T2-weighted sequences are an integral part of magnetic resonance (MR) imaging performed for the characterization of adnexal lesions. A relatively small number of these lesions demonstrate low signal intensity on T2-weighted MR images. In the majority of cases, a specific diagnosis can be made by interpreting the signal intensity of the lesion with respect to certain pathologic correlates, including blood products, smooth muscle, fibrous tissue, and calcification, as well as high lesion cellularity. For example, lesions that are at least as dark as skeletal muscle are almost always benign, whereas those whose T2 signal intensity is higher than that of skeletal muscle constitute a more heterogeneous group composed of benign, borderline, and malignant disease entities. The authors propose a diagnostic algorithm that takes these features into account, as well as the appearances of the lesion with additional pulse sequences, to aid in the correct interpretation of T2-hypointense adnexal lesions. Knowledge of the anatomy, the T1-weighted imaging features, and the enhancement characteristics of adnexal lesions allows accurate characterization of these lesions, resulting in appropriate patient management.
Introduction

Magnetic resonance (MR) imaging is optimal for the evaluation of adnexal masses due to its multiplanar capability and inherent soft-tissue contrast. The MR imaging features of indeterminate adnexal masses can provide unique morphologic information regarding the lesion, including its location, size, and cystic-solid composition (1). T2-weighted sequences are an integral part of MR imaging performed for the characterization of adnexal masses. The majority of adnexal lesions contain cystic components, which demonstrate high signal intensity on T2-weighted images. The finding of a T2-hypointense adnexal lesion is less common and should be interpreted with respect to specific pathologic correlates, including blood products, smooth muscle, fibrous tissue, and calcification, as well as high lesion cellularity. In this article, we discuss the differential diagnosis for T2-hypointense adnexal lesions and describe imaging features that allow a more specific diagnosis. In addition, we propose a diagnostic algorithm that takes these features into account, as well as the appearances of the lesion with additional pulse sequences, to aid in the correct interpretation of T2-hypointense adnexal lesions.

Normal Anatomy of the Adnexa Uteri

To accurately characterize indeterminate adnexal lesions, it is important to first be familiar with their normal appearance and to assess the relationship of the lesion to the pelvic organs. The adnexa include the fallopian tubes and the ovaries as well as structures that originate from the uterus and its supporting ligaments. Identifying the anatomic origin of an adnexal lesion aids in characterizing the lesion and narrowing the differential diagnosis. The imaging appearance of the ovaries will vary depending on the patient’s physiologic state (stage of menstrual cycle, age, pregnancy status) or previous treatment and procedures. The fallopian tube is a serpentine structure filled with interdigitating plicae, and typically no lumen is visualized (2). The identification of a tubal structure separate from the ovary aids in making the diagnosis. Although multiplanar MR imaging is superior to other imaging techniques in demonstrating the pelvic anatomy, identification of specific anatomic structures and of the origin of the lesion can remain a diagnostic challenge in some cases.

Location of T2-Hypointense Adnexal Lesions

When a parauterine adnexal mass is visualized, verification of the origin of the mass is essential for appropriate patient management. If the gonadal vessels lead to the lesion and no ipsilateral ovary is visualized, an ovarian lesion is considered to be a possibility. On the other hand, visualization of both ovaries as separate and distinct from the lesion confirms that the lesion is extraovarian in origin. Visualization of hyperintense ovarian follicles or of a functional cyst at T2-weighted imaging helps identify the ovaries. The presence of a pedicle between the uterus and the lesion indicates that the lesion arises from the uterus. Dynamic ultrasonography (US) may be helpful for demonstrating movement of the mass with the uterus; however, the pedicle of a subserosal pedunculated leiomyoma can be very narrow and is more easily identified at MR imaging (3). The “bridging vessel” sign represents tortuous vascular structures passing between the uterus and the lesion and may be seen at US; however, this sign is most clearly depicted at gadolinium-based contrast material–enhanced T1-weighted imaging or T2-weighted imaging, which nicely demonstrate vascular flow voids (3). The bridging vessel sign confirms that the lesion originates from the uterus and excludes an ovarian origin (Fig 1), although intravenous administration of contrast material can be helpful in confirming an ovarian vascular supply to the mass (4).

