could be detected within the mass or immediately around it on CDI, and these patients were excluded from the analysis. Of the remaining 26 patients, PI and RI

Table 1 Cross-tabulation of histopathologic diagnosis with pulsatility index using 1.0 as a cutoff value

Tumor status	Positive (cutoff $\leq$1.0)	Negative (cutoff$>$1.0)	Total
Malignant	19	0	19
Benign	1	6	7
Total	20	6	26

Sensitivity = 100% (19/19); specificity = 85.72% (6/7); positive predictive value = 95% (19/20); negative predictive value = 100% (6/6); $P<0.001$.

Table 2 Cross-tabulation of histopathologic diagnosis with resistance index using a cutoff value of 0.6

Tumor status	Positive (cutoff ≤0.6)	Negative (cutoff >0.6)	Total
Malignant	19	0	19
Benign	2	5	7
Total	21	5	26

Sensitivity = 100% (19/19); specificity = 71.43% (5/7); positive predictive value = 90.48% (19/21); negative predictive value = 100% (5/5).

were significantly lower in malignant than in benign lesions (Tables 1 and 2). Of the 24 patients in whom no color flow was obtained despite an extensive examination lasting 20 min, 21 had a benign and 3 had a malignant tumor.

Ultrasonography and CDI were performed prior to surgery in 50 women who underwent laparotomy or laparoscopic surgery for a primary ovarian tumor. Their age ranged from 8 to 60 years, for a mean of 35.27 years. Mean age was 34 years for those with benign tumors and 36.55 years for those with malignant tumors. There were 8 nulliparous, 39 premenopausal, 6 postmenopausal, and 3 premenarchal patients (one 8-year-old and two 12-year-old girls). Of the 50 patients, 2 had previously undergone hysterectomy for benign lesions of the uterus and their tumor was detected a few years later; 2 were diagnosed to have mixed germ cell tumor; and 1 presented with acute abdominal pain and had a twisted ovarian cyst.

The most common presenting symptoms were abdominal pain (in 36 patients [72%]) and a palpable mass (in 26 patients [52%]); 3 patients had no symptoms and were accidentally diagnosed (Table 3). There was a histopathologic diagnosis of 27 benign tumors, 1 benign tumor with borderline features (it was included among the benign tumors in the statistical analysis), and 22 malignant tumors (Table 4). Serous cyst adenoma was the most common histologic type of benign tumors (about 46% of those).

Ultrasonographic evaluation by SMS with a score greater than 9 as the cutoff value [11] was found to have the highest sensitivity (100%), specificity (71.43%), PPV (73.33%), and NPV (100%) in detecting malignant ovarian tumors ($P<0.001$) (Table 5).

Based on a cutoff value of 1.0 or less for PI [12], CDI had a sensitivity of 100%, specificity of 85.72%, PPV of 95%, and NPV of 100% in the detection of malignant ovarian tumors ($P<0.001$); and with a cutoff value of 0.6 or less for RI [13], CDI had a sensitivity of 100%, specificity of 71.43%, PPV of 90.48%, and NPV of 100% in detecting malignant ovarian tumors ($P<0.001$).

Table 3 Distribution of symptoms in malignant and benign tumor

Symptom	Malignant ($n=22$)	Benign ($n=28$)
Menstrual complaints	2 (9%)	5 (17.9%)
Pain	15 (68.2%)	21 (75%)
Distension/lump	16 (72.8%)	10 (35.7%)
Asymptomatic	0	3 (10.7%)

Table 4 Histopathologic typing of benign and malignant ovarian tumors

Benign tumors ($n=28$)	No.	Malignant tumors ($n=22$)	No.
Serous cystadenoma	13	Serous adenocarcinoma	8
Endometrioma	1	Mucinous adenocarcinoma	5
Hemorrhagic cyst	4	Mixed germ cell tumor	3
Para ovarian cyst	1	Dysgerminoma	3
Twisted ovarian cyst	1	Malignant sertoli tumor	1
Fibroma	1	Malignant stromal cell tumor	1
Benign cystic teratoma	2	Leiomyosarcoma	1
Inflammatory	2		
Papillary cyst adenoma with focal borderline feature	1		

4. Discussion

Ovarian cancer is the most common cause of death from gynecological cancer. The lifetime risk of ovarian carcinoma for women in the United States is about 1.4% [14]. The type of surgery may be planned according to the individual patient's needs, age, parity, and desire for childbearing after the nature of tumor is known. Different morphological criteria and scores have been sug-

Table 5 Cross-tabulation of histopathologic diagnosis with sonographic morphology score using a cutoff value of 9

Tumor status	Sonographic morphology score		
	Positive (>9)	Negative (≤9)	Total
Malignant	22	0	22
Benign	8	20	28
Total	30	20	50

Sensitivity = 100% (22/22); specificity = 71.43% (20/28); positive predictive value = 73.33% (22/30); negative predictive value = 100% (20/20); $P<0.001$.

