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MV-Flow™ and its quantitative Vascular Index (VI) for differential diagnosis of benign or malignant adnexal mass

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Introduction

· Background

Ovarian cancer ranks seventh among cancers affecting women globally and is the eighth leading cause of cancer-related deaths[1]. Ultrasound(US) is the preferred initial imaging modality for screening ovarian-adnexal tumors[2,3]. Color Doppler can visualize tumor blood flow, and Pulsed wave(PW) Doppler with a resistance index(RI) ≤ 0.4 indicates a higher likelihood of malignancy[4]. However, Doppler technology has limitations regarding blood flow velocity and angles. Contrast-enhanced ultrasound (CEUS) offers greater sensitivity and accuracy in distinguishing between benign and malignant ovarian tumors compared to conventional grayscale and Doppler US, albeit with lower specificity[5]. Furthermore, CEUS is costlier, requires extended observation periods, and carries potential risks of adverse reactions. MV-Flow™ is the technique that detects microvascular flow undetectable by conventional Doppler imaging. Unlike color or power Doppler, where low-velocity blood flow can be mistaken for background tissue or noise, MV-Flow™ offers suitable sensitivity and resolution by suppressing tissue noise. Meanwhile, MV-Flow™ offers a semi-quantitative measuring tool, the Vascularity Index(VI^{MV}). VI^{MV} is a ratio of the MV-Flow™ pixels(or area) to the total pixels(or area) in the region of interest(ROI). It represents the abundance of blood vessels within the ROI. In the absence of a standardized criterion for MV-Flow™ interpretation, VI^{MV} can serve as a useful judgment index for evaluating MV-Flow™ findings. Ultimately, MV-Flow™ excels in detecting microvascular flow within tissues and organs, surpassing the capabilities of conventional Doppler technology.

· Purpose

The purpose of this study was to observe the value of MV-Flow™ for differential diagnosis of ovarian-adnexal masses.

Methods

· Study design and population

The study was performed under ethics approval from Institutional Clinical Research Ethics Committee of the First Affiliated Hospital of Xinjiang Medical University. Written informed consent was obtained from all participants.

From June 2021 to July 2022, a total of 107 patients with ovarian-adnexal masses who were treated at this hospital were included. The inclusion criteria are: ① Ovarian-Adnexal Reporting and Data System (O-RADS) diagnosed as category 2 to 5[6]; ② no treatment before the transvaginal US examination; ③ within 7 days before the operation; ④ definitive diagnosis could be confirmed by surgical pathology or by follow-up.

· Ultrasound parameters acquisition

All patients underwent transvaginal US examination and MV-Flow™ imaging by two US doctors who had more than 8 years practicing experience in obstetrician and gynecologic sonography, using Samsung HERA W10 diagnostic ultrasound system with a transvaginal probe EV3-10B.

The patient lies supine on the examination table. The uterus and adnexa were scanned from multiple planes and angles. When lesions were present in both adnexal regions, if their US appearances were similar, the one with the larger maximum diameter or more complex sonographic features was selected for analysis; if different, each was included separately.

First, routine US examination of the mass was performed and the mass was categorized according to O-RADS. Then MV-Flow™ images were retained from areas with abundant blood flow (Figure 1.a). The US doctors outlined the largest area of the tumor using Manual Trace to obtain its VI^{MV} value (Figure 1.b). If the tumor is too large and exceeds the probe's scanning range, the area with the most abundant blood flow should be displayed, and the lesion's maximum area should be marked as much as possible. For complex cystic tumors, if the echogenicity of solid component within was < 50%, then measure the VI^{MV} of the solid component (Figure 2.a). If the solid component has an echogenicity ≥50%, then measure the VI of the entire tumor (Figure 2.b). Each US doctors measured each lesion at least 3 times, and selected the maximum VI^{MV} from the respective measurements as the result.