In the setting of an adnexal mass that is neither ovarian nor uterine in origin, the possibility of tubal disease must be considered. Tubal masses are separate from the uterus as well as the ovary, although they may be attached to the ovary by adhesions. The most common T2-hypointense tubal lesion is hematosalpinx (discussed later), followed by tubal leiomyoma, fibroma, and abscess. Although extraterine leiomyomas are uncommon, they can arise from a fallopian tube or round ligament. Endovaginal US may provide assurance...
of separation of the uterus and ovaries from the mass. MR imaging is extremely useful due to its superb multiplanar capability and its capacity to demonstrate the typical signal characteristics of leiomyoma (see “Smooth Muscle”) (5).

**Signal Characteristics of T2-Hypointense Adnexal Lesions**

Tissue characterization at MR imaging is based primarily on differences in longitudinal (T1) and transverse (T2) relaxation times (6). The majority of adnexal lesions contain cystic components and are, therefore, T2 hyperintense. However, there are a few distinctive histologic and morphologic entities that result in shortening of T2 relaxation time and hence manifest with low signal intensity at T2-weighted imaging, including blood products, muscle, fibrous tissue, calcification, air or flow-related artifact, and paramagnetic substances such as melanin (7). For the purposes of this article, T2-hypointense adnexal masses are grouped according to their predominant component (Table 1).
We divide T2-hypointense adnexal lesions into two subgroups. The first subgroup includes masses that are as dark as or darker than skeletal muscle on T2-weighted MR images, whereas the second subgroup contains lesions whose T2 signal intensity is higher than that of skeletal muscle (Table 2). T2-hypointense adnexal lesions that are at least as dark as skeletal muscle help narrow the differential diagnosis and improve specificity. Nearly all of these lesions are benign nonaggressive entities. Adnexal lesions that are hypointense on T2-weighted MR images, but whose signal intensity is higher than that of skeletal muscle, are a more heterogeneous group composed of benign, borderline, and malignant disease entities. In the appropriate clinical context, these entities should be included in the differential diagnosis for lesions that are not as hypointense as skeletal muscle.

Pathologic Correlates

Blood Products
The signal characteristics of a hemorrhagic lesion at MR imaging depend on the age of the hemorrhage and whether the blood products are intracellular or extracellular in location (Table 3), even though time-related changes in hemorrhage are not as predictable for extracranial bleeding as for intracranial bleeding. Intracellular deoxyhemoglobin (acute hemorrhage) and intracellular methemoglobin (early subacute hemorrhage) result in T2 shortening and are, therefore, T2 hypointense. Intracellular deposits of ferritin or hemosiderin in the wall of a mature hematoma also lead to decreased T2 signal intensity due to magnetic susceptibility effects. In contrast, extracellular methemoglobin (late subacute hemorrhage) is T2 hyperintense, whereas intracellular methemoglobin results in high T1 values due to paramagnetic effects (7).

**Endometrioma**.—At US, an endometrioma typically appears as a homogeneous hypoechoic mass with low-level echoes. MR imaging has been shown to be more specific than US or computed tomography (CT) for the diagnosis of endometrioma (9). Iron overload (10), a high concentration of protein, and increased viscosity over time are well-recognized characteristics of endometriomas due to repeated bleeding and degradation of old blood products, resulting in low T2 signal intensity (11). Diagnostic MR imaging criteria with a high specificity for endometriosis include multiple hyperintense cysts on fat-suppressed T1-weighted images (Fig 2) and, in the case of a solitary lesion, a T1-hyperintense and T2-hypointense cyst (Fig 3) (12). Homogeneous T2 shading is a characteristic feature of endometrioma. The term shading refers to signal loss on T2-weighted MR images in an ovarian cyst that appears hyperintense on T1-weighted images (13). Hemorrhage-containing lesions that (like skeletal muscle) are markedly hypointense on T2-weighted images are highly specific for endometriomas. However, not all endometriomas show this degree of T2 shortening, depending on their age, the amount of hemosiderin, and the protein concentration. Dependent layering and a hypointense fluid level representing different-aged blood products can be seen within an endometrioma. A hypointense peripheral ring caused by hemosiderin staining may be seen in

