Ovarian Masses and O-RADS: A Systematic Approach to Evaluating and Characterizing Adnexal Masses with MRI

Description

Given that ovarian and adnexal masses are commonly encountered in daily clinical practice, it is important to be able to recognize worrisome features on MRI. Once these are identified, it is important to accurately classify ovarian masses according to criteria ranging from low-risk to high-risk lesions. Recognizing and categorizing ovarian masses is important for determining that no further treatment or imaging is required for benign or low-risk lesions. Similarly, recognition of a worrisome feature and proper classification of high-risk masses are necessary to permit appropriate referral of these patients to a surgical oncologist.

Learning Objectives

Upon completing this activity, the reader should be able to:

- Explain various types of ovarian tumors, including their malignancy potential;
- Identify the specific features on MRI that are worrisome for malignancy; and,
- Classify ovarian masses into different categories ranging from low-risk to high -isk.

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- Radiologists
- Related Imaging Professionals

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Editor's note: This is the second part of a two-part series. Part 1 appeared in the May-June 2021 issue of Applied Radiology.

In evaluating any pelvic mass, determining first if the mass is arising from the ovaries, the uterus, or another location is important. Imaging can then be helpful in establishing a more accurate diagnosis. For instance, when the mass is of ovarian origin, determining whether it is cystic, solid, or complex, and whether fat or calcium is present in the mass, are key features.

Part 1 of this article summarized the role of ultrasound as a definitive modality for ovarian mass characterization, even for more aggressive-appearing tumors using the O-RADS classification system. In many circumstances, however, initial imaging results may be inconclusive in certain adnexal masses. In these cases, the O-RADS group recommends further evaluation by an ultrasound specialist, or the use of MRI to classify the mass.[1] The majority of cases may be accurately diagnosed by an ultrasound expert. However, pelvic MRI may provide a more definitive diagnosis in difficult cases. This article reviews the modality's role in the evaluation and diagnosis of these masses.

MRI in Diagnosis of Ovarian Masses

Magnetic resonance imaging is commonly used to evaluate cystic or solid adnexal masses with inconclusive or worrisome ultrasound features. The modality often helps identify the origin of the mass and determine if it is cystic, solid, or complex. It can also be used to identify macroscopic fat within a mass, which is diagnostic of a dermoid. A mass that is completely or partially hyperintense on T1 imaging and loses signal after applying fat saturation contains macroscopic fat. MRI can also identify chronic hemorrhage as T2 "shading" within a mass, which refers to a lesion that is hyperintense on a T1 sequence, but with decreased signal intensity on a T2 sequence. This feature is sensitive, but not specific, for an endometrioma. Dark spots on T2 imaging are highly specific for chronic hemorrhage, thereby differentiating endometriomas from hemorrhagic cysts.[2] MRI may show solid ovarian masses with decreased signal intensity on T1 and T2 images, potentially indicating a fibroma, fibrothecoma, or Brenner tumor. Finally, MRI will reveal a combination of findings, including avidly enhancing solid components, suggesting more aggressive ovarian malignancies.

Risk Stratification Using MRI

The American College of Radiology (ACR) has recently developed an MRI risk stratification and management system for ovarian masses,[3] featuring certain governing concepts within this O-RAD MRI scoring system. Patients are categorized as either pre- or post-menopausal, with post-menopausal patients defined as those with greater than one year of amenorrhea. In patients with multiple lesions, each lesion should be characterized, and management is based on the lesion with the highest O-RADS MRI score. Like the O-RADS ultrasound system, the O-RADS MRI score ranges between 0 and 5. Within this system, soft tissue is defined as a lesion component that enhances and conforms to one of these morphological descriptors: papillary projection, mural nodule, irregular septation/wall, or other larger solid portions. For instance, a lesion featuring peritoneal, mesenteric, or omental nodularity with or without ascites is classified as O-RADS MRI-5.

T2 signal intensity within solid tissue (eg, low or intermediate compared to the outer myometrium) and diffusion-weighted signal intensity within the solid tissue (eg, high

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Table 1. O-RADS MRI Risk Score

ABBREVIATED SCHEMATIC FOR INITIAL ASSESSMENT FOR O-RADS MRI SCORES 1 (NO ADNEXAL LESION), 2 (ALMOST CERTAINLY BENIGN ADNEXAL LESION) AND 5 (HIGH RISK FOR MALIGNANT ADNEXAL LESION)	
O-RADS MRI 1	No tubo-ovarian lesion.
	Physiologic follicle, corpus luteum, or hemorrhagic cyst <3cm in pre-menopausal woman.
O-RADS MRI 2	Unilocular cyst with no enhancing wall and no solid tissue.
	Characteristic simple hydrosalpinx, peritoneal inclusion cyst, endometrioma, or mature teratoma with no solid tissue.
	Solid tissue with very low homogeneous signal on T2 and DWI.
O-RADS MRI 5	Adnexal lesion with solid tissue with a high-risk time intensity curve on DCE MRI.
	Adnexal lesion with solid tissue enhancing > myometrium at 30-40 seconds on the non-DCE MRI.
	Definite peritoneal or omental thickening or nodules.

Table shows ovarian-adnexal reporting and data system (O-RADS) MRI risk scoring concept adapted from Reference #4 with permission from the American College of Radiology
T2I = T2 image; DWI = Diffusion weighted image; DCE MRI = Dynamic contrast enhancement magnetic resonance imaging

diffusion-weighted signal intensity within the solid tissue as compared to serous tissue, such as urine in the bladder) is also analyzed. For instance, an MRI score of 2 is given for a purely cystic mass, a purely fatty mass, or a purely endometriotic mass. Furthermore, an MRI score of 2 is given for solid tissue that has homogeneous T2 signal hypointensity as well as homogeneous hypointense high b-value of DWI solid tissue, also known as a dark-dark pattern.

Dynamic contrast enhancement (DCE) with perfusion-timed intensity curves are preferred over non-dynamic postcontrast imaging for risk assessment. Dynamic contrast enhancement timing should be 15 seconds or lower. Time intensity curves are graphed from low risk to high risk; the lesions are then scored 0-5, in a fashion like those classified under the O-RADS ultrasound system. However, if DCE time intensity curves are not available, then lesions may be classified based on their enhancement at 30-40 seconds. O-RADS MRI 4 lesions have less enhancement than the myometrium at 30-40 seconds, while O-RADS MRI 5 lesions have enhancement greater than the myometrium at 30-40 seconds (excluding T2 dark/DWI dark solid tissue). A more complete review of all the parameters used in the O-RADS MRI system is beyond the scope of this review but is better detailed in reference 3 (Tables 1, 2).