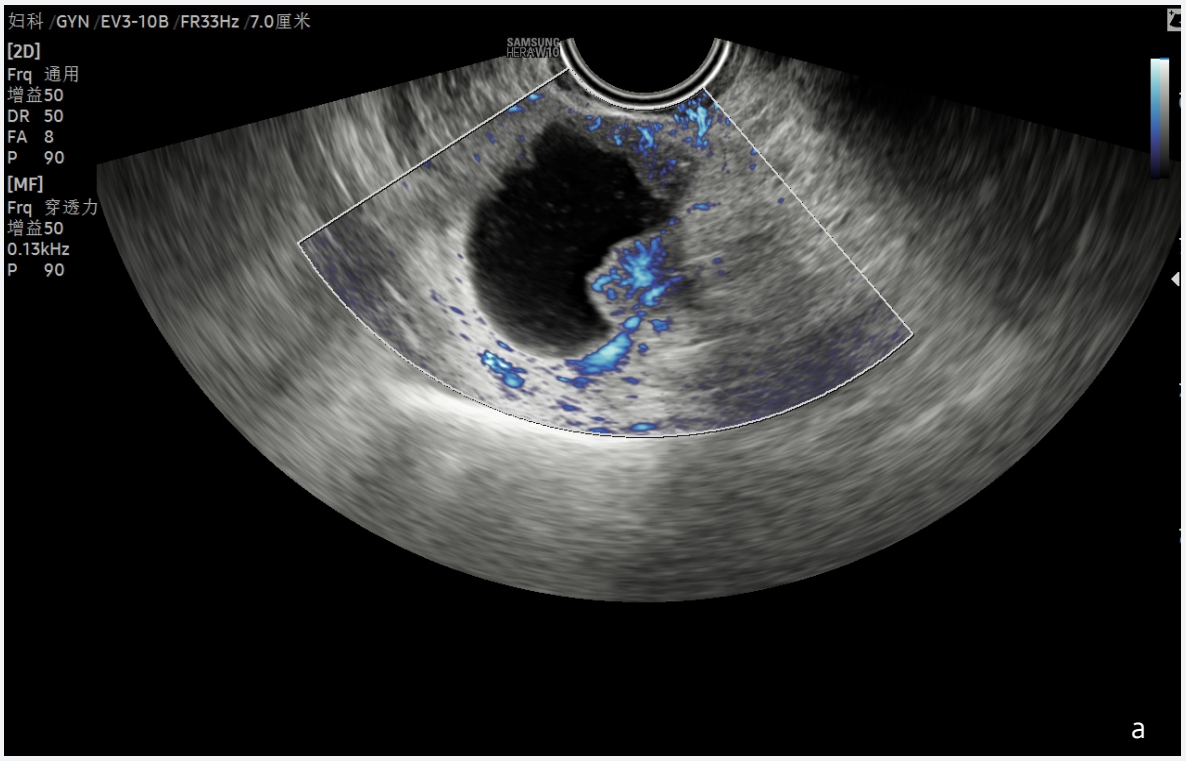
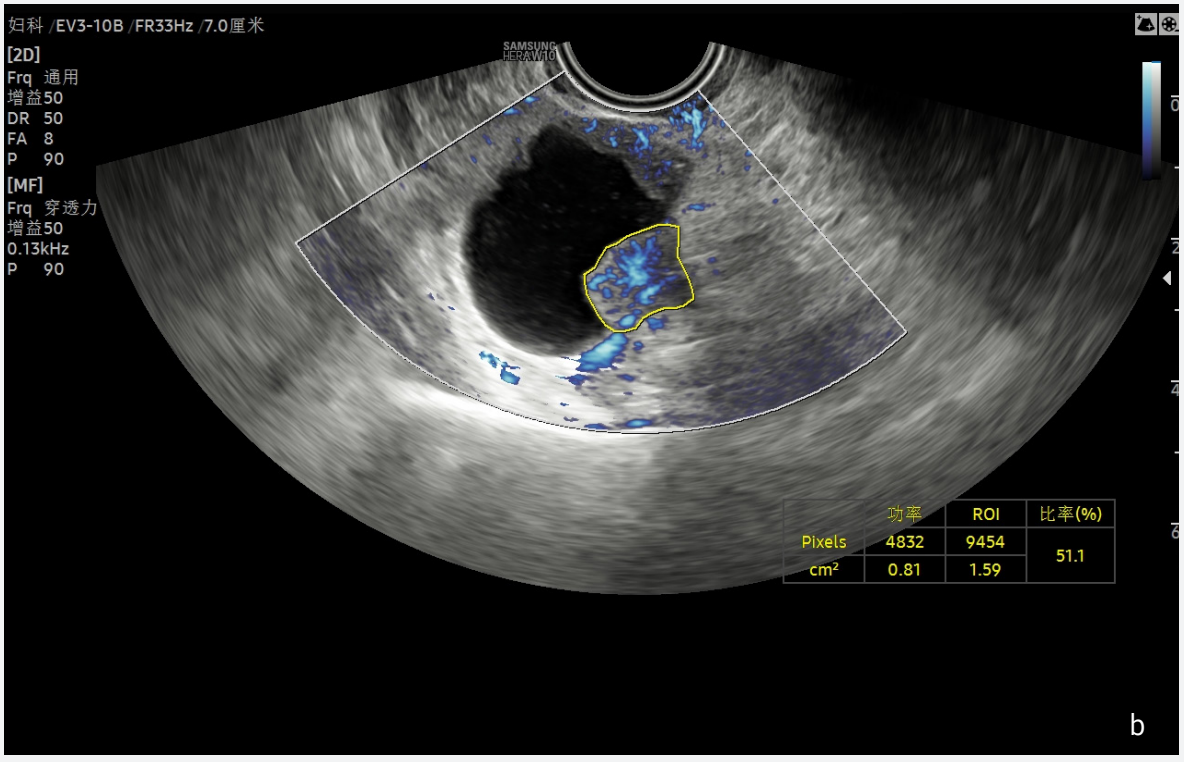