| Table 1 Classification of T2-Hypointense Adnexal Masses according to Predominant Component |
| Blood products     | Endometrioma | Hemorrhagic cyst | Hematosalpinx | Cystic adenomyosis |
| Smooth muscle      | Uterine leiomyoma | Fibrous tissue  | Fibroma | Fibrothecoma | Cystadenofibroma |
| Mixed cellularity  | Brenner tumor | Struma ovarii | Krukenberg tumor |

| Table 2 Classification of T2-Hypointense Lesions according to Degree of Signal Loss |
| T2 isointense relative to muscle |
| Endometrioma | Cystic adenomyosis | Hematosalpinx | Leiomyoma | Fibroma | Fibrothecoma | Cystadenofibroma | Struma ovarii |
| T2 hypointense relative to muscle |
| Hemorrhagic cyst | Malignant transformation of endometrioma | Mucinous cystic neoplasm | Krukenberg tumor |
chronic lesions (14). Margins that are slightly angled or distorted and not completely round due to adjacent scarring and fibrosis are also characteristic of endometriomas.

Malignant transformation is a rare complication of endometriosis and is estimated to occur in about 1% of patients (15). The most common histologic subtypes include endometrioid and clear cell carcinoma (16). Suspicious features include a large or growing endometrioma and lack of the characteristic shading on T2-weighted images. Loss of T2 shading following malignant...

<table>
<thead>
<tr>
<th>Principal Component</th>
<th>Time Range</th>
<th>Age of Hemorrhage</th>
<th>T1 Signal Intensity</th>
<th>T2 Signal Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intracellular oxyhemoglobin</td>
<td>Hyperacute</td>
<td>Minutes–24 h</td>
<td>Low-intermediate</td>
<td>High</td>
</tr>
<tr>
<td>Intracellular deoxyhemoglobin</td>
<td>Acute</td>
<td>1–3 d</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Intracellular methemoglobin</td>
<td>Early subacute</td>
<td>3–7 d</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Extracellular methemoglobin</td>
<td>Late subacute</td>
<td>1 wk–months</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Hemosiderin and ferritin</td>
<td>Chronic</td>
<td>Months–years</td>
<td>Very low</td>
<td>Very low</td>
</tr>
</tbody>
</table>

Source: Reference 8.
transformation of an endometrioma is thought to be related to dilution of the hemorrhagic content by tumor secretion (Fig 4) (17).

In these cases, careful assessment for the presence of an enhancing mural nodule must be made. Solid mural nodules seem to be the most valuable imaging finding in suggesting malignant transformation of an endometrioma (18). Positive enhancement of the nodule is best appreciated on dynamic contrast-enhanced subtraction T1-weighted MR images (19), on which the nodule is clearly highlighted on a background of unchanged signal intensity in the rest of the lesion.

**Hemorrhagic Ovarian Cyst.**—Functional hemorrhagic ovarian cysts, including follicular cysts (usually <1 cm) and corpus luteal cysts (often >1 cm) (20), are related to ovulation and are typically not seen after menopause (21). Distinguishing between a hemorrhagic cyst and an endometrioma remains a diagnostic problem in some cases (22). Both entities may have similar US features and appear hyperintense on fat-suppressed T1-weighted MR images. Frequently, endometriomas will have a very bright “light bulb” appearance, which can help differentiate them from hemorrhagic cysts. Hemorrhagic cysts show heterogeneous and relatively mild signal loss with no shading on T2-weighted images, whereas endometriomas show marked T2 signal loss. This is due to the absence of repeated bleeding and, therefore, a lower concentration of blood products and viscosity in hemorrhagic cysts than in endometriomas (Fig 5).
Figure 5. Hemorrhagic right ovarian cyst in a 39-year-old woman. (a) Short-axis fat-saturated T1-weighted MR image shows a predominantly hyperintense right ovarian lesion (arrow). (b) On an axial T2-weighted MR image, the lesion (white arrow) demonstrates mild signal loss relative to skeletal muscle (*), and typical endometrioma (cf Fig 3). Note the functional simple cyst (black arrow) in the left ovary.

