MR Imaging of Endometriosis of the Adnexa

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KEYWORDS

- Endometriosis • Endometrioma • Kissing ovaries • Hematosalpinx
- Endometriosis-associated ovarian cancer • Decidualized endometrioma
- Spontaneous hemorrhage in pregnancy

KEY POINTS

- Protocols should include pre-contrast T1-weighted imaging with fat saturation, T2-weighted imaging without fat saturation, opposed- and in-phase or Dixon imaging, administration of contrast media, and subtraction imaging to assist in the evaluation of endometriomas versus other masses, deep infiltrating endometriosis, and endometriosis-associated ovarian cancer.
- MR imaging is useful to characterize endometriomas based on multiplicity and bilaterality, associated deep infiltrating endometriosis, homogenous T1-weighted hyperintensity, T2 shading, T2 dark spot sign, and lack of fat or enhancing solid tissue. Hematosalpinges present as dilated thin-walled T1-weighted hyperintense fallopian tubes, although may not contain shading.
- Endometriosis-associated ovarian cancer is associated with larger lesions, loss of T2 shading, enhancing solid components, and diffusion restriction of solid components.
- Decidualized endometriosis can mimic malignant transformation of endometriosis due to solid projections within endometriomas; however, the projections have a characteristic rounded morphology, follow signal characteristics of decidualized placenta, and follow-up will show stabilization of growth. Spontaneous hemorrhage of endometriomas and other forms of endometriosis can occur during pregnancy.

INTRODUCTION

Endometriosis is the presence of ectopic endometrial glands outside of the uterus. It is estimated to occur in 10% of women and can cause lifelong chronic pain, disability, and infertility.[1] Routine transvaginal ultrasound is the first-line imaging modality to detect endometriomas and hematosalpinges, both of which are markers for deep infiltrating endometriosis (DIE).[2] MR imaging can provide a more comprehensive assessment by characterizing adnexal findings, detecting the presence and extent of DIE and evaluating malignancy risk. Endometriosis of the adnexa is often multifocal and can involve all adnexal structures including the ovaries, fallopian tubes, and broad ligaments. MR is also valuable in

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assessing adnexal manifestations of endometriosis in the setting of pregnancy, when the gravid uterus may limit ultrasound evaluation.

MR IMAGING PROTOCOL

An optimized MR imaging protocol is important to promote visualization and diagnosis of endometriosis and to characterize benign and malignant lesions. In this review, the authors focus on MR imaging protocol components crucial for characterization and assessment of the adnexa (**Table 1**).

The MR imaging protocol for endometriosis is designed to maximize the visualization of hemorrhagic products in endometriomas and the adjacent desmoplastic reaction elicited by repetitive, cyclical hemorrhage of this ectopic glandular tissue. Patient preparation can optionally include allowing the urinary bladder to be full, application of vaginal and/or rectal contrast, bowel preparation, and administration of a bowel antiperistaltic agent.[3–5] The most important sequence for both anatomic and endometriosis visualization is a T2 fast spin echo without fat suppression (FS). The background of T2 hyperintense fat contrasts the anatomic structures and the low signal of endometriomas and endometriotic implants. Two imaging planes should be used at minimum, most commonly the sagittal and axial planes.[5,6] An additional coronal plane may also be included for better localization. Conventional axial and coronal planes are sufficient; however, axial and coronal planes obliqued to the cervical canal or uterine ligaments may provide better visualization of disease in those regions.[3,7]

T1-weighted imaging (T1WI) with FS is important to include as blood products in endometriosis are typically T1 hyperintense and stand out against the suppressed fat signal. Again, at least two planes are recommended, typically sagittal small field-of-view and axial large field-of-view acquisitions.[3] A single axial plane of T1WI with opposed- and in-phase or Dixon imaging is imperative to distinguish blood products from bulk fat.[8]

Post-contrast T1WI is also important to include in the MR imaging protocol, especially when adnexal lesions are present. Although post-contrast imaging does not improve the detection of endometriomas or other deposits, it is helpful in distinguishing endometriomas from infectious ovarian lesions and for evaluating enhancing components associated with malignant transformation.[3,6,9] Subtraction images, where pre-contrast T1WI is subtracted from post-contrast T1WI, are an especially important tool as the hyperintense T1 signal in blood products may obscure enhancing components. Sagittal and axial imaging planes are recommended with optional coronal plane.[3]

Similar to post-contrast T1WI, diffusion-weighted image (DWI) helps to evaluate for malignancy and infection. DWI has the additional benefit of identifying abnormal lymph nodes or pelvic malignant implants in the setting of neoplasm.[9] Given the many fluid-filled structures in the pelvis such as the urinary bladder, bowel, and ovarian cysts, both a low b-value and a high b-value of at least 800 to 1000 s/mm^2 are recommended to suppress normal fluid signal.[9,10] Apparent diffusion coefficient (ADC) maps are also recommended to confirm true diffusion restriction.

Susceptibility-weighted imaging (SWI) may be helpful in identifying endometriosis through the visualization of hemosiderin from chronic blood products. SWI uses high-resolution gradient-recalled echo sequences with phase and magnitude

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Table 1
Basics of a recommended MR imaging protocol for endometriosis

Sequence	Fat Suppression	Acquisition Planes	Notes
T2 FSE	No	Sagittal, axial	Optional planes: coronal, oblique coronal, oblique axial
T1WI	Yes	Sagittal, axial	Optional planes: coronal, oblique coronal, oblique axial
T1WI in and out of phase/Dixon	No	Axial	
T1WI post-contrast with fat suppression	Yes	Sagittal, axial	Optional planes: Coronal
Diffusion-weighted image	Yes	Axial	• Include high b-value of 800–1000 s/mm^2 • Include ADC map

Abbreviations: T1WI, T1-weighted image; T2 FSE, T2 fast spin echo.

information. It is more sensitive to susceptibility artifact than conventional T2*-weighted imaging, particularly with a 3-T field strength.[11] However, differentiating blood and calcification in vascular structures, calcification in the ovary, and foreign bodies such as tubal ligation clips may be difficult, and intended findings may be obscured by susceptibility from bowel gas. The utility of SWI in practice is, therefore, variable and uncommonly used.

ENDOMETRIOMAS

Endometriomas are a common manifestation of endometriosis. These ovarian or para-ovarian cysts contain ectopic endometrial elements and blood products of varying age due to repeated cyclic hemorrhage. They are often multiple and can be bilateral.[12–14] Endometriomas are frequently easily diagnosed with ultrasound and MR imaging. In unclear cases, concomitant DIE on imaging, clinical history suggesting endometriosis, and chronicity can be used to differentiate endometriomas from other adnexal masses.

Endometriomas have markedly hyperintense and homogenous T1-weighted (T1W) signal intensity (SI) owing to frequent and short-interval cyclic accumulation of methemoglobin, high protein concentration, and viscosity (Fig. 1). This appearance is most conspicuous on T1WI when fat saturation is applied. Heterogeneous signal may develop when acute on chronic hemorrhage is present, however, most of the T1W SI will remain markedly hyperintense and otherwise overall homogenous. Other lesions with T1W hyperintensity that can be mistaken for endometriomas include hemorrhagic cysts, teratomas, mucin-containing tumors, and tubo-ovarian complex (Table 2).

