

REVIEW

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ESR Essentials: characterisation and staging of adnexal masses with MRI and CT—practice recommendations by ESUR

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Abstract

Ovarian masses encompass various conditions, from benign to highly malignant, and imaging plays a vital role in their diagnosis and management. Ultrasound, particularly transvaginal ultrasound, is the foremost diagnostic method for adnexal masses. Magnetic Resonance Imaging (MRI) is advised for more precise characterisation if ultrasound results are inconclusive. The ovarian-adnexal reporting and data system (O-RADS) MRI lexicon and scoring system provides a standardised method for describing, assessing, and categorising the risk of each ovarian mass. Determining a histological differential diagnosis of the mass may influence treatment decision-making and treatment planning. When ultrasound or MRI suggests the possibility of cancer, computed tomography (CT) is the preferred imaging technique for staging. It is essential to outline the extent of the malignancy, guide treatment decisions, and evaluate the feasibility of cytoreductive surgery.

This article provides a comprehensive overview of the key imaging processes in evaluating and managing ovarian masses, from initial diagnosis to initial treatment. It also includes pertinent recommendations for properly performing and interpreting various imaging modalities.

Key Points

- MRI is the modality of choice for indeterminate ovarian masses at ultrasound, and the O-RADS MRI lexicon and score enable unequivocal communication with clinicians.
- CT is the recommended modality for suspected ovarian masses to tailor treatment and surgery.
- Multidisciplinary meetings integrate information and help decide the most appropriate treatment for each patient.

Keywords Ovarian neoplasms, X-ray computed tomography, Magnetic resonance imaging, Patient care, Workflow

Key recommendations

1. Ultrasound is the first-line technique for detecting and characterising adnexal masses, and MRI should be used to characterise all ultrasonographically

indeterminate ones (level of evidence: high) [1]. The standardised O-RADS MRI lexicon is recommended to improve consistency and reproducibility, especially for less experienced readers; O-RADS MRI application provides a risk score of malignancy for adnexal masses (level of evidence: high), but a histological diagnosis may be given to ensure unequivocal and univocal communication with clinicians (level of evidence: moderate).

2. CT of the thorax, abdomen, and pelvis is the recommended technique for preoperatively staging suspected ovarian cancer (level of evidence: high); a

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standardised lexicon and approach to reporting disease locations is recommended to ensure optimised treatment selection and surgical planning (level of evidence: moderate).

3. Imaging should be discussed in dedicated multidisciplinary meetings to consider possible options in the specific centre and offer a personalised treatment based on preoperative findings (level of evidence: high).

Introduction

Ovarian masses are a heterogeneous group of diseases, ranging from benign to aggressively malignant.

Ultrasound (US) is the first-line imaging technique to evaluate suspected ovarian neoplasm, while magnetic resonance imaging (MRI) plays an essential role as a second-line examination to characterise adnexal masses indeterminate at US [2]. Given that imaging features of different ovarian entities may overlap, it is fundamental for the radiologist to be familiar with the main imaging characteristics of different histological subtypes and integrate them with clinical information and laboratory data, such as tumour markers, in order to narrow the differential diagnosis [3] and ideally reach a specific one.

When ovarian cancer (OC) is suspected at US or MRI, the International Federation of Obstetrics and Gynaecologists advocates the use of contrast-enhanced computed tomography for the evaluation of the extent of the disease since it provides clinically relevant information, including primary tumour extension, size and location of any peritoneal implants and lymph nodes (LNs). This information is crucial for treatment planning and to predict cytoreductive resectability.

Figure 1 shows the flowchart for how and when each technique is used.

Adnexal mass characterisation

Ultrasound

Transvaginal ultrasound (TVUS) is the first diagnostic modality for suspect adnexal masses and correctly classifies up to 80%. An in-depth explanation of the role of TVUS goes beyond the scope of this paper and detailed information can be found in publications/guidelines of the International Ovarian Tumour Analysis group and on the ovarian-adnexal reporting and data system ultrasound (O-RADS US) [4].

Magnetic resonance imaging

Indication

Twenty percent of ovarian lesions are not adequately characterised in the US [5]. In such situations, MRI becomes the imaging modality of choice for

further characterisation [2] due to superior contrast resolution that allows for distinguishing different tissue types.

Patient preparation and protocol

The MRI exam should be performed using a high-field MRI (1.5 T or 3 T), in a supine position using a surface array multichannel coil.

Fasting for 4–6 h prior to an MRI examination is no longer recommended. To reduce motion artefacts from bowel and uterine peristalsis, the administration of an antiperistaltic agent is highly suggested. Intramuscular administration has an increased length of action of approximately 30–60 min, while intravenous injection lasts 10 min. To avoid motion artefacts caused by the full bladder, it is advocated to empty the bladder 30 min before the examination.

It is crucial to optimise and standardise the MRI protocol to facilitate the characterisation of adnexal findings. A suggested protocol is provided in Table 1.

MRI evaluation

The O-RADS MRI score [2, 6] is the validated worldwide classification system to characterise adnexal masses based on a multivariate analysis of the most predictive features of malignancy. O-RADS MRI identifies five risk categories (Table 2) with a reported sensitivity and specificity exceeding 90% for the detection of malignancy [7].

A detailed overview of the O-RADS MRI lexicon has been described by Reinhold et al [8]. It is crucial to note the difference between solid components, i.e. any part of an adnexal lesion that is not simple fluid (smooth wall or septation, clot, debris, and fat), and solid tissue, which is a solid component displaying post-contrast enhancement and exhibiting the presence of at least one of the following morphologies: papillary projections, mural nodules, irregular septations or walls, and a larger solid portion (Fig. 2).

A diagnostic approach to MRI interpretation is proposed below (Fig. 3):

1. Identify the origin of the mass: it is fundamental to identify each ovary following the ovarian pedicle, followed by the evaluation of the lesion's origin through the analysis of T2-weighted images (WI) in different planes since suspected indeterminate adnexal masses on the US can have different origins (uterus, gastrointestinal tract, retroperitoneum, O-RADS 1). An overview of the main MRI findings helpful in distinguishing between different origins of a pelvic mass has been reported by Forstner et al [9].
2. Verify the presence of wall enhancement in a cyst: if absent, the lesion is almost certainly benign (O-RADS 2).