Figure 6. Endometriosis in a 33-year-old woman with hematosalpinx. (a) Axial fat-saturated T1-weighted MR image demonstrates bilateral hyperintense serpentine structures (arrows) and the waist sign (arrowheads), findings that are compatible with hematosalpinx. (b) Axial T2-weighted MR image reveals hypointense blood contents (arrows) in the fallopian tubes. The presence of hypointense irregular plaque in the cul-de-sac (arrowhead) associated with bowel tethering confirms the diagnosis of pelvic endometriosis.

Functional hemorrhagic ovarian cysts are more commonly unilateral than bilateral and show a thin, well-defined smooth wall. Hemorrhagic cysts frequently contain heterogeneous contents due to clot formation and retraction. At follow-up imaging performed after a few physiologic cycles, a hemorrhagic cyst will demonstrate complete or partial resolution, whereas an endometrioma usually has a stable and persistent appearance.

Hematosalpinx.—A hematosalpinx can be recognized at both US and MR imaging as a tubular or corkscrew-shaped structure centered in the fallopian tube. The most helpful and specific findings of a hematosalpinx are T2 hypointensity, a tubular shape with small round projections, and diametrically opposed indentations in the walls resulting in the “waist” sign, which reflects a tubular cystic structure with a folded configuration (23). Hematosalpinx may be the only imaging finding of pelvic endometriosis (24). However, it may in fact be associated with endometriosis; therefore, detection of a hematosalpinx should prompt careful evaluation for endometrial deposits and endometriomas, and vice versa (Fig 6).
Cystic Adenomyosis.—Subserosal cystic adenomyosis of the uterus may also mimic a T2-hypointense adnexal lesion (25). It is characterized by a cystic myometrial lesion with extensive glandular changes and hemorrhage. The hemorrhage can be seen at different stages of organization, from subacute blood to hemosiderin deposits in the wall of the adenomyotic cyst, and thus can appear similar to an endometriotic cyst (26). The uterine origin of cystic adenomyosis can be confirmed on the basis of (a) the presence of myometrial splaying around the lesion, (b) visualization of the bridging vessel sign, and (c) identification of the ovaries as separate and distinct entities (Fig 7) (27).

Smooth Muscle
Compared with other soft tissues in the body, both smooth muscle and skeletal muscle demonstrate lower signal intensity on T2-weighted MR images, which results from the T2 shortening effects of intramuscular actin, myosin, and collagen, as well as decreased extracellular fluid relative to surrounding tissues (28). Normal pelvic structures that demonstrate very low signal intensity on T2-weighted MR images include the junctional zone of the uterus; the vaginal, urethral, and rectal muscularis; and the bladder detrusor muscle (7). Uterine leiomyoma represents the classic example of a pelvic neoplasm that is composed predominantly of smooth muscle and therefore typically demonstrates low signal intensity on T2-weighted MR images and low to intermediate signal intensity on T1-weighted images (Fig 8). This characteristic signal intensity aids in making the diagnosis and is seen in up to 60% of uterine leiomyomas, showing a hyaline subtype of degeneration. The T2 signal of leiomyomas may vary in less common subtypes of degeneration (cystic, myxoid, and red) due to the presence of specific components (edema, hemorrhage, necrosis, and calcification) or in unusual subtypes (lipoleiomyoma and myxoid leiomyoma).
Figure 8. Multiple uterine leiomyomas in a 66-year-old woman. (a) Coronal T2-weighted MR image depicts predominantly hypointense intramuscular (white arrow) and exophytic (black arrow) subserosal leiomyomas. The exophytic leiomyoma should be differentiated from an adnexal mass. (b) On an axial fatsaturated T1-weighted image, the leiomyomas (arrows) are isointense relative to uterine myometrium (*).