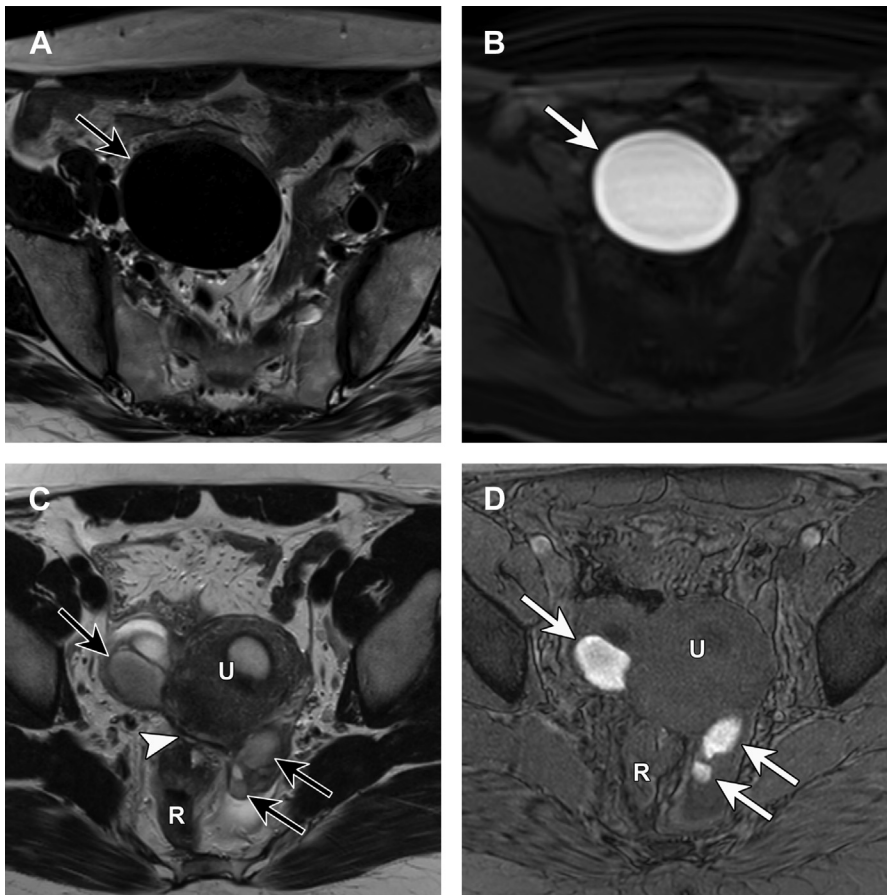**Fig. 1.** Examples of endometriomas with variable T2 shading in two patients (*A* and *B* vs *C* and *D*). T2-weighted axial MR images (*A*, *C*) show endometriomas with T2-weighted hypointensity consistent with T2 shading (*black arrows*). T1-weighted axial MR images with fat saturation (*B*, *D*) showing corresponding marked homogenous hyperintense signal (*white arrows*). (*C*) and (*D*) Multiple endometriomas in both ovaries. The axial T2-weighted image (*C*) also shows a hypointense fibrotic deposit of deep infiltrating endometriosis between the ovaries overlying the posterior uterus (*white arrowhead*). U, uterus; R, rectum.

Table 2
Differentiating T1-weighted hyperintense lesions

T1-Weighted Hyperintense Lesions	Distinguishing Characteristics
Endometrioma	Often multiple and bilateral, homogenous marked T1W SI, T2 shading, T2 dark spot, does not resolve on short-term follow-up, can restrict diffusion, no internal enhancement
Hemorrhagic cyst	Singular and unilateral, heterogeneous or peripheral T1W SI, retractile clot is not as hypointense as T2 dark spot, T2 shading possible
Mature teratoma	T1W SI suppresses with fat suppression, India ink artifact with opposed-phase imaging indicates macroscopic fat, T1W SI can be heterogeneous due to other germ cell layers
Mucin-containing masses (eg, mucinous cystadenoma)	Variable T1W SI depending on mucin concentration, multilocular with variable SI between locules, hemorrhage can occur and sequela chronically persist resulting in T2 dark spot, calcifications can mimic T2 dark spot
Tubo-ovarian complex	Variable T1W SI, can be heterogeneous, enhancing thickened walls, restricts diffusion, other inflammatory changes including peritonitis

Abbreviations: SI, signal intensity; T1W, T1-weighted.

T2W imaging features of endometriomas include T2 shading and the T2 dark spot sign. T2 shading is signal intensity that is less than simple fluid and/or adjacent follicles on T2W imaging[12] (see **Fig. 1**). T2 shading results from the accumulation of deoxyhemoglobin, methemoglobin, and hemosiderin. T2 shading can have a variety of appearances ranging from marked to mild hypointensity, homogeneous to heterogeneous, and appear as a gradient of layering hypointensity within an otherwise hyperintense structure.[2] T2 shading alone is highly sensitive (83%) but less specific (45%) for endometriomas due to overlap with hemorrhage in cysts and malignant lesions.[14] A thickened T2W hypointense rim also reflects hemosiderin-laden macrophages and fibrous tissue in the wall of the endometrioma. Fluid–fluid levels may also reflect acute on chronic hemorrhage.

The T2 dark spot is a discrete and well-defined markedly T2W hypointense structure within or along the wall of an endometrioma, with an average size of 6.3 mm, thought to reflect chronic retracted blood clot.[14] There is often associated hyperintense T1W SI. The T2 dark spot does not enhance, an important feature that is assessed well on post-contrast subtraction imaging. The presence of an enhancing mural nodule is concerning for malignant transformation.

Endometriomas also restrict diffusion due to T2W hypointensity and "T2 blackout effect." ADC values are based on the slope of SI loss between acquisitions obtained with lower and higher b-values. Because the T2W SI is already low, there is less SI loss with higher b-values and the resultant ADC value is low[12](**Fig. 2**).

Differentiating Endometriomas from Other Adnexal Masses

Hemorrhagic cysts

Functional hemorrhagic cysts are frequently hyperintense on T1WI with shading on T2WI. Compared with endometriomas, the T1W hyperintense signal within hemorrhagic cysts is typically less pronounced, more heterogeneous, and often occupies only a portion of the cyst due to the quantity and age of the blood resulting in absence of or low concentration of methemoglobin. This yields a more heterogenous T1WI appearance or there may be a T1W hyperintense rim peripherally in the lesion[15](**Fig. 3**). Although heterogeneity is the more likely appearance, hemorrhagic cysts can still be homogenous on T1WI and have T2 shading,[15] making differentiation with endometriomas difficult. In such cases, follow-up imaging or comparison with recent prior imaging is helpful.