WORKFLOW DIAGRAM FOR SUSPECTED OVARIAN MASS

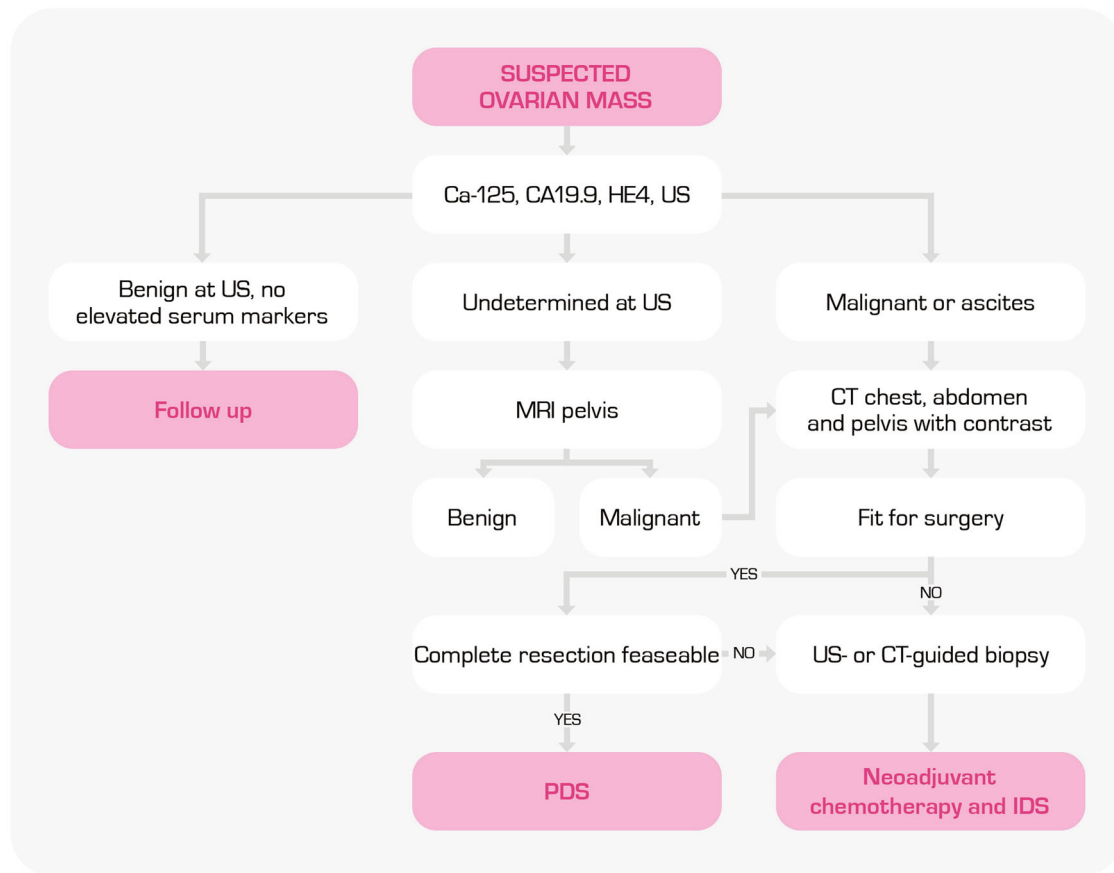


Fig. 1 Workflow diagram for suspected ovarian lesions

- Evaluate the signal characteristics and morphology on unenhanced T1WI and T2WI:
 - T1WI hypointense and T2WI markedly hyperintense (fluid components): the presence of a unilocular cyst with a simple fluid component provides us with strong diagnostic assurance for a benign lesion (simple cyst, O-RADS 2).
 - T1WI hyperintense (T1 “bright”) fluid components:
 - High signal intensity (SI) on T2 and unenhanced T1WI with suppression at T1 fat-saturated images indicates the presence of macroscopic fat, while a drop of signal intensity in the opposed phase of chemical

shift imaging suggests the presence of microscopic fat. Intralesional fat gives us good diagnostic confidence for a benign lesion since the vast majority of the lipid-containing mass are dermoid cysts (ORADS 2). The other less common fat-containing benign ovarian lesions are germ tumours (struma ovarii), where cystic spaces may show marked hypointensity on T2WI and intermediate signal intensity on T1WI due to thyroid colloid of the struma [10]. Immature teratomas are uncommon large malignant tumours, usually seen in adolescent women, characterised by a heterogeneous signal intensity with a prominent solid

Table 1 Suggested MRI protocol for ovarian mass characterisations

Sequences	Plane*	Slice thickness*	Additional requirements
T2-weighted without fat sat	Sagittal or coronal	4 mm	
T2-weighted without fat sat	Axial	3 mm	
T1-weighted in- and opposed- phase gradient echo or Dixon T1-weighted	Axial	3-4 mm	– Can use the in/out phase images from the 3D T1 WI pre-contrast if using the Dixon technique, however these should be 3mm
Diffusion weighted	Axial	4-5 mm	– Low B-values: 0 or 50 – High B-value: 1000 – 1200 – If 4mm, skip 2mm; if 5mm, skip 1mm
Dynamic contrast enhanced (DCE) T1-weighted (Pre- and Post-contrast in same series)	Axial	3 mm	– Pre- and Post-contrast in a single series are required to perform the subtraction series – Minimal temporal resolution < 15 seconds – Continuous acquisition, starting with the pre-contrast phase, injection of contrast after the pre-contrast phase is acquired and continuing for a total of 3 minutes
Non-dynamic 3D T1WI with fat sat (Pre- and Post-contrast in separate series)	Axial	3 mm	– Obtain one series pre-contrast – If not acquiring a DCE MRI, obtain, one phase scanned at 30-40 seconds after the end of the contrast injection – If acquiring a DCE MRI, obtain a post-contrast series after the DCE is completed

*For very large lesion changes in plane and slice thickness adjustments may be needed to assure coverage of the entire lesion, however small papillary projections may be missed.

Note: reproduced with permission from the American College of Radiology Committee on O-RADS, O-RADS Assessment Categories 2022. Available at https://www.acr.org/-/media/ACR/Files/RADS/O-RADS/O-RADS-MRI-Risk-Score_v1_2020_May-2023-_Final.pdf. Accessed on January 12, 2024

- component and an infiltrative growth pattern (O-RADS 4).
- High SI on unenhanced T1WI with fat saturation reflects T1 shortening from extracellular methemoglobin, indicating the presence of blood breakdown products. If it is associated with a loss of signal intensity within the lesion on T2WI (the “shading” sign), the lesion is almost certainly an endometrioma, which is benign (O-RADS 2). On the other hand, the presence of haemorrhagic, mucinous, and proteinaceous fluid components, which show variable hyperintensity on unenhanced T1 and T2WI, indicates a low risk of malignancy (O-RADS 3).
4. Check for the presence of internal enhancement in a cyst:
- Internal enhancement corresponding to a solid tissue:
 - Solid tissue with homogeneous hypointense SI on T2WI and DWI (“dark T2, dark-

- DWI”): This finding configures a probably benign lesion due to the presence of fibrous tissue. If the mass is predominantly solid and with homogeneous SI, the positive predictive value of malignancy is close to zero and DCE sequences are not needed (O-RADS 2; i.e. fibromas, cystadenofibromas).
- Solid tissue with intermediate SI on T2WI and restricted diffusion on DWI: contrast enhancement (CE) sequences need to be evaluated. Dynamic contrast-enhanced sequences (DCE) are recommended as they allow the building of time-intensity curves (TICs, Fig. 4) by placing one region of interest within the area of early solid tissue enhancement in the lesion and another on the outer myometrium. If DCE MRI is not feasible, non-DCE MRI can be performed as a single post-contrast T1-weighted sequence at 30 s with fat saturation and the enhancement of the solid tissue in the lesion is compared to the outer myometrium.