(29), resulting in a heterogeneous “cobblestone” appearance. Exophytic uterine leiomyomas may mimic adnexal masses in some cases. In these instances, determining the origin of the mass will allow a correct diagnosis to be made.

Extraterine leiomyomas are rare and often pose a significant diagnostic challenge. These masses may originate from the adnexa, including the ovaries, fallopian tubes, and round ligament. Parasitic leiomyoma arises from the broad ligament of the uterus and, unlike other leiomyomas, can grow after hysterectomy. Primary ovarian leiomyoma is a very rare pathologic entity, with less than 80 cases having been reported in the literature. Ovarian leiomyoma coexists with uterine leiomyoma in 80% of cases, with typical MR imaging characteristics similar to those of smooth muscle (5). Because leiomyomas are the most common gynecologic tumors and are usually benign, they should be included in the differential diagnosis given the characteristic T2 hypointensity of smooth muscle tumors.

Fibrous Tissue

Fibrous tissue represents low-cellularity or acellular material in combination with spindle, oval, or round cells that result in collagen formation. Fibrosis typically demonstrates intermediate signal intensity on T1-weighted MR images and very low signal intensity on T2-weighted images (7). The solid fibrous component of fibroma, fibrothecoma, and cystadenofibroma characteristically demonstrates very low T2 signal intensity, allowing the differentiation of these benign tumors from malignant solid ovarian lesions.

Although MR imaging criteria for malignant ovarian tumors include visualization of a solid mass or a large solid component in association with a cystic mass, awareness of the typical MR imaging characteristics of fiber-containing tumors allows the diagnosis of benign ovarian disease to be made.

Fibroma and Fibrothecoma.—Fibroma and fibrothecoma represent a spectrum of benign stromal ovarian tumors composed of fibrous tissue and theca cells. Fibromas can be associated with ascites and pleural effusions in classic Meigs syndrome (30), or with elevated carcinoembryonic antigen levels (31). These solid tumors have a variable appearance at US and not uncommonly remain indeterminate. With T1-weighted sequences, fibrothecomas demonstrate nonspecific hypo- to isointensity with mild enhancement following the intravenous administration of a gadolinium chelate.

Therefore, identification of the characteristic predominantly low signal intensity of fibromas at T2-weighted imaging allows their differentiation from other solid ovarian masses (32).
Figure 9. Ovarian fibroma in a 71-year-old woman. (a) Sagittal T2-weighted MR image demonstrates a very low-signal-intensity ovarian mass (arrow), a finding that is typical of fibroma. The presence of a few simple cysts (arrowhead) helps verify the ovarian origin of the lesion. (b) On a sagittal contrast-enhanced T1-weighted MR image, the fibroma (arrow) shows mild enhancement.

Fibrothecomas are responsible for the endocrine activity that results in endometrial hyperplasia and polyps in some cases (33). Visualization of a thickened endometrium or endometrial polyp associated with a hypointense ovarian mass at T2-weighted imaging favors the diagnosis of a fibrothecoma (Fig 10). In larger lesions, various combinations of T2-hypointense theca and fibrous components can be seen in association with T2-bright edema and cysts, resulting in mixed low to high signal intensity on T2-weighted MR images (32).