A Simplified Approach to Ovarian Mass Evaluation

Some characteristic masses can be confidently diagnosed with MRI regardless of their O-RADS MRI score. A simple way to evaluate ovarian masses with MRI is to use four key sequences: T1 imaging, T1 imaging with fat saturation, T2 imaging, and contrast-enhanced imaging. Differentiating and diagnosing ovarian or adnexal masses requires only a few steps. The first consists of evaluating the signal characteristics of masses on T1 imaging. Masses may demonstrate either increased or decreased signal and may be categorized accordingly.

MRI can easily distinguish teratomas from most other adnexal masses by demonstrating macroscopic fat within the ovarian mass (Table 3). Masses that are hyperintense on T1 imaging may reflect fat, hemorrhage, or other proteinaceous materials. Signal loss after applying fat saturation, however, indicates macroscopic fat and is characteristic of a teratoma (Figure 1). Most teratomas are mature, at which point they are known as dermoids. Within the O-RADS MRI grading system, mature teratomas (dermoids) are characteristic cystic lesions containing macroscopic fat and scored as O-RADS MRI 2, owing to their low risk of malignancy. Characteristic benign mature teratomas may contain septations or mild enhancement of the Rokitansky nodules, but these findings do not upgrade these lesions. However, fatty adnexal lesions that contain much enhancing soft tissue are classified as O-RADS MRI 4 owing to the risk of immature teratomas. Immature teratomas are rare, constituting only 1% of all teratomas. Growing rapidly, they are seen in younger patients and often malignant. Dysgerminoma is another unusual germ cell tumor and usually appears as a multilobulated solid mass, often with a low-attenuation center on CT (Table 4).

A lesion with increased T1 signal that does not drop out with fat saturation sequences should undergo T2 imaging to see if it contains shading (Table 3). The majority of endometriomas have T2 shading, while only about 40% of hemorrhagic cysts have T2 shading. Unfortunately, malignant tumors with chronic hemorrhage may have T2 shading. T2 dark spots are seen only in endometriomas and malignant tumors.

The final step is to perform contrast-enhanced MR imaging to identify any nodularity or areas of abnormal enhancement. On MRI, endometriomas most commonly demonstrate increased signal intensity on T1 images and no loss of signal on fat saturation images. T2 images demonstrate the "shading" decrease in signal intensity (Figure 2). This is a classic appearance of endometriomas, but it can also be

Table 2. O-RADS MRI Risk Stratification and Management System

			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 ▪ No wall enhancement ▪No enhancing solid tissue*
			Cyst: Unilocular – simple or endometriotic fluid content ▪ Smooth enhancing wall ▪ No enhancing solid tissue
			Lesion with lipid content** ▪ No enhancing solid tissue
			Lesion with "dark T2/dark DWI" solid tissue ▪ Homogeneously hypointense on T2 and DWI
			Dilated fallopian tube - simple fluid content ▪ Thin, smooth wall/endosalpingeal folds with enhancement ▪ No enhancing solid tissue
			Para-ovarian cyst – any type of fluid ▪ Thin, smooth wall +/- enhancement ▪ No enhancing solid tissue
3	Low Risk	~5%^	Cyst: Unilocular – proteinaceous, hemorrhagic or mucinous fluid content*** ▪ Smooth enhancing wall ▪ No enhancing solid tissue
			Cyst: Multilocular - Any type of fluid, no lipid content ▪ Smooth septae and wall with enhancement ▪ No enhancing solid tissue
			Lesion with solid tissue (excluding T2 dark/DWI dark) ▪ Low-risk time intensity curve on DCE MRI
			Dilated fallopian tube ▪ 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) ▪ Intermediate risk time intensity curve on DCE MRI ▪ If DCE MRI is not feasible, score 4 is any lesion with solid tissue (excluding T2 dark/DWI dark) that is enhancing ≤ myometrium at 30-40s on non-DCE MRI
			Lesion with lipid content ▪Large-volume enhancing solid tissue
5	High Risk	~90%^	Lesion with solid tissue (excluding T2 dark/DWI dark) ▪ High risk time intensity curve on DCE MRI ▪ if DCE MRI is not feasible, score 5 is any lesion with solid tissue (excluding T2 dark/DWI dark) that is enhancing > myometrium at 30-40s on non-DCE MRI
			Peritoneal, mesenteric or omental nodularity or irregular thickening with or without ascites

Table shows more complete assessment for ovarian-adnexal reporting and data system (O-RADS) MRI risk stratification and management system adapted from Reference #3 with permission from the American College of Radiology.
^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.*
DCE = dynamic contrast enhancement with a time resolution of 15 seconds or less; DWI = diffusion weighted images; MRI = magnetic resonance imaging.