Table 2 ORADS MRI risk stratification table

O-RADS MRI Score	Risk Category	Positive Predictive Value for Malignancy [^]	Lexicon Description
0	Incomplete Evaluation	N/A	N/A
1	Normal Ovaries	N/A	No ovarian lesion Follicle defined as simple cyst ≤ 3 cm in a premenopausal woman Hemorrhagic cyst ≤ 3 cm in a premenopausal woman Corpus luteum +/- hemorrhage ≤ 3 cm in a premenopausal woman
2	Almost Certainly Benign	<0.5% [^]	Cyst: Unilocular- any type of fluid content <ul style="list-style-type: none"> No wall enhancement No enhancing solid tissue* Cyst: Unilocular – simple or endometriotic fluid content <ul style="list-style-type: none"> Smooth enhancing wall No enhancing solid tissue Lesion with lipid content** <ul style="list-style-type: none"> No enhancing solid tissue Lesion with “dark T2/dark DWI” solid tissue <ul style="list-style-type: none"> Homogeneously hypointense on T2 and DWI Dilated fallopian tube - simple fluid content <ul style="list-style-type: none"> Thin, smooth wall/endosalpingeal folds with enhancement No enhancing solid tissue Para-ovarian cyst – any type of fluid <ul style="list-style-type: none"> Thin, smooth wall +/- enhancement No enhancing solid tissue
3	Low Risk	~5% [^]	Cyst: Unilocular – proteinaceous, hemorrhagic or mucinous fluid content*** <ul style="list-style-type: none"> Smooth enhancing wall No enhancing solid tissue Cyst: Multilocular - Any type of fluid, no lipid content <ul style="list-style-type: none"> Smooth septae and wall with enhancement No enhancing solid tissue Lesion with solid tissue (excluding T2 dark/DWI dark) <ul style="list-style-type: none"> Low risk time intensity curve on DCE MRI Dilated fallopian tube – <ul style="list-style-type: none"> Non-simple fluid: Thin wall /folds Simple fluid: Thick, smooth wall/ folds No enhancing solid tissue
4	Intermediate Risk	~50% [^]	Lesion with solid tissue (excluding T2 dark/DWI dark) <ul style="list-style-type: none"> Intermediate risk time intensity curve on DCE MRI Any lesion with solid tissue enhancing ≤ myometrium at 30-40s on non-DCE MRI**** Lesion with lipid content <ul style="list-style-type: none"> Large volume enhancing solid tissue
5	High Risk	~90% [^]	Lesion with solid tissue (excluding T2 dark/DWI dark) <ul style="list-style-type: none"> High risk time intensity curve on DCE MRI Any lesion with solid tissue enhancing > myometrium at 30-40s on non-DCE MRI Peritoneal, mesenteric or omental nodularity or irregular thickening with or without ascites

[^]Approximate PPV based on data from Thomassin-Naggara, et al. O-RADS MRI Score for Risk Stratification of Sonographically Indeterminate Adnexal Masses. *JAMA Network Open*. 2020;3(1):e1919896. Please note that the PPV provided applies to the score category overall and not to individual characteristics. Definitive PPV are not currently available for individual characteristics. The PPV values for malignancy include both borderline tumors and invasive cancers.

* Solid tissue is defined as a lesion component that enhances and conforms to one of these morphologies: papillary projection, mural nodule, irregular septation/wall or other larger solid portions.

** Minimal enhancement of Rokitansky nodules in lesion containing lipid does not change to O-RADS MRI 4.

*** Hemorrhagic cyst ≤3cm in pre-menopausal woman is O-RADS MRI 1.

****Decreased accuracy of O-RADS MRI score when DCE is not utilized

DCE = dynamic contrast enhancement with a time resolution of 15 seconds or less

DWI = diffusion weighted images

MRI = magnetic resonance imaging

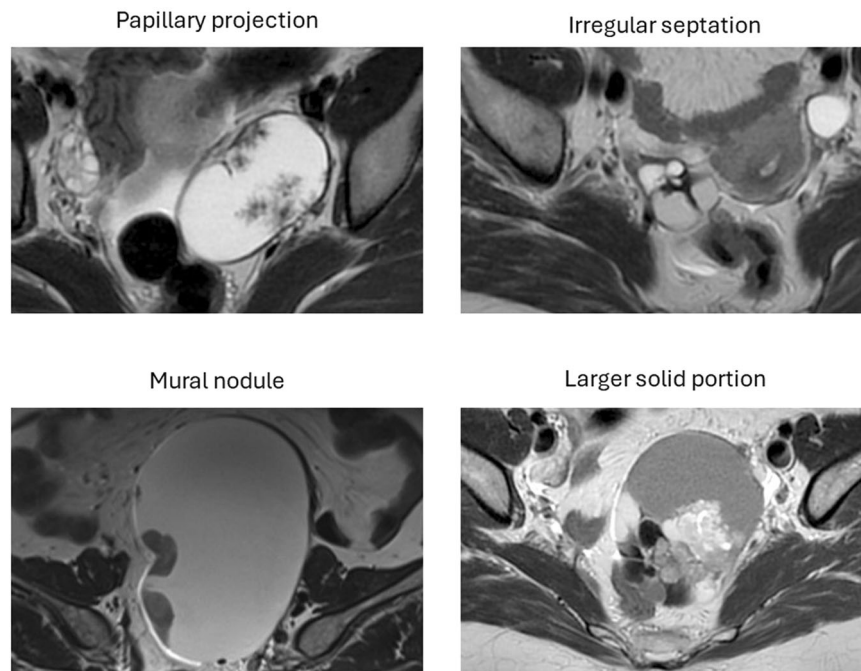


Fig. 2 Solid tissue morphologies

The evaluation of the post-contrast dynamics of the solid tissue let us improve the risk assessment of the mass (O-RADS 3, 4, and 5; Fig. 4).

- Internal enhancement non-corresponding to a solid tissue: CE is probably due to thin or thick smooth septa in a bilocular or multilocular cyst or to endosalpingeal folds in a pyosalpinx (O-RADS 3).
5. Look for peritoneal carcinomatosis: if peritoneal carcinomatosis is detected, the likelihood of malignancy is high (O-RADS 5), and gynaecologic oncologist counselling is needed.

Independent from O-RADS and its risk classification, it may be important for patient management to give a histological differential diagnosis of the mass because it would give important information to plan the subsequent treatment. For example, a multilocular mucinous cystadenoma and a borderline serous ovarian tumour with papillae with an uncommon low-risk curve of enhancement might fall under the same category of O-RADS MRI 3. However, they should be treated with different priorities and possibly with different surgical approaches. To help with this, an overview of the distinguishing MRI features of different ovarian neoplasms, clinical information, and laboratory data is shown in Table 3.