Figure 10. Left ovarian fibrothecoma in a 65-year-old woman. (a) Axial T2-weighted MR image shows a heterogeneously hypointense ovarian mass, with the most hypointense components (arrowheads) representing fibrous tissue. Ut = uterus. (b) Short-axis T2-weighted MR image shows an endometrial polyp (arrow) and a uterus (Ut) that is hyperstimulated for the patient’s age. (c) Postcontrast T1-weighted MR image demonstrates multifocal endometrial enhancement (arrow) as well as mild enhancement of the fibrothecoma (arrowheads). Ut = uterus.
Cystadenofibroma.—Cystadenofibroma is another example of a usually benign ovarian tumor that contains fibrous stroma in combination with an epithelial cystic component. These tumors are classified according to epithelial cell type into serous, endometrioid, mucinous, clear cell, and mixed subtypes, whereas the relationship between epithelial proliferation and the stromal component of the tumor is used to classify tumors as benign, borderline, or malignant (34). At MR imaging, a cystadenofibroma typically appears as a multiloculated cystic mass, with a solid fibrous component that demonstrates low signal intensity at T2-weighted imaging. The imaging appearance of cystadenofibromas varies depending on whether the cystic or fibrous component predominates (Figs 11, 12). In patients with primarily cystic cystadenofibromas, the solid fibrous component may result in irregular wall thickening (possibly >3 mm) with mild enhancement on postcontrast images. Therefore, recognition of the typical very low-signal-intensity appearance of the solid fibrous component at T2-weighted imaging plays a crucial role in assessing for possible ovarian malignancy (35). Although most ovarian cystadenofibromas are benign, they do have malignant potential and therefore are removed surgically. However, making the correct diagnosis of cystadenofibroma may help avoid unnecessary extensive surgery.

Figures 11, 12. (11) Ovarian cystadenofibroma in a 74-year-old woman. (a) Endovaginal Doppler US image depicts an indeterminate cystic ovarian mass with a thick wall. (b) On an axial T2-weighted MR image, the fibroid solid component in the cystic wall has the typical very low-signal-intensity appearance (arrows). (c) Axial contrast-enhanced subtraction T1-weighted MR image shows mild enhancement of the fibroid solid component (arrows). (12) Ovarian cystadenofibroma in a 65-year-old woman. Coronal T2-weighted MR image shows a left ovarian mass (arrow) that is partially multicystic and partially solid. The solid component has considerable hypointense signal, similar to skeletal muscle (*).
Mixed-Cellularity Tumors

**Brenner Tumor.**—Brenner tumor is an uncommon epithelial-stromal tumor that represents about 2% of ovarian neoplasms and typically contains a fibrous stromal component in association with calcifications and transitional cells that are histologically similar to urothelial epithelium (36). The fibrous components, as well as calcifications (when present), are markedly hypointense on T2-weighted MR images. Brenner tumors are usually discovered incidentally at pathologic analysis, and up to 20% of these tumors are associated with mucinous cystadenomas or other epithelial neoplasms (37). In these cases, the lesion has a complex cystic and solid appearance, with the Brenner tumor (representing the solid part) characteristically demonstrating very low signal intensity at T2-weighted imaging (Fig 13). Although the T2-weighted imaging findings of Brenner tumors overlap with those of fibrothecomas, Brenner tumors typically demonstrate at least moderate enhancement after contrast material administration, whereas fibrothecomas are hypovascular. The presence of calcification and coexisting epithelial neoplasms favors a diagnosis of Brenner tumor over fibrothecoma. In rare cases, benign Brenner tumor shows “borderline” characteristics or even malignant transformation to transitional cell carcinoma (38). According to a few MR imaging studies, borderline Brenner tumors typically manifest as cystic masses with papillary and solid elements (38), whereas malignant Brenner tumors typically manifest as multilocular cystic masses with large solid components. In such borderline or even malignant tumors, a solid component composed of poorly differentiated cells demonstrates iso- to hyperintensity at T2-weighted MR imaging, as opposed to the marked T2 hypointensity of the fibrous stromal component seen in the more typical benign Brenner tumors (39).