Table 3. MRI Features of Ovarian Masses

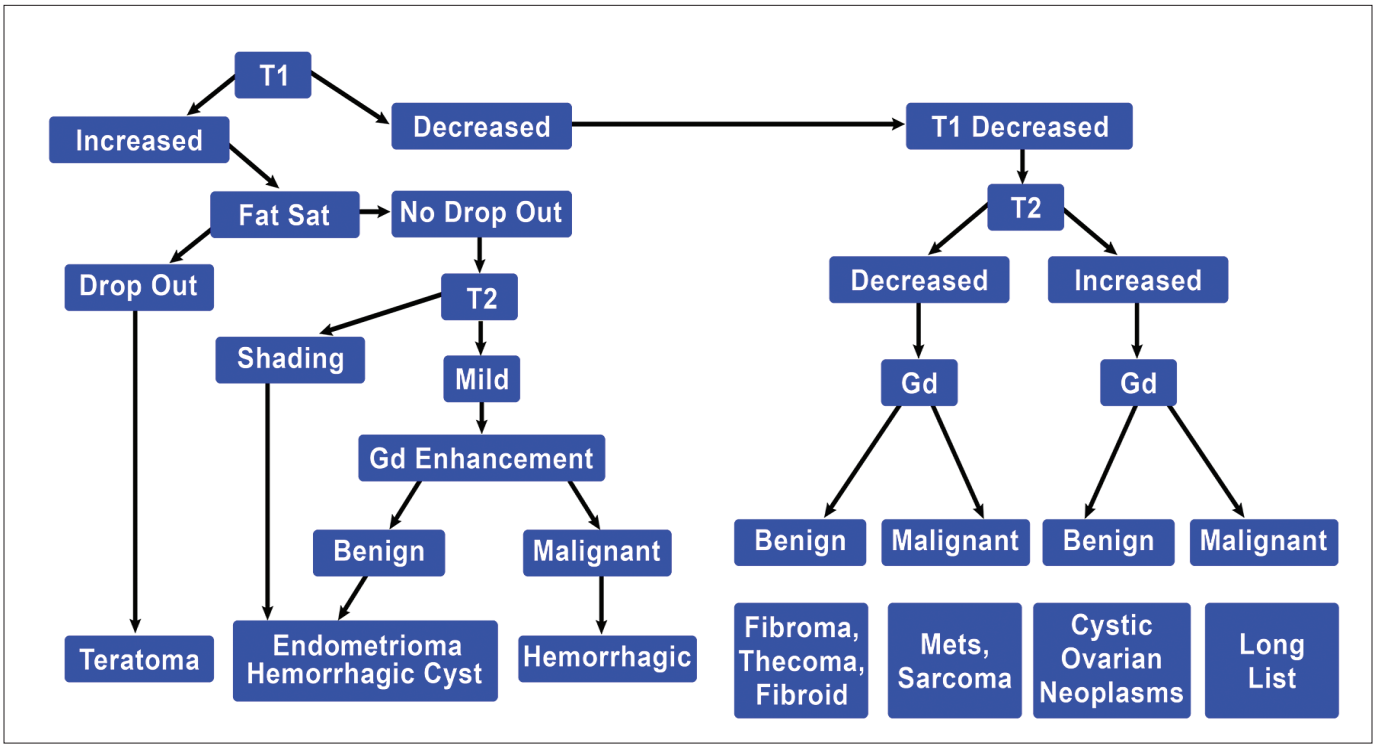
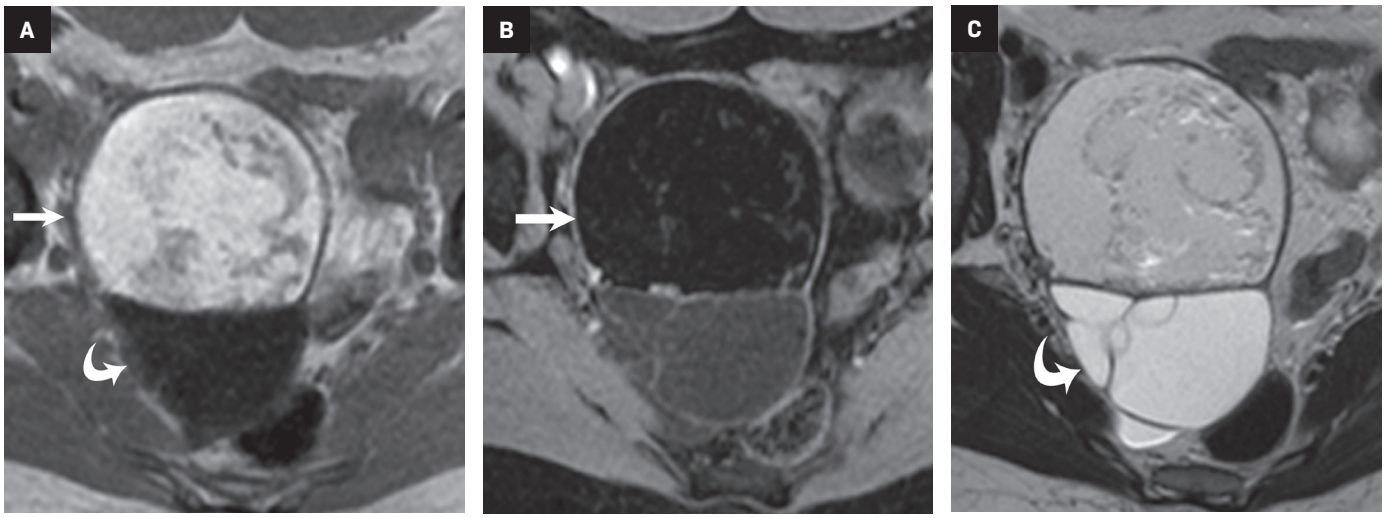


Table shows four sequences (T1, T1 fat saturation, T2, and dynamic contrast enhancement) that may be used as basic sequence and as a guideline to help categorize ovarian masses. Other sequences are helpful to better categorize ovarian masses.

Figure 1. Dermoid on MRI. (A) Axial T1 image of an ovarian mass demonstrates two separate components. The anterior component is of high signal intensity (arrow) and the posterior component of low signal intensity (curved arrow). (B) T1 image with fat saturation sequence depicts low signal intensity in the anterior portion of this mass (arrow), indicating suppression of macroscopic fat, typical of a dermoid. (C) T2 image reveals increased signal intensity of the more posterior component, indicative of a cystic component to this dermoid (curved arrow) (O-RADS MRI 2).



seen in hemorrhagic cysts or hemorrhage occurring within certain neoplasms, such as clear cell carcinomas. Administration of a gadolinium-based contrast agent may help to ensure there are no regions of contrast enhancement along the wall of the presumed endometrioma, which may be indicative of a necrotic ovarian tumor, such as a clear cell carcinoma.

Masses with Decreased Signal Intensity on T1 Imaging

When the T1 signal of a mass is decreased, the next step is to perform T2 imaging, followed by gadolinium contrast-enhanced imaging, independent of the T2 signal finding (Table 3). If the mass is of decreased signal intensity on T1, with no significant increase signal on T2 imaging and with fairly homogeneous enhancement after administration of gadolinium, an ovarian stromal (sex cord) tumor should be considered.

Ovarian stromal tumors are an interesting group of tumors that appear as solid ovarian masses (Table 4) but are rarely malignant. This group is composed of a variety of tumors including fibroma, fibrothecoma, cystadenofibroma, Sertoli-, and Leydig-cell tumors. More common sex-cord stromal tumors include components of fibrous tissue, which are fibromas and/or lipid-rich tissues, including thecomas. Many of these tumors, such as fibrothecomas, have combined elements. These tumors may, rarely, result in Meig syndrome (fibroma with ascites and pleural effusions). Ultrasound can determine the solid nature of these neoplasms. MRI will demonstrate a solid tumor with decreased signal intensity on T1 and T2 images (Figure 3).[3] Thus, the differential diagnosis includes fibroma, fibrothecoma, or cystadenofibroma (Table 3).

Potential pitfalls include a Brenner tumor, which is usually solid or

Table 4. Ovarian Neoplasms

	ORIGIN			
	Surface epithelium	Germ cells	Parenchyma (sex cord- stroma)	Metastases
Frequency	65 – 70%	15 – 20%	5 – 10%	5%
% malignant	90%	3 – 5 %	2 – 3%	5%
Age	20+	0 – 25+	All	Variable
Types	Serous Mucinous Endometrioid Clear Cell Brenner	Teratoma Dysgerminoma Endodermal sinus Choriocarcinoma	Fibroma Granulosa-theca cell tumor Sertoli-Leydig cell tumor Cystadenofibroma	

Adapted from: Robbins and Cotran; Pathologic Basis of Disease, 7th Ed. Copyright © 2005 Elsevier Junqueira and Carneiro; Basic His-tology, 11th Ed Copyright © 2005 McGraw-Hill

Table shows basic classification of main types of ovarian neoplasms including their overall frequency, subtypes, age at discovery, and malignancy percentage.

