Pelvis

Pelvic anatomy is ideal for magnetic resonance imaging (MRI) assessment because image quality is usually not degraded by respiration. On T1-weighted images, the pelvic organs are highlighted by surrounding extraperitoneal fat. On T2-weighted images, in particular, the internal architecture of the organs (e.g., the uterus) is depicted as the consequence of the superb tissue contrast provided by MRI. For imaging of the pelvis successful MRI examination requires careful preparation of the patient. However, imaging in general is not as difficult as in the upper abdomen.

Although respiratory motion and bowel motion are minimal when imaging the pelvis, they will degrade image quality if precautions are not taken. To minimize bowel motion, the patient should fast or have clear liquids at least 4 to 6 hours before MRI examination of the pelvis. In addition, intramuscular administration of 1 mg glucagon should be performed immediately before imaging to decrease bowel motion if no medical contraindication is present. Ideally, the bladder should be only moderately distended and the patient should not drink water immediately before the study.

Opacification of the small bowel and the colon is not routinely performed for MRI of the pelvis. Sometimes the bowel may account for errors in interpreting images of the pelvis by mistaking an unopacified bowel loop for a mass, lymph node, or abscess. Thus, in certain circumstances, when ovarian or bowel abnormality is suspected, oral contrast should be given. In Europe, a formulation of gadolinium (Gd)-DTPA for oral administration is approved and used in routine clinical practice. No such approval or specific formulation for oral use exists in the United States. Administration of this oral formulation results in high signal intensity of the bowel lumen. Typically, the patient should drink the Gd-DTPA solution approximately 1 to 2 hours before the examination.

Imaging sequences should include both T1- and T2-weighted multiplanar spin echo images, which are essential for imaging of the pelvis. On T1-weighted images, there is good contrast between pelvic fat and the normal pelvic organs, so infiltration of fat planes and adjacent organs by certain diseases such as cervical carcinoma can be readily identified. T2-weighted images are essential for evaluating internal organ morphology (e.g., the zonal anatomy of the uterus). T2-weighted images should be acquired in at least two imaging planes with either conventional or fast spin echo sequences. Chemical shift imaging with fat- or water-suppression techniques is useful to differentiate between lipid- and blood-containing lesions that have high signal intensity on T1-weighted images and that are isointense to fat on T2-weighted images. This is of importance in, for example, identifying mature teratomas, which typically contain fat, and detecting endometriosis. In endometriosis, the high signal intensity on T1-weighted images caused by subacute hemorrhage cannot be suppressed on T1-weighted fast spin images. To achieve high resolution in imaging of the pelvis, a dedicated phased-array coil should be used, which makes it possible to detect even small tumors and subtle invasion by malignancies (e.g., in bladder cancer).

Intravenous contrast administration, employing a Gd chelate, is useful in imaging the pelvis in some clinical situations. Contrast-enhanced images have been demonstrated to be useful in the evaluation of the internal architecture of pelvic masses, particular in differentiation between clot and debris from solid components (e.g., in endometrial or cervical carcinoma).

In our standard protocol, we perform imaging of the pelvis with 5- to 6-mm-thick sections and a gap of 1.5 mm. First, a sagittal T2-weighted sequence is acquired followed by axial T1- and T2-weighted sequences. If a high-signal-intensity lesion is detected on T1-weighted images, additional fat-suppression or water-suppression sequences, or a combination, are performed covering the detected lesion. Images in the coronal plane are complementary in the evaluation of the uterus and the vagina. They should be used as an adjunct in assessment of uterine morphology, the parametrium, and the levator ani muscle, and they offer the opportunity to identify lymphadenopathy. In special cases (e.g., a leiomyoma of the uterus), off-axis images should also be obtained. In evaluation of the uterus, these are typically images perpendicular to the long axis of the uterine cavity to allow accurate evaluation of intramural versus submucosal localization of a leiomyoma in a planned surgical resection. The same is true for evaluation of the depth of infiltration in endometrial carcinoma.

BLADDER

Most bladder tumors are malignant. Approximately 90% of bladder carcinomas are of transitional cell types; ade-
nocarcinomas make up less than 5% of malignant neoplasms and squamous cell carcinomas less than 10%. Bladder carcinomas may have a papillary, infiltrative, or mixed pattern of growth.

Bladder carcinoma is the fourth most common cancer in men and accounts for 5% and 3% of all cancer deaths in men and women, respectively. Both prognosis and treatment depend on the stage of the tumor. Clinical staging of bladder carcinoma includes cystoscopy and biopsy with supplementary evaluation under anesthesia and intravenous urogram.