Hemorrhagic cysts tend to appear with menstrual cycles and decrease in size over time. Endometriomas, however, do not tend to regress unless treated hormonally. Hemorrhagic lesions less than 3 cm, such as follicles and corpus luteum cysts, can be difficult to differentiate from endometriomas, and chronicity may also be the only feature favoring endometrioma.[15] Given hemorrhagic cysts are physiologic, they are often unilateral and singular, rather than multiple and bilateral.
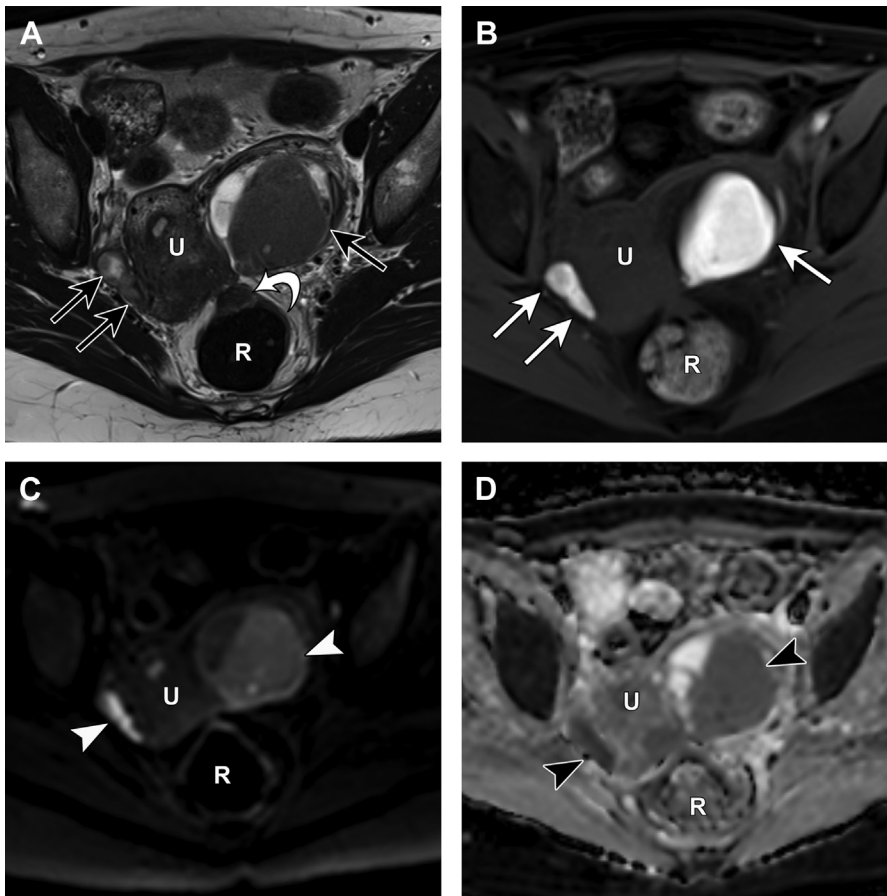
Fig. 2. Endometriomas can restrict diffusion due to highly viscous proteinaceous and hemorrhagic contents. Axial T2-weighted image (*A*) shows T2 shading in endometriomas bilaterally (*black arrows*). A hypointense fibrotic deep infiltrating endometriosis nodule tethers the uterus and anterior rectal wall (*white curved arrow*). Axial T1-weighted MR image with fat saturation (*B*) shows marked hyperintense homogenous signal within multiple endometriomas bilaterally (*white arrows*). Axial diffusion-weighted MR image (b-value = 800) (*C*) with intermediate to high signal within the endometriomas (*white arrowheads*). (*D*) Axial apparent diffusion coefficient map shows low signal within the endometriomas, confirming diffusion restriction (*black arrowheads*). U, uterus; R, rectum.

The T2 dark spot sign is also a useful imaging feature to distinguish endometriomas from hemorrhagic cysts (**Fig. 4**). This is a highly specific (93%) sign of chronic hemorrhage, usually indicative of an endometrioma. Unfortunately, the sensitivity is low (36%) and the absence of the sign does not mean a lesion is not an endometrioma.[14] In contrast to retracting blood clot in a hemorrhagic cyst (see **Fig. 3**), the T2 dark spot is markedly hypointense and smaller.

Teratomas

A mature cystic teratoma can be T1W hyperintense or have T1W hyperintense components (**Fig. 5**) due to its fat content. Tissue components from other germ cell layers are often present. The T1W hyperintense signal will become hypointense with frequency-selective fat saturation. Use of opposed- and in-phase gradient-echo imaging is also helpful where macroscopic lipid will be indicated by India ink artifact at the lipid–water interfaces or intracellular lipid will become hypointense on opposed-phase images.[16] However, if short tau inversion recovery imaging is used in the protocol, the loss of T1W SI is not frequency-specific and can occur with both fat and hemorrhage.[12] The T2W SI for fatty components in mature cystic teratomas is also high.[8]

Other masses containing hemorrhagic and proteinaceous contents

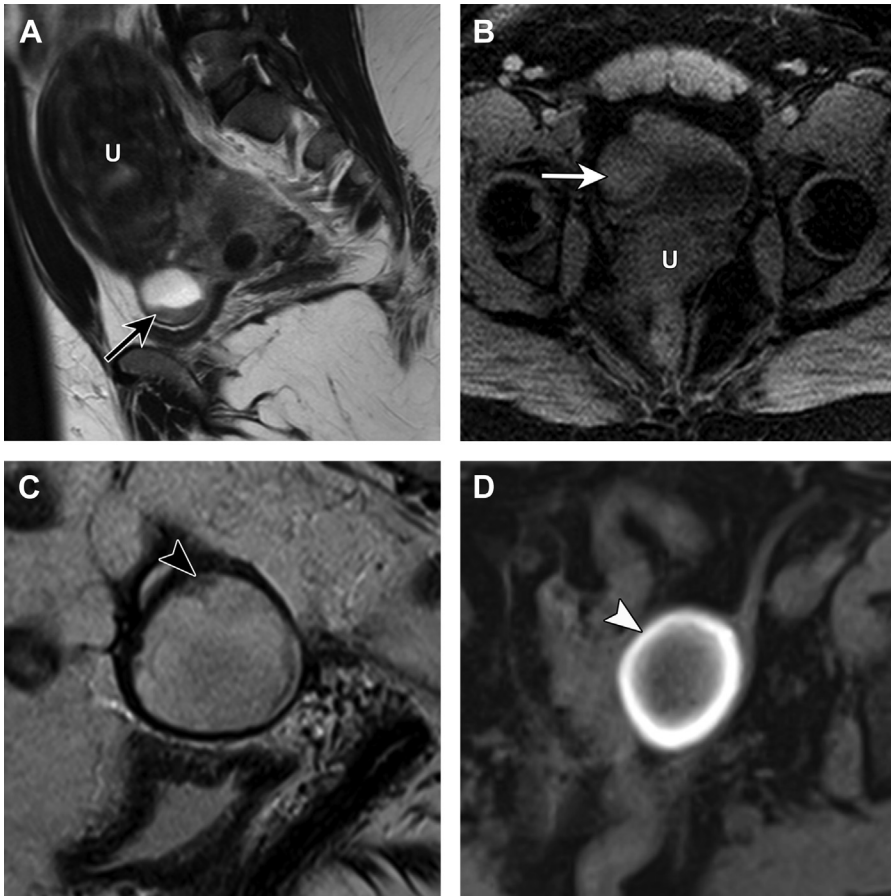Mucin-containing masses can also be T1W hyperintense, but the intensity of mucin is variable

Fig. 3. Hemorrhagic cysts in two patients (*A* and *B* vs *C* and *D*). Sagittal T2-weighted MR image (*A*) shows a cyst with layering hypointense signal compatible with blood clot (*black arrow*). Incidental fibroids present in the uterus (U). Axial T1-weighted MR image with fat saturation (*B*) shows mild heterogeneous hyperintense signal within the hemorrhagic cyst at the level of the blood clot (*white arrow*). Sagittal T2-weighted MR from a different patient with a hemorrhagic cyst (*C*) shows mild internal T2-weighted hypointensity (*black arrowhead*). Axial T1-weighted image with fat saturation from the same patient (*D*) shows peripheral T1-weighted hyperintense signal (*white arrowhead*). Note the T2-weighted hypointensity in both cases is not as hypointense as for the T2 dark spot sign (see **Fig. 4**).

depending on viscosity. Mucinous cystadenomas are often multilocular, whereas endometriomas are often unilocular. The SI often differs between locules due to variable mucin content causing a stained-glass appearance[17,18] (**Fig. 6**). However, some mucinous neoplasms are unilocular, and the absence of heterogeneous T2 shading is helpful to distinguish from endometriomas.