Figure 1. An MV-Flow™ image of a case of high-grade serous carcinoma of the left ovary, for illustrating how we obtained the section and VI^{MV} values.
a. MV-Flow™ images were retained from areas with abundant blood flow.



b. Outlined the largest area of the tumor using Manual Trace to obtain its VI^{MV} value.

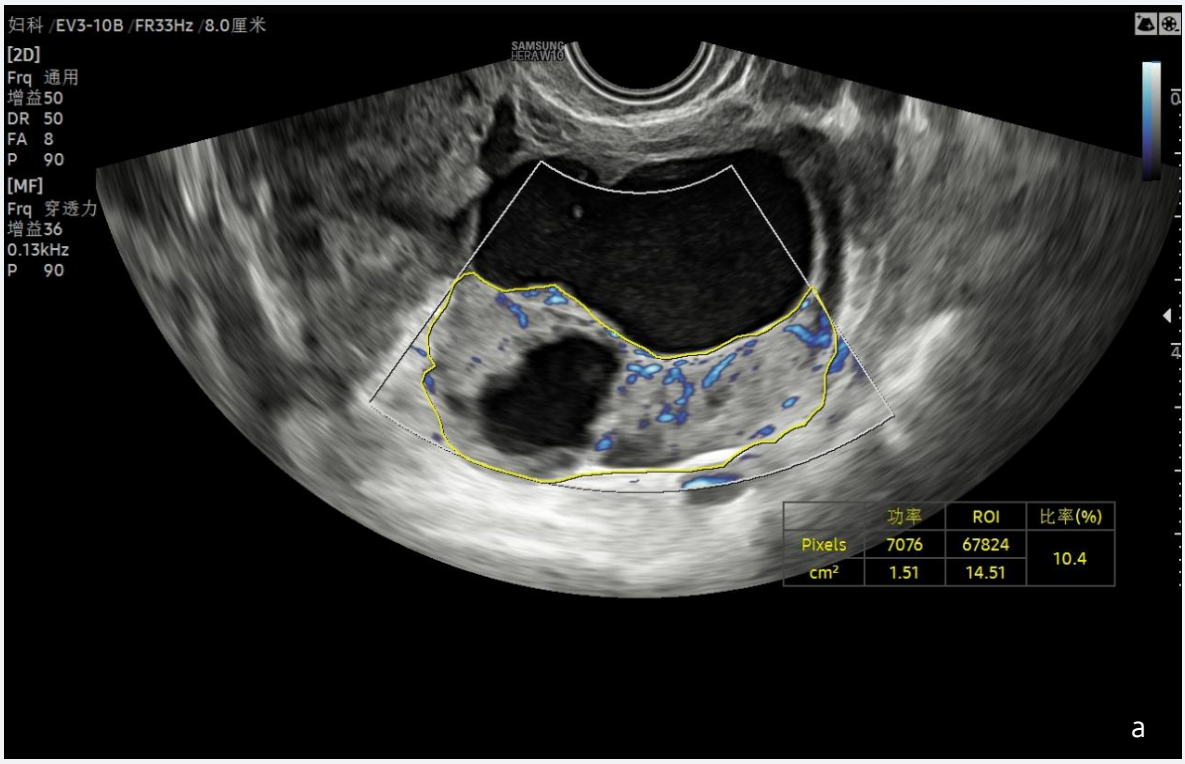
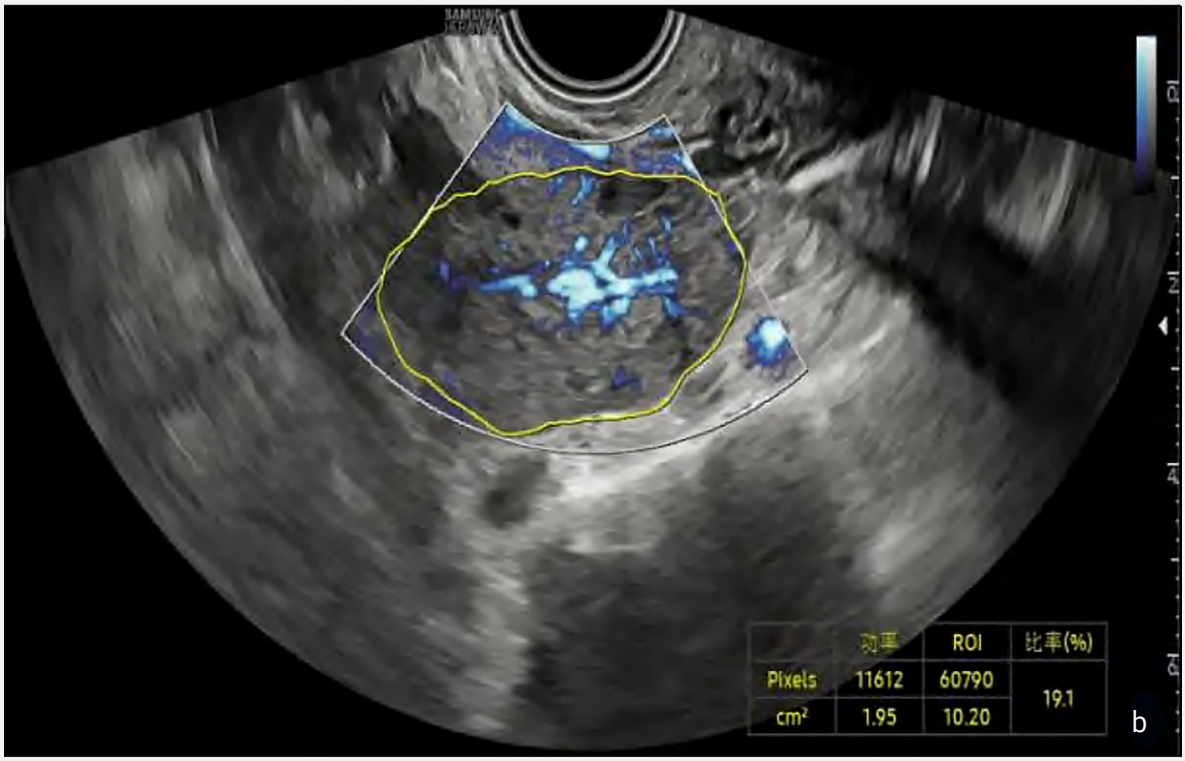


Figure 2. The different methods of drawing the ROI for VI^{MV} in tumors with varying proportions of solid components.

a. If the echogenicity of solid component within was < 50%, then measure the VI^{MV} of the solid component (this case is a right ovarian serous carcinoma).



b. If the solid component has an echogenicity ≥50%, then measure the VI^{MV} of the entire tumor (this case is a left ovarian borderline serous cystadenoma).

· Pathological Histological Examination

The benign or malignant diagnosis of the tumor was confirmed by surgical pathology or through follow-up.

