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The 'lead vessel': a vascular ultrasound feature of metastasis in the ovaries

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ABSTRACT

Objective *To investigate, in a series of metastatic and primary invasive ovarian lesions examined by color Doppler, the prevalence of a main peripheral vessel penetrating into the central part of the ovarian mass with a tree-shaped morphology, defined as the 'lead vessel'.*

Methods *This was a retrospective study of 31 patients with histopathologically confirmed metastatic involvement of the ovary and 106 patients with confirmed primary invasive ovarian carcinoma, who had undergone standardized ultrasound examination, with established definitions of ultrasound characteristics. We retrieved sonographic images and videoclips, focusing on the detection of the lead vessel.*

Results *The presence of the lead vessel was detected in 11/31 (35.4%) metastatic ovarian tumors, and in only two (0.01%) cases of primary ovarian carcinoma ($P = 0.0001$). At color Doppler analysis, metastatic ovarian lesions were characterized by significantly lower pulsatility index ($P = 0.0001$) and resistance index ($P = 0.0001$) values, and significantly higher peak systolic velocity ($P = 0.0002$) and time-averaged maximum velocity ($P = 0.04$) values, when compared with primary ovarian carcinomas. The lead vessel was detected in 11/21 (52%) solid metastatic lesions and in no cases of multilocular or multilocular-solid lesions ($P = 0.008$).*

Conclusion *The lead vessel is a novel sonographic feature of vascular morphology in solid ovarian metastases. The more frequent observation of this feature in metastatic ovarian tumors compared with primary invasive ovarian carcinomas warrants further investigation in order to explore its potential role in the diagnosis of metastatic ovarian masses.*

INTRODUCTION

It is not rare to encounter metastasis in the ovaries, with 5–20% of ovarian malignancies representing a secondary localization of a primary tumor from another site[1–3]. Discrimination of primary ovarian cancer and a metastatic tumor in the ovary is clinically important, because their management is different; for instance, surgical cytoreduction is of the utmost importance in the treatment of primary ovarian cancer, while the impact of surgery on the clinical outcome of ovarian metastases is controversial[4,5].

The preoperative diagnosis of metastatic ovarian tumors is challenging, and the information deriving from a patient's history and clinical and imaging examinations, despite sophisticated techniques, is unable to provide a sufficiently accurate diagnostic assumption[6]. Differences in ultrasound findings between primary ovarian malignancies and ovarian metastases have been described in several studies[6–12], but no specific sonographic features characterizing metastatic lesions have been reported. In these studies, metastases in the ovaries were found to be predominantly or purely solid. We recently reported[13] that ovarian metastases from stomach cancer, breast cancer, lymphoma and uterine cancer are solid in almost all cases, whereas metastases derived from colorectal and biliary tract carcinomas show more heterogeneous morphological patterns, the majority of lesions exhibiting multilocular morphology, with several locules and irregular borders.

As far as vascularization is concerned, there seems to be no definitive data in the literature characterizing metastatic lesions in the ovary[8–11]: in the International Ovarian Tumor Analysis (IOTA) series[13], most (78%) metastases appeared to be well-vascularized at color or power Doppler ultrasound examination, although no difference in the distribution of vascular indices according

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to the origin of the primary tumor has been documented. At Color Doppler examination, we have occasionally observed that cases of metastases to the ovaries are characterized by a main peripheral vessel which penetrates into the central part of the ovarian mass with a tree-shaped morphology. These observations prompted us to conduct a thorough investigation of the prevalence of this feature in a series of metastatic and primary invasive ovarian lesions.