Hemorrhage can also occur in other preexisting benign or malignant adnexal neoplasms. The T1W hyperintensity may not be as striking but the T2W sequelae of chronic hemorrhage, including a T2 dark spot, may exist due to the chronicity of the lesion. Peripheral calcification can also mimic the T2 dark spot, thus evaluation of both T1W and T2W sequences and comparison modalities is advised. Other mucin-containing tumors, such as metastases and mucinous cystadenocarcinoma, will often be heterogeneous with solid components and may be very large in size.[18]

Tubo-ovarian abscesses can also be T1W hyperintense and T2W hypointense and restrict diffusion due to protein-rich content and potential associated hemorrhage[19] (**Fig. 7**). The T1W hyperintensity can be homogenous or variable. Clinical context in addition to wall thickening and enhancement, inflammatory change, and pyosalpinx may assist in the diagnosis.

SUSCEPTIBILITY-WEIGHTED IMAGING OF ENDOMETRIOMAS

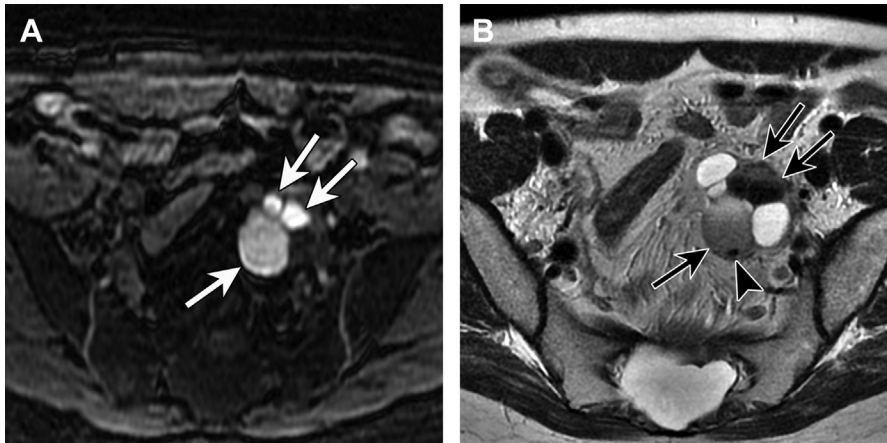Some endometriomas do not show the typical features of T2 shading and T1W hyperintensity. These

Fig. 4. T2 dark spot sign in an endometrioma. Axial T1-weighted MR image (*A*) shows homogenous hyperintense signal in multiple left endometriomas (*white arrows*). Axial oblique T2-weighted MR image (*B*) shows the corresponding variable appearance of T2 shading (*black arrow*) and a T2 dark spot (*black arrowhead*) in a posterior endometrioma. Incidental follicles present.

can be mistaken for non-endometriotic cysts due to higher fluid content or solid-appearing fibrotic masses due to markedly low T2W SI. In these atypical endometriomas, SWI may be helpful for diagnosing these lesions as endometriomas.

SWI depicts local magnetic field inhomogeneity as signal voids and may be used to detect the sequela of hemorrhage. Endometriomas may contain punctate or curved signal voids along the wall resulting from hemosiderin-laden macrophages or throughout the cyst due to deoxyhemoglobin and hemosiderin from repeat hemorrhage. A study of 42 pathology-proven endometriomas showed that adding SWI increased the MRI diagnosis in 76.2% to 97.6% of the endometriomas.[11]

Hemorrhagic cysts did not show signal voids, although there were only two in the study.[11] Of note, the amount of signal void and appearance may vary with the menstrual cycle and the phase of evolving blood products.[20]

OVARIAN POSITIONING

Endometriomas are associated with DIE, and the configuration of the ovaries and/or endometriomas may be a predictor of more severe disease.[21,22] When endometriotic implants occur in the posterior pelvis, they can elicit significant inflammation and fibrosis. The subsequent adhesion formation frequently extends between the
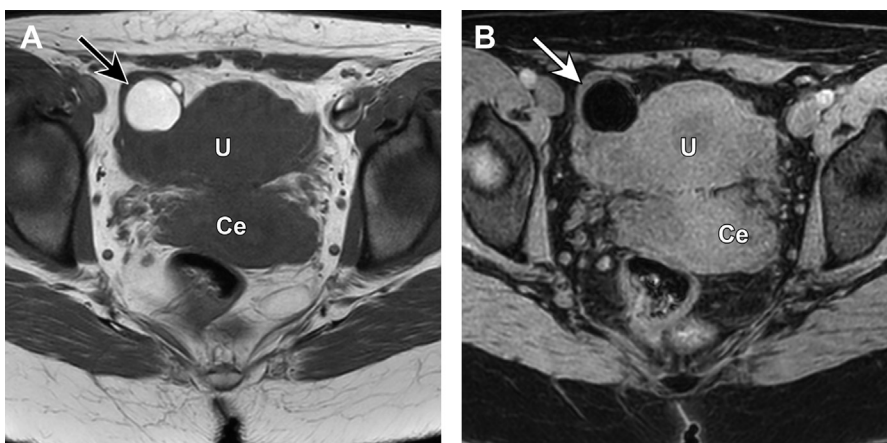

Fig. 5. Mature cystic teratoma of the right ovary (arrow). Axial precontrast T1-weighted MR image (*A*) shows a unilocular lesion with homogenous hyperintense signal (*black arrow*). Axial T1-weighted image with fat saturation (*B*) shows loss of signal within the lesion indicating macroscopic fat, characteristic of a mature cystic teratoma (*white arrow*). No internal enhancement. U, uterus; Ce, cervix.
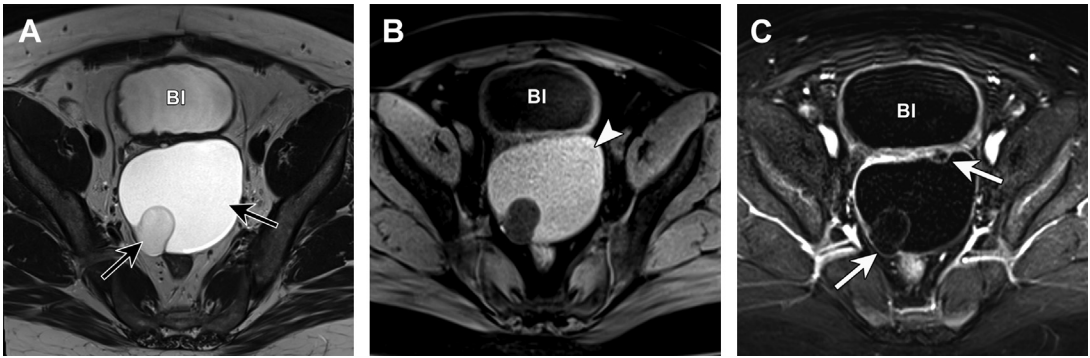
Fig. 6. Mucinous cystadenoma of the right ovary which is located posterior to the bladder. Axial T2-weighted MR image (*A*) shows a multilocular cystic mass with differing signal intensity within different locules (*black arrows*). Axial T1-weighted MR image with fat saturation (*B*) shows homogenous hyperintense signal in one of the locules due to variation in mucin content (*white arrowhead*). Axial post-contrast T1-weighted image with fat saturation (*C*) shows thin enhancing septations (*white arrows*) and no enhancing solid components. Bl, bladder.

