Transvaginal Doppler ultrasound with colour flow imaging in benign and malignant ovarian lesions

W. SAWICKI - B. SPIEWANKIEWICZ
K. CENDROWSKI - J. STELMACHÓW

Summary: Since early detection of ovarian cancer is difficult, most cases are diagnosed at advanced stages. The imaging diganosis is based on pattern classification and is limited with respect to the precise determination of malignancy. High-frequency transvaginal sonography improves the ability to detect malignant ovarian tumors over that of transabdominal route, however, the predictive values are unsatisfactory because of inability to distinquish between malignant and benign tumors that have similar morphologic characteristics. The introduction of transvaginal colour flow imaging has allowed detection of low-resistance intratumoral blood vessels, characteristic of malignant tumors, and visually reflected the state of blood flow of an ovarian tumor.

These two ultrasonographic methods were used for diagnosis of ovarian tumors in 65 women treated in our Department of Obstetrics and Gynecology. Waveforms of the parenchymal tumor arteries or tumor surface arteries were compared using value of the resistance index (RI). The sensitivity, specificity and accuracy of the preoperative RI in detecting malignant ovarian tumors were 100%, 94%, 95.4% respectively. The sensitivity, specificity and accuracy of preoperative suspicious sonographic findings in detecting malignant ovarian tumors were 100%, 61% and 71%. Positive and negative predictive values of colour flow imaging were 85% and 100%, whereas for grey-scale transvaginal ultrasonography they were 46% and 100% respectively. The findings of this study suggest that transvaginal colour Doppler is a method which is superior to the other methods for preoperative evaluation of ovarian malignancy.

Key words: Doppler ultrasound; Ovarian lesions.

INTRODUCTION

Ovarian carcinoma still remains the most lethal of the gynecological malignancies and its incidence continues to rise with age ([31]). Since early detection of ovarian cancer is difficult, most cases are diagnosed at advanced stages. To discriminate between benign and malignant ovarian tumors several diagnostic methods have been introduced, including physical examinations, computed tomography scan ([8]), tumor markers such as CA 125 ([10, 11, 12]) and ultrasound ([9]). The imaging diagnosis is based on pattern classification and is limited with respect to the precise determination of malignancy.

The vaginal approach produces greater image resolution than the abdominal ([15]),

Received 1-8-1994 from the
I Department of Obstetrics and Gynecology
II Faculty of Medical Academy
Warsaw, Poland

Revised manuscript accepted for publication 30-9-1994.

thus allowing detailed morphologic assessment of ovarian masses. However, the predictive values are unsatisfactory because of the frequent inability to distinquish between malignant and benign tumors that have similar morphologic characteristics.

Transvaginal Doppler ultrasound with colour flow imaging allows detection of low-resistance intratumoral blood vessels, characteristic of malignant tumors ([16, 17]). It is possible to demonstrate colour flow even in small vascular branches within tissues in pathological condition ([16, 24]). Being very thin and randomly dispersed within the tissue, such vessels are difficult to find unless transvaginal colour Doppler in used. Transvaginal colour flow mapping allows us to identify potentially malignant ovarian masses and helps to elucidate the early stages of tumorigenesis. The functional behavior of the organ can be investigated by observation of hemodynamic characteristics. Quantification of colour flow can be performed by pulsed Doppler waveform analysis of signals obtained from the "hot" colour-coded area within masses. The peak-systolic and end-diastolic Doppler shift frequency can be recorded and the Pourcelot resistance index may be calculated ([7]). The Pourcelot resistance index (RI) is a useful method of expressing blood flow impedance distal to the point of sampling ([21]). It is believed that an increased value of the RI results from increased peripheral vascular resistance ([22]).

In this study we detected blood flow on the surface and in the parenchyma of ovarian tumors, and evaluated the relationship between the waveforms of the arteries and malignancy of the ovarian tumors. We studied the accuracy of transvaginal colour flow imaging for predicting the malignancy of ovarian tumors and compared the results with those obtained by transvaginal grey-scale ultrasonography.