Although cross-sectional imaging techniques play an important role in the evaluation of other major viscera of the genitourinary systems, they have been less critical in the assessment of the urinary bladder. MRI examinations in patients with bladder carcinoma are indicated only after clinical, conventional radiographic, and endoscopic studies that have yielded provisional diagnoses. MRI is mainly used to provide multiplanar delineation of complex anatomy and to document the extent of luminal, mural, and perivesical disease. MRI is appropriate for the anatomic staging of previously detected and diagnosed bladder neoplasm, for planning of radiation therapy, and for evaluating therapeutic response.

The normal urinary bladder is clearly delineated on MR images. On T1-weighted images, the bladder is seen as a low-signal-intensity, variably ovoid structure. Its margins are well defined because of the contrast between low-signal-intensity urine and muscular bladder wall, and adjacent high-signal-intensity perivesical fat is marked. On T2-weighted images, the intravesical urine shows a very high signal intensity, whereas the bladder wall shows a rather low signal intensity. The thickness of the bladder wall varies with the degree of bladder distension. When the bladder is fully distended, the wall should not exceed 5 mm in thickness. The signal intensity of the perivesical fat should be relatively homogeneous on both T1- and T2-weighted sequences. The lateral margins of the urinary bladder are best defined in transverse and coronal plane images; the bladder dome and the bladder neck are optimally delineated in sagittal and coronal plane images. T2-weighted images are typically used to evaluate the integrity of the bladder wall. In this context, it is important to realize that visualization of the bladder wall is often affected by chemical shift artifacts in the direction of the frequency-encoding gradient. This artifact can cause one margin of the bladder to appear thinned and obscured, whereas the opposite margin will appear thickened. For example, if the frequency-encoding direction in a particular image is from the patient’s left to right, the chemical shift misregistration is seen as a low-intensity band on the left side of the bladder and a symmetric, high-intensity band on the right side, which leads to the just-mentioned observation.

**Bladder Carcinoma**

On T2-weighted images, transitional cell carcinoma tends to have intermediate to high signal intensity that is typically greater than the normal detrusor muscle (Fig. 12-1). On precontrast T1-weighted images, the bladder wall and tumor have similar low to intermediate signal intensity and cannot be adequately differentiated. On T2-weighted images, the preservation of the low-signal-intensity bladder wall at the center of the tumor suggests that the tumor is stage I or less. In certain cases, Gd enhancement can improve the accuracy of staging of bladder cancer. Applying fat-suppressed T1-weighted sequences postcontrast is, for example, beneficial in detecting perivesical fat invasion. Perivesical tumor extension is less conspicuous on T2-weighted images unless fat saturation is used. Tumor extension into the pelvic side wall musculature is most readily demonstrated on T2-weighted images in which medium- to high-signal-intensity tumor will alter the normal low signal intensity of striated muscle. Lymph node enlargements are most easily detected on T2-weighted images; lymph nodes larger than 10 mm are considered pathologic. These size criteria actually are used alone to determine the presence or absence of lymph node disease. In general, MRI is capable of distinguishing superficial from deeply invasive lesions. However, MRI cannot reliably document microscopic invasion of superficial bladder cancer. If segmental cystectomy is planned to provide control of pelvic disease while maintaining continence, contraindications such as extravesical tumor growth, invasion of the bladder neck, and invasion of the ureter can be depicted on MRI. Multiphasic MR images allow a better anatomic evaluation compared with computed tomography (CT), particularly when tumors involve the bladder dome, base, or bladder neck. In other locations, MRI is approximately equal to staging by conventional CT.

Other bladder diseases that can be evaluated by MRI include bladder diverticula, urachal anomalies that include cysts, diverticula, sinuses, and persistent patency as well as inflammatory disease of the urinary bladder.

Mesenchymal neoplasms of the urinary bladder are sarcomas that arise from the bladder wall, which have to be considered in particular with masses detected in children (Fig. 12-2). In general, sarcomas arising from the urinary bladder are indistinguishable from transitional cell carcinoma. However, these tumors are more often bulky and extensive at diagnosis.

In summary, MRI is considered as an adjuvant method of evaluating bladder disease and frequently is used to evaluate the extent of diseases previously detected and diagnosed by endoscopic methods or conventional radiographic studies. The major strength of MRI in evaluating the complex anatomic relationships of the pelvic viscera lies in its multiplanar capability and its high soft tissue contrast resolution.