ovaries and the surrounding pelvic structures (posterior uterine wall, uterosacral ligaments, and anterior rectum). When the ovaries are retracted posteriorly and medially and/or when situated next to each other, this is known as a "kissing ovary" configuration (**Fig. 8**). This appearance has been associated with higher severity of endometriosis on intraoperative staging.[22,23]
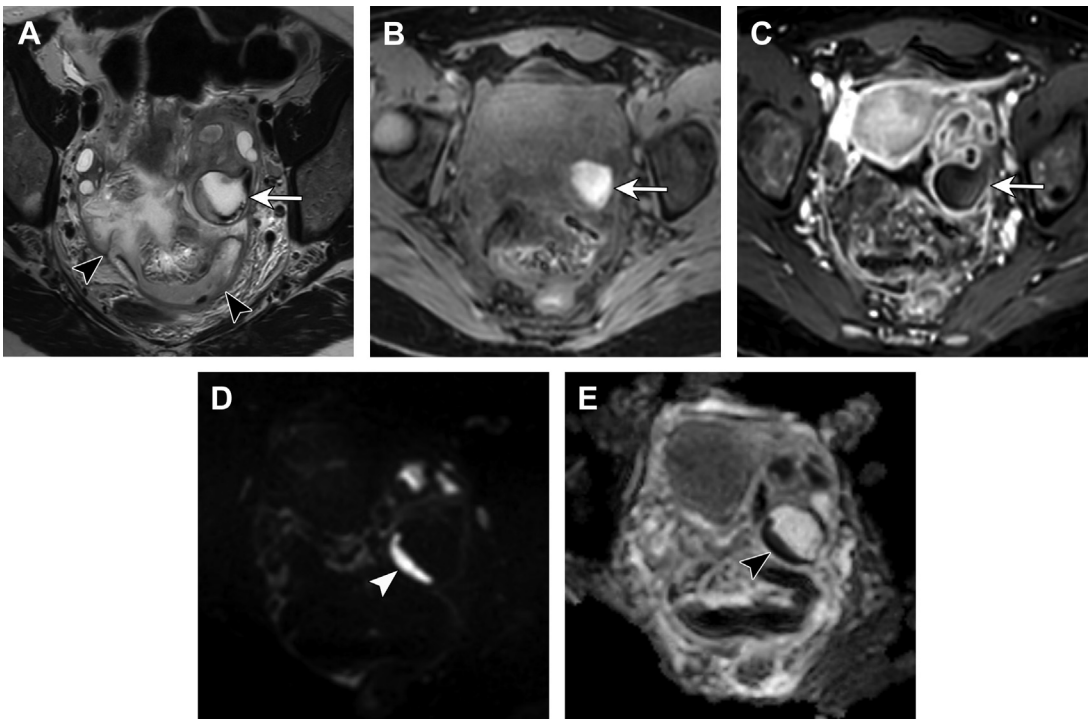

Fig. 7. Left tubo-ovarian abscess. Short axis oblique T2-weighted MR image (*A*) shows an enlarged left ovary with diffuse, mild increased signal intensity of the ovarian stroma and a cystic component (*white arrow*). Inflammatory peritoneal thickening (*black arrowheads*) and heterogeneous ascites are also present. Axial T1-weighted image with fat saturation (*B*) shows hyperintense signal within the left ovarian cystic structure (*white arrow*). Axial subtraction post-contrast T1-weighted image with fat saturation (*C*) shows rim enhancement of multiple locules, including the cystic structure (*white arrow*). Axial diffusion weighted image (b-value = 1600) (*D*) shows markedly hyperintense signal within the cystic component (*white arrowhead*). Axial apparent diffusion coefficient map (*E*) shows corresponding hypointensity of the cystic component which restricts diffusion (*black arrowhead*).
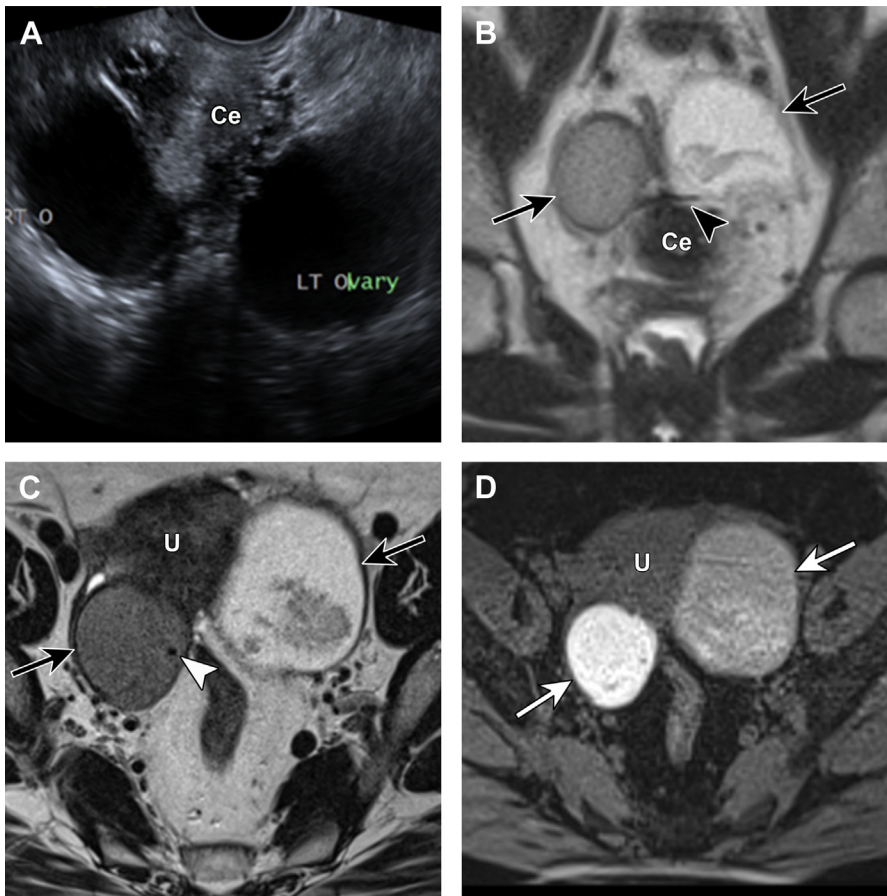
Fig. 8. Kissing ovaries/endometriomas indicating concomitant deep infiltrating endometriosis. Transvaginal pelvic ultrasound (*A*) shows bilateral cystic lesions oriented adjacent and posterior to the cervix (Ce). Coronal T2-weighted MR image (*B*) and axial T2-weighted MR image (*C*) show bilateral kissing ovaries (*black arrows*) posterior to the cervix (Ce) and uterus (U) with abutment of bilateral cystic lesions. There is a thin fibrotic band of adhesion between the ovaries and cervix (*black arrowhead*) and further adhesion along the uterus. There is T2 shading in both lesions and a T2 dark spot on the right (*white arrowhead*). Axial T1-weighted MR image (*D*) without contrast and with fat saturation shows typical T1-weighted hyperintensity of an endometrioma on the right and heterogeneity of the lesion on the left (*white arrows*). Given the pattern of disease, the left sided lesion is likely also an endometrioma, although a hemorrhagic cyst could also have this appearance.