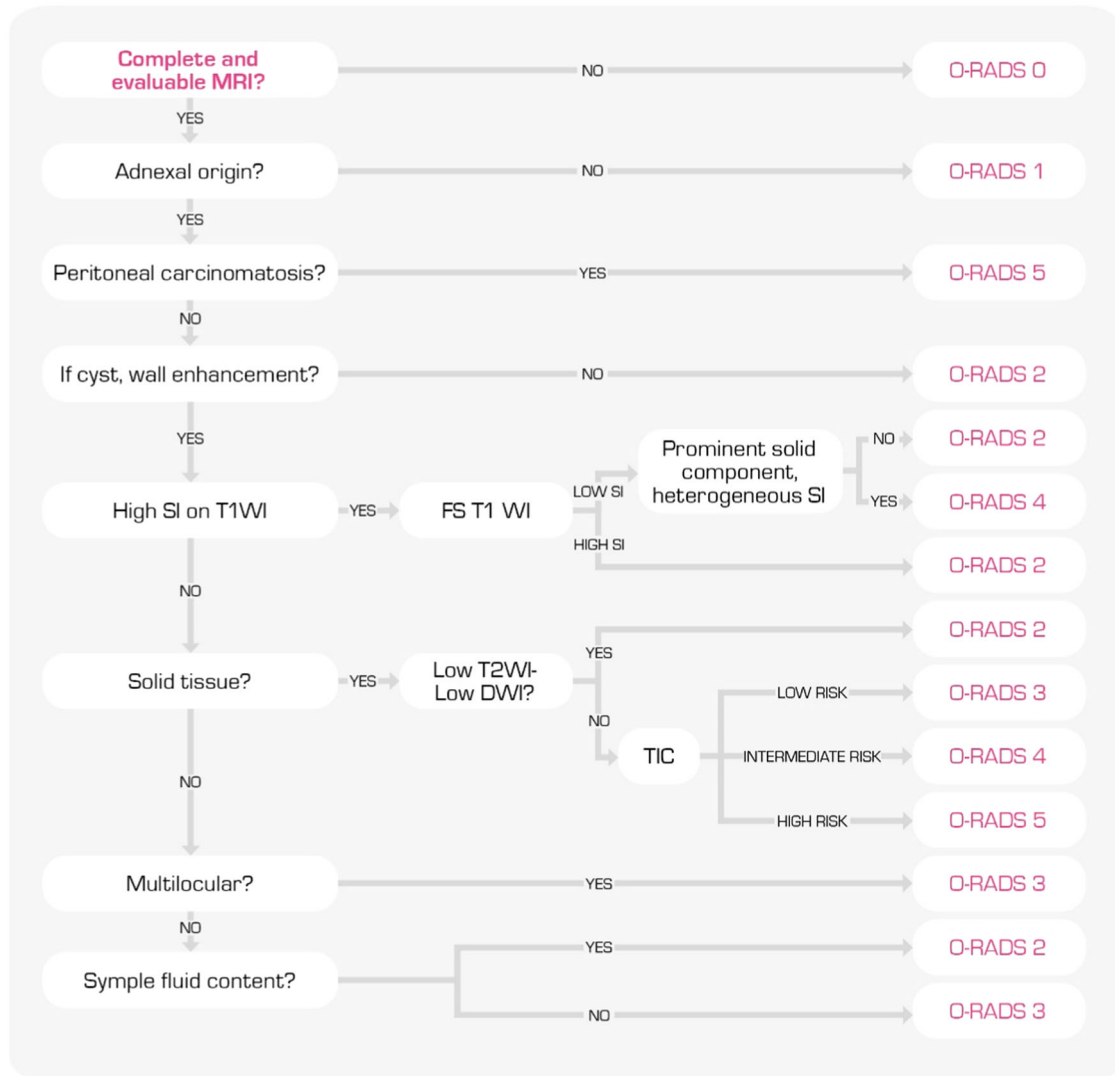
While contrast-enhanced MRI score is preferred [2], non-contrast MRI scores have shown good accuracy in

predicting the risk of malignancy [11]. This score emphasises the importance of morphological sequences and DWI for evaluating solid tissue and includes in the risk stratification ancillary features like ascites, lymphadenopathy, and peritoneal implants. Non-contrast MRI scores can be a suitable diagnostic alternative when the administration of intravenous contrast medium is not feasible, such as in pregnant women, particularly during the first trimester [12].

Staging and surgical treatment planning Objectives

In OC, the established treatment is a combination of surgery for complete cytoreduction and platinum-based chemotherapy. The objective of surgery is the excision of all visible tumour localisations [13]. Incomplete resection is a strong negative prognostic factor and should be avoided. When possible, surgery is done as the first treatment (primary debulking surgery, PDS), but if the complete gross resection is considered too difficult to achieve, neoadjuvant chemotherapy followed by interval debulking surgery should be performed. A significant issue in the pre-surgical evaluation of debulking feasibility is the lack of universally accepted standardised criteria, with different individual criteria and preferences depending on the skill and experience of the surgical team. Discussion of suitability for PDS in multidisciplinary tumour boards is an essential part of treatment planning [14]. In this context, imaging to determine

MRI WORKFLOW DIAGRAM FOR OVARIAN MASS CHARACTERISATION



ABBREVIATIONS:

T1WI = T1-weighted images
FS T1WI = fat-saturated T1-weighted images
SI = signal intensity

T2WI = T2-weighted images
DWI = diffusion-weighted images [b>1000]
TIC = Time-Intensity Curve

Fig. 3 MRI Workflow diagram for ovarian mass characterisation

the extent and spread of the tumour is vital for tailoring treatment plans [15, 16].

Imaging modalities

Currently, multidetector CT is the preferred method for staging OC due to its broad availability, relatively low cost, fast scanning time, and large coverage.

While MRI matches CT in diagnostic accuracy, it is generally considered a secondary modality for OC staging.

MRI is the best modality in cases where CT is not suitable, such as for patients with allergies to contrast media, renal insufficiency/failure, pregnancy, and young patients. However, the lower availability, the longer scan time, and the higher cost limit its use. DWI is the most useful sequence in peritoneal implant detection, as they usually show restricted diffusion (high signal intensity in high B-value sequence and low in apparent diffusion coefficient maps), as well as an intermediate signal intensity in T2WI.

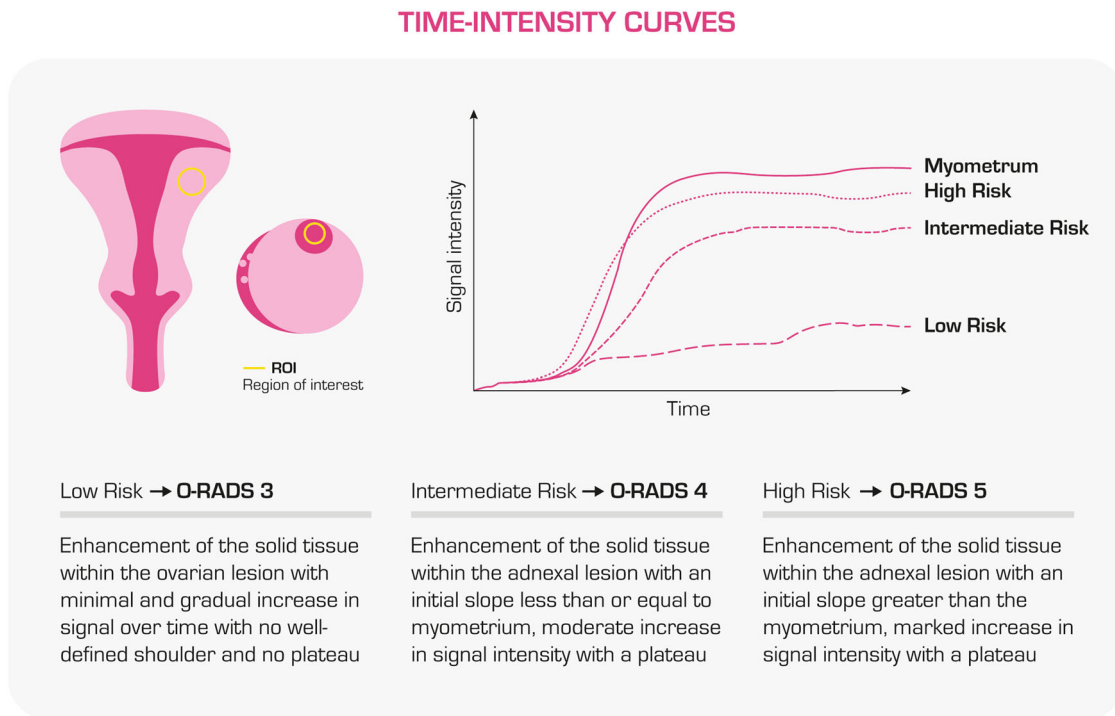


Fig. 4 TICs and risk assessment

Guidelines do not suggest using [^{18}F]fluorodeoxyglucose positron emission tomography for the initial diagnosis and staging of OC [17].