SUBJECTS AND METHODS

Included in this retrospective study were 31 consecutive patients with histopathologically confirmed metastatic involvement of the ovary from different primary tumors, and 106 with confirmed primary invasive epithelial ovarian carcinoma. Borderline ovarian tumors, recurrences of primary ovarian tumors and primary peritoneal extraovarian tumors were not included in this series. All patients were enrolled at the Gynecology Oncology Unit of the Catholic University of Sacred Heart in Rome between January 2000 and January 2006 and their ovarian masses were analyzed by ultrasound examination according to the IOTA criteria[14]. We retrieved sonographic images and videoclips from the sonographic database, focusing on the detection of one specific sonographic vascular feature: a major vessel penetrating from the periphery into the central part of the ovarian mass in a tree-shaped morphology, defined as the 'lead vessel'. Clinical and histopathological data were collected from clinical charts.

Sonographic examinations were performed by an experienced operator (A.C.T.) using commercially available equipment (ESAOTE, Technos, Genova, Italy) with color and power Doppler capabilities. Transabdominal and transvaginal examinations were performed in all cases. Transabdominal examination was performed with a 3.5–5.0-MHz convex transducer, and transvaginal examination with a 9.0–5.0-MHz broadband transducer. The examination technique and the terms and definitions used were as standardized and described in a previous publication[15]. Ovarian lesions were classified as unilocular, unilocular-solid, multilocular, multilocular-solid or solid. The external margins of the lesions were analyzed retrospectively on the basis of the stored images and videoclips.

For color Doppler examination, standardized settings were used, and a subjective semiquantitative assessment of the amount of detectable blood flow within each tumor was made using a color score: a color score of 1 was given when no color could be detected in the lesion, a score of 2 was given when only minimal color could be detected, a color score of 3 was given when a moderate amount of color was present, and a color score of 4 was given when the tumor appeared highly vascularized[14]. When color Doppler signals were detected, the ultrasound examiner tried to identify the tumoral artery with the highest blood flow velocity. To achieve this, the color Doppler sensitivity was reduced by increasing the pulse repetition frequency until only one vessel was detectable. Pulsed Doppler examination of this vessel enabled spectral analysis of the blood flow. The pulsatility index (PI), resistance index (RI), peak systolic velocity (PSV) and time-averaged maximum velocity (TAMXV) were recorded.

Statistical analysis

In cases of metastatic disease to both ovaries, the mass with the most heterogeneous echogenicity, or the largest mass if the sonographic appearance was similar, was selected for statistical analysis. We used Fisher's exact test for proportions and the Mann–Whitney rank sum test for non-parametric data. Tests were two-sided, and $P < 0.05$ was considered statistically significant. The analysis was performed using the SPSS 9.0 statistical package (SPSS Inc, Chicago, IL, USA).

RESULTS

A total of 137 patients was considered for analysis. The median age was 56 (range, 25–87) years. The 106 primary invasive ovarian carcinomas included 93 epithelial ovarian tumors, 12 sex-cord stroma tumors, and one case of germ cell tumor. The FIGO stage[16] of the primary epithelial ovarian tumors was Stage I in 25 cases (27%), Stage II in six cases (6%), and Stage III–IV in 62 (67%) cases. In the 31 cases with metastatic disease in the ovary, the primary tumor was located in the colorectum in six cases, the stomach in 11, the appendix in one, the biliary tract in five, the pancreas in one, the endometrium in three and the breast tissue in two, and corresponded to lymphoma in two cases. Overall, ovarian masses were associated with the presence of ascites in 35% of cases. At surgery, 49 (36%) patients were found to have bilateral ovarian lesions; in seven (14%) of these, this was not detected at the preoperative ultrasound examination.

Figure 1 shows two representative examples of the sonographic appearance of the lead vessel, i.e. a major vessel penetrating from the periphery into the central part of the ovarian mass with a tree-shaped morphology. The distribution of this peculiar vascular feature and other sonographic characteristics in primary and secondary neoplastic lesions of the ovary is shown in Tables 1 and 2. Presence of the lead vessel was detected in 11/31 (35.4%) metastatic tumors, and in only two (0.01%) cases of primary ovarian carcinoma ($P = 0.0001$); in these two cases, histology indicated serous ovarian carcinoma and ovarian fibrosarcoma.