FALLOPIAN TUBE INVOLVEMENT/ HEMATOSALPINX

Endometriosis is a frequent cause of fallopian tube dilation with approximately 30% of women having tubal involvement on laparoscopy.[24,25] Endometriotic implants most commonly involve the serosa and subserosa of the fallopian tubes and are not typically visible on imaging. These superficial implants elicit repetitive bouts of hemorrhage and fibrosis, which lead to peritubal adhesions and fallopian tube dilation.[26] Transmural or mucosal involvement is less commonly encountered.[27]

Hematosalpinx is highly suggestive of endometriosis, even in the absence of endometriosis elsewhere in the pelvis.[25,28] In fact, it may be the only finding indicative of underlying endometriosis.[24,27] The intraluminal appearance on T2WI is variable and frequently does not demonstrate T2 shading classically associated with endometriomas (**Fig. 9**). The absence of intraluminal T2W hypointensity may be related to the extraluminal location of the implants, which restricts the chronic, cyclical nature of hemorrhage deposition classically encountered within the ovary. Unlike pyosalpinx, the fallopian tube walls are typically thinner in the setting of endometriosis.[25]

BROAD LIGAMENT ENDOMETRIOSIS

Endometriosis can involve the broad ligament, which is the adnexal suspensory ligament and
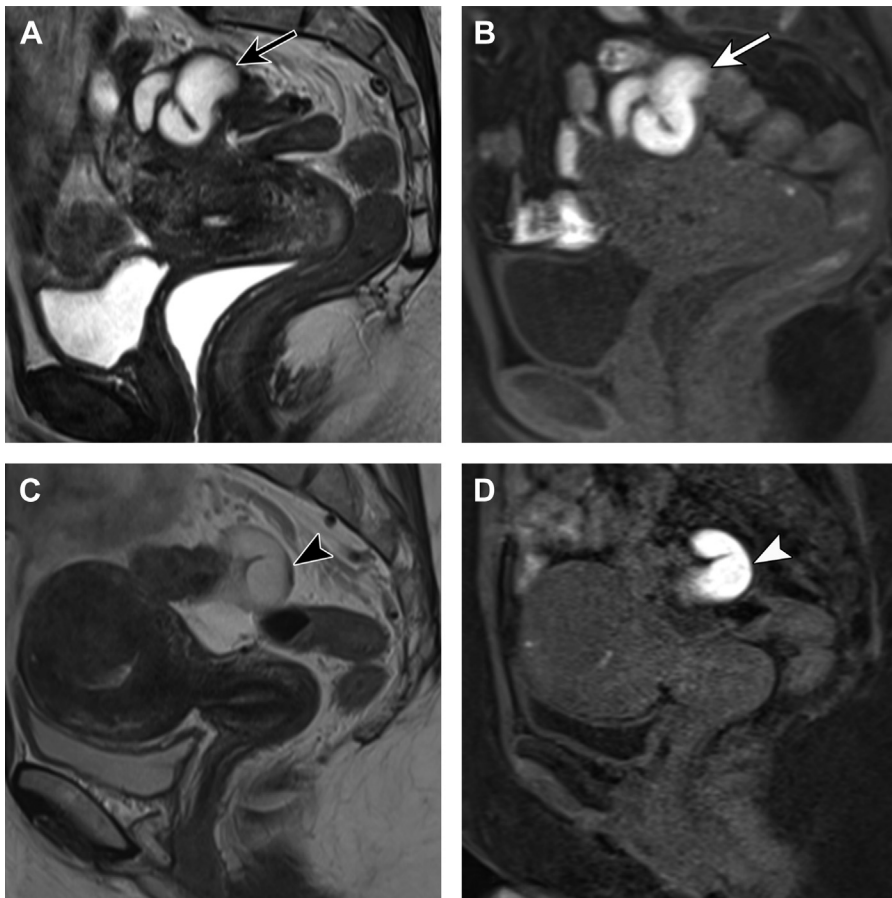
Fig. 9. Hematosalpinx in two patients (*A* and *B* vs *C* and *D*). Sagittal T2-weighted MR image (*A*) shows a dilated tubular structure posterior and superior to the uterus (*black arrow*) with hyperintensity and no shading. Corresponding sagittal T1-weighted MR image with fat saturation (*B*) shows diffuse hyperintense signal compatible with hematosalpinx (*white arrow*). Sagittal T2-weighted MR image (*C*) in a different patient shows a dilated tubular structure posterior to the uterine-cervical junction which is predominantly hyperintense but with layering hypointensity posteriorly consistent with T2 shading (*black arrowhead*). Corresponding sagittal T1-weighted MR image with fat saturation (*D*) shows hyperintensity consistent with hematosalpinx (*white arrowhead*).

serves as the mesentery to the ovary and fallopian tube. The broad ligament is the lateral extension of the anterior and posterior peritoneal surfaces of the uterus, which come together laterally and extend to the pelvic side wall and pelvic floor inferiorly. The presence of the broad ligament results in anterior and posterior peritoneal recesses. Endometriomas and DIE can therefore also involve the broad ligament, the recesses, and the adjacent but separate structures such as the ureters and uterosacral ligaments. The proximal round ligament courses through the broad ligament and can be involved by DIE. Endometriosis of the broad ligament can manifest as an adnexal extra-ovarian mass or endometrioma, isolated as unifocal disease, or be contiguous with adjacent DIE deposits[2,29] (**Fig. 10**).

ENDOMETRIOSIS-ASSOCIATED OVARIAN CANCER

Endometriosis-associated ovarian cancer (EAOC) is a subset of ovarian cancers defined as an ovarian cancer in association with ipsilateral or contralateral ovarian endometriosis, pelvic endometriosis, or histopathology showing endometriosis. The mechanism for transition from benign disease to malignancy is the subject of ongoing research but likely multifactorial including molecular genomic alterations, biologic modulators, and hormonal factors.[30]

This unique group of cancers tends to occur at an earlier age and is associated with better prognosis and outcomes as compared with ovarian cancers in the general population. The most common

Fig. 10. Deep infiltrating endometriosis of the right broad ligament. This presented as a right adnexal mass separate from the right ovary (*white arrowhead*) in a patient with cyclic flank pain and hematuria. The mass was encasing the right ureter and caused cyclic hydronephrosis (not present at the time of MR imaging and not shown here). Axial T2-weighted MR image (*A*) shows an irregular T2-weighted hypointense mass (*black arrow*) between the uterus and cervix and right ovary. Axial T1-weighted MR image with fat saturation (*B*) shows intrinsic hyperintensity (*white arrow*) within the mass due to active glandular components of deep infiltrating endometriosis (DIE). Axial T1-weighted post-contrast MR image with fat saturation and subtraction (*C*) shows enhancement due to a chronic fibrotic component (also represented by T2-weighted hypointensity) of DIE (*curved white arrow*). The right ureter coursed into the posterior aspect of the mass.

histology for EAOC includes endometrioid adenocarcinoma and clear cell carcinoma followed by mucinous borderline tumors, endometrial stromal sarcoma, and Mullerian adenosarcomas.[31]