**FEMALE PELVIS**

Primary gynecologic examination and evaluation of pelvic complaints are traditionally based on clinical symptoms, inspection, palpation, biopsy, and clinical as well as laboratory parameters. Ultrasonography still is the primary imaging modality for the evaluation of the female pelvis, representing the most important routine screening method in obstetric and gynecologic disorders. However, sonography is not suitable for one of the largest potential clinical applications: the staging of gynecologic tumors. In recent years, MRI has added a
FIGURE 12–1. Bladder carcinoma in a 74-year-old woman with dysuria and hematuria. A, On the T2-weighted sagittal image thickening of the posterior bladder wall by an intermediate signal-intensity mass is demonstrated. The normal low signal intensity of the detrusor muscle in this area (arrow) is not preserved, indicating muscle invasion. On axial T1-(B) and T2-weighted (C) images, bladder wall thickening of the right lateral aspect without infiltration of the tumor into the surrounding pelvic fat is seen. D, After contrast administration, strong enhancement of this area on the T1-weighted fat-suppressed image is visible. However, as a result of contrast in the bladder, diagnostic information is reduced.
new dimension to the evaluation of pelvic disorders, including the diagnosis, staging, preoperative planning, and follow-up of almost all gynecologic entities.

Multiple studies have shown the high accuracy of MRI for imaging of gynecologic abnormalities, thus becoming the imaging procedure of choice if available, complementing or even replacing sonography and CT. In particular, when sonography can only inadequately characterize pelvic abnormalities or if exact pretherapeutic staging is necessary, MRI has been shown to have high accuracy and diagnostic reliability. MRI is routinely used for staging of endometrial and cervical cancer and for follow-up examinations of both entities during and after therapy. MRI is also used to evaluate the origin and extension of adnexal masses if ultrasonography does not provide sufficient diagnostic information. MRI is also used in examinations of children and pregnant patients and for the detection and classification of congenital malformations. The advantages of multiplanar imaging are especially evident in demarcation and differentiation of gynecologic disorders relative to other pelvic benign and malignant diseases (e.g., vesical and colorectal tumors).

Uterus

The normal uterus on a T1-weighted image is seen as a homogeneous, medium-signal-intensity structure, with relatively indistinct uterine zonal anatomy. On the T2-weighted image, the anatomic uterine division into corpus, isthmus, and cervix is readily delineated. On T2-weighted sequences, the components of the corpus, myometrium, and endometrium are imaged with different signal intensities separated by the junctional zone, a low-signal-intensity line between them. The junctional zone is thought to represent vascular structures, mainly veins located within the inner third of the myometrium as well as compressed myometrium. The low-intensity line is seen on in vivo imaging of the normal menstruating uterus but is not seen or is indistinct on in vitro imaging as well as in histologic studies.

The uterine appearance on MRI varies with hormonal
Reproductive-age females have reproducible changes in uterine appearance during their menstrual cycles. The endometrial width changes during the menstrual cycle and is seen at its largest dimension during the midsecretory phase. The volume and signal intensity of the myometrium also varies. During the secretory phase, the myometrium signal intensity is greatest, as seen on T2-weighted scans. During the secretory phase, the total uterine volume changes to the greatest extent. Females of reproductive age taking oral contraceptives have a different uterine appearance. The separation between the myometrium and endometrium becomes indistinct, and endometrial atrophy is observed with inconsistent demonstration of the junctional zone.

MRIs of a premenarchal or postmenarchal uterus differ from the appearance of a reproductive-age uterus. The former uteri are small, and there is absent or atrophic cyclic endometrium. The length of the corpus uteri equals that of the cervix. The uterus of postmenopausal women on exogenous estrogens or with an estrogen-producing ovarian malignancy appears similar to the uterus of reproductive-age women.

**Congenital Anomalies of the Uterus**

With an incidence of 0.1% to 0.5%, clinically significant congenital uterine abnormalities are unusual. The two major categories of congenital abnormalities are atresia or aplasia of the uterus and vagina and anomalies in development of the müllerian ducts.

Before the introduction of MRI, laparoscopy and hysteroscopy were often necessary for diagnostic evaluation because assessment with physical examination and imaging studies, including sonography, was often inconclusive. MRI has been shown to be an accurate, noninvasive method for the evaluation of congenital anomalies of the uterus and vagina.