Figure 2. Endometrioma on MRI. (A) Axial T1 fat-saturated pelvic MR image demonstrates three regions of increased signal intensity (arrows). On T1 fat saturation, the masses demonstrated no change in signal intensity from the T1 sequence. (B) Axial T2 fat-saturated image demonstrates decreased signal, or so called T2 "shading," in all three lesions (arrows). No enhancing regions were identified after administration of gadolinium. Findings were consistent with multiple endometriomas (O-RADS MRI 2).

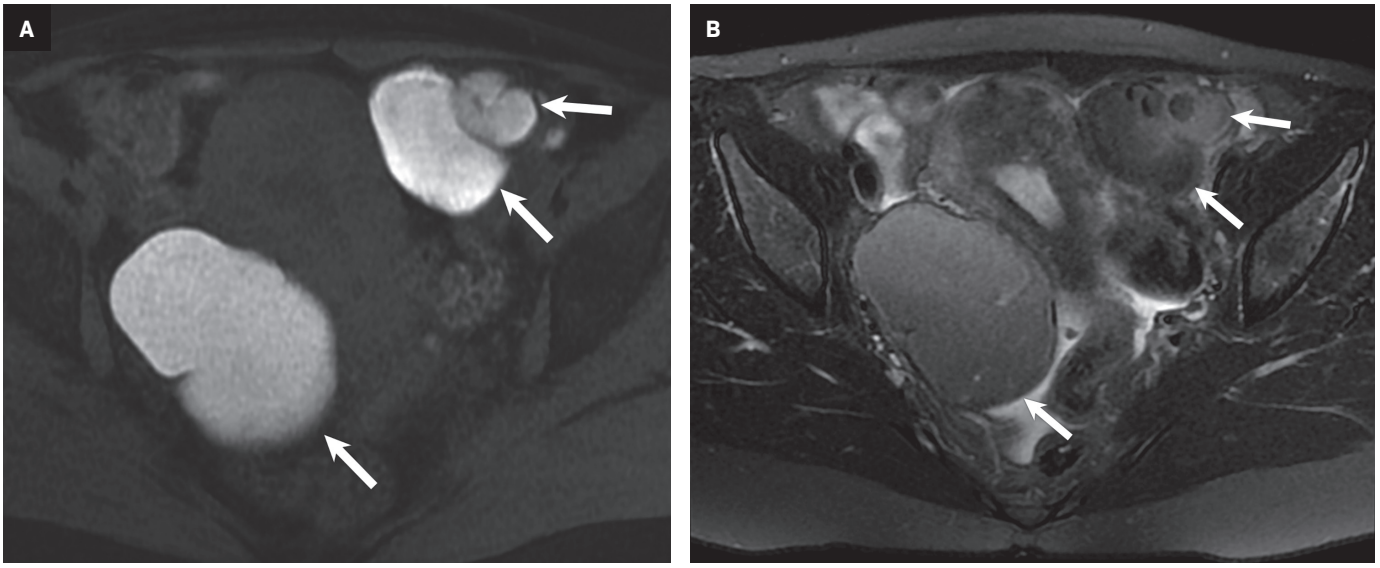
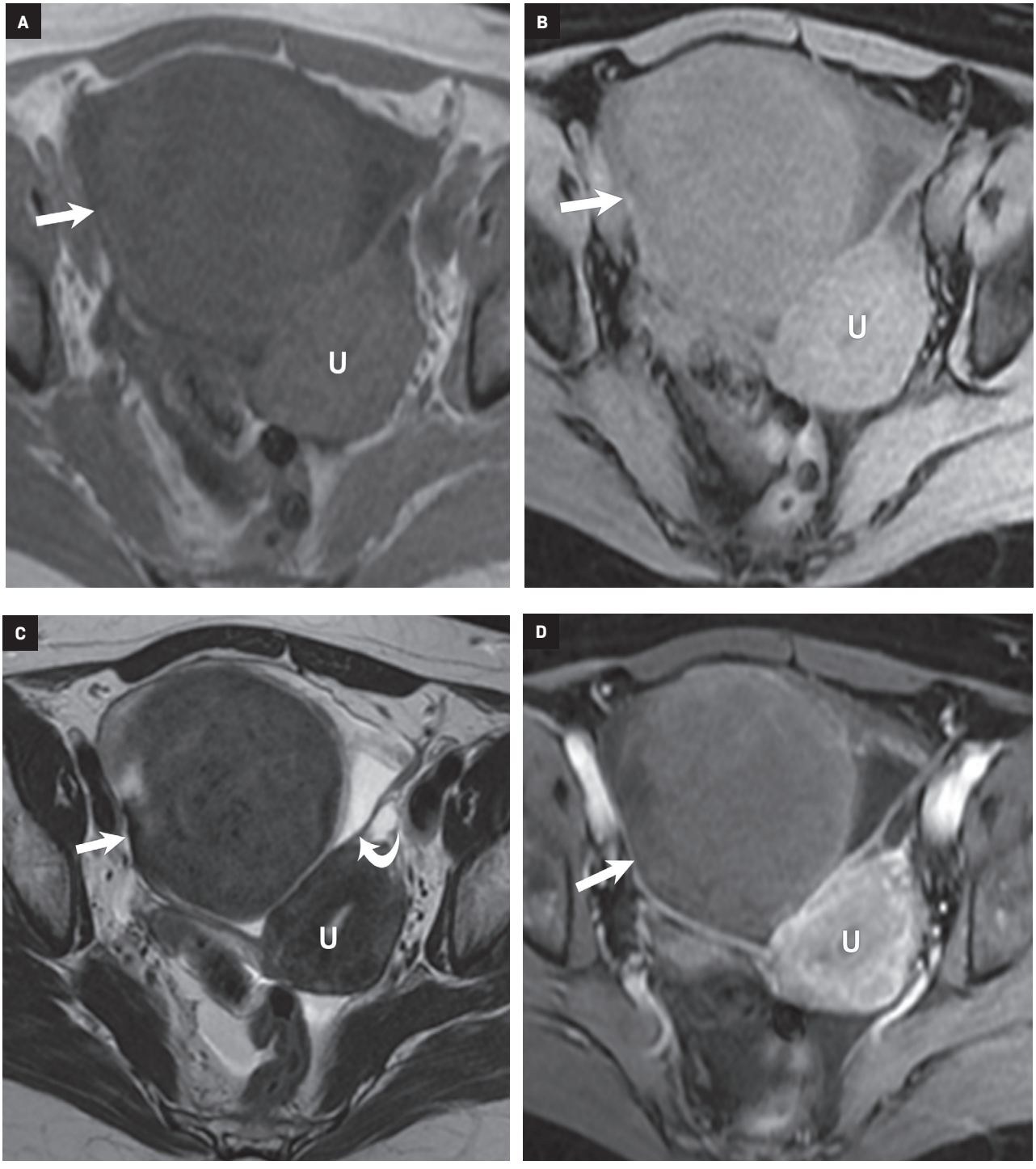