Protocol

For staging advanced OC, CT scans of the chest, abdomen, and pelvis are recommended. Using intravenous iodinated contrast agents is mandatory as non-contrast CT does not provide essential information. Oral contrast is less widely accepted but recommended by the ACR appropriateness criteria [18]. A positive oral contrast agent is particularly effective in making bowel loops visible and identifying peritoneal deposits on the serosal intestinal surface and within the mesentery. However, small calcified implants, more common in low-grade serous OC, might be less visible with positive oral contrast and could be more clearly detected using a negative oral contrast like water. Additionally, examining reconstructed coronal and sagittal images alongside the standard axial images can enhance the detection of peritoneal implants.

Main findings to report

Utilising a disease-focused approach and standardised terminology can aid radiologists in comprehensively and coherently documenting all critical disease sites [19]. The standardised lexicon proposed by the Society of

Abdominal Radiology (SAR) and the European Society of Urogenital Radiology (ESUR) is recommended [20].

From a surgical standpoint, specific disease sites may pose more challenges than others to be resected, and these locations should be specifically highlighted [21].

The European Society of Gynaecologic Oncology enlists the following findings as “criteria against abdominal debulking” [22]:

- Diffuse deep infiltration of the root of small bowel mesentery.
- Diffuse carcinomatosis of the small bowel which would lead to short bowel syndrome (remaining bowel < 1.5 m) or total colectomy.
- Diffuse involvement/deep infiltration of stomach/duodenum (limited excision is possible) or pancreas head.
- Involvement of coeliac axis and its branches (coeliac nodes can be resected).

Upper abdomen

Implants located in the fissure for ligamentum venosum (the area between the caudate and left hepatic lobes), falciform ligament, the porta hepatis, the lesser omentum (including the hepatogastric and hepatoduodenal ligaments), and those with direct liver tissue invasion often necessitate more complex liver surgery, possibly requiring the expertise of a hepatobiliary surgeon. Parenchymal

invasion is suspected when unclear, nodular, or merged boundaries with the liver are noted.

In the left upper quadrant, tumours located in the splenic hilum or within the spleen may require a splenectomy. If anticipated by imaging, this procedure can be carried out along with removing the omentum.

Bowel and mesentery

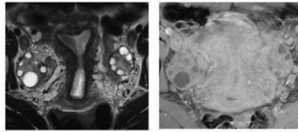
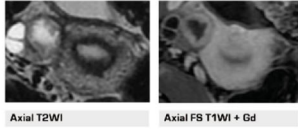
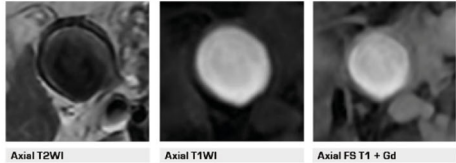
The lesion morphology and location, number of affected segments, and proximity to the bowel of mesenteric lesions are crucial for surgical decision-making. Surgeons must consider the risks of extensive bowel resection, including increased operating time and potential complications. CT scans often underestimate small bowel involvement and particular attention should be paid to this aspect.

While most mesenteric disease is resectable, implants in the central mesentery can lead to less effective debulking or higher morbidity if resection is attempted. These implants range from fat infiltration to small nodules or large, irregular masses, typically surrounding mesenteric vessels, affecting resectability. Secondary signs like bowel loop retraction, tethering, and angulation are also crucial for radiologists to identify mesenteric involvement. Discrete nodules are resectable but extend the surgery time. Diffuse infiltration and retraction, indicating central mesentery involvement, require neoadjuvant chemotherapy before surgery.

Lymph nodes

Radiologic reports should include all abnormal LNs, although certain LN locations pose more significant

Table 3 Imaging and laboratory characteristics of main ovarian tumours

<p>OVARIAN TUMOUR-LIKE LESIONS</p> <ul style="list-style-type: none"> • Main types: <ul style="list-style-type: none"> - Follicle - Corpus luteum - Endometrioma 		
TYPE	IMAGING FEATURES	IMAGES
FOLLICLE	<ul style="list-style-type: none"> • Simple cyst ≤ 3 cm in pre-menopausal women. • T1: ↓ SI • T2: ↑ SI • CE: absent 	 <p>Axial T2WI Axial FS T1WI</p>
CORPUS LUTEUM	<ul style="list-style-type: none"> • Cyst ≤ 3 cm with enhancing crenulated wall on subtracted post-contrast T1WI +/- blood clot or haemorrhagic content in pre-menopausal women. 	 <p>Axial T2WI Axial FS T1WI + Gd</p>
ENDOMETRIOMA	<ul style="list-style-type: none"> • Reproductive age • Haemorrhagic content • T2WI: intermediate to low with shading sign • T1WI: ↑ SI • DWI: possible restricted diffusion • CE: absent 	 <p>Axial T2WI Axial T1WI Axial FS T1 + Gd</p>

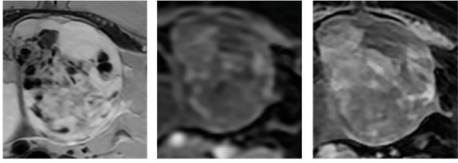
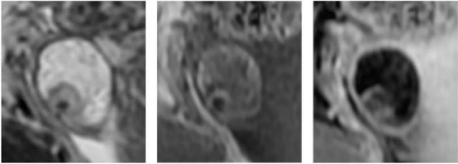

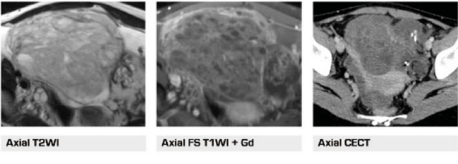
ABBREVIATIONS:

T1WI = T1-weighted images
 FS T1WI = fat-saturated T1-weighted images
 SI = signal intensity

T2WI = T2-weighted images
 DWI = diffusion-weighted images (b>1000)
 CE = contrast-enhanced images

