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O-RADS scoring system for adnexal lesions: Diagnostic performance on TVUS performed by an expert sonographer and MRI

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ABSTRACT

Rationale and Objective: To determine the diagnostic performance of transvaginal ultrasound (TVUS) performed by an US specialist and MRI based on the O-RADS scoring system.
Materials and methods: Between March 5th 2013 and December 31st 2021, 227 patients, referred to our center, underwent TVUS and pelvic MRI for characterization of an adnexal lesion proven by surgery or two years of negative follow-up. All lesions were classified according to O-RADS US and O-RADS MRI risk scoring systems. Imaging data were then correlated with histopathological diagnosis or negative follow-up for 2 years.
Results: The prevalence of malignancy was 11.1%. Sensitivity of O-RADS US / O-RADS MRI were respectively of 83.3%/83.3% and specificity was 73.2%/92.9% ($p < 0.001$). O-RADS MRI was more accurate than O-RADS US even when performed by an US specialist ($p < 0.001$). When MRI was used after US, 51 lesions were reclassified correctly by MRI and only 4 lesions incorrectly reclassified. Most of the lesions (49/51) rated O-RADS US 4 or 5 and reclassified correctly by MRI were benign, mainly including cystadenomas or cystadenofibromas. Only 4 lesions were misclassified by MRI but correctly classified by ultrasound.
Conclusion: Our study suggests that MR imaging has equally high sensitivity but higher specificity than TVUS for the characterization of adnexal lesions based on O-RADS scoring system. MRI should be the recommended second-line technique when a mass is discovered during TVUS and is rated O-RADS 4 and 5 over than TVUS by an US specialist.

1. Introduction

Transvaginal ultrasonography (TVUS) is the first-line imaging technique for evaluating adnexal lesions [1]. Predicting the risk of malignancy of adnexal lesions is crucial for determining when a lesion can be followed or needs surgical evaluation. Studies have shown that the risk of malignancy increases with the presence of solid tissue. Both US and MRI can assess for solid components. On US, solid tissues and solid components such as blood, debris and fat can be difficult to differentiate due to their echoic appearance [2,3]. However, on MRI, the added benefit of contrast allows differentiation of these solid appearing components.

MRI is often recommended when an adnexal lesion is considered "complex" or "indeterminate" at ultrasonography [4]. However, the main limitation was the absence of a definition of the terms "complex" and "indeterminate." Recently an international group of experts coordinated by the American College of Radiology proposed a new classification named O-RADS US to standardize the description of adnexal lesions [5]. This group suggests that TVUS performed by an US specialist or a pelvic MRI have similar added value to characterize O-RADS US 3 and 4 in which both are equally recommended by the panel [6].

Recently, a prospective European international cohort was conducted to validate the O-RADS MRI score which demonstrates an accuracy higher than 94% [7,8]. However, the selection of patients was not based on any US classification or sonographer expertise and until now, no studies have compared the diagnostic value of O-RADS MRI

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classification with O-RADS US performed by an expert. Thus, the purpose of our study was to evaluate the diagnostic performance of O-RADS US performed by an expert sonographer and O-RADS MRI scores to determine for which lesions TVUS or MRI should be recommended according to the different categories defined by O-RADS classification system from the American College of Radiology.

2. Materials and methods

Our institutional ethics committees approved the study and granted a waiver of informed consent (IRB = CRM-2205–261).

Between March 2013 and December 2021, we conducted a retrospective review of our MR imaging database to identify women who had undergone pelvic MRI for the characterization of an adnexal mass. In our center, patients with adnexal mass are referred for pelvic MRI 1) if the mass is considered as indeterminate or complex on TVUS 2) If the cyst is larger than 10 cm^3) in premenopausal women in a preoperative conservative context. We subsequently excluded any patients who had not undergone a pelvic ultrasound at our referral center within the preceding 6 months (no image available), and patients who either did not undergo surgery with pathological correlation within 6 months or lacked a minimum of two years of follow-up if no surgery was performed.

2.1. Transvaginal ultrasonography

TVUS in our referral center was performed on Aplio i800 (Canon) or Voluson E8 (GE) ultrasound systems, by a pelvic imaging specialist with at least 5 years of experience (from 5 to 35 years) (M.B., A.B., E.K., I.T. N., B.F., A.M., A.C., C.V.L., L.R.). Two radiologists, with over five years of expertise in gynecological ultrasound and training in O-RADS-US classification, conducted a retrospective review of all recorded ultrasound images (A.C., C.V.L.). They also examined any available ultrasound supplementary reports if available, assigning an O-RADS-US score to each adnexal mass in accordance with the 2022 version of the O-RADS-US guidelines. This review was conducted independently of the MRI scoring and without knowledge of the final diagnosis, which was established either by histology findings post-surgery or through a two-year follow-up. In cases where a radiologist encountered difficulties interpreting a recorded image (n = 50), all the ultrasound images were re-evaluated by our department's most experienced sonographer, who has more than 35 years of extensive expertise in pelvic ultrasonography (**) (Table 1). The interrater agreement was evaluated between the two readers using a subset consisting of the first 50 patients analyzed.

Table 1
O-RADS US classification.