Figure 3. Fibrothecoma. (A) Axial T1 image demonstrates a low signal intensity mass (arrow) anterior to the uterus (U). (B) T1 fat saturation sequence demonstrates this mass (arrow) maintains a similar signal intensity as the uterus (U). (C) T2 sequence demonstrates the mass has a similar signal intensity as the uterus (U). Also note the small amount of fluid (curved arrow) between the mass (arrow) and the uterus (U), indicating the mass originates from the adnexa and is separate from the uterus. (D) After contrast administration, the mass shows less enhancement (arrow) compared to the uterus (U) (O-RADS MRI 3).



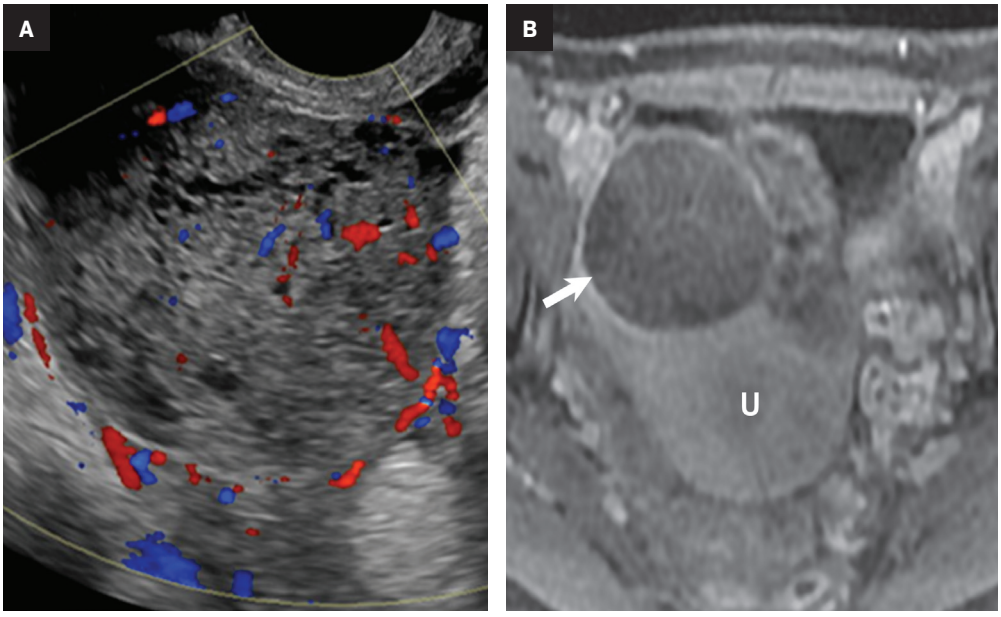


Figure 4. Ovarian metastasis. (A) Ultrasound demonstrates a solid mass with some internal color flow in a patient who underwent resection of a solid pseudopapillary epithelial neoplasm of the pancreas three years earlier. (B) Contrast-enhanced MRI shows the mass (arrow) with less avid contrast enhancement than the uterus (U). This was biopsy-proven to be a metastasis from the pancreatic primary tumor.

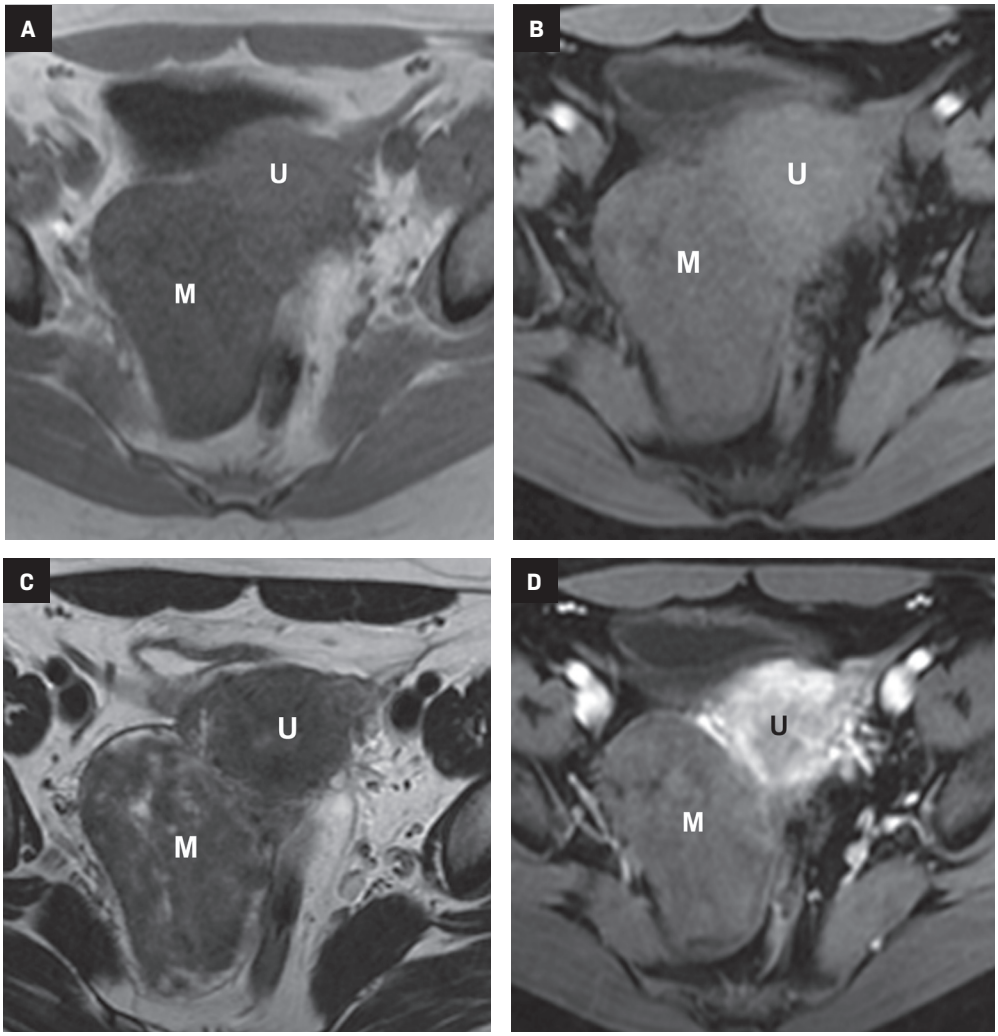


Figure 5. Broad ligament leiomyoma. (A) T1 image demonstrates a mass within the right adnexa, posterior to the uterus. (B) T1 fat saturation shows the mass does not change signal intensity and maintains a similar signal intensity as the uterus. (C) T2 image demonstrates the mass appears to be contiguous with the uterus. (D) With contrast administration the mass enhances less than the uterus and is shown to be a broad ligament leiomyoma (fibroid). (M=Mass, U=Uterus).