At Color Doppler analysis, the color score was not significantly different between the two groups, with a color score >2 being documented in 60/106 (57%) cases of primary tumor and in 23/31 (74%) cases of metastatic tumor. Metastatic ovarian lesions were characterized by significantly lower PI ($P = 0.0001$) and RI ($P = 0.0001$) values, and significantly higher PSV ($P = 0.0002$) and TAMXV ($P = 0.04$) values, when compared with primary ovarian carcinomas.

Among the ultrasound findings, only the type of the mass and the presence of papillary projections showed

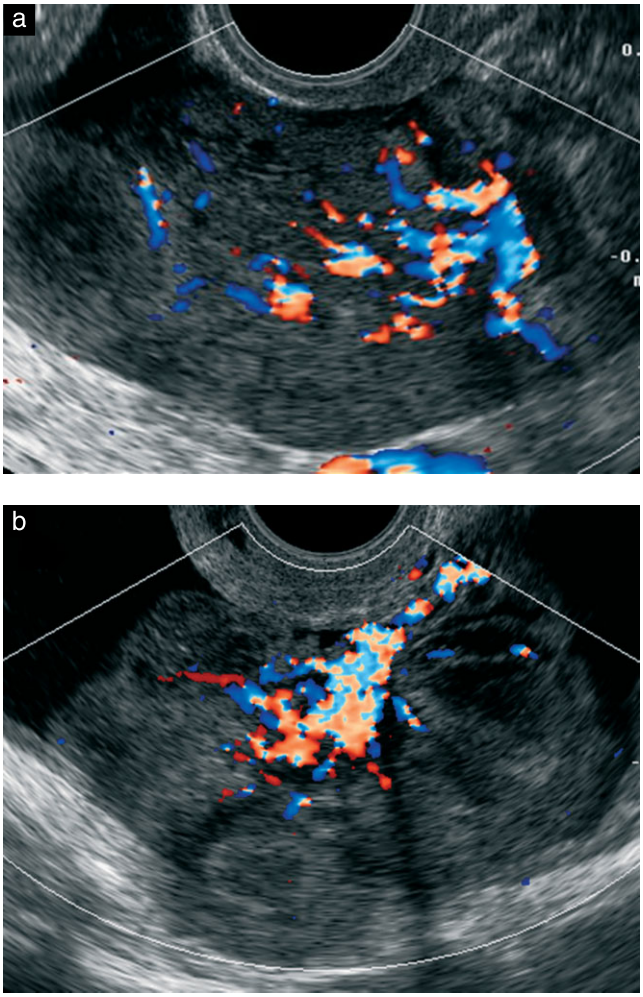

Figure 1 Color Doppler images from two patients with ovarian metastasis from a gastric tumor. A main vessel exhibiting a tree-shaped morphology, and penetrating from the periphery into the central part of the ovarian mass, is visible.

a statistically significant difference in distribution in primary ovarian cancer versus metastatic ovaries: in particular, there was a higher prevalence of multilocular morphology in metastatic compared with primary ovarian tumors, which conversely were more frequently characterized by a multilocular-solid phenotype; and papillary projections were observed more frequently in cases of primary ovarian tumor.

We analyzed whether the presence of a lead vessel in metastatic ovarian lesions was associated with the histology of the primary tumor or the ultrasound-derived characteristics of the ovarian masses. The lead vessel was detected more frequently in ovarian metastases derived from stomach (6/11, 54%), breast (2/2, 100%) and lymph nodes (2/2, 100%) than it was from colorectum, biliary tract, pancreas and endometrial cancer (0/15). The lead vessel was detected in 11/21 (52%) solid metastatic lesions and in no cases of multilocular or multilocular-solid lesions ($P = 0.008$).