	Benign% (Nb)	BL% (Nb)	Invasive% (Nb)
O-RADS US 1 (n = 5)	**100 (5)**	**0**	**0**
Follicle and corpus luteum (<3cm) in women during the period of reproductive activity	100 (5)	0	0
O-RADS US 2 (n = 110)	**100 (110)**	**0**	**0**
Simple unilocular cyst of 3–10 cm (reproductive activity) or 1–10 cm in menopausal women (including hydrosalpinx)	40 (44) 2.7 (3)38 (42)13.6	000,000	000,000
Hemorrhagic luteal cyst < 10 cm	(15)2.7		
Typical dermoid cyst < 10 cm	(3)2.7		
Typical endometriotic cyst < 10 cm	(3)		
Para-ovarian cyst any size and peritoneal pseudo-cyst any size			
Non-simple but unilocular cyst with smooth margins 3–10 cm			
O-RADS US 3 (n = 65)	**92.3 (60)**	**6.1 (4)**	**1.5 (1)**
Simple or non-simple unilocular cyst > 10 cm	1.5 (1)	0	0
Hemorrhagic luteal cyst, endometrioma and typical dermoid cyst > 10 cm	1.5 (1)9.2 (6)70	0	0
Unilocular cyst with irregular walls (i.e. thickness < 3 mm)	(46)9.2 (6)	06.1 (4)	01.5 (1)
Multilocular cyst with thin and regular wall/septa < 10 cm with CS = 1–3			
Purely regular solid mass CS = 1;			
O-RADS US 4 (n = 67)	**83.6 (56)**	**8.9 (6)**	**7.5 (5)**
Multilocular cyst > 10 cm with regular wall/septa CS = 1–3	3 (2)	0	0
Multilocular cyst with regular wall/septa CS = 4 any size	0	0	0
Multilocular cyst with irregular septum any size or CS	28 (19) 13.5 (9)	1.5 (1) 4.5 (3)	03 (2)3 (2)1.5 (1)
Unilocular cyst with solid component of 0–3 vegetations any size or CS	10.5 (7)	0 (0)	
Multilocular cyst with a solid component CS = 1–2 any size			
Regular solid mass CS = 2–3			
O-RADS US 5 (n = 22)	**36.3 (8)**	**9 (2)**	**54.5 (12)**
Unilocular cyst with a solid component ≥ 4 vegetations any size or CS	9 (2)18 (4)	9 (2) 0	9 (2)4.5 (1)13.6
Multilocular cyst with a solid component any size CS = 3–4	09 (2) 0	0 00	(3)27.3 (6) 0
Regular solid mass CS = 4 any size			
Irregular solid mass any size or CSAscites and/or peritoneal implants			

Overall subjective assessment of color Doppler flow within the entire lesion (wall and/or internal component) was graded from 1 to 4 according to Color score (CS): 1 = no flow, 2 = minimal flow, 3 = moderate flow, 4=<very strong flow).

2.2. MR imaging

MRI sequences were acquired at 1.5 T (GE HDXT, Milwaukee, USA) (n = 154) or at 3 T (GE, Architect, Milwaukee, USA) (n = 73) using a phased array pelvic coil. Patients fasted for three hours and received an antispasmodic drug intravenously (10 mg of tiemonium methylsulfate; Visceralgine; Organon®) before MRI to reduce bowel peristalsis. Sagittal and axial turbo-spin-echo (TSE) T2-weighted and axial gradient-echo T1-weighted sequences were obtained with and without fat suppression. Axial diffusion-weighted MR images were acquired using a single-shot echo-planar imaging sequence with a high b-value (≥b1200). Then, dynamic contrast enhanced T1 weighted imaging was performed with a temporal resolution higher than 5sec and a minimum delay of 3mn after gadolinium injection. Gadolinium chelate (DOTAREM®, Guerbet) was given at a dose of 0.2 $ml.kg^{-1}$ via a Power Injector (Medrad, Maastricht) at a rate of 2 $ml.sec^{-1}$, followed by 20 ml of normal saline to flush the tubing. Finally, post-contrast 3D axial T1-weighted gradient-echo sequences were systematically acquired. MR time duration was about 30 min.

All of the MR images were reviewed on a Picture Archiving and Communication System (PACS) workstation (Agfa HealthCare, a division of Agfa-Gefaert Group). The O-RADS MRI classification (Table 2) was retrospectively assessed by a 5 to 15 years experienced radiologist in pelvic imaging (**). Both prospective and retrospective readings were performed blinded to TVUS O-RADS results performed by a specialist.

2.3. Surgical procedure and pathological analysis

Surgical procedures were decided during gynecologic multidisciplinary tumor board following national and international guidelines [9,10]. When feasible, mini-invasive surgery was performed, i.e. laparoscopic or robotic approach and a complete staging, including lymphadenectomy in a secondary surgery, was also performed by mini-invasive approach if needed. In other cases, i.e. voluminous suspicious masses, a laparotomic approach with extemporaneous analysis was performed to avoid any tumoral rupture and surgical spill. If needed, complete staging including lymphadenectomy was performed during

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Table 2
O-RADS MRI classification.

	Benign% (Nb)	BL% (Nb)	Invasive% (Nb)
O-RADS MR 1 (n = 15)	**100 (15)**	**0**	**0**
No adnexal mass or origin no adnexalFollicle (simple cyst ≤ 3 cm in premenopausal women) Corpus luteum or hemorrhagic cyst ≤ 3 cm in premenopausal women	26.7 (4) 53.3 (8)20 (3)	0 00	0 00
O-RADS MR 2 (n = 148)	**100 (148)**	**0**	**0**
Simple unilocular cyst any type of fluid content no wall enhancement Para-tubal or *para*-ovarian cyst Typical endometrioma Typical dermoid cyst Dilated fallopian tubes with simple fluid content Lesion with "dark T2/dark DWI" solid tissue	31.7 (47) 2.7 (4)9.5 (14)31 (46)4 (6) 20.9 (31)	000,000	000,000
O-RADS MR 3 (n = 64)	**92.2 (59)**	**6.2 (4)**	**1.6 (1)**
Multilocular cysts without solid tissueSolid tissue (excluding darkT2/dark DWI) with LR TIC on DCE Unilocular cyst any type of fluid content with wall enhancement or non-typical of endometrioma or dermoid cyst Dilated fallopian tube with a non-simple fluid content	65.6 (42) 18.7 (12)6.2 (4)1.6 (1)	3.1 (2) 3.1 (2) 0 0	01.6 (1) 0 0
O-RADS MR 4 (n = 30)	**53.3 (16)**	**26.7 (8)**	**20 (6)**
Solid tissue (excluding darkT2/dark DWI) with intermediate-risk time intensity curve (type 2) on DCELarge volume enhancing solid tissue in a lesion with lipid content	50 (15)3 (1)	26.7 (8) 0	20 (6) 0
O-RADS MR 5 (n = 12)	**8.3 (1)**	**0 (0)**	**91.7 (11)**
Solid tissue (excluding darkT2/dark DWI) with HR TIC on DCE or enhancing > myometrium at 30–40 s on non-DCEPeritoneal, mesenteric or omental nodularity with or without ascites	8.3 (1) 0	0 0	41.7 (5)50 (6)

LR: Low Risk - IR: Intermediate risk – HR: High risk TIC: Time Intensity Curve DCE: Dynamic contrast Enhancement.

the same surgery. All tumors resected were sent for pathological analysis in our tertiary referral center for ovarian tumors.