Figure 6. Serous cystadenoma on MRI. (A) T1 image demonstrates low signal intensity mass (arrow) with signal intensity as expected for the bladder. This can be a pitfall in mistaking the cyst for the bladder. (U = uterus). (B) T2 fat-saturated image demonstrates high signal intensity within the mass (arrow), which is cystic (U = uterus). (C) Post-gadolinium image demonstrates no mural nodularity and no abnormal regions of enhancement in the mass (arrow) (U = uterus). (D) Surgical specimen demonstrating well-contained cyst consistent with serous cystadenoma (O-RADS 3).

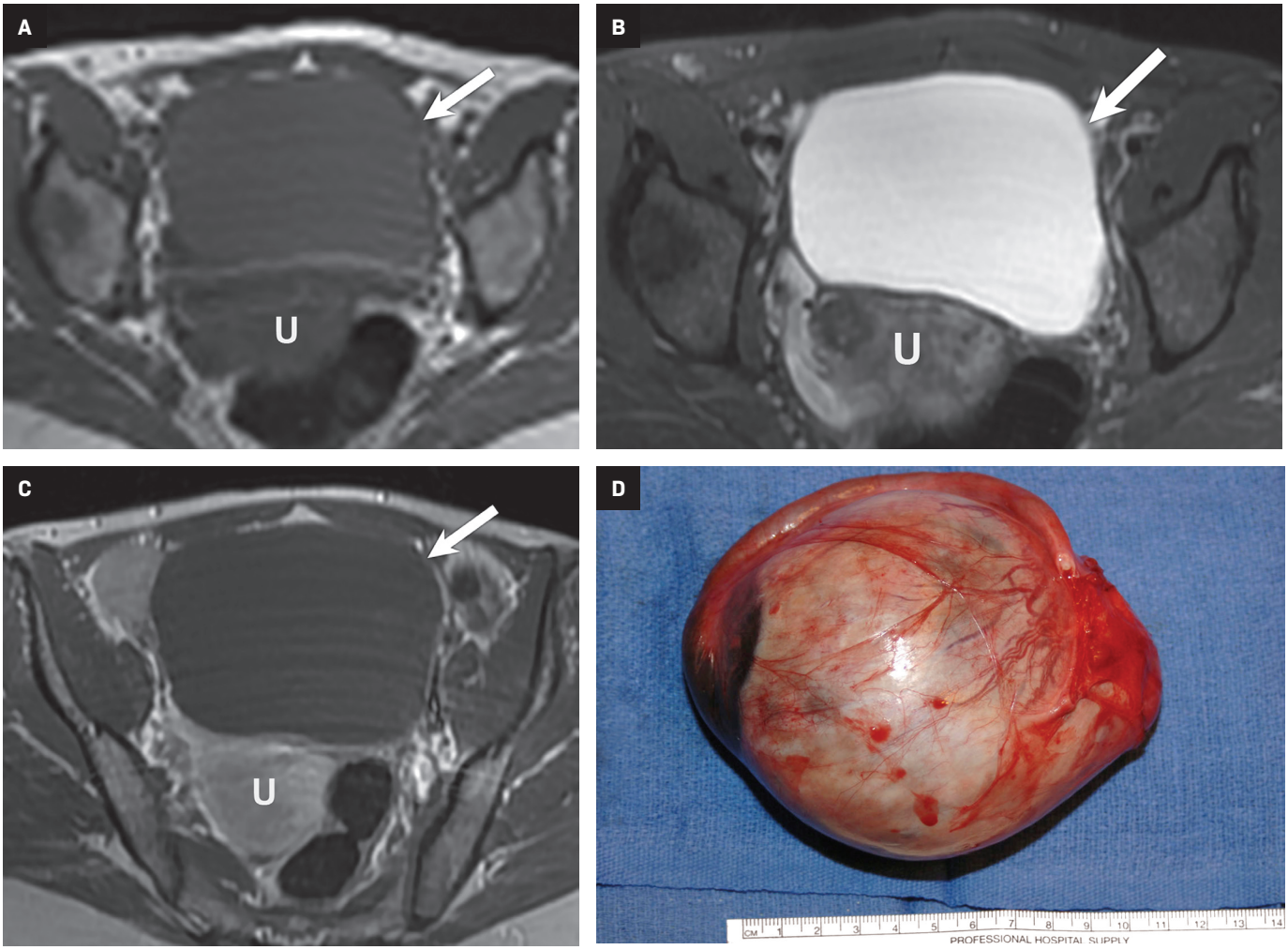
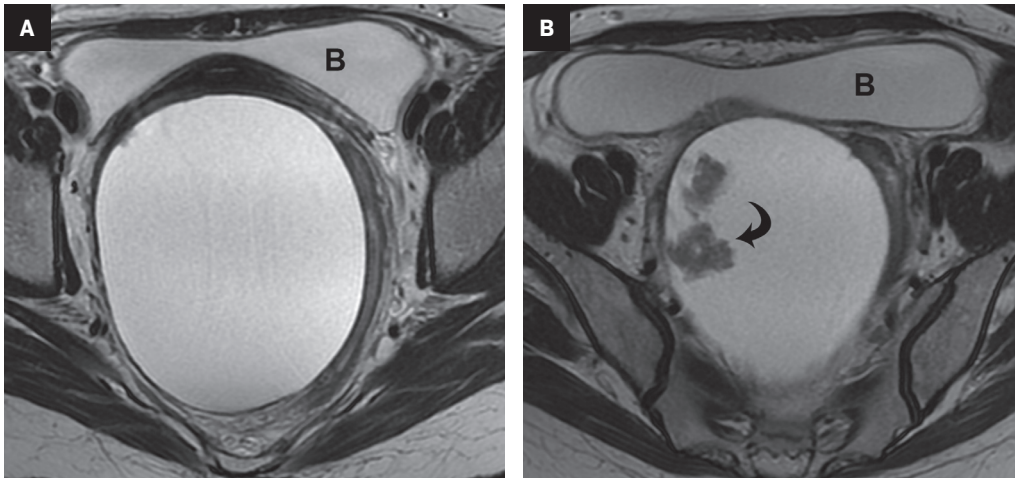
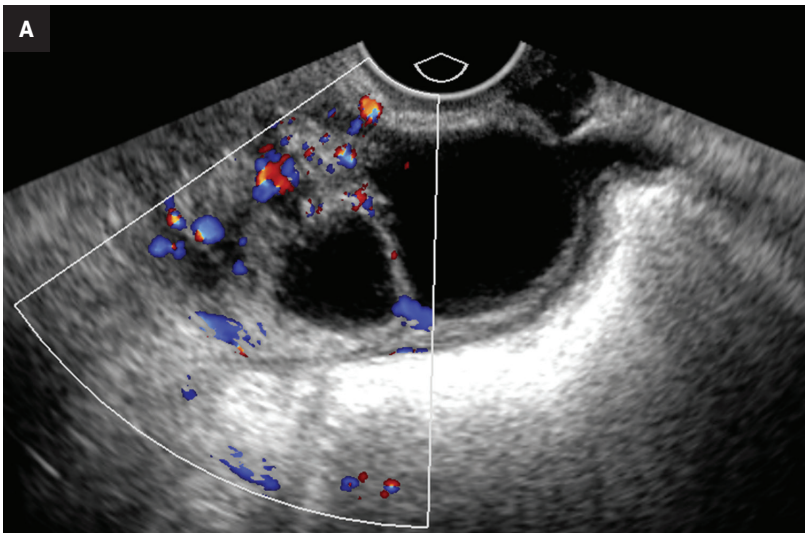
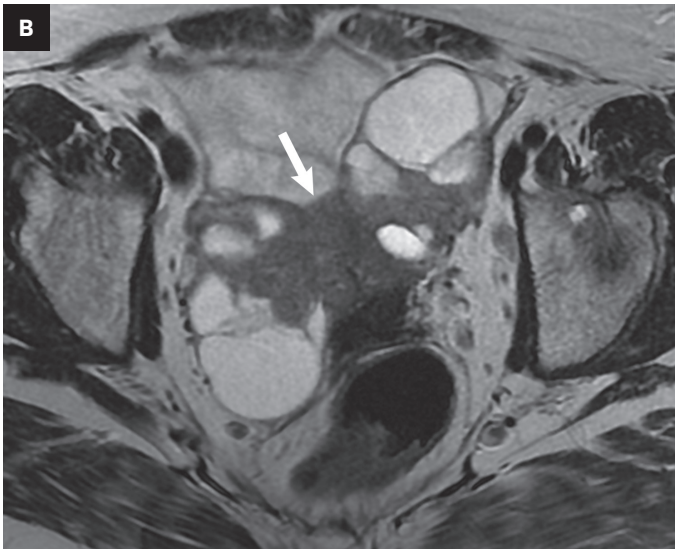