Müllerian duct anomalies result from nondevelopment or partial or complete nonfusion of the müllerian ducts (Fig. 12-3). They are found in up to 15% of
women. They are clinically associated with an increased incidence of impaired fertility and menstrual disorders. Mullerian duct anomalies may be associated with renal anomalies such as ipsilateral renal agenesis or ectopia. One of the most widely accepted morphologic classifications of mullerian duct anomalies was proposed by Buttram and Gibbons in 1979 and was modified by the American Society for Reproductive Medicine. The anomalies are classified by the number and configuration of the uterine elements (Fig. 12-4).

Uterine segmental agenesis or hypoplasia (class I) results from nondevelopment or partial development of the müllerian ducts. It may include varying degrees of uterine body, cervical, vaginal, and tubal hypoplasia. In the case of functioning endometrium, hematocolpos or endometriosis may be the cause of clinical symptoms. Unicorntate uterus (class II) results from hypoplasia or agenesis of one of the paired müllerian ducts. Uterus didelphys (class III) results from lack of fusion of the müllerian ducts, with the development of two normalized uteri and cervixes and sometimes an upper vaginal septum. Bicornuate uterus (class IV) results from partial failure of müllerian duct fusion, in which the resulting septum is composed of myometrium. The patients may present with repeated spontaneous abortions, premature rupture of the membranes, and malpresentations. Septate uterus (class V) results from failure of resorption of the fibrous septum between the components of the müllerian ducts and has the highest rate of associated reproductive dysfunction.

Uterine Tumors
Leiomyoma is the most common solid uterine neoplasm, occurring in 20% to 40% of all females of reproductive age (Fig. 12-5). These tumors are benign and are composed predominantly of smooth muscle with varying amounts of fibrous connective tissue. They are usually well circumscribed and surrounded by a pseudocapsule. Myomas may be solitary (Fig. 12-6) or multiple (Fig. 12-7) and may occur in submucosal (Fig. 12-8), intramural, and subserosal locations of the myometrium. Although most myomas involve the body or fundus of the uterus, some occur in the cervix or even the broad ligament. The clinical presentation of uterine leiomyomas varies depending on the size, number, and location of lesions. Most patients have few or no symptoms, and the myoma is detected incidentally on physical examination as an enlargement of the uterus or on imaging examination. Patients with symptoms typically present with hypermenorrhea or other forms of dysfunctional uterine bleeding. Other symptoms include pelvic pain, infertility, recurrent spontaneous abortions, preterm labor, and in utero growth retardation. If large enough, a leiomyoma can produce symptoms as a result of compression of the adjacent organs, such as the urinary bladder, rectum, or distal ureters. Because these tumors are estrogen dependent, they may grow rapidly during pregnancy and usually regress after menopause. During menopause they may be calcified. Sudden growth of a leiomyoma in postmenopausal women not on exogenous estrogens indicates malignant transformation into a leiomyosarcoma.

There is a variable MRI appearance of leiomyoma within the uterus that depends on the presence or absence of hyaline, mucinous, myxomatous (Fig. 12-9), cystic, and fatty degeneration and on calcification. MRI can provide accurate assessment of the number, size, and precise location of leiomyomas, particularly in patients with planned surgical excision.

The optimal imaging technique for the diagnosis of intramural and submucosal leiomyomas is a T2-weighted sequence in which nondegenerative leiomyomas are displayed with a low signal intensity (see Fig. 12-8). On T1-weighted images, leiomyomas have intermediate signal intensity; thus, they are often indistinguishable from surrounding myometrium. However, it is important to obtain both T1- and T2-weighted sequences for tissue characterization of a myoma or other abnormality within the uterus. Chemical shift imaging may be useful to evaluate fatty degeneration or hemorrhage within large leiomyoma.

Adenomyosis is another benign entity within the uterus, defined as the presence of heterotopic endometrium located within the myometrium. Adenomyosis is most likely the result of direct invasion of the basal endometrium into the myometrium and may be microscopic, focal, or diffuse. These foci are surrounded by smooth muscle proliferation. Adenomyosis is found in up to 20% of hysterectomy specimens. Most symptomatic women present in the fourth or fifth decades of life, and the incidence is increased in multiparous women. Clinical presentation is similar to that of leiomyomas: hypermenorrhea, dysmenorrhea, pelvic pain, and infertility. The clinical distinction between adenomyosis and leiomyoma can be difficult because both may demonstrate increased size of the uterus on physical examination. This can be even more complicated by the occasional coexistence of adenomyosis and leiomyomas. Leiomyomas can be treated by selective myomectomy, whereas symptomatic adenomyosis often requires hysterectomy for definitive therapy. Medical treatment, including hormonal therapy with gonadotropin-releasing hormone (GnRH) analogues, is evolving for both conditions.