· Statistical analysis

MedCalc 19.0 statistical analysis software was used to evaluate the consistency of the measurement of VI^{MV} between the 2 US doctors by intra-class correlation coefficient(ICC), and ICC>0.75 was considered to be a high level of consistency, and the data could be used for subsequent analysis. The median (upper and lower quartiles) was used to express the data that did not conform to normal distribution, and non-parametric tests were performed. The receiver operating characteristic (ROC) curve was plotted and the area under the curve (AUC) was calculated to evaluate the value of differential diagnosis of benign and malignant ovarian-adnexal tumors by VI^{MV} obtained from MV-Flow™ imaging, and a difference of $P<0.05$ was considered statistically significant.

Results

· Participant characteristics

A total of 107 patients, aged between 22 and 81 years, with a mean age of 42.2 ± 13.2 years, were enrolled. Additionally, 115 ovarian-adnexal tumors were included, comprising 33 malignant (including borderline) and 82 benign tumors. One benign lesion disappeared after three follow-up visits, confirmed as enlarged adnexal tissue, while the remaining 114 tumors were verified through surgical pathology (Table 1).

Table 1. The pathological results of 114 surgically confirmed

Benign masses (n=81)	NO.
Endometrial implantation cyst	29
Mature teratoma of ovary	16
Serous cystadenoma	7
Serous Adenofibroma	7
Pure ovarian cyst/Ovarian crown cyst	6
Functional cysts/Luteal cysts	3
Serous cyst	2
Mucinous cystadenoma	2
Fallopian tube abscess	2
Thecoma	2
Plasma-mucinous cystadenoma	1
Laevicellulare	1
Accessory ovary	1
Tuberculosis	1
Broad Ligament Leiomyoma	1

Malignant masses (n=33)	NO.
Serous carcinoma	18
Granulose cell tumor	3
Borderline tumor	3
Mucinous carcinoma	2
Clear cell carcinoma	3
Immature teratoma	2
Endometrioid carcinoma	1
Dysgerminoma	1

· The MV-Flow™ imaging results

MV-Flow™ imaging showed that in malignant ovarian-adnexal tumors, blood flow appeared mostly linear and centrally distributed, whereas in benign tumors, blood flow was predominantly punctate or showed limited linear flow with a peripheral distribution.