Figure 7. Clear cell carcinoma of the ovary. (A) T2 image demonstrates a large, purely cystic appearing mass posterior to the bladder (B). (B) T2 image in a different plane demonstrates papillary projections on the right side of the mass (curved arrow) (O-RADS MRI 5).







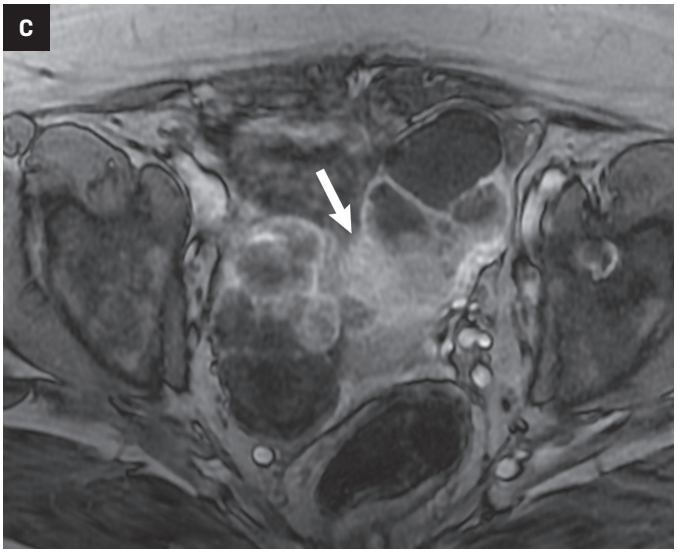


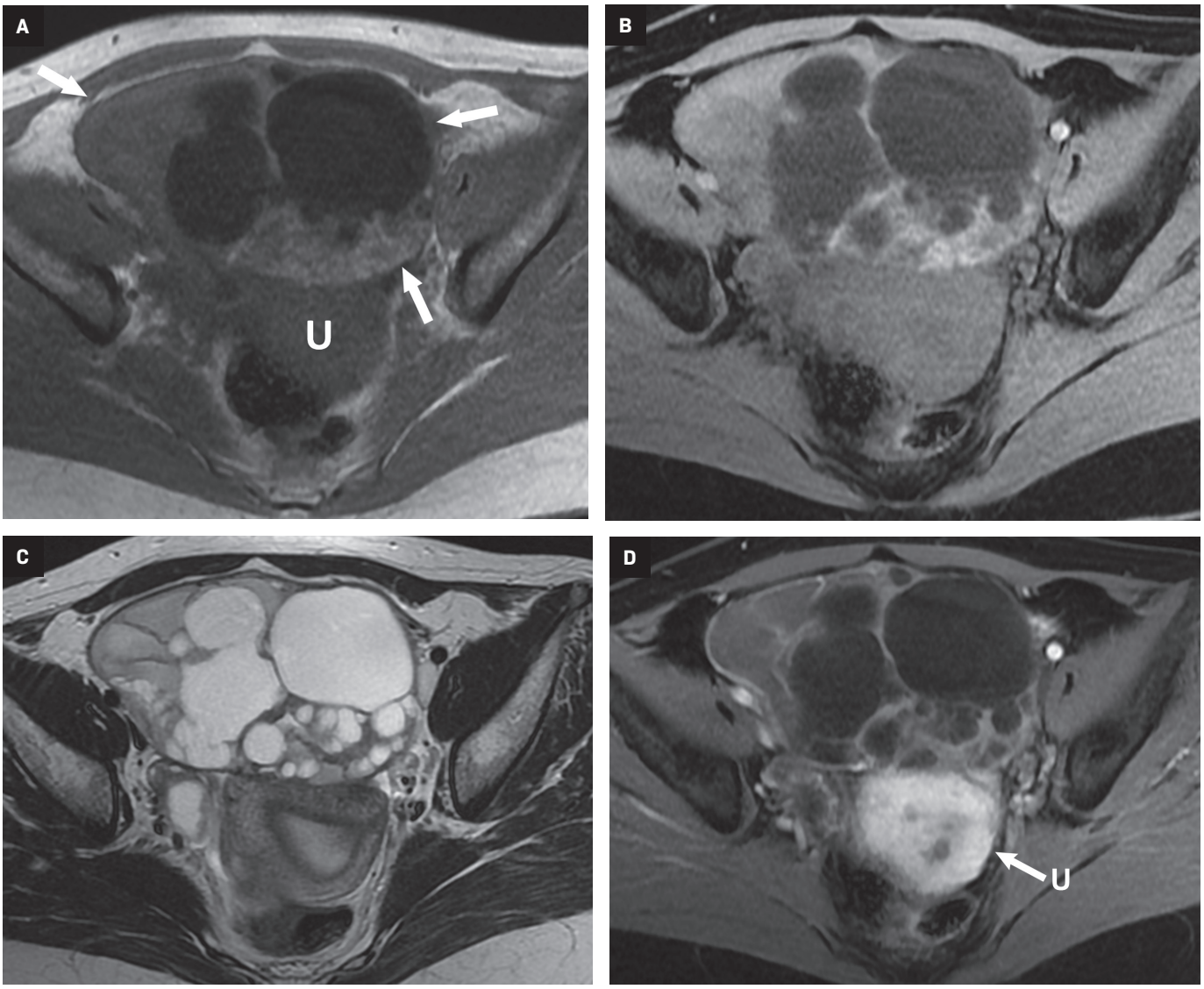
Figure 8. Bilateral serous papillary carcinoma of the ovaries. (A) Endovaginal ultrasound demonstrated bilateral cystic masses with thick septations and solid components with areas of increased color flow. (B) T2 image demonstrates a complex mass with a central solid component (arrow) with bilateral cystic-appearing masses. (C) Dynamic administration of gadolinium demonstrated rapid enhancement of the masses (arrow) (O-RADS MRI 5).