2.4. Reference standard

The final diagnosis was established by pathological analysis if surgical resection or biopsy (of unresectable lesions) were performed. In cases where surgery was not indicated, diagnosis was based on a minimum of 2 years of follow-up stability. Management decision was made by multidisciplinary team according to standard practice in each site. Lesions were classified histologically as benign, borderline, or malignant according to the World Health Organization's (WHO) International Classification of Diseases for Oncology (ICD-O). Borderline lesions were considered as not invasive malignant lesions for the purpose of this analysis.

2.5. Statistical analysis

We determined the diagnostic performances of each imaging modality calculating sensitivity, specificity, positive and negative likelihood ratios, positive and negative predictive values, accuracy, and odds ratios accuracies using McNemar test. Quadratic κ coefficients were calculated to assess interobserver agreements for O-RADS US score. We applied a correction procedure by computing an intracluster correlation factor as several lesions may exist in each patient [11]. A p value of<0.05 was considered to indicate a statistically significant difference. Statistical analyses were performed using MedCalc software (MedCalc version 9.3.0.0; Belgium).

3. Results

3.1. Population

Between March 5th 2013 and December 31st 2021, 1268 women underwent a pelvic MRI and transvaginal ultrasonography (TVUS) for characterization of an adnexal mass in our center. We excluded 1) 972 women who did not have pelvic ultrasound by an expert at our hospital within 6 months of the MRI 2) 69 women due to lack of gold standard (subsequent surgery with pathological correlation within 6 months or 2 years of follow-up) (Fig. 1).

Thus, the final population consisted of 227 women (mean age 40 years, 19–82 years) including 269 adnexal lesions (40 women had two adnexal lesions, one woman had 3 adnexal lesions). Median delay between expert TVUS and MRI was 7 days.

The diagnoses were determined by surgical pathology (n = 116) or based on two years of negative follow up (n = 153) either by MRI, TVUS or, rarely, clinical follow up for functional adnexal lesions. Median time interval between MRI and surgery was 144 days (min–max = 6–167 days). Surgical procedures (n = 116) consisted of unilateral or bilateral ovarian cystectomy (n = 43), unilateral salpingo-oophorectomy (n = 34), bilateral salpingo-oophorectomy (n = 21), bilateral salpingo-oophorectomy with hysterectomy, omentectomy, peritoneal biopsies, appendectomy, lymph node dissection (n = 18).

Reference standard (surgical pathology or 2 years follow-up) finding included 239 benign lesions, 12 borderline and 18 invasive tumors. Borderline and invasive tumors were grouped into malignant tumors (n = 30). Thus, the prevalence of malignancy was 11.1% (30/269).

3.2. Performance of O-RADS-US performed by an US specialist

Two-thirds of adnexal lesions (180/269) were classified O-RADS US 1, 2 or 3 and one third (89/269) were classified O-RADS US 4 or 5 (Tables 1 and 3). Adnexal lesions were classified O-RADS-US 1 in 5/269 (1.8%) or O-RADS US 2 in 110/269 (40.9%), all correctly classified (PPV of malignancy = 0%). Adnexal lesions were classified O-RADS US 3 in 65/269 (24.2%) with a PPV of malignancy of 7.7% (5/65). Adnexal lesions were classified O-RADS US 4 in 67/269 (24.9%) with a PPV of malignancy of 16.4% (11/67) Adnexal lesions were classified O-RADS US 5 in 22/269 (8.2%) with a PPV of malignancy of 63.9% (14/22).

Interrater agreement was excellent with a quadratic Kappa (K = 0.91 (95% CI 0.83–1)).

3.3. Performance of O-RADS MRI

Adnexal lesions were rated O-RADS MRI 1, 2 or 3 in 84.4% of patients (227/269) and O-RADS MR 4 or 5 in 15.6% (42/269) (Tables 2 and 3).

Adnexal lesions were classified O-RADS MRI 1 in 15/269 (5.6%) and classified O-RADS MR 2 in 148/269 (55.0%), all correctly classified (PPV of malignancy = 0). Adnexal lesions were classified O-RADS MRI 3 in 64/269 (23.8%) with a PPV of malignancy of 7.8% (5/64). Adnexal lesions were classified O-RADS MRI 4 in 30/269 (11.1%) with a PPV of malignancy of 46,7% (14/30). Adnexal lesions were classified O-RADS MRI 5 in 12/269 (4.5%) with a PPV of malignancy of 91.7% (11/12).

3.4. Comparison of O-RADS US and O-RADS MRI performance

Sensitivity, specificity, positive and, negative predictive values and diagnostic performance of O-RADS US/MRI are given in Table 4. Sensitivity of O-RADS US and O-RADS MRI were equal as 83% (IC95 % 95.3–94.4) but specificities were 73% (IC95 % 67.1–78.8) and 93% (IC95 % 88.9–95.8) ($p < 0.001$), respectively.

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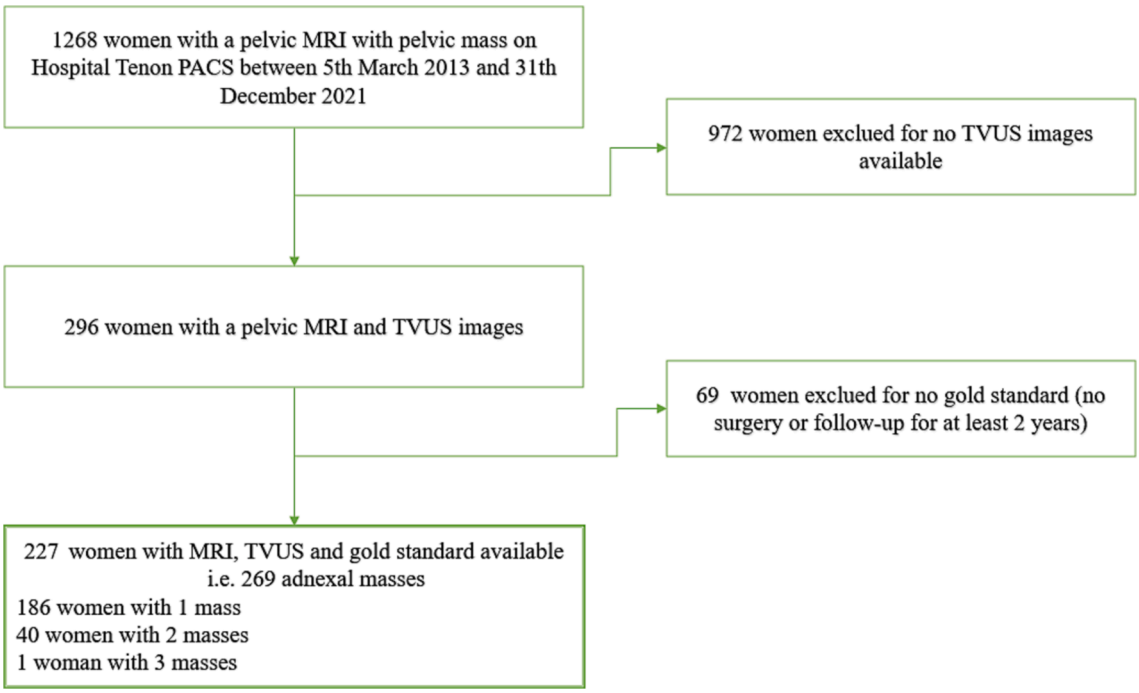