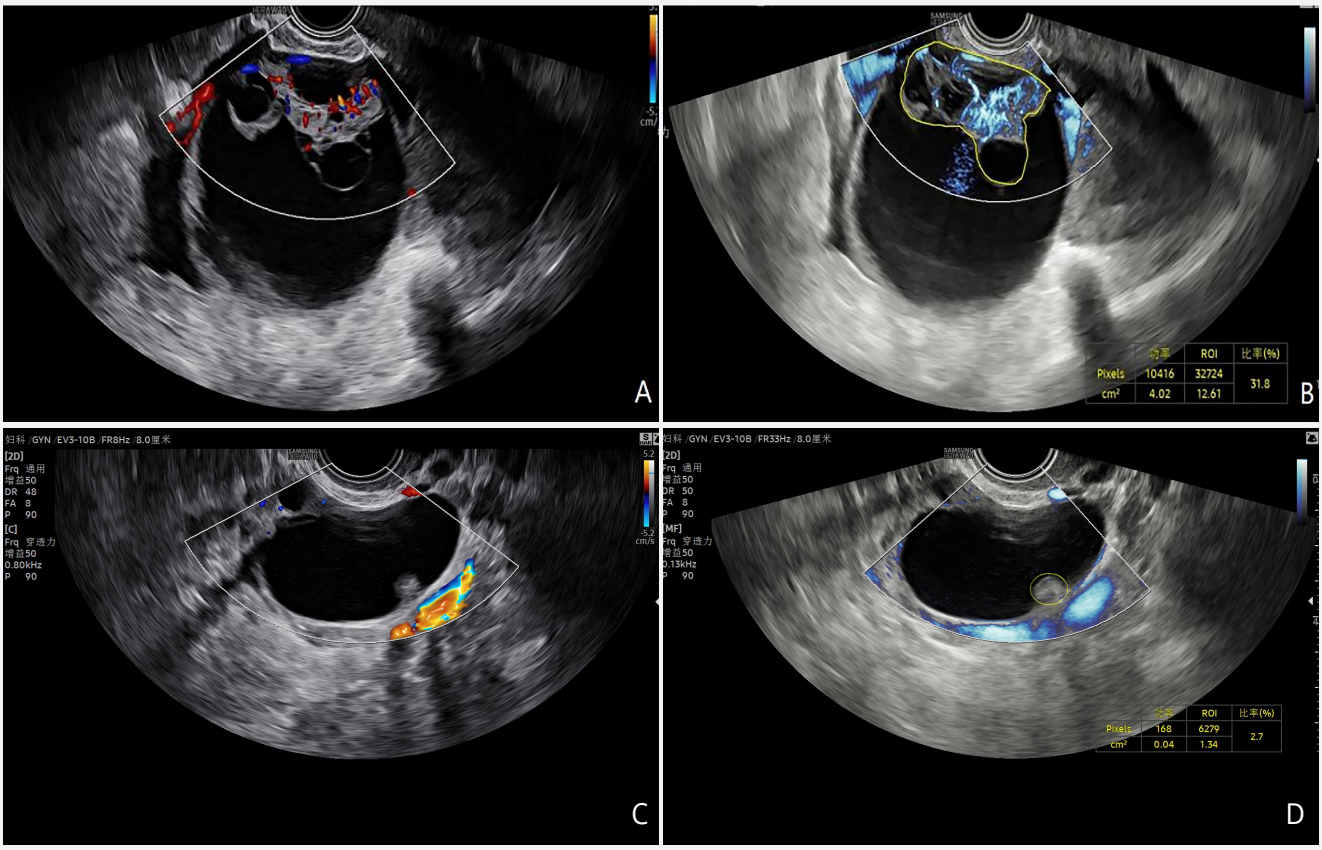


Figure 3.
a/b. A malignant Granulose cell tumor with color Doppler & MV-Flow™ showing blood flow centrally distributed.
c/d. A benign Serous Adenofibroma with color Doppler & MV-Flow™, showing the limited blood flow peripherally distributed.

· The VI^{MV} diagnostic efficacy

The ICC of the tumor VI^{MV} measured by two doctors is 0.987 (P<0.001), indicating high consistency.

The median VI^{MV}(%) of malignant ovarian-adnexal tumors was 16.57 (8.85, 24.50), while that of benign tumors was 1.20 (0.58, 3.05). The difference was statistically significant (Z=6.995, P<0.001).

VI^{MV}(%) for distinguishing between benign and malignant ovarian-adnexal tumors had an AUC of 0.918 (0.852, 0.961). Using a cutoff value of VI^{MV}(%) ≥ 7.15, the accuracy for diagnosing malignant masses was 