mostly solid. Ovarian metastases, including Krukenberg tumor, may be mistaken for a solid sex-cord stromal tumor and can appear as solid or complex ovarian masses (Figure 4). However, most solid ovarian masses will be surgically removed, except for pedunculated leiomyomata (fibroids) that mimic ovarian masses (Figure 5). Distinguishing a benign, solid ovarian mass from a solid metastasis may be difficult. In rare situations, biopsy may be performed. Usually the solid component of the mass is biopsied, with good diagnostic yield in select cases.[4]

Masses with decreased signal intensity on T1 but increased signal intensity on T2 have a cystic component. If these cysts are simple, they should have been characterized by ultrasound and no further evaluation is needed.[1,5] Similarly, as previously described, O-RADS 2 lesions such as hemorrhagic cysts, dermoid cysts, endometriomas, hydrosalpinx, and peritoneal inclusion cysts have a fairly classic appearance and no further imaging is needed.[1] If there is doubt, O-RADS recommends consultation with an ultrasound expert or the use of MRI, since the range of cystic ovarian neoplasms is broad.

For instance, both benign and malignant ovarian masses may have a cystic component on ultrasound or MRI. After identifying such a cystic component, the next step is to administer gadolinium for evaluation of any solid components or papillary projections. O-RADS MRI prefers DCE with perfusion time intensity curves over non-dynamic DCE post-contrast imaging for risk assessment. The guidelines recommend time resolution less than 15 seconds. As mentioned previously, if DCE is not available, contrast enhancement of the mass is compared to being less than (O-RADS MRI 4) or greater than (O-RADS MRI 5) the contrast enhancement of the myometrium at 30 to 40 seconds (Table 1,2). Gadolinium-enhanced imaging may show

Figure 9. Left ovarian mucinous borderline tumor. (A) T1 image demonstrating complex pelvic mass (arrows) anterior to the uterus (U). (B) T1 fat saturation image showing no signal dropout of any portion of the mass. (C) T2 image showing most of the mass consists of multiple cysts and/or cysts with septations. (D) Following contrast administration, there was minimal enhancement of the solid components of the mass and much less enhancement compared to that of the uterus (U) at approximately 30 seconds (O-RADS MRI 4-5).



these solid components, surface nodularity, and/or thick septa, which are worrisome for a malignant ovarian neoplasm.[3]

The most concerning tumors are surface epithelial neoplasms (Tables 3, 4). These include serous or mucinous cystadenomas and serous or mucinous cystadenocarcinomas. Serous neoplasms have a higher frequency of malignancy than mucinous ovarian neoplasms. Some of these tumors are simple in appearance with no worrisome features, such as a serous cystadenoma (Figure 6). Clear cell carcinoma is another type of surface epithelial neoplasm that is predominantly cystic, with few solid components. Clear cell carcinoma accounts for 5% of all ovarian cancers. They are predominantly cystic, but they do have solid components along the wall of the tumor. Although the cystic component is the dominant feature, the peripheral nodularity must not be overlooked (Figure 7) as it may be indicative of a malignant neoplasm, and thus alter management. However, this nodularity in clear cell carcinoma may be subtle and located only at the periphery of the mass.

Mucinous tumors often have multiple septations with the appearance of multiple cysts. Concerning features include septations with

Doppler flow on ultrasound, and papillary projections or solid enhancing components on MRI within the cystic portions of the tumor. It is important to identify imaging features that may differentiate benign from malignant cystic ovarian neoplasms. Malignancies are usually larger and have a heterogeneous architecture and thick walls. Septations are often thick and/or irregular with regions of enhancement. Mural nodularity and necrosis are often present (Figure 8; Tables 1, 2). MRI may be useful to identify peritoneal nodularity with or without ascites, a high-risk feature (O-RADS MRI).[3] At times, some of these tumors may appear malignant on imaging but are considered pathologically as "borderline" tumors. These have a low potential for malignancy, occur in a younger population, and have a 10-year survival rate as high as 95%. However, these tumors may be difficult to distinguish from other, more aggressive surface epithelial neoplasms. Ultrasound color Doppler or MRI enhancement is usually not as robust with borderline neoplasms as with more aggressive lesions (Figure 9). Ovarian metastases are not surface epithelial neoplasms, but they may mimic the imaging appearance of some of these tumors, often being more solid or mixed solid and cystic.

Conclusion

Ultrasound can be used to classify ovarian lesions under most circumstances. However, there are cases where MRI is needed to problem solve and establish a more conclusive diagnosis. This stepwise approach should be helpful as a general guide to help radiologists differentiate ovarian pathology on MRI.

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