Fig. 1. Population selection.

Table 3
Final diagnosis.

	Nb	O-RADS US					O-RADS MRI				
		1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	5
BENIGN	**239**	**5**	**110**	**60**	**56**	**8**	**15**	**148**	**59**	**16**	**1**
Serous cystadenomas	70	1.4 (1)	45.7 (32)	22.9 (16)	27.1 (19)	2.9(2)	1.3 (1)	60 (42)	34.3 (24)	4.3(3)	0
Cystadenofibromas	33	0	9.1 (3)	48.5 (16)	39.4 (13)	3 (1)	0	54.5 (18)	39.4 (13)	6.1 (2)	0
Mucinous cystadenomas	12	0	0	75 (9)	25 (3)	0	0	0	75 (9)	25 (3)	0
Serous *para*-tubal	7	0	28.6 (2)	42.9 (3)	28.6 (2)	0	0	57.1 (4)	42.9 (3)	0	0
Endometrioid cystadenomas	2	0	0	0	100 (2)	0	0	0	0	100 (2)	0
Mature Cystic Teratoma	45	0	93.3 (42)	2.22 (1)	4.4 (2)	0	0	97.7 (44)	0	2.2 (1)	0
Struma ovarii	2	0	50 (1)	50 (1)	0	0	0	0	100 (2)	0	0
Fibroma, fibrothecoma	12	8.3 (1)		3.3 (4)	50 (6)	8.3 (1)	0	50 (6)	16.6 (2)	25 (3)	8.3 (1)
Endometrioma	19	0	78.9 (15)	10.5 (2)	10.5 (2)	0	0	94.7 (18)	0	5.2 (1)	0
Hydrosalpinx	6	0	83.3 (5)	0	16.7 (1)	0	0	100 (6)	0	0	0
Luteoma	1	0	0	0	100 (1)	0	0	100 (1)	0	0	0
Functional simple cyst	17	5.8 (1)	41.1(7)	23.5 (4)	11.7 (2)	17.6 (3)	41.1 (7)	23.5 (4)	29.1 (5)	5.8 (1)	0
Hemorrhagic luteal cyst	3	0	100 (3)	0	0	0	0	100 (3)	0	0	0
Corpus luteum	3	66.7 (2)	0	33.3 (1)	0	0	100 (3)	0	0	0	0
Normal ovaries	1	0	0	0	100 (1)	0	0	0	100 (1)	0	0
Pseudoperitoneal cyst	3	0	0	33.3 (1)	66.7 (2)	0	66.7 (2)	33.3 (1)	0	0	0
Myomas	2	0	0	100 (2)	0	0	100 (2)	0	0	0	0
Hematoma	1	0	0	0	0	100 (1)	0	100 (1)	0	0	0
BORDERLINE	**12**	**0**	**0**	**4**	**6**	**2**	**0**	**0**	**4**	**8**	**0**
Serous	5	0	0	20 (1)	40 (2)	40 (2)	0	0	20 (1)	80 (4)	0
Mucinous	5	0	0	60 (3)	40 (2)	0	0	0	60 (3)	40 (2)	0
Cystadenofibromas	2	0	0	0	100 (2)	0	0	0	0	100 (2)	0
INVASIVE	**18**	**0**	**0**	**1**	**5**	**12**	**0**	**0**	**1**	**6**	**11**
Serouscystadenocarcinoma	5	0	0	20 (1)	40 (2)	40 (2)	0	0	20(1)	40 (2)	40(2)
Serous tubal adenocarcinoma	3	0	0	0	0	100 (3)	0	0	0	0	100 (3)
Clear cells cystadenocarcinoma	2	0	0	0	0	100 (2)	0	0	0	50 (1)	50 (1)
Stromal cells	2	0	0	0	50 (1)	50(1)	0	0	0	100 (2)	0
Endometrioid cystadenocarcinoma	3	0	0	0	33.3 (1)	66.7 (2)	0	0	0	33.3 (1)	66.7 (2)
Others*	3	0	0	0	33.3 (1)	66.7 (2)	0	0	0	0	100 (3)

% (Nb) / *(Intraperitoneal solitary fibrous tumor, Choriocarcinoma, Metastasis).

O-RADS MRI score was more accurate than O-RADS US score with 91.8% (IC95 % 87.9–94.8) and 75.4% (IC95% 68.7–79.5) respectively ($p < 0.001$). O-RADS MRI showed a significant increase in specificity ($p < 0.001$), the positive likelihood ratio ($p < 0.001$) and positive predictive value ($p < 0.001$). O-RADS MRI score correctly reclassified 51 lesions misclassified by O-RADS US (including 49 benign lesions) while TVUS correctly reclassified only 4 lesions misclassified by MRI ($p < 0.001$) (Table 5).

Among the 64 adnexal lesions misclassified as O-RADS US 4 (n = 56) or 5 (n = 8), 76.5% (49/64) were correctly reclassified with O-RADS

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Table 4
Diagnostic performance of the O-RADS US performed by a specialist / O-RADS MRI.