Clinical symptoms of EAOC are nonspecific and may overlap with endometriosis. Tumor markers such as CA-125 are not reliable to establish a diagnosis as they can be elevated in women with benign endometriosis and normal in women with ovarian cancers. Given that imaging studies are frequently performed for women with endometriosis, it is crucial that radiologists evaluate endometriomas for evidence of malignant transformation.[31]

MR imaging is more sensitive than ultrasound for distinguishing benign from malignant ovarian lesions and is an important tool in ovarian lesion assessment. Studies evaluating MR imaging features of EAOC have shown a larger lesion size among malignant lesions (11.2 cm) as compared with benign (7.8 cm).[32] The characteristic T2 shading of cyst fluid in benign endometriomas is often lost or absent in malignant lesions. This has been attributed to dilution of endometriotic cyst contents by serous or mucin-producing tumors. Benign endometriomas can contain internal septa due to hemorrhagic contents. Septa in benign lesions tend to be smooth and avascular, whereas septa in malignant lesions may be nodular and show post-contrast enhancement or restricted diffusion.[31] Enhancing mural nodules and papillary projections are imaging features of malignant ovarian lesions. These solid elements can show variable pre-contrast SI and may exhibit a restricted diffusion pattern on DWI. Post-contrast subtraction imaging is helpful to recognize enhancement of solid elements as lesions may have cyst fluid with intrinsic hyperintense signal on T1WI (**Fig. 11**).

DECIDUALIZED ENDOMETRIOSIS

Pregnancy is a progesterone-predominant state, where there is a relative decline in estrogen and increase in progesterone hormone levels.[33] Decidualization is a physiologic response of the eutopic normal endometrial lining to these hormonal changes in pregnancy, where the endometrium hypertrophies and becomes more vascular to support the growing fetus. Ectopic endometrium present in endometriomas and DIE can also respond to these hormonal changes and undergo decidualization.[33] Overall, as endometriosis is an estrogen driven disorder, the progesterone-predominant state of pregnancy favors an improvement in endometriosis.[33]

With decidualization, endometriomas can demonstrate a rapid growth, particularly early in pregnancy after which they may stabilize or continue to increase in size.[34–36] Decidualized endometriomas usually appear as unilocular or multilocular cystic masses with a solid component on ultrasound (**Fig. 12**). Rounded, smooth, highly vascularized, solid papillary projections in the internal wall of endometriomas seem to be the most consistently reported characteristic of decidualization.[37] In a study by Mascilini and colleagues, the smooth, rounded appearance of the papillary projections signaled benignity with a large majority of patients with decidualized endometriomas (82%) demonstrating this feature.[36]
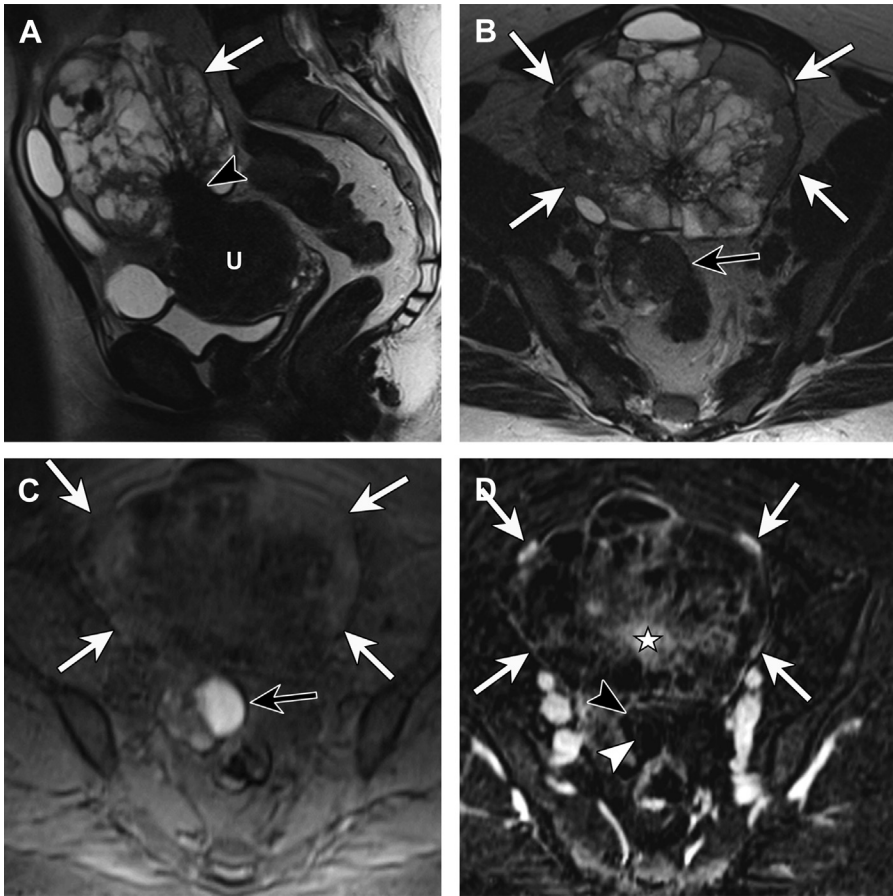
Fig. 11. Endometriosis-associated ovarian cancer. Premenopausal woman with chronic pelvic pain and irregular menses. Sagittal T2-weighted MR image (*A*) shows a large hypointense deep infiltrative endometriosis (DIE) lesion (*black arrowhead*) that extends from the posterior uterus (U) to the large left ovarian mass (*white arrow*). Axial T2-weighted MR image (*B*) shows a unilocular right ovarian lesion with T2 shading, characteristic of an endometrioma (*black arrow*) and the large, multiloculated left ovarian mass with numerous irregular septations and heterogeneous signal (*white arrows*). Axial pre-contrast T1-weighted image (*C*) with fat suppression shows homogeneous hyperintense signal within the unilocular right ovarian lesion characteristic of an endometrioma (*black arrow*). The large left ovarian lesion is heterogeneous (*white arrows*). Axial post-contrast T1-weighted MR image (*D*) with fat suppression and subtraction shows enhancement of solid elements (*star*) and irregular septations throughout the left ovarian mass (*white arrows*). Enhancing septa (*white arrowhead*) and nodule (*black arrowhead*) was also noted within the right ovarian lesion. Histopathology showed well-differentiated mixed epithelial carcinomas (seromucinous and endometrioid) arising in a background of endometriosis in both ovaries.