CT = computed tomography
 Gd = Gadolinium

Table 3 continued

OVARIAN GERM CELL TUMOURS		
TYPE	IMAGING FEATURES	IMAGES
<p>BENIGN (95%)</p> <p>Most common: mature cystic teratoma (dermoid cyst)</p> <ul style="list-style-type: none"> • Age: young women (mean age 35 y) <p>Less Common: Struma ovarii</p> <ul style="list-style-type: none"> • Age: mean age 50 y.o. • Predominant mature histologic cell type (thyroid tissue) • Can be associated with hyperthyroidism • Rarely malignant transformation (papillary carcinoma) 	<p>STRUMA OVARIII</p> <ul style="list-style-type: none"> • T1 and T2WI: cystic spaces with both high and low signal intensity, often low signal intensity in both T1 and T2WI because of the colloid of the struma • DWI: variable restricted diffusion • CE: vivid enhancement of the solid components 	 <p>Axial T2WI Axial T1WI Axial T1WI + Gd</p>
	<p>MATURE CYSTIC TERATOMA</p> <ul style="list-style-type: none"> • T1WI: visible Fat (↑ SI foci on T1WI with ↓ SI on T1WI fat-sat) • T2WI: Variable • DWI: Restricted diffusion • CE: Solid tissue may be present (Rokitansky nodules), but is not malignant • CT: regular margins, large foci of fat and coarse calcifications 	 <p>Axial T2WI Axial T1WI Axial FS T1WI + Gd</p>
<p>MALIGNANT (5%)</p> <p>Most common: dysgerminoma, immature teratoma, yolk sac tumor, mixed germ cell tumor</p> <ul style="list-style-type: none"> • Age: 10-20 years • Tumour markers: AFP, LDH, β-hCG 	<p>DYSGERMINOMA</p> <ul style="list-style-type: none"> • Large unilateral mass • ↑ LDH • T2WI: Solid, intermediate-SI mass with septa • DWI: Restricted diffusion • CE: Homogenously enhancement with avidly enhancing septa 	 <p>Sagittal T2WI Sagittal FS T1WI + Gd Axial ADC</p>
	<p>IMMATURE TERATOMA</p> <ul style="list-style-type: none"> • T1WI: Small foci of fat (↑ SI foci on T1WI with ↓ SI on T1WI fat-sat) • T2WI: Large mixed mass (solid > cystic) with irregular margins • CE: conspicuous amount of enhancing solid tissue • CT: foci of fat and calcifications, smaller than mature cystic teratoma 	 <p>Axial T2WI Axial FS T1WI + Gd Axial CECT</p>

ABBREVIATIONS:

T1WI = T1-weighted images
FS T1WI = fat-saturated T1-weighted images
SI = signal intensity

T2WI = T2-weighted images
DWI = diffusion-weighted images (b>1000)
CE = contrast-enhanced images

CECT = contrast-enhanced computed tomography
CT = computed tomography
Gd = Gadolinium

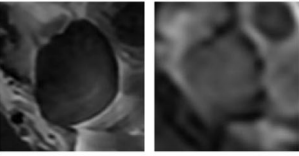
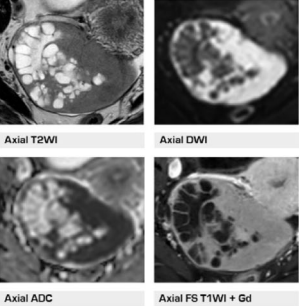
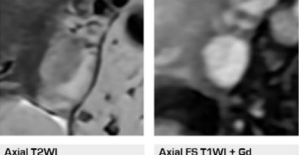
surgical challenges. These include LNs in the para-aortic area above the renal vessels, near the porta hepatis, adjacent to the coeliac axis, within the mesentery, and in the retrocrural area. Cardiophrenic LNs are considered abnormal if they exceed 0.5 cm in the short axis [23] and can be resected when in the anterior position. Inguinal LNs larger than 1.5 cm are also considered abnormal but can be excised even in stage IVB cases.

Other localisations

Other stage IV sites, like splenic parenchymal metastases, can be addressed through splenectomy. However, metastases in liver tissue, lungs, pleura, abdominal wall, or other soft tissues are usually considered not resectable except when limited or isolated.

The main peritoneal locations of disease that should be reported are listed in Fig. 5, with typical examples of CT findings.

Table 3 continued

<p>OVARIAN SEX-CORD STROMAL TUMOUR</p>		
TYPE	IMAGING FEATURES	IMAGES
<p>BENIGN (70%)</p> <ul style="list-style-type: none"> • Fibroma > 50% (peri- and postmenopausal women) • Thecoma • Sclerosing stromal tumor (rare) 	<p>FIBROMA</p> <ul style="list-style-type: none"> • T2WI: homogenous ↓ SI (fibrous content, « T2-dark ») • Less frequent: black sponge-like appearance: tiny, scattered, fluid-filled cavities with a higher signal intensity within the dark SI solid component in T2-weighted images • ↑ SI if oedema/cystic in large lesions or if thecoma component is present • DWI: « T2-DWI dark-dark » • ↓ SI on T2WI and high b-value DWI • Thecoma may show restricted diffusion • CE: mild delayed enhancement 	 <p>Axial T2WI Axial DWI</p>
<p>MALIGNANT (30%)</p> <p>Most common: granulosa cell tumour (70%)</p> <ul style="list-style-type: none"> • Tumour marker: Inhibin • ↑ endometrium can be thickened due to oestrogen hyperproduction <p>Types:</p> <ul style="list-style-type: none"> • Adult type (95%): peri-menopausal women • Juvenile type (5%): pre-pubertal girls <p>Less common: Sertoli-Leydig tumour (women < 30 yo)</p>	<p>GRANULOSA CELL TUMOUR</p> <ul style="list-style-type: none"> • T1WI: haemorrhage can be present (↑ SI foci) • T2WI: <ul style="list-style-type: none"> – Sponge-like appearance: common – Solid or entirely cystic with peripheral nodules or wall thickening: less common • DWI: restricted diffusion • CE: solid tissue with contrast enhancement 	 <p>Axial T2WI Axial DWI Axial ADC Axial FS T1WI + Gd</p>
	<p>SERTOLI-LEYDIG TUMOR</p> <ul style="list-style-type: none"> • T2WI: solid intermediate SI mass: ↑ SI (cystic areas) can be present • DWI: restricted diffusion • CE: solid tissue with avid contrast enhancement 	 <p>Axial T2WI Axial FS T1WI + Gd</p>

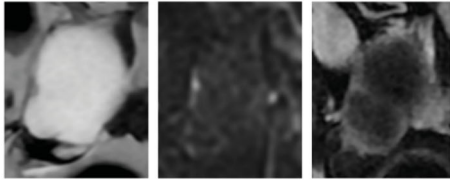
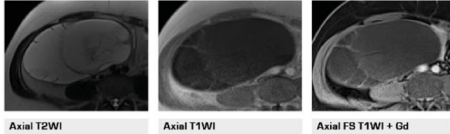
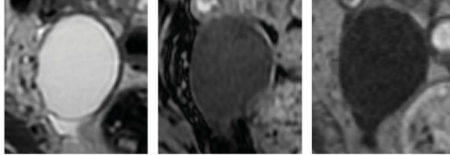
ABBREVIATIONS:

T1WI = T1-weighted images
FS T1WI = fat-saturated T1-weighted images
SI = signal intensity

T2WI = T2-weighted images
DWI = diffusion-weighted images (b>1000)
CE = contrast-enhanced images