89.57% (103/115), with a sensitivity of 84.85% (28/33), specificity of 91.46% (75/82), positive predictive value of 80.00% (28/35), negative predictive value of 93.75% (75/80), positive likelihood ratio of 9.94, and negative likelihood ratio of 0.17.

Table 2. VI^{MV}(%) for Differential Diagnosis of Benign and Malignant Ovarian-adnexal Tumors

VI^{MV} (%)	Pathology (NO.)		SUM
	Malignant	Benign	
≥7.15	28	7	35
<7.15	5	75	80
SUM	33	82	115

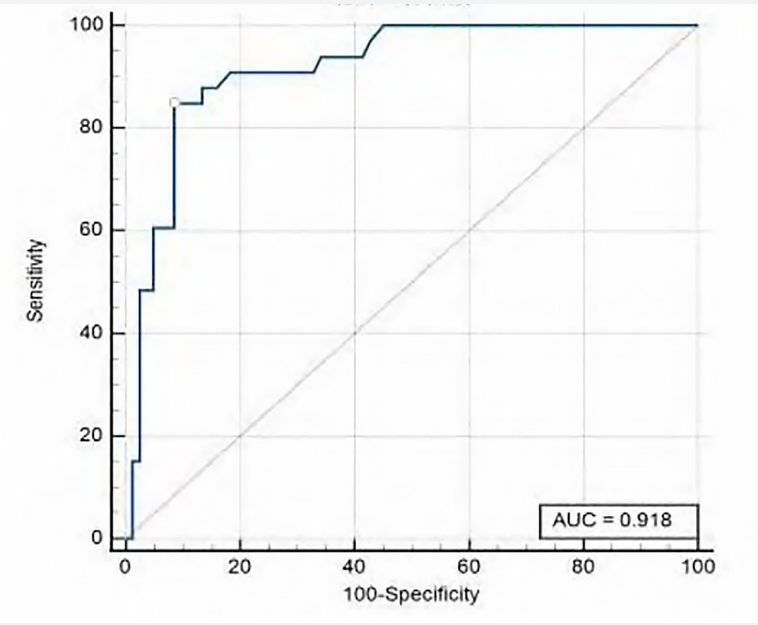


Figure 4. ROC curve for differential diagnosis of benign and malignant ovarian-adnexal tumors using VI^{MV}(%)

Discussion

Using ultrasound to assess the abundance of blood flow signals is one of the important imaging methods for differential diagnosis of benign and malignant ovarian-adnexal tumors, and the O-RADS system also includes content on color scoring[6].