Table 6 Morphologic criteria used by Sassone and colleagues to predict ovarian malignancy [4]

Criterion	Score
Inner wall structure	
Smooth	1
Irregularities<3 mm	2
Papillarities>3 mm	3
Not applicable, mostly solid	4
Wall thickness	
<3 mm	1
>3 mm	2
Not applicable, mostly solid	3
Septa	
No septum = 1	
3 mm = 2	
<3 mm = 3	
Echogenicity	
Sonolucent = 1	
Low echogenecity = 2	
Low echogenicity with echogenic core = 3	
Mixed echogenicity = 4	
High echogenicity = 5	
Total highest score = 15	

gested to distinguish between benign and malignant adnexal masses [4,5,14].

In this study, ultrasonographic evaluation was done by means of the score devised by Sassone and colleagues [4] (Table 6). The sensitivity of SMS was 100% and the specificity was 71.43% when the cutoff value was higher than 9. If the cutoff value was higher than 10 it was a better indicator of malignancy, with a sensitivity of 100% and a specificity of 78.57%.

Gerardo Zanelta and colleagues [15] compared conventional ultrasonography plus measurement of cancer antigen 125 with CDI and found CDI to be more accurate in discriminating malignant from benign tumors. Since then, CDI has often been used as an additional tool to distinguish between benign and malignant ovarian tumors [16–21]. Angiogenesis and neovascularization in malignant tumors result in a high number of additional, atypical tumor vessels [22], which decreases flow resistance. Although the RI and PI of the Doppler waveform have been measured in ovarian tumors by several investigators, the use of CDI for routine diagnosis of ovarian tumors remains controversial. Some authors have suggested that CDI is more sensitive and specific than conventional sonography [5,15,18]; on the other hand, because of the overlap between benign and malignant ovarian tumors, others consider that they do not obtain additional information from CDI [15].

Several investigators have studied the RI and PI of color Doppler waveforms, using values from 0.4 to 0.8 as cutoffs for RI [8,13] and 1 to 1.25 as cutoffs for PI [5,15,16]. In the present study, of 28 benign tumors, 21 (75%) did not show any color flow because they were avascular; and in 3 malignant tumors, the color flow was not sufficient to calculate a PI and RI.

Whether the cutoff value chosen for PI was 1.1 or less than 1.0 did not affect sensitivity, specificity, PPV, or NPV. When the cutoff value for RI was similar to the studied RI value, i.e., 0.6 or less, sensitivity was 100%, specificity was 71.43%, PPV was 90.48%, and NPV was 100%.

The better index was found to be PI for discrimination between benign and malignant ovarian tumors because of its better specificity — which is explained by measuring the mean of many points in the waveforms. Individual sonographic values of RI and PI differ, but they almost coincided with the original cutoffs in this study.

The sensitivity of CDI in the literature ranges from 57% to 100% and its specificity from 53% to 97% [5,7,13,16,18]. In the present study, the overall sensitivity and specificity of PI were 100% and 85.72%, respectively. In the study of Benjapibal and colleagues published in 2002 [19], PI sensitivity was 82.9%, specificity was 80.8%, PPV was 65.9%, and NPV was 91.3%, which are less than those achieved in the present study. In this study, PI was less than 1.01 for 1 patient whose ovarian mass turned out to be inflammatory. All other tumors showing color flow and a PI less than 1.0 were malignant, there by indicating that a value less than 1.0 for PI can be considered a cutoff for malignancy.

In the present comparison of SMS sensitivity and specificity with those of PI and RI, the CDI indices were slightly better in specificity and sensitivity was the same [20]. Therefore, the overall efficiency in diagnosing the nature of tumors is very high if both SMS and CDI indices are used.

Power Doppler vascular sampling has been recently explored as a third step to discriminate benign and malignant adnexal masses in B-mode and CDI. It seems to be a promising tool for predicting ovarian cancer in vascularized complex adnexal masses [10]. Three-dimensional power Doppler imaging, however, does not seem to provide a better diagnostic than 2-dimensional power-Doppler imaging in the discrimination between complex benign and malignant adnexal masses [21,22].

5. Conclusion

When SMS specificity and sensitivity were compared with those of PI and RI obtained from CDI, sensitivity was found to 100% for both methods, and specificity to be the same for SMS and RI (71.43%) but better for PI (85.72%), thereby suggesting that CDI is better. Overall efficiency in diagnosing the nature of tumor is very high when both ultrasonography (SMS) and CDI are used in all patients with ovarian tumors. Hence, both methods should be combined to evaluate ovarian tumors, particularly in young women in whom conservative treatment could be possible.

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