DISCUSSION

We have described a novel sonographic feature of vascular morphology in solid ovarian metastases: a major vessel penetrating from the periphery of the lesion into the inner part of the mass, which we have defined as the 'lead vessel'. This sonographic parameter was present in approximately one third of metastatic tumors, while it was identified in only 0.01% of primary ovarian tumors. This observation could be helpful in the diagnosis of metastatic ovarian masses, because there are currently no specific sonographic parameters for differentiating these from primary invasive ovarian tumors[7,8,12]. So far, only the prevalence of solid morphology has been reported to be higher in metastatic vs. primary invasive ovarian carcinomas[8,12].

We also found that all masses in which the lead vessel was identified appeared solid. It is difficult to explain why the lead vessel was not detectable in metastatic masses with multilocular morphology; it is possible that the architecture of the lesion (a grouping of cystic concamerations) may prevent its visualization.

The more frequent detection of the lead vessel in ovarian metastases from stomach, breast and lymph nodes is likely to reflect the association between specific primary tumor histotype and the ultrasound-evaluated solid morphology of the ovarian lesions, as previously reported by the IOTA group[13].

At present, we are unable to explain why the lead vessel was detected only in solid metastatic disease. We also cannot provide evidence that the lead vessel represents the ovarian pedicle (which is hardly detectable

Table 1 Color Doppler findings of primary invasive ovarian tumors and metastatic tumors in the ovaries

Color Doppler finding	*Primary invasive ovarian carcinoma* (n = *106*)	*Metastatic tumors in the ovaries* (n = *31*)	P
Presence of 'lead vessel' (*n* (%))	2 (0.01)	11 (35.4)	0.0001
Color score (*n* (%))			
1–2	46 (43.4)	8 (25.8)	NS
3–4	60 (56.6)	23 (74.2)	
Pulsatility index (median (range))*	0.70 (0.29–3.07)	0.53 (0.36–0.83)	0.0001
Resistance index (median (range))*	0.49 (0.25–1.00)	0.40 (0.2–0.55)	0.0001
Peak systolic velocity (cm/s, median (range))*	17.7 (5–60)	29.1 (9–66)	0.0002
Time-averaged maximum velocity (cm/s, median (range))*	11.6 (3–48)	21.3 (5–44)	0.04

*Calculated in cases with color score >1. NS, not significant.

Table 2 Ultrasound findings of primary invasive ovarian tumors and metastatic tumors in the ovaries

Ultrasound finding	*Primary invasive ovarian carcinoma (n = 106)*	*Metastatic tumors in the ovaries (n = 31)*	P
Diameter of mass (mm, median (range))	95.5 (12–280)	104 (44–220)	NS
Type of mass (*n* (%))			*
Unilocular	2 (1.9)	0	
Unilocular-solid	7 (6.6)	0	
Multilocular	2 (1.9)	6 (19.3)	
Multilocular-solid	40 (37.7)	4 (13.0)	
Solid	55 (51.9)	21 (67.7)	
Presence of irregular margins (*n* (%))	94 (88.7)	25 (81.0)	NS
Echogenicity of cyst fluid (n (%))			
Anechoic	7 (6.6)	3 (9.7)	
Low level	29 (27.4)	11 (35.5)	
Ground glass	13 (12.3)	0	
Mixed	3 (2.8)	1 (3.2)	
No cyst fluid	54 (50.9)	16 (51.6)	
Papillary projections present (*n* (%))	20 (18.9)	1 (3.0)	0.04
Bilaterality (*n* (%))	29 (27.3)	13 (41.9)	NS

*Solid masses vs. non-solid masses: not significant; multilocular vs. other type of mass: $P = 0.002$. NS, not significant.

in normal ovaries) or is the result of an exuberant tumor-derived neangiogenetic process. However, the existence of a sonographic 'marker' of metastatic involvement of the ovary might represent an important step towards the preoperative characterization of metastatic ovarian masses. In particular, this sonographic feature could be analyzed prospectively in order to assess its potential usefulness to solve difficult diagnoses such as those represented by solid ovarian masses.

In conclusion, we present the first description of a new finding whose potential role in the characterization of metastatic ovarian masses warrants investigation in a larger series.

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