Differentiation with malignancy can be particularly challenging, especially in the absence of previous imaging documentation of endometriomas. On MR imaging, the mural nodules seen in malignancy are T1 hypointense and T2 hyperintense.[38] The decidualized solid components of endometriomas demonstrate SI similar to the decidualized endometrium or placenta and can be T2 hypointense.[11,35,39] Note that gadolinium-based contrast is not given during pregnancy to evaluate for enhancement due to potential safety concerns for the fetus. Solid components of both decidualized endometriomas and malignancy can restrict diffusion on DWI. Higher b-value DWI and ADC maps can be helpful for differentiation. Decidualized endometriomas show decreased signal at higher b-values (b-value = 1500), whereas cancers maintain their restricted diffusion, especially on higher b-values.[39] Takeuchi and colleagues also showed that decidualized endometriomas exhibit high SI on DWI (b-values = 800) due to T2 shine-through effect.[39] Despite this, given the current sparse literature on this topic, patient-centered decision-making is advised with close monitoring during pregnancy (**Fig. 13**). Conservative management can be pursued, if decidualized endometriosis is highly suspected, such as in scenarios wherein the growth of the mass stabilizes on follow-up.
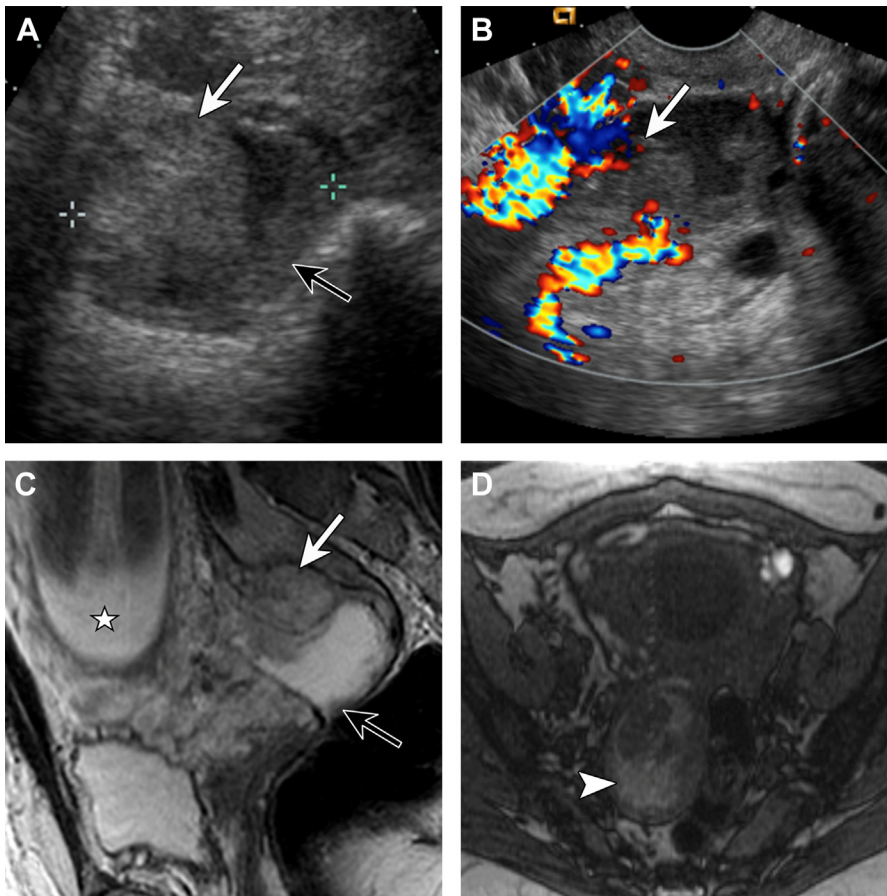
Fig. 12. Decidualized endometrioma mimicking ovarian malignancy. A 34-year-old woman found to have an incidental adnexal mass during routine obstetric ultrasound, proven to be a decidualized endometrioma after surgical resection at the time of cesarean section. Gray scale ultrasound (US) image (*A*) demonstrates a unilocular mass (calipers) with solid components (*black* and *white arrows*). As shown here, decidualization can be nonuniform presenting as solid nodules (*white arrow*) or solid tissue (*black arrow*) along the wall of the endometrioma. Color Doppler US (*B*) shows the mass to be markedly hypervascular. Note the smooth and rounded appearance of the solid component that has been described to be typical of decidualized endometriomas (*white arrow*). Sagittal T2-weighted MR image (*C*) shows the same cystic mass with nonuniform solid components (*white* and *black arrows*). Note the gestation in the uterus (*star*). Axial T1-weighted image (*D*) shows intrinsic T1 hyperintensity of the fluid contents (*white arrowhead*), which is suggestive of hemorrhagic contents, that can be seen in endometriomas. However, imaging distinction from malignancy remains challenging.

Spontaneous hemoperitoneum in pregnancy (SHiP) is unprovoked (nontraumatic) intraperitoneal bleeding during pregnancy and up to 42 days postpartum arising from endometriomas or DIE, particularly in patients status post fertility assistance with ovarian stimulation and in vitro fertilization.[40] In patients who underwent surgical interventions, active hemorrhage was noted from endometriotic implants, ruptured utero-ovarian vessels, hemorrhagic nodules of decidualized cells, and/or pseudoaneurysms. Imaging usually demonstrates unexplained intraperitoneal free fluid and hemorrhage. Presumed decidual reaction in DIE can result in pseudoaneurysms likely secondary to decidualization and neovascularity,

which can lead to catastrophic hemorrhage.[41] There are no current tools to identify patients at risk of SHiP; therefore, when unexplained hemoperitoneum is seen, hemorrhage related to endometriosis should be considered in the differential.

SUMMARY

Endometriomas are a common manifestation of endometriosis and can occur in isolation or associated with hematosalpinx or DIE. Utilization of a proper MR protocol can assist in differentiation with other adnexal masses and increase detection of EAOC. The hormonal changes of pregnancy can
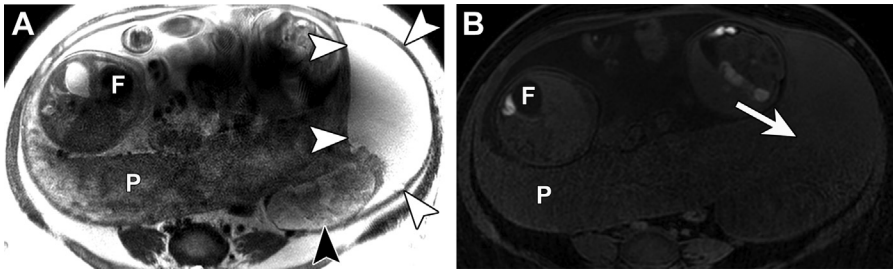
Fig. 13. 34-year-old woman with history of endometriosis presents with a large left adnexal mass in pregnancy. The mass was resected at the time of cesarean section delivery and found to represent a clear cell cancer. Axial T2-weighted image (*A*) shows a large cystic mass (*white arrowheads*) with a large solid component (*black arrowhead*). Axial T1-weighted image (*B*) does not demonstrate hyperintensity in the cyst fluid (*white arrow*), in contrast to **Fig. 11**. The mass and the solid component demonstrated exponential growth in pregnancy, which was suspicious for malignancy. F, fetus; P, placenta.

cause decidualization of endometriosis. A potential complication of endometriosis is spontaneous hemorrhage in pregnancy.

CLINICS CARE POINTS

- Endometriomas have marked homogenous T1-weighted hyperintensity, T2 shading, and some will have the T2 dark spot sign. They are often multiple and bilateral.

- Hematosalpinges appear as dilated tubular structures that are also hyperintense on T1-weighted imaging. However, T2 shading may or may not be present.

- Post contrast subtraction imaging is vital to evaluate for endometriosis associated ovarian cancer as lesions may have cyst fluid with intrinsic T1-weighted hyperintensity.

- Endometriomas can decidualize in pregnancy and mimic ovarian cancer due to solid components and rapid growth. Solid components will have smooth round projections and match signal of the endometrium and placenta. Growth tends to stabilize; however, if growth continues, suspect malignancy.

- If a pregnant or post-partum patient presents with nontraumatic abdominal pain and hemoperitoneum, evaluate for signs of endometriosis as a source because spontaneous hemorrhage in pregnancy can occur.

DISCLOSURE

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