	O-RADS US	O-RADS MRI
True-positive result, *n*	25	25
False-negative result, *n*	5	5
True-negative result, *n*	175	222
False-positive result, *n*	64	17
Sensitivity (%)	83.3 (65.3–94.4)	83.3 (65.3–94.4)
Specificity (%)	73.0 (67.1–78.8)	92.9 (88.9–95.8)
Positive likelihood ratio	3.1 (2.4–4.1)	11.8 (7.2–19.1)
Negative likelihood ratio	0.2 (0.1–0.5)	0.2 (0.1–0.4)
Positive predictive value (%)	28.1 (23.1–33.7)	59.5 (47.5–70.5)
Negative predictive value (%)	97.2 (94.0–98.8)	97.8 (95.2–99.0)
Accuracy %	75.4 (68.7–79.5)	91.8 (87.9–94.8)
Diagnostic odds ratio (95% CI)	13.6 (4.8–47.2)	62.83 (20.45–236.74)

Table 5
Comparison of the accuracies of O-RADS US and MRI score.

		O-RADS MRI score Diagnostic confidence improved in 17.5% (47/269)		
		correct	misclassified	Total
O-RADS US score	correct	**196**	**4**	**200**
		173B + 23 M	2B + 2 M	175B + 25 M
$p < 0.01$	misclassified	**51**	**18**	**69**
		49B + 2 M	15B + 3 M	64B + 5 M
	Total	**247**	**22**	**269**
		222B + 25 M	17B + 5 M	239B + 30 M

B: Benign – M: Malignant.

MRI including 43 lesions rated O-RADS US 4 (Figs. 2, 3, 4) and 6 lesions rated O-RADS US 5 (Fig. 5). These lesions included serous cystadenomas (including papillary serous cystadenomas) (n = 18), cystadenofibromas (n = 13), ovarian fibromas (n = 3), mucinous cystadenomas (n = 2), paratubal cysts (n = 2), mature cystic teratoma (n = 1), pseudocyst (n = 1), hydrosalpinx (n = 1), corpus luteum (n = 1), endometriomas (n = 2), luteoma (n = 1), calcification adjacent to a follicle (n = 1), hematoma (n = 1). In addition, two normal ovaries were misdiagnosed as adnexal lesions using TVUS. Among the 5 malignant adnexal lesions misclassified O-RADS US 2 or 3, only two were reclassified O-RADS 4 or 5 using MRI.

Among the 22 adnexal lesions misclassified with O-RADS MRI, only two benign (one cystadenofibroma and one benign mucinous cystadenoma) and two malignant adnexal lesions (two borderline cystadenomas, one serous and one mucinous) were correctly reclassified using TVUS (18.8%, 4/22).

4. Discussion

Our study demonstrates that O-RADS MRI score has a higher accuracy than TVUS performed by an US specialist for reclassification of adnexal lesions, particularly in adnexal lesions rated O-RADS US 4 or 5, many of which were reclassified as benign adnexal lesions ($p < 0.001$). O-RADS MRI correctly reclassified more lesions compared to O-RADS US, with 73.9% (51/69) of masses reclassified by MRI and 18.8% (4/22) reclassified by US. Most lesions correctly reclassified by MRI were cystadenomas or cystadenofibromas (31/51; 60.8%).

TVUS is the first-line imaging technique for adnexal lesions due to its low cost, wide availability, excellent spatial resolution and potential ability to detect flow in solid components [12]. However, as others have noted, TVUS has lower specificity and positive predictive value than MRI due to a significant number of TVUS false positive cases as previously published, especially for the O-RADS 4 category [13–16]. Our results demonstrate that MRI has a higher accuracy, specificity, and PPV than TVUS, even when performed by an US specialist with 18.2% (49/269) of the masses overrated with O-RADS US correctly reclassified with MRI. This result confirms that the preponderant contribution of MRI in adnexal lesion evaluation is its increased specificity, and its ability to provide a confident diagnosis of many benign adnexal lesions, as previously suggested [17]. Many studies have compared the value of TVUS