This study showed that different adnexal tumors exhibit different characteristics on MV-Flow™ imaging. Malignant tumors tend to have abundant blood supply, complex and relatively tortuous blood vessels, more branching vessels, and the main blood vessels are often distributed near the center of the mass or within solid components. In contrast, benign tumors generally possess less blood supply, simpler vessel pathways, with blood vessels distributed around the periphery or within the septa of the mass, often appearing as punctate or scanty linear structures.

MV-Flow™ imaging-derived vascularity index(VI^{MV}) also demonstrated high diagnostic efficacy in distinguishing between benign and malignant adnexal tumors. With a cutoff value of 7.15(%), the AUC for distinguishing benign from malignant tumors was 0.918, with a sensitivity of 84.85% and specificity of 91.46%.

In another similar study by my team, we compared the diagnostic performance of VI^{MV} with O-RADS system. Using cutoff values 7.15(%) for VI^{MV} and categorizing O-RADS into 5 classes, the AUCs for distinguishing between benign and malignant ovarian-adnexal tumors were 0.923 and 0.929 separately. They were very similar. When these two methods were combined, the AUC was 0.955 (Figure 5)[7].

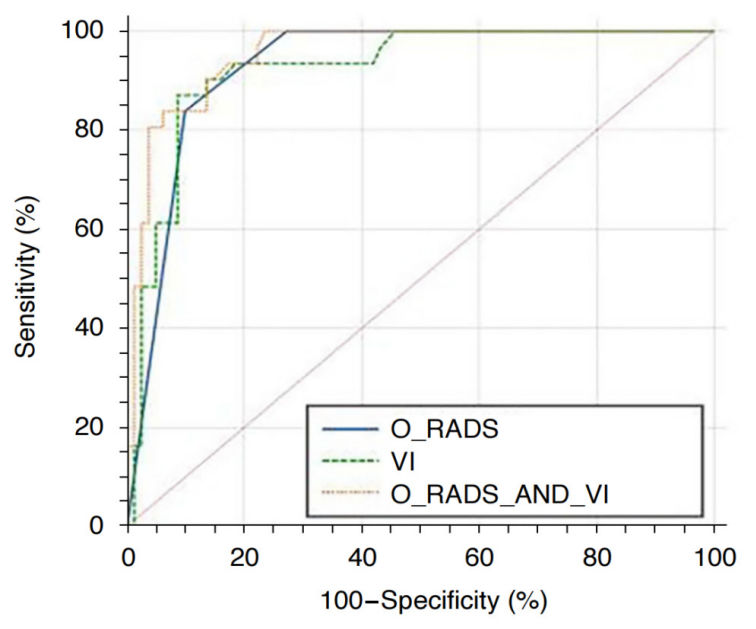


Figure 5. Receiver operating characteristic curves of O-RADS US and MV-Flow (VI^{MV}) alone and in combination for diagnosing benign and malignant ovarian-adnexal masses. O-RADS US, Ovarian Adnexal Reporting and Data System Ultrasound; VI^{MV}, Vascular index from MV-Flow [7].

However, the O-RADS system is complex, and MV-Flow™ and VI^{MV} measurements are relatively simple, consistent, and easy for young doctors to master.
In this study, we also found that when used for small tumors (e.g., diameter < 10 cm), MV-Flow™ imaging exhibited fewer artifacts and smaller errors in VI measurements. Thus, MV-Flow™ imaging is more valuable for distinguishing relatively small-volume ovarian-adnexal tumors.

Conclusion

MV-Flow™ imaging and its quantitative VI^{MV} are highly effective in the differential diagnosis of benign and malignant ovarian-adnexal tumors.

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