MATERIALS AND METHODS

We studied 65 women with ovarian tumors hospitalized in our Gynecologic & Obstetric Department. Their ages ranged from 21 to 79 years, mean 46.2. Details on the size and morphology of the tumors, the presence of neovascularization, and the characteristics of intratumoral blood flow velocity waveforms were assessed by transvaginal grey-scale ultrasound (Siemens Sonoline AC) using 6.0 MHz transducer and transvaginal pulsed colour Doppler ultrasound (Bruel-Kjaer) using 5.0 MHz probe. All women were examined in the lithotomy position with an empty urinary bladder. Ultrasonographic pattern was determined according to the modified ultrasonographic classification of ovarian tumors ([14]).

Suspicious sonographic findings consisted of papillae, septa, daughter cysts, solid tumors, and loculations ([18]) (Table 1).

After visualizing the ovarian tumor, we inquired into colour signals and then blood flow velocity waveforms were recorded by activating the pulsed Doppler over the coloured vessel.

To assess the impedance of blood flow the Pourcelot resistance index (RI), defined as the difference between peak-systolic and end-diastolic flow velocity divided by peak-systolic flow velocity, was calculated ([7]). At least five separate cardiac cycles were observed and the mean value of the RI was calcuated.

Table 1. – *Ultrasonographic classification of ovarian tumors.*

Benign pattern:

1) Simple cyst without internal echo
2) Simple cyst with scattered echoes
3) Polycystic echoes
4) Polypoid smooth mural echoes
5) Central dense round echoes
6) Thin or thick multiple linear echoes
7) Thin or thick multiple linear echoes with dense part
8) Polycystic echoes with thick septa

Malignant pattern:

9) Cystic echoes with papillary or indented part
10) Polycystic echoes with irregularly thick
11) Solid pattern (solid part >50%) heterogenous component with irregular cystic part
12) Completely solid with homogenous component

The sensitivity, specificity, accuracy, positive and negative predictive values for detecting the malignancy of ovarian tumors were determined separately for both methods: transvaginal colour flow imaging and transvaginal gray-scale ultrasound.

The final verification of investigated ovarian tumors was supported on postoperative histological examination according to the World Health Organization classification [13].

RESULTS

Forty nine women had benign (including one interligamentous myoma, preoperatively diagnosed as solid ovarian tumor) and sixteen had malignant ovarian tumors on histopathologic examination. The mean age was 41 years (range 21-74) in benign disease subjects and 49 years (range 21-79) for malignant. The mean maximum tumor diameter was 9.9 cm (range 4-30) in benign and 13.5 cm (range 4-20) in malignant disease.

By colour Doppler we succeded to state blood vessels in all cases of benign and malignant ovarian tumors, though in most of benign lesions they were located on its surface, whereas in malignant they were in parenchyma or inside septa. Most of these blood vessels could not be detected by transvaginal pulsed Doppler ultrasound without use of the colour mode.

Figure 2 gives the relationship between RI, ultrasonographic pattern and histologic findings. Low-resistance blood vessels (RI less than 0.4) were demonstrated in all 16 (100%) subjects with malignant and in 3 of the 49 (6%) benign ovarian tumors (i.e.: dermoid cyst-1, hemorrhagic ovarian cyst-1, pyosalpinx-1). The malignant pattern on ultrasonogram showed 19 of 49 (39%) benign ovarian lesions. The RI was greater than 0.4 in 46 of the 49 (94%) benign tumors, even when suspicious sonographic findings were obtained.

Table 3 shows the Pourcelot resistance index in each type of ovarian malignancy.