CT = computed tomography
Gd = Gadolinium

Table 3 continued

<p>BENIGN EPITHELIAL TUMOUR</p> <ul style="list-style-type: none"> • 60%-80% of the ovarian tumours • Three main types: <ul style="list-style-type: none"> - Serous cystoadenoma - Mucinous cystoadenoma • Markers: CA-125 can rise mildly 		
TYPE	IMAGING FEATURES	IMAGES
<p>SEROUS OR MUCINOUS CYSTOADENOFIBROMA</p>	<ul style="list-style-type: none"> • Common: cystic content with thick septa and solid fibrous tissue • Uncommon: purely cystic content • T1 and T2WI: Variable (mucinous or serous), with possible solid tissue with low SI on T2WI due to fibrous content • CE: mild delayed enhancement if solid tissue is present 	 <p>Axial T2WI *serous Axial DWI *serous Axial FS T1WI + Gd *serous</p>
<p>MUCINOUS CYSTOADENOMA</p> <ul style="list-style-type: none"> • Women 30-50 y 	<ul style="list-style-type: none"> • Unilateral, thin regular wall, possible several septations, no solid tissue • T1 and T2WI: Variable signal intensity (stained glass appearance) • DWI: no restricted diffusion • CE: smooth septal enhancement, but no solid tissue 	 <p>Axial T2WI Axial T1WI Axial FS T1WI + Gd</p>
<p>SEROUS CYSTOADENOMA</p> <ul style="list-style-type: none"> • Women 50-60 y 	<ul style="list-style-type: none"> • Often bilateral, thin regular wall (< 3 mm) • No internal septations nor solid tissue • T2WI: ↑ SI • T1WI: ↓ SI • DWI: no restricted diffusion • CE: absent 	 <p>Axial T2WI Axial FS T1WI Axial T1WI + Gd</p>

ABBREVIATIONS:

T1WI = T1-weighted images	T2WI = T2-weighted images	CT = computed tomography
FS T1WI = fat-saturated T1-weighted images	DWI = diffusion-weighted images (>1000)	Gd = Gadolinium
SI = signal intensity	CE = contrast-enhanced images	

Structured report

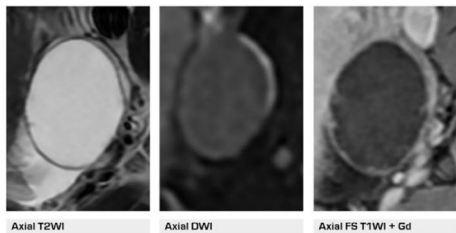
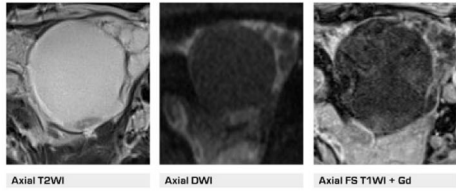
It is recommended to summarise MRI and CT findings in a structured report, including the size, location, imaging characteristics, and conclusion specifying any differential diagnosis, to improve consistency in reporting disease and promote communication between radiologists and clinicians [24]. An example of a structured report is in Supplementary Table 1.

Future perspectives

In certain cases, ovarian mass characterisation, as well as subtle peritoneal implants detection, may be challenging. In recent years, many researchers have tried to

implement the use of quantitative methods relying upon artificial intelligence (AI) techniques. These methodologies can analyse complex patterns related to the microstructure of tissues that may not be visible to the human eye by feature extraction, like in radiomics, eventually with automated analysis using convolutional neural networks. These techniques and the integration with other high-throughput data (genomic, proteomic, etc.) [25] may lead to more accurate diagnosis by tracking tumour evolution and treatment response. The use of AI may improve personalised therapeutic approaches, leading to more individualised treatment plans in the future [26].

Table 3 continued

<p>BORDERLINE EPITHELIAL TUMOUR</p> <ul style="list-style-type: none"> • Derived from atypical epithelial proliferation without stromal invasion • 10-15% of epithelial ovarian neoplasms • Premenopausal women • Main types: <ul style="list-style-type: none"> – Borderline Serous Tumour: – Borderline Mucinous Tumour: • Markers: CA-125 may rise 		
TYPE	IMAGING FEATURES	IMAGES
<p>BORDERLINE SEROUS TUMOUR (75%)</p>	<ul style="list-style-type: none"> • Unilateral or bilateral (15-40%) • T2WI: cystic, cystic-solid, or solid adnexal mass with papillary projections; ↑ SI (cystic component) and intermediate SI (solid tissue) • T1WI: ↓ SI (cystic component) and intermediate SI (solid tissue) • DWI: solid tissue with restricted diffusion • CE: solid tissue (more frequently papillary projections); intermediate risk curve or high risk curve • Other imaging findings: ascites, peritoneal implants, lymphadenopathies may be present 	 <p>Axial T2WI Axial DWI Axial FS T1WI + Gd</p>
<p>BORDERLINE MUCINOUS TUMOUR (25%)</p>	<ul style="list-style-type: none"> • Unilocular • T2WI: Multilocular cystic mass with multiple variable SI honeycomb locules and thickened septa/walls (stained glass appearance) • T1WI: variable SI (mucin) and intermediate SI (solid tissue) • DWI: Variable • CE: Enhancing septa/wall. Solid tissue with intermediate risk curve or high risk curve 	 <p>Axial T2WI Axial DWI Axial FS T1WI + Gd</p>

ABBREVIATIONS:

T1WI = T1-weighted images
 FS T1WI = fat-saturated T1-weighted images
 SI = signal intensity

T2WI = T2-weighted images
 DWI = diffusion-weighted images (>1000)
 CE = contrast-enhanced images

CT = computed tomography
 Gd = Gadolinium

Summary statement

Imaging in the initial workup of suspected ovarian masses is fundamental.

The first-line approach should be done by TVUS, ideally performed by an expert in the field, and interpreted together with clinical and serum findings. This simple and widely available first step can solve most diagnostic problems.

In 8–30% of cases, the suspected mass is indeterminate in the US. In those cases, an MRI should be performed, which has a higher accuracy in tissue characterisation. In MRI interpretation, the O-RADS lexicon and stratification risk assessment are useful and should be applied;

nonetheless, including any suspected histopathological diagnosis in the radiological report can benefit clinicians in treatment planning.

When an adnexal mass is suspected of malignancy at the US or MRI, a contrast-enhanced CT should be performed to study the thorax, abdomen, and pelvis. Also, in CT, the standard lexicon should be used, and the precise locations of the metastases should be systematically reported, possibly using a structured report. This can help with the correct interpretation and discussion of each case in a multidisciplinary tumour board, which is a fundamental step to personalising the treatment, which can differ among centres and patients.

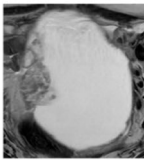
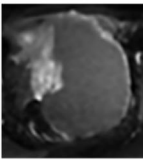
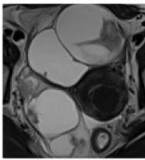
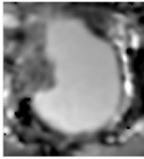
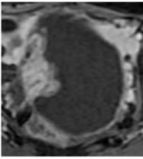
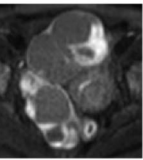
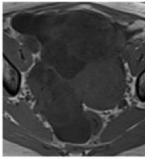
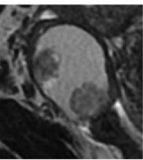
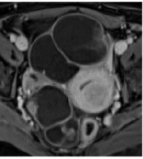
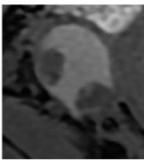
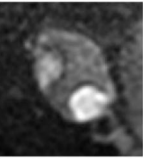
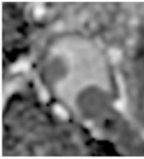
Table 3 continued

INVASIVE EPITHELIAL TUMOUR

- Derived from atypical epithelial proliferation with stromal invasion
- Most common gynaecologic malignancy
- Postmenopausal women (less common in women <45 y)
- Main types:
 - High Grade Serous (70%)
 - Endometrioid (10%)
 - Clear cell (10%)
 - High Grade Mucinous (3%)
 - Low grade serous (<5%)
- Markers: ↑ CA-125