On T1-weighted images, diffuse adenomyosis is seen as a wide low-signal-intensity band with an uneven distribution that surrounds the normal high-signal-intensity endometrium, producing a diffuse thickening of the junctional zone (Fig. 12-10). In the case of focal adenomyosis, an ill-defined, poorly margined mass can be observed within the myometrium with low signal intensity on T2-weighted images. In most cases, the mass is contiguous with the junctional zone, and, in contrast to the usually rounded shape of leiomyoma, focal adenomyosis shows a more oval shape. On T1-weighted images, focal adenomyosis blends with the surrounding myometrium. The hallmark of adenomyosis is the ill-defined border of the lesion because, in contrast to leiomyoma, which presents with a pseudocapsule of compressed myometrium, adenomyosis typically shows a more infiltrative-appearing growth pattern. Small foci of adenomyosis may simulate a leiomyoma because the pseudocapsule and the well-defined borders of leiomyoma may not be

Text continued on page 363
FIGURE 12–4. Congenital abnormalities of the female genitourinary tract. Uterine malformations are often associated with renal abnormalities (particularly renal agenesis) and vice versa (see Gartner's duct cyst).

FIGURE 12-6. Large leiomyoma of the uterus with partial cystic degeneration in a 37-year-old nulliparous woman. A large pelvic mass was detected ultrasonographically. On T2-weighted sagittal (A) and axial (B) images, a large, mainly hypointense mass with small cystic areas is demonstrated consistent with a large leiomyoma with cystic degeneration. C, However, on the T1-weighted unenhanced image, the tumor is almost isointense to normal uterine parenchyma, and internal morphology is not evaluable.

FIGURE 12-7. Uterus myomatosus in a 40-year-old woman. A, Sagittal T2-weighted imaging shows a significantly enlarged uterus with multiple myometrial leiomyomas. Some of the larger tumors have central areas of high signal consistent with cystic degeneration, which is better visible on T1-weighted axial imaging (B).
Submucosal leiomyoma in a 34-year-old woman with recurrent habitual abortions. A, A sagittal T2-weighted image shows a large low-signal-intensity (SI) mass protruding into the cavum uteri with depiction of high SI endometrium just at the surface of the tumor. B, This submucosal localization is also confirmed on axial T2-weighted imaging. Note as well the right-sided ovarian cysts. C, The lesion has a slightly lower SI on T1-weighted imaging compared with surrounding myometrium and is hypointense on the T1-weighted fatsaturated image after contrast administration (D).
FIGURE 12–9. Leiomyoma with hyaline and myxomatous degeneration in a 42-year-old woman. A, On an axial T2-weighted image, a left-sided mass arising from the myometrium of the uterine fundus is demonstrated. The lesion shows central high signal intensity (SI) surrounded by a low SI stroma. B, On T1-weighted unenhanced sagittal imaging, the central areas of the tumor also display high SI consistent with tissue that shows a high protein content.

FIGURE 12–10. Adenomyosis in a 38-year-old woman with menorrhagia. A, The T2-weighted sagittal image shows a diffuse, irregular thickening of the junctional zone. B, Ill-defined borders are also displayed in the axial image. Note some small hyperintense cystic areas within the low-signal-intensity lesion.
so obvious in small lesions. Sometimes small areas of high signal intensity on T1- and T2-weighted images may be observed in adenomyosis that correspond to small foci of hemorrhage. If these small foci are only observed on T2-weighted images, they are thought to represent endometrial tissue.

Endometrial carcinoma is the most common invasive carcinoma of the female genital tract, usually occurring in postmenopausal women. The development of endometrial carcinoma is promoted by unopposed estrogen stimulation. Histologically, 80% are endometrioid adenocarcinomas. Other histologic types include papillary serous, mucinous, and clear cell adenocarcinomas. Sarcomas and carcinosarcomas (malignant mixed müllerian tumors) also occur but are rare. Endometrial carcinoma tends to grow within the endometrial cavity as either a localized polypoid or exophytic mass or as a diffuse tumor involving the entire endometrial surface. Invasion through the myometrium or into the endocervical canal or cervical stroma may occur. Metastases to the adnexa or vagina are common. Lymphatic invasion produces a localized polypoid or exophytic mass or as a diffuse tumor involving the entire endometrial surface. Invasion through the myometrium or into the endocervical canal or cervical stroma may occur. Metastases to the adnexa or vagina are common. Lymphatic invasion produces spread to the pelvic, periaortic, and aortocaval lymph nodes. Positive peritoneal cytologic results are far more common than gross peritoneal spread. Distant metastases occur most often in the peritoneum, lung, liver, and supraclavicular lymph nodes. Sometimes there is coexisting ovarian carcinoma.