Table 2. – *Characteristics of benign and malignant ovarian tumors.*

Histopatology	(n)	Resistance Index RI <0.4	Suspicious sonographic findings
Benign serous cystadenoma	(24)	0	7
Benign mucinous cystadenoma	(2)	0	0
Endometriotic cyst	(6)	0	4
Dermoid cyst	(5)	1	3
Hemorrhagic ovarian cyst	(5)	1	1
Pyosalpinx	(4)	1	3
L.U.F. (luteinized unruptured follicle)	(1)	0	0
Ovarian fibroma	(1)	0	1
Interligamentous myoma	(1)	0	0
Serous cystadenocarcinoma	(5)	5	5
Mucinous cystadenocarcinoma	(4)	4	4
Endometrioid carcinoma	(4)	4	4
Adenosquamous carcinoma	(1)	1	1
Microfocal cystadenocarcinoma (infiltration of endometrial carcinoma)	(1)	1	1
Dysgerminoma	(1)	1	1

Table 3. – *Pourcelot resistance index (RI) in ovarian malignancy.*

Type of ovarian cancer	n	RI
Serous cystadenocarcinoma	5	0.31 ± 0.02
Mucinous cystadenocarcinoma	4	0.29 ± 0.02
Endometrioid carcinoma	4	0.36 ± 0.03
Adenosquamous carcinoma	1	0.37
Microfocal cystadenocarcinoma (infiltration of endometrial carcinoma)	1	0.32
Dysgerminoma	1	0.29

Table 4 lists the test statistics calculated for each of the two sonographic methods. High sensitivity (100%) specificity (94%) and accuracy (95.4%) characterized the RI, whereas grey-scale sonography carried a high sensitivity (100%) but relatively

Table 4. – *Sensitivity, Specificity, Accuracy, Negative and Positive Predictive Values of Sonographic Findings and Pourcelot Resistance Index in Detecting Malignant Ovarian Tumors.*

	Pourcelot resistance index	Sonographic findings
Sensitivity	100%	100%
Specificity	94%	61%
Accuracy	95%	71%
Negative predictive value	100%	100%
Positive predictive value	85%	46%

low specificity (61%) and accuracy (71%). The positive predictive value was high for colour imaging (85%), but low for suspicious sonographic findings (46%).

DISCUSSION

Transvaginal ultrasonography is widely used in examinations for ovarian cancer, and is now becoming a valuable tool for mass screening ([9]). It allows the detailed assessment of characteristic morphologic features of ovarian masses. Therefore high-frequency transvaginal sonography improves the ability to detect malignant ovarian tumors over that of the transabdominal route. According to Rodriquez & Platt ([1]) and Nocera ([2]) sensitivity of endosonography in detection of ovarian malignancy depends on cancer type and oscillates from 60 to 90%. False positive results arise from morphological similarity of some malignant and benign lesions. The authors pay special attention to common "ultrasonic" features of serous or mucinous cancer and myomas with degenerative changes, inflammatory pseudocyts, pyosalpinx and endometriotic or dermoid cysts. This affects a real reduction of diagnostic sensitivity and specificity of that method. On the other hand its great usefulness in screening examinations for ovarian cancer, through ovarian volume measurement in postmenopausal women is well known ([3, 4, 5, 6]). However there are some critical voices raised on that matter. The small size and location of the typical postmenopausal ovary often makes sonography difficult. The ovary in the postmenopausal woman average less than 1.5 cm in size and 2 cm^3 in volume and is frequently located deep in the bowel ([4]). Fleischer ([32]) by endosonography was able to delineate preoperatively only about 20% of normal postmenopausal ovaries. This indicates possible limits to the accuracy of identifying early tumors as textural abnormalities within normal sized ovaries. Additionally, the sonographic appearance of the tumor does not always correlate with its histological composition ([33]). A study of 150 masses in postmenopausal women shows only 3% malignancy in lesions less that 5 cm in size ([34]). Therefore investigations of new methods that could state the diagnosis more precisely are understandable.

Kurjak *et al.* ([16, 23, 24, 25, 26,, 27]) and Zalud and Kurjak ([28]) were the first to report that transvaginal colour flow imaging can be used in the assessement of pelvic circulation, and to differentiate between benign and malignant pelvic tumors. They examined 147 cases of ovarian tumors ([20]). In all 23 cases of malignant ovarian tumor, the colour flow imaging was detectable and the resistance index was 0.25 - 0.40. They reported that accuracy of this new diagnostic procedure was 99.3%. In the other study ([29]) they stated presence of neovascularization in almost all of 56 malignant ovarian tumors. All malignant tumors had a resistance index lower than 0.40 and all benign tumors had RI higher than 0.40. One false-positive findings was obtained in the inflammatory pseudocyst (RI = 0.39).