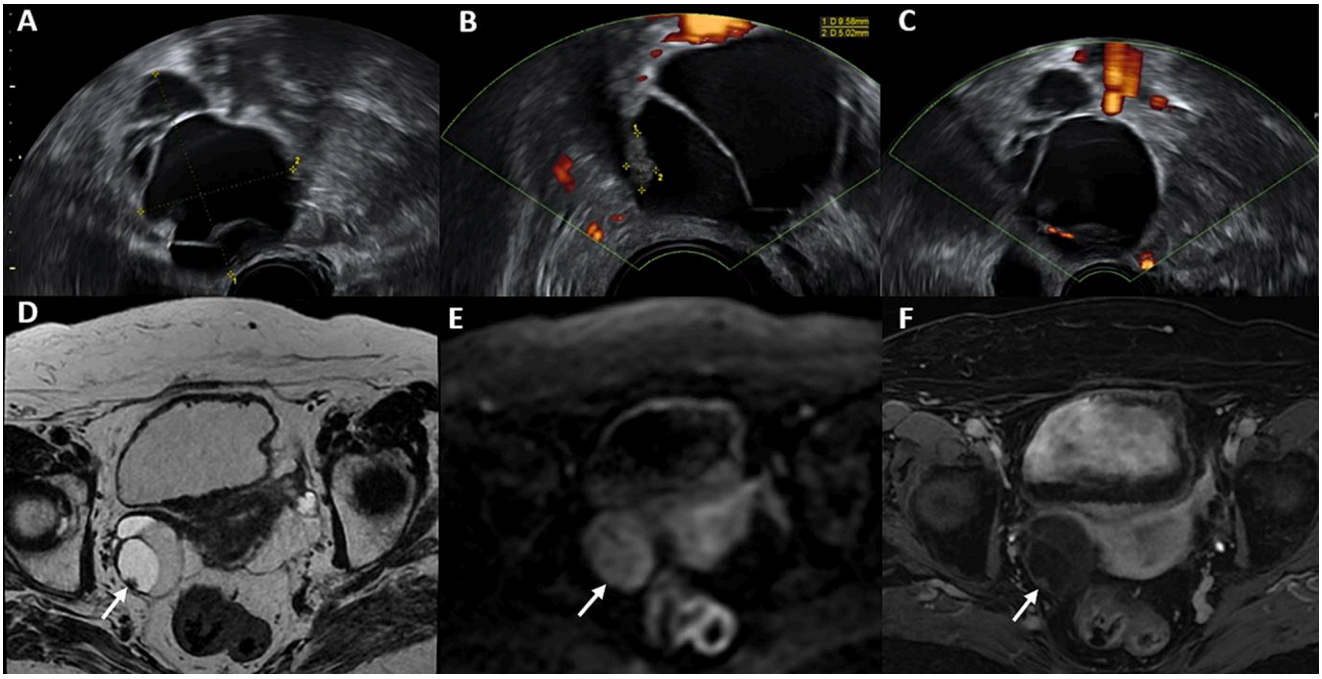

Fig. 2. A 78-year-old female patient with a multilocular cyst measuring 62 mm on transvaginal pelvic ultrasound (A), with smooth inner walls, and a solid component corresponding to an irregular inner wall measuring 5 mm in height and 10 mm in long axis, with no Doppler flow visualized (B), and smooth septations (C), classified as O-RADS US 4. Pelvic MRI revealed that the mass contained solid tissue (indicated by the arrow) corresponding to a papillary projection in lowT2W signal (D) and low DW signal (E). This solid tissue enhanced on the Dixon T1 sequence after the injection of gadolinium (F). The MRI classification was O-RADS MRI 2, suggesting the diagnosis of cystadenofibroma, which was confirmed by pathological analysis.

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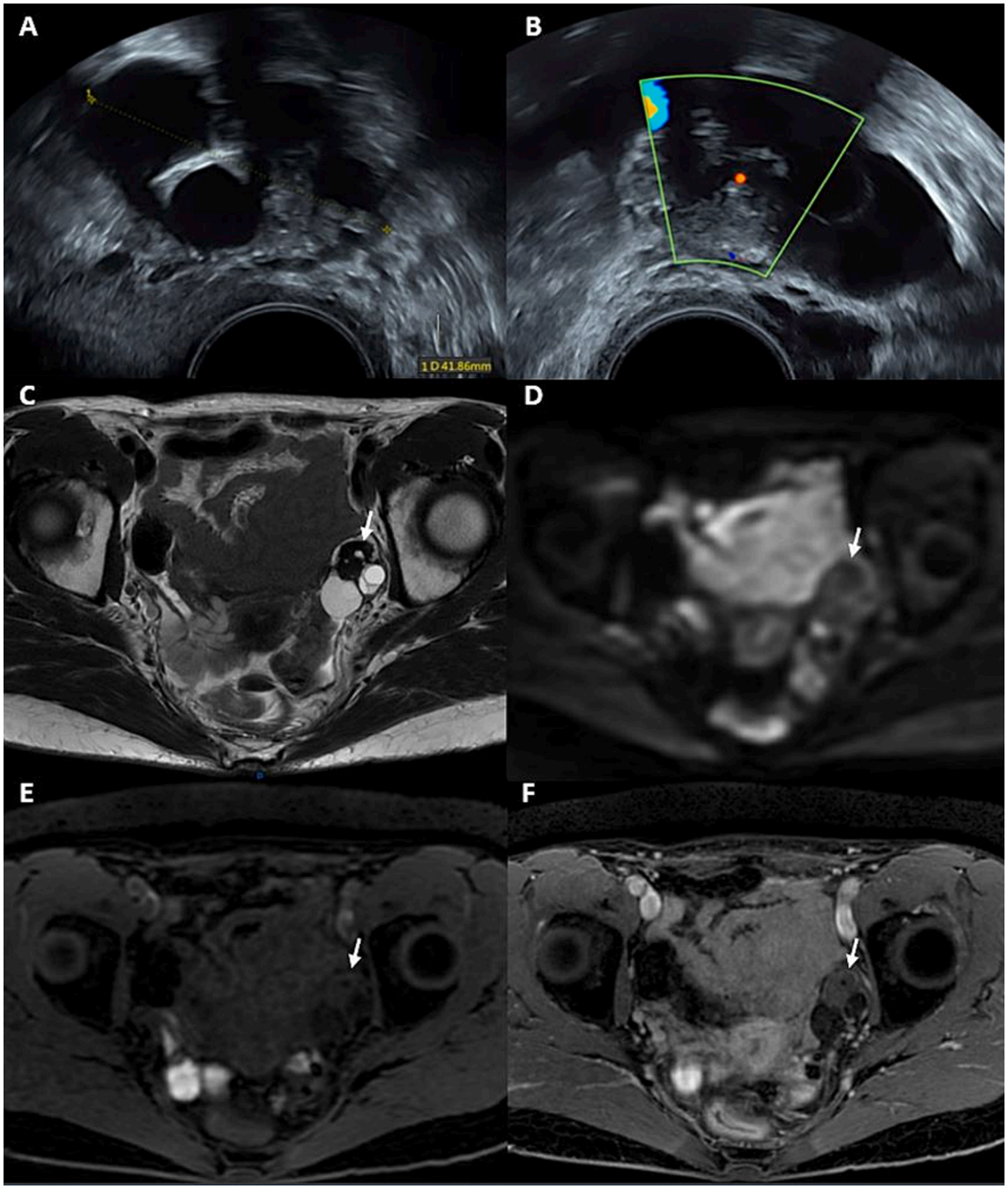

Fig. 3. A 60-year-old female patient presenting on transvaginal pelvic ultrasound with a multilocular cyst measuring 41 mm (A), with a solid component with no Doppler flow visualized (B) classified O-RADS US 4. Pelvic MRI demonstrates that a solid tissue (indicated by the arrow) is in lowT2W signal (C) and low DW signal (D), enhancing on the Dixon T1 sequence after the injection of gadolinium (E,F), classified as O-RADS MRI 2, suggesting the diagnosis of cystadenofibroma, which was confirmed by pathological analysis.

and MRI and established the superiority of MRI for the characterization of adnexal lesions [8,18,19]. However, according to stratification table for management published in O-RADS US paper by American College of Radiology (ACR) (Andreotti et al. Radiology 2019), a TVUS performed by a specialist is an alternative to MRI as a second line technique for adnexal masses rated O-RADS US score 3 and 4. In our paper, we compared the value of O-RADS US performed by an US specialist with MRI and showed that MR imaging has equal sensitivity but higher specificity than TVUS even when performed by an US specialist. This is particularly relevant for pre-menopausal women where the preservation of fertility and avoiding early hormonal menopause may be desired. Moreover, MRI has the advantage to be reviewed with surgeons during tumor board meetings, which is crucial for surgical planification. The surgeon will be able to assess the possibility/contra-indication of a mini-invasive approach depending on the size, location and presence of normal ovarian parenchyma, proportion of liquid and the ability to reduce the tumor volume within endobag, etc.