**Struma Ovarii.**—Struma ovarii is a rare type of ovarian lesion that accounts for 0.30%–0.65% of ovarian tumors and 2% of ovarian teratomas (40). Struma ovarii is a highly specialized form
Figure 14. Struma ovarii in a 59-year-old woman. (a) Sagittal T2-weighted MR image shows a multiloculated, heterogeneous left ovarian lesion with very low signal intensity (arrow). (b, c) Corresponding axial in-phase (b) and opposed-phase (c) T1-weighted MR images reveal a hypointense mass with chemical shift artifact in its ventral aspect (arrowhead), a finding that is compatible with a small amount of fat. (d) Axial postcontrast T1-weighted MR image shows significant enhancement of the ovarian lesion (arrow) with sparing of its inferior aspect.

of ovarian teratoma and is composed entirely or predominantly of thyroid tissue with large follicles containing colloid material (41). About 5% of patients with struma ovarii develop clinical evidence of hyperthyroidism (42). At US, struma ovarii has a nonspecific solid and cystic appearance. High-attenuation cystic components and calcifications may be recognized at CT. MR imaging demonstrates a loculated cystic mass with variable signal characteristics. Cystic spaces may show marked hypointensity at T2-weighted imaging and intermediate signal intensity at T1-weighted imaging due to the thick, gelatinous colloid of the struma, whereas other locules are T1 hyperintense owing to hemorrhage (43). Some locules may contain microscopic fat, as indicated by signal drop-off and surrounding chemical shift artifact on opposed-phase T1-weighted MR images. Struma ovarii typically demonstrates strong enhancement of the solid components on postcontrast T1-weighted images (Fig 14). At times, it can be difficult to distinguish these lesions from borderline mucinous epithelial ovarian lesions. In mucinous lesions, the T1 and T2 relaxation times are shortened owing to the high protein content and viscosity of the mucinous tumor, with high signal intensity on T1-weighted images and low signal intensity on T2-weighted images (44). In addition, mucinous ovarian neoplasms (Fig 15)
are typically less hypointense than struma ovarii on T2-weighted MR images. Struma ovarii are benign in 95% of cases and usually occur in premenopausal women; therefore, preoperative diagnosis is essential to avoid unnecessary radical surgery (45).

**Krukenberg Tumor.—**Krukenberg tumors are metastatic ovarian adenocarcinomas that most commonly originate from the stomach (70% of cases), followed by the breast, colon, and appendix. Krukenberg tumors account for 1%–2% of all ovarian tumors worldwide and are bilateral in 60%–80% of patients (46). The ovaries are usually not recognized. Krukenberg tumors commonly appear as solid masses with well-demarcated or
(owing to cystic necrosis or hemorrhage) ill-defined intratumoral cysts. They often demonstrate variable hypointensity on T2-weighted images due to the presence of metastatic mucin-filled signet-ring cells in the ovarian stroma and abundant collagen formation (Fig 16) (47). Moderate to marked enhancement of the solid component and pericystic rim is noted, a finding that is unusual in other solid ovarian lesions (48). Krukenberg tumor is a rare but significant malignancy that should be included in the differential diagnosis for T2-hypointense adnexal masses in the appropriate clinical context. For differential purposes, the possibility of Krukenberg tumors may be considered in cases of heterogeneous solid and cystic bilateral ovarian masses that show at least moderate enhancement, as well as T2 hypointensity of the solid component that is relatively mild compared with the signal intensity of skeletal muscle.

**Diagnostic Workup of T2-Hypointense Adnexal Lesions**

Both benign and malignant adnexal masses show variable signal intensity on T2-weighted MR images. However, when a T2-hypointense adnexal mass is visualized, an algorithmic approach to image analysis can help significantly narrow the differential diagnosis (Fig 17).

First, the radiologist should exclude a uterine origin for the lesion by assessing for the bridging vessel sign, splaying of the myometrium, and separate identification of the ovaries on T2-weighted and postcontrast T1-weighted MR images. Exophytic pedunculated leiomyoma and cystic adenomyosis are the most common T2-hypointense uterine lesions that can mimic an ovarian mass.