Bourne *et al.* ([17]) reported that this method can be used to differentiate between primary ovarian cancer and other forms of benign pelvic masses. In their study they showed that in seven of eight cases of ova-

rian cancer there were low-resistance blood vessels within the lesion.

Because tumor growth is dependent on blood supply, it is evident that tumors induce new blood vessels. In most cancers, there is vessel proliferation which was not formerly identified until colour Doppler imaging was introduced. Malignant neoplasms have vessels with low resistange-high flow. Folkman *et al.* ([19]) showed that tumor angiogenesis factor (TAF) is essential for the promotion of neovascularization in malignant lesions. Newly formed vessels are large capillaries (endothelial-lined capillary-like channels), or sinusoids, and contain no smooth muscle in their walls, but only some fibrous connective tissue. Another alteration in malignancy is the presence of arteriovenous shunting, that may result from a large, focal, direct communication ([30]), or may reflect multiple microscopic communications in the abnormal tumor microcirculation. Since most of the resistance to flow depends on the level of the muscular arterioles, vessels poor in these muscular elements present diminished resistance to flow and therefore receive a larger volume of flow than vessels with a high impedance.

In agreement with all referred authors, the findings of this study suggest that transvaginal colour Doppler is a method which can offer the high sensitivity, specificity, accuracy, positive and negative predictive values and is superior to the other methods for preoperative evaluation of ovarian malignancy. Transvaginal ultrasound accurately identifies significant morphological changes of an ovarian enlargement. Colour flow Doppler helps to identify the presence of abnormal blood vessels, measures the systolic-diastolic flow components, and through that differentiates vessels into high- and low-resistance and can diagnose more accurately the benign or malignant nature in those cases that are difficult to diagnose by ultrasonographic pattern classification.

REFERENCES

1) Rodriquez M. H. *et al.*: *Am. J. Obst. Gyn.*, 1988, *159,* 810.
2) Nocera R. M. *et al.*: "Cystic parametrial fibroids mimicking ovarian cystadenoma". *J. Ultr. Med.,* 1984, *3,* 183.
3) Andolf E. G. M.: "Sonography of the female pelvis wit hemphasis on ovarian tumors". *Diss. Abstr. Int. C.,* 1989, *50 (3),* 485.
4) Grandberg S. *et al.*: "Comparison between endovaginal and transabdominal transducers for measuring ovarian volume". *J. Ultr. Med.,* 1987, *6 (11),* 649.
5) Higgins R. V. *et al.*: "Transvaginal sonography as a screening method for ovarian cancer". *Gyn. Oncol.,* 1989, *34 (3),* 402.
6) Van Nagel J. R. *et al.*: "Transvaginal sonography as a screening method for ovarian cancer". *Cancer,* 1990, *65 (3),* 573.
7) Thompson R. S. *et al.*: "Doppler ultrasound waveformindices: A/B ratio, pulsatility index and Pourcelot ratio". *Br. J. Obst. Gyn.,* 1988, *95,* 581.
8) Kormano M. *et al.*: "Predicting malignancy of suspected ovarian tumors by CT". *Eur. J. Radiol.,* 1984, *4,* 61.
9) Campbell S. *et al.*: "Transabdominal ultrasound screening for early ovarian cancer". *Br. Med. J.,* 1989, *299,* 1363.
10) Bast R. C. *et al.*: "Reactivity of a monoclonal antibody with human ovarian carcinoma". *J. Clin. Invest.,* 1981, *68,* 1331.
11) Bast R. C. *et al.*: "A radioimmunoassay using a monoclonal antibody to monitor the course of epithelial ovarian cancer". *N. Engl. J. Med.,* 1983, *309,* 883.
12) Kuzuya K. *et al.*: "Evaluation of CA-125 as a circulating tumor marker for ovarian cancer". *Acta Obst. Gyn. Jpn.,* 1986, *38,* 949.
13) Serov S. F. *et al.*: "Histological typing of ovarian tumors: international histological classification of tumors, no. 9". Geneva, World Health Organization, 1973.
14) Vera M. T. *et al.*: "Ultrasonic evaluation and classification of ovarian tumors. Asia Oceania". *J. Obst. Gyn.,* 1986, *12,* 89.
15) Timor-Tritsch I. E. *et al.*: "The technique of transvaginal sonography with the use of a 6.5 MHz probe". *Am. J. Obst. Gyn.*, 1988, *158,* 1019.
16) Kurjak A. *et al.*: "Transvaginal colour Doppler imaging". *JCU,* 1990, *18,* 227.
17) Bourne T. *et al.*: "Transvaginal colour flow imaging. A possible new screening for ovarian cancer". *Br. Med. J.,* 1989, *299,* 1367.