Second, this study demonstrates comparable sensitivity of O-RADS US and MRI to diagnose ovarian malignancy. Our results confirm that TVUS performance in detecting ovarian cancer is excellent with high sensitivity when performed by an expert and moderate specificity, which is in line with literature findings [15,16,20]. The O-RADS US classification [21] was designed to provide consistent interpretations, to decrease ambiguity in US reports and to provide a management

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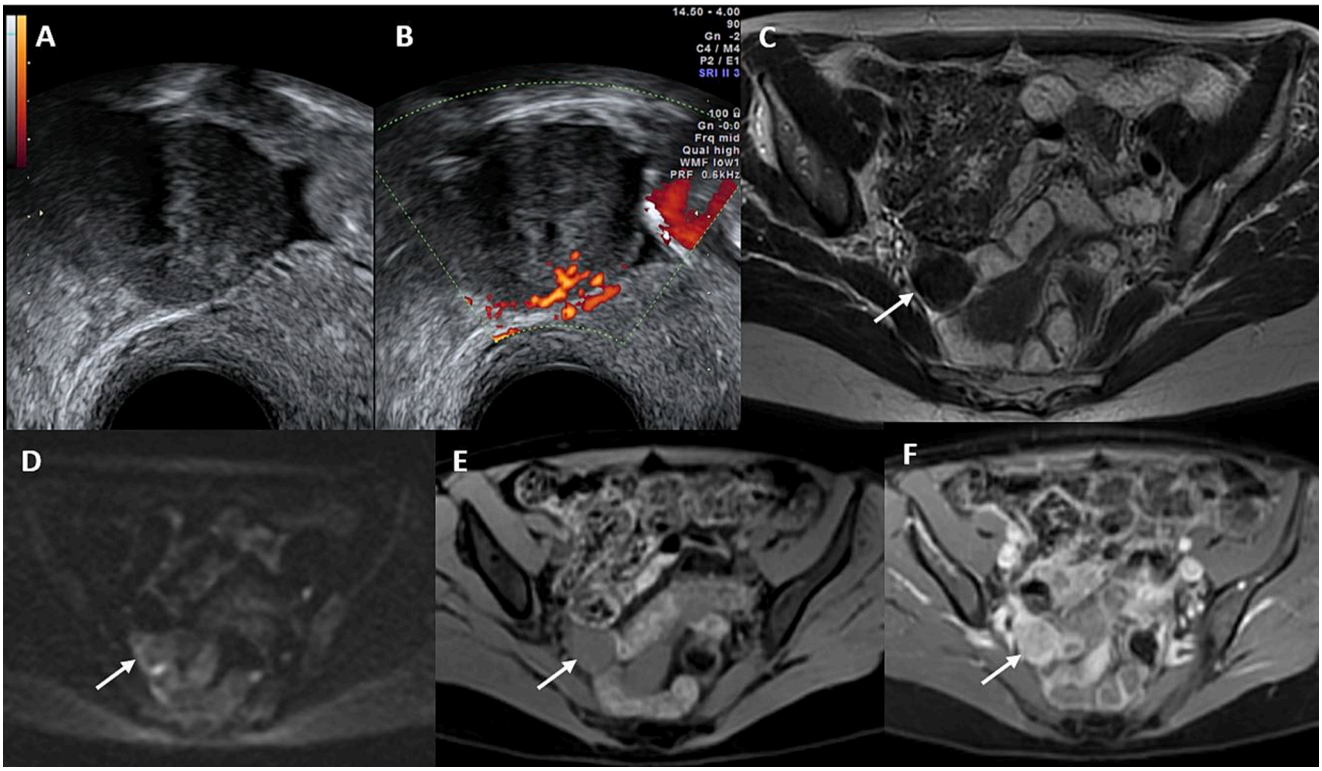

Fig. 4. A 60-year-old female patient presenting on transvaginal pelvic ultrasound with a regular solid mass measuring 29 mm, with posterior acoustic shadowing (A), and minimal doppler flow (CS = 2) visualized (B), classified O-RADS US 4. Pelvis MRI demonstrates that a purely solid mass exhibits low T2W signal (C), and low DW signal (D), low T1W signal (E) and enhances after the injection of gadolinium (F), classified O-RADS MRI 2, and suggesting the diagnosis of ovarian fibroma, which was confirmed by pathological analysis.

recommendation for each risk category. The results of our study are consistent with the first consensus guideline from ACR Ovarian Adnexal Reporting and Data System Committee, which estimates the risk of malignancy for adnexal lesions classified as O-RADS US 3 from 1% to 10% (7,6% in our study) and from 10% to 50% for O-RADS US 4 (16,4% in our study) [5]. These rates of malignancy by categories were validated by a recent *meta*-analysis, which highlights the interest of combining O-RADS US 4 and 5 to predict the risk of malignancy with high sensitivity and moderate specificity [16].

This preliminary study suggests that MRI has no higher value for adnexal lesions rated O-RADS US 3 even when performed by an expert. However, MRI is more accurate than TVUS for adnexal lesions rated O-RADS US 4, even if TVUS is performed by an expert. Thus, this data supports the use of MRI as a second-line technique recommended after initial TVUS if a mass is rated O-RADS US 4. In addition, our study proves that MRI is useful in case of lesions rated O-RADS US 5 as 8 benign adnexal lesions were overrated, while only one was overrated with a score 5 according to O-RADS MRI score. This data underlines that MRI should be recommended not only for lesions rated O-RADS US 4 but also O-RADS US 5.

In this setting, several studies have demonstrated the value of MRI in suspicious adnexal lesions to discriminate primary ovarian cystadenocarcinoma from ovarian metastasis [22] and to correctly reclassify as non-ovarian origin any pelvic malignant tumors from the digestive or urothelial tract or uterine tumors [7]. This is a common situation in clinical routine during multidisciplinary sessions and depending on imaging conclusion, the management of the patient can be radically modified. As the role of imaging techniques is to show the highest degree of certainty to be included in management decisions, pelvic MRI should also be recommended for mass rated O-RADS US 5 in the same time than CT scan for local staging.