When a uterine source for an adnexal lesion is ruled out, attention should be paid to the degree of signal loss on T2-weighted MR images. Endometrioma, leiomyoma, fibrous lesions, hematosalpinx, and struma ovarii can all show very low signal intensity on T2-weighted images that is comparable to that of skeletal muscle (7). Applying this criterion results in very high specificity for a benign lesion, allowing appropriate conservative or (if surgical removal is indicated) laparoscopic management. When an adnexal lesion is hypointense on T2-weighted images but has a
signal intensity that is clearly higher than that of skeletal muscle, the specificity for benign disease decreases and there is greater overlap with findings for malignant lesions. Lesions within this group include both benign and malignant entities (e.g., hemorrhagic cyst, malignant transformation of an endometriotic cyst, mucinous epithelial neoplasm, and Krukenberg tumor) (Table 2). Therefore, the degree of signal loss relative to skeletal muscle at T2-weighted imaging provides an additional criterion for characterizing adnexal lesions.

The classic imaging features of the lesion at MR imaging performed with additional sequences as outlined earlier help further characterize T2-hypointense adnexal masses (Table 4). Hemorrhagic adnexal lesions, particularly those with recurrent bleeding, are typically hyperintense on fat-saturated T1-weighted MR images and include endometrioma, cystic adenomyosis, and hematosalpinx. Mucinous epithelial neoplasms may also be T2 hypointense and T1 hyperintense, although to a lesser extent.

Loss of shading on T2-weighted MR images compared with prior images, and visualization of an enhancing mural nodule within an endometriotic cyst on postcontrast T1-weighted images, are highly suggestive of malignant transformation of the endometrioma.

Visualization of a thickened endometrium or an endometrial polyp associated with a significantly T2-hypointense ovarian mass would favor the diagnosis of a fibrothecoma. A Brenner tumor can be diagnosed in the setting of a markedly T2-hypointense ovarian mass that shows moderate vascularity, is associated with an epithelial neoplasm, and contains coarse calcifications (better appreciated at CT). A multiloculated cyst with thick, markedly T2-hypointense walls is sugges-
tive of a cystadenofibroma. A heterogeneous but significantly T2-hypointense ovarian mass with marked enhancement may represent a struma ovarii in certain clinical contexts, whereas a borderline mucinous neoplasm shows only a mild degree of T2 hypointensity. In addition, microscopic fat can be found in struma ovarii, in keeping with signal drop-off on in-phase and out-of-phase T1-weighted images.

This diagnostic algorithm, coupled with appropriate clinical information, should allow an accurate diagnosis to be made in the majority of T2-hypointense adnexal masses.

Conclusions
Identification of T2-hypointense adnexal masses at MR imaging is an important diagnostic criterion that can help narrow the differential diagnosis. In masses with signal intensity comparable to that of skeletal muscle on T2-weighted images, a diagnosis of a benign disease entity can be made with a high degree of confidence. Knowledge of the anatomy, the T1-weighted imaging features and enhancement characteristics of the lesion, and the various physical entities that cause T2 shortening should allow the radiologist to accurately characterize the lesion, resulting in appropriate patient management.

References
The “bridging vessel” sign represents tortuous vascular structures passing between the uterus and the lesion and may be seen at US; however, this sign is most clearly depicted at gadolinium-based contrast material–enhanced T1-weighted imaging or T2-weighted imaging, which nicely demonstrate vascular flow voids (3).

T2-hypointense adnexal lesions that are at least as dark as skeletal muscle help narrow the differential diagnosis and improve specificity.

The term shading refers to signal loss on T2-weighted MR images in an ovarian cyst that appears hyperintense on T1-weighted images (13).

Hemorrhagic cysts show heterogeneous and relatively mild signal loss with no shading on T2-weighted images, whereas endometriomas show marked T2 signal loss.

The solid fibrous component of fibroma, fibrothecoma, and cystadenofibroma characteristically demonstrates very low T2 signal intensity, allowing the differentiation of these benign tumors from malignant solid ovarian lesions.