TYPE	IMAGING FEATURES
MAIN TYPES: <ul style="list-style-type: none"> • HIGH GRADE SEROUS TUMOUR • HIGH GRADE MUCINOUS TUMOUR • ENDOMETRIOID TUMOUR 	<ul style="list-style-type: none"> • Large size, bilateral (serous more frequently) • If endometrioid: associated with endometriosis • T2WI: <ul style="list-style-type: none"> – cystic, cystic-solid, or solid masses – ↑ SI (cystic component) and intermediate SI (solid tissue) – Thickened septa or walls (> 3 mm) – If mucinous: variable • T1WI: <ul style="list-style-type: none"> – ↓ SI (cystic component) and intermediate SI (solid tissue) – If endometrioid: haemorrhagic areas (↑ SI) • DWI: solid tissue with restricted diffusion • CE: solid tissue with vivid enhancement [high risk curve] • Other imaging findings: ascites, peritoneal implants, lymphadenopathies

IMAGES

HIGH GRADE SEROUS TUMOUR	HIGH GRADE MUCINOUS TUMOUR	ENDOMETRIOID TUMOUR
 <small>Axial T2WI</small>	 <small>Axial DWI</small>	 <small>Axial T2WI</small>
 <small>Axial ADC</small>	 <small>Axial FS T1WI + Gd</small>	 <small>Axial DWI</small>
	 <small>Axial T1WI</small>	 <small>Axial T2WI</small>
	 <small>Axial FS T1WI + Gd</small>	 <small>Axial T1WI</small>
		 <small>Axial DWI</small>
		 <small>Axial ADC</small>

ABBREVIATIONS:

T1WI = T1-weighted images	T2WI = T2-weighted images	CT = computed tomography
FS T1WI = fat-saturated T1-weighted images	DWI = diffusion-weighted images (b>1000)	Gd = Gadolinium
SI = signal intensity	CE = contrast-enhanced images	

Patient summary

Ovarian masses are a frequent medical problem, and treatments can differ widely. Correct diagnosis and evaluation of the spread of disease are fundamental for the correct management. US is the first imaging step, followed by MRI for unclear cases. MRI differentiates tissue types and, along with the O-RADS MRI score, helps in

risk assessment. When cancer is suspected, contrast-enhanced CT is used for staging and guiding treatment planning. Accurate imaging is crucial in managing OC, aiding in diagnosis, staging, and determining appropriate treatment. Management should decide on a dedicated meeting with all physicians involved in diagnosis and treatment.

PERITONEAL CARCINOSIS IN OVARIAN CANCER

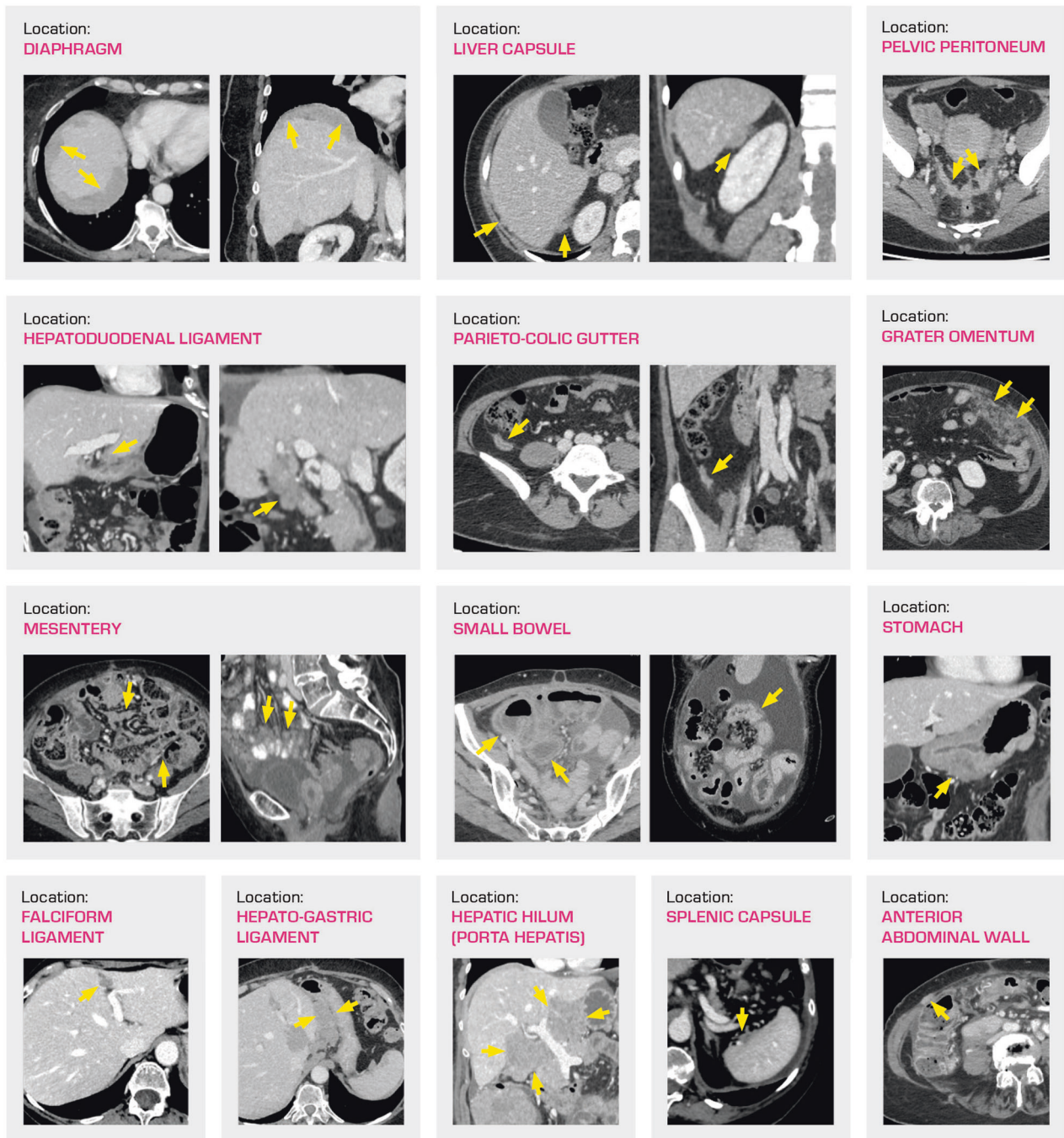


Fig. 5 Examples of principal locations of peritoneal carcinosis to be reported

Abbreviations

OC	Ovarian cancer
O-RADS	Ovarian-adnexal reporting and data system
TVUS	Transvaginal ultrasound

Supplementary information

The online version contains supplementary material available at <https://doi.org/10.1007/s00330-024-10817-1>.

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Compliance with ethical standards**Guarantor**

The scientific guarantor of this publication is Evis Sala.

Conflict of interest

The authors of this manuscript declare no relationships with any companies whose products or services may be related to the subject matter of the article.

Statistics and biometry

No complex statistical methods were necessary for this paper.

Informed consent

Written informed consent was not required.

Ethical approval

Institutional Review Board approval was not required.

Study subjects or cohorts overlap

Not applicable.

Methodology

- Practice recommendations

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