An additional benefit of MRI is its ability to diagnose epithelial tumors, specifically, serous cystadenomas or cystadenofibromas. The O-RADS US score does not consider essential morphological elements in tissue characterization that are crucial for epithelial tumors, such as grouped septations in favor of borderline territory or posterior acoustic shadowing (found mainly in cystadenofibromas) is in favor of benignity. A recent study showed that adding acoustic shadowing as a benign finding further improved the performance of O-RADS US and may be of interest in future iterations [6]. Specifically in this group of tumors, MRI is well-known to be accurate to characterize fibrous tissue, as published many years ago by Siegelman and Outwater with T2W sequence [3]. Furthermore, the development of DW MR sequence has improved the diagnostic accuracy [23] thanks to the combination of dark T2W and dark DW signal to predict benignity (NPV = 100%) [24].

Our study has several limitations. First, the prevalence of malignancy is quite low due to the retrospective design of the study. We selected patients who benefit from both MRI and expert TVUS to compare their added value as a second line technique. In our clinical routine, expert TVUS is more frequently combined with MRI when the surgeon needs to decide between surgery and imaging follow up. In our population, most lesions were managed with follow up (56.8%, 153/269). Second, another limitation is that our study included few cases of borderline ovarian tumors (n = 12) and a subgroup analysis for this pathology was not possible to distinguish them from malignant tumors.

In conclusion, O-RADS MRI has equal sensitivity compared to O-RADS US when performed by an expert, with correct reclassification of a significant number of lesions as benign on MRI. Pelvic MRI can improve characterization of adnexal lesions prior to final management, particularly when an adnexal lesion is rated as O-RADS US 4 or 5 on TVUS.

CRediT authorship contribution statement

Audrey Campos: Writing – original draft, Funding acquisition,

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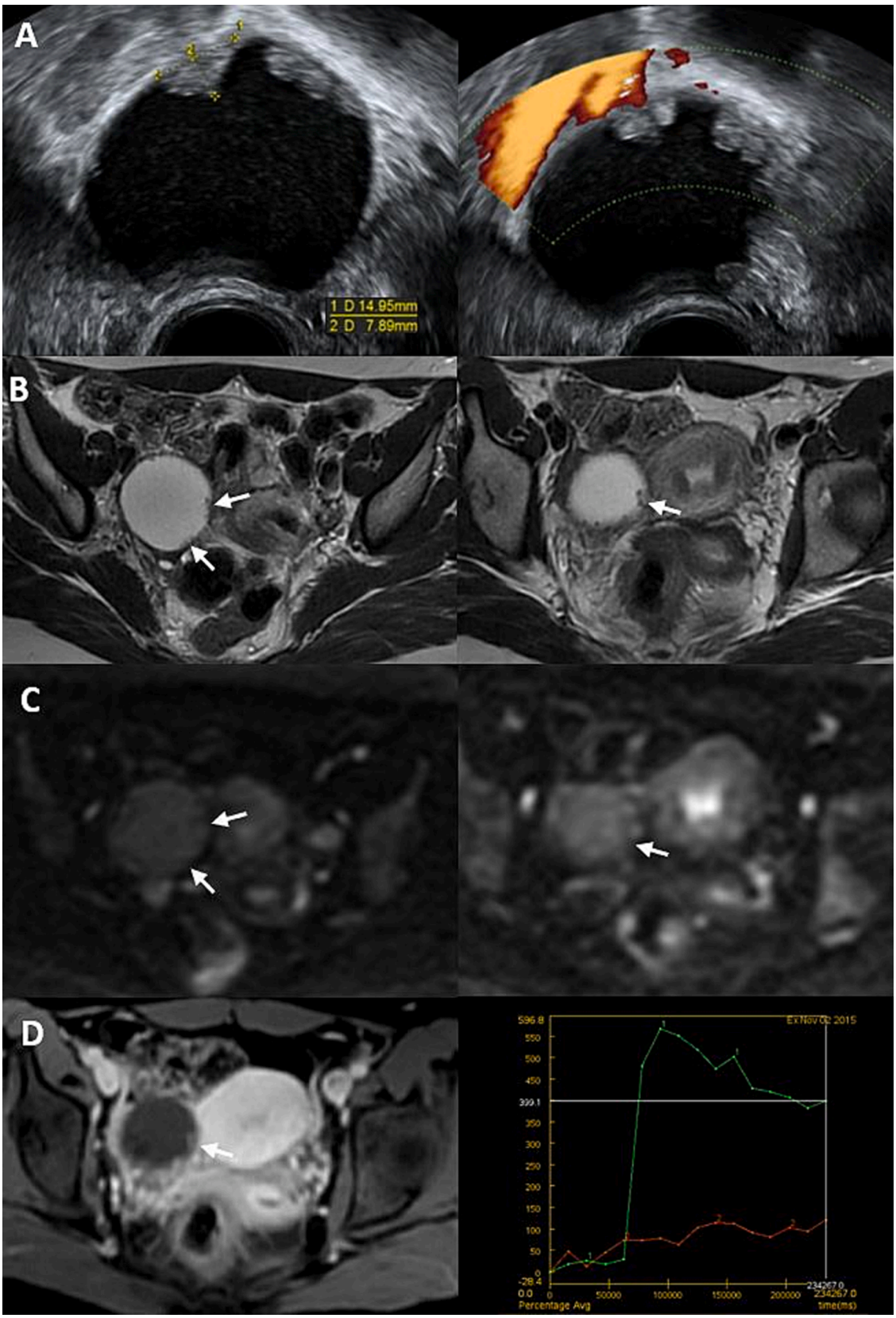

Fig. 5. A 22-year-old female patient presenting on transvaginal pelvic ultrasound with a unilocular cyst measuring 52 mm with more than 4 vegetations, and no Doppler flow visualized, classified O-RADS US 5 (B,C,D). Pelvic MRI with T2, DW and T1 sequences with fat saturation after the injection of gadolinium demonstrates an unilocular cyst with vegetations (indicated by the arrow) in intermediate T2W signal, low DW signal, with a low-risk time intensity curve on DCE, classified O-RADS MRI 3, suggesting the diagnostic of a benign serous papillary cystadenoma, and confirmed by pathological findings.

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Conceptualization. **Camille Villermain-Lécolier:** Writing – original draft, Funding acquisition, Data curation. **Elizabeth A. Sadowski:** Writing – review & editing. **Marc Bazot:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis, Conceptualization. **Cyril Touboul:** Writing – review & editing. **Léo Razakamanantsoa:** Writing – review & editing, Supervision. **Isabelle Thomassin-Naggara:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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