18) Rottem S. *et al.:* "Classification of ovarian lesions by high frequency transvaginal sonography". *JCU,* 1990, *18,* 359.
19) Folkman J. i wsp.: "Induction of angiogenesis during the transition from hyperplasia to neoplasia". *Nature,* 1989, *339,* 58.
20) Kurjak A. *et al.:* "Transvaginal colour flow imaging and ovarian cancer (letter)". *Br. Med. J.,* 1990, *300,* 330.
21) Pourcelot L.: "Application clinique de l'examen Doppler transcutane". In: Perroneau 'Velocimetre ultrasonore doppler'. 1974, vol. 34, pp. 213-40.
22) Kujak A. *et al.:* "Conventional and colour Doppler in the assessment of fetal and maternal circulation". *Ultrasound Med. Biol.,* 1988, *14,* 337.
23) Kurjak A. *et al.:* "Transvaginal colour Doppler for the assessment of pelvic circulation". *Acta Obest. Gyn. Scand.,* 1989, *68,* 131.
24) Kurjak A. *et al.:* "The assessment of abnormal pelvic blood flow by transvaginal colour Doppler". *Ultras. Med. Biol.,* 1990.
25) Kurjak A. *et al.:* "Early diagnosis of ovarian tumors: transvaginal colour Doppler ultrasound". ECO Italia 89, Napoli, 1989 October 2-7, Abstr. p. 189.
26) Kurjak A.: "Transvaginal colour Doppler in the detection of ovarian malignancy". The 7th Congress of the Eur. Feder. of Societies for Ultras. in Med .and Biol., Jerusalem, May 6-11, Abstr. p. 91.
27) Kurjak A. i wsp.: "Transvaginal colour Doppler". Handbook of Ultrasound in Obst. and Gynecol., 1990, vol. 2, pp. 305-12.
28) Zalud I., Kurjak A.: "The assessment of luteal blood flow in pregnant and non-pregnant women by transvaginal colour Doppler". *J. Perinat. Med.,* 1990, *18,* 215.
29) Kurjak A.: "Transvaginal Colour Doppler. A comprehensive guide to transvaginal colour Doppler sonography in obstetrics and gynecology". The Parthenon Publishing Group. Lancs, New Jersey, 1991, p. 113.
30) Okuda G. *et al.:* "Angiographic demonstration of intrahepatic arterioportal anastomoses in hepatocellular carcinoma". *Radiol.,* 1977, *122,* 53.
31) Dykes P. *et al.:* "Radioimmunotherapy of cancer: clinical studies and limiting factors". *Cancer Treat. Rev.,* 1987, *14,* 87.
32) Fleischer A. C.: "Transvaginal sonography helps find ovarian cancer". *Diagn. Imaging.,* 1988, *10,* 124.
33) Moyle J. W., *et al.:* "Sonography of ovarian tumors: predictability of tumor type". *Am. J. Rentgenol.,* 1983, *141,* 985.
34) Rulin M. C., *et al.:* "Adnexal masses in postmenopausal women". *Obst. Gyn.,* 1987, *70,* 578.

Address reprint requests to:
J. STELMACHÓW
Medical Academy in Warsam
Dept. Obst/Gyn. Kondrakowicza, 8
03242 Warsaw (Poland)