Most patients present in the early stages of the disease with postmenopausal bleeding. Prognosis of endometrial carcinoma and the choice of therapy are mainly influenced by the clinical stage of the tumor, the depth of the myometrial invasion, histologic grade of the tumor, and presence of lymph node metastases at diagnosis. Patients with deep myometrial invasion (>50% of myometrial thickness) are at high risk for lymph node metastasis. In these patients, more extensive para-aortic lymph node sampling should be planned for during surgery.

On MRI, endometrial carcinoma is seen as an abnormality within the central endometrial cavity. On T2-weighted MRI images, the signal intensity of small endometrial cancers is similar to that of normal endometrium (Fig. 12-11). Indirect signs that can be observed in the presence of endometrial cancer include increased thickening or lobulation of the endometrial cavity. The postmenopausal uterus usually shows a central canal of high signal intensity approximately 3 to 5 mm wide on T2-weighted images. With endometrial carcinoma, the central high-signal-intensity endometrium is routinely wider (Fig. 12-12). Another important finding is disruption of the junctional zone between the myometrium and endometrium, which can be an important indicator of myometrial invasion (Fig. 12-13). In patients with endometrial carcinoma, visualization of the junctional zone indicates that the tumor is still confined to the endometrium. However, nonvisualization of the junctional zone does not necessarily indicate invasion, because occasionally the junctional zone is absent in normal postmenopausal women.

There is a variable appearance of endometrial carcinoma on MRI. There may be increased size of the high-signal-intensity endometrial cavity without evidence of medium-intensity masses within the cavity on T2-weighted sequences. Often larger tumors are displayed as a heterogeneous high-signal-intensity mass on T2-weighted images with overall lower signal intensity compared with normal endometrium. In other patients, there may be high signal intensity or medium signal intensity on a T1-weighted sequence, but on the T2-weighted sequence the tumor may blend with the surrounding high-signal-intensity endometrium. However, similar changes may be observed in submucosal degenerating leiomyoma, adenomatous hyperplasia, or endometrial polyps, so histologic diagnosis remains essential. The use of Gd chelates on contrast-enhanced T1-weighted images may be beneficial to differentiate tumor from necrosis or fluid (e.g., hematometra or pyometra), which leads to an overall improvement in staging accuracy.

Malignant mesenchymal tumors of the uterus account for less than 5% of malignancies. The three most common histologic types are malignant mixed müllerian tumor, leiomyosarcoma, and endometrial stromal sarcoma. Malignant müllerian mixed sarcoma is believed to be derived from pluripotential müllerian tissue and exhibits differentiation toward endometrial (adenocarcinoma) and mesodermal (sarcomatous) cells. Malignant müllerian mixed sarcomas of the uterus arise similar to endometrial carcinoma, typically in postmenopausal women, and are frequently associated with a history of irradiation. Lymphatic and myometrial invasion occur in more than 80%. On MRI the tumor is typically seen as a large polyoid mass arising from the endometrial cavity.

Leiomyosarcomas arise from the myometrium and usually occur in perimenopausal women between 40 and 60 years old. Rapid enlargement of a leiomyoma or the uterus, especially in postmenopausal women, should raise concern. On MRI a heterogeneous myometrial mass with indistinct borders may be observed. Differential diagnosis mainly includes degenerative leiomyoma.

**Cervix**

The normal cervix is best delineated on T2-weighted sequences and has at least two separate zones. The central zone is imaged with high signal intensity and presumably represents the cervical epithelium and mucous. The central canal is surrounded by a discrete region of low signal intensity, presumably representing the fibrous cervical stroma. Occasionally, a third narrow band of medium signal intensity is seen peripheral to the low-signal-intensity band and is very similar to the intensity of the myometrium of the uterus. The parametrium is seen as low or medium intensity, flanking the cervix on T1-weighted images, and is separate from the low-intensity cervical stroma on both T1- and T2-weighted sequences. On T2-weighted sequences, there is a relative increase in signal intensity of the parametrium, often blending with surrounding fat.

Benign cervical masses occasionally seen on MRI include the common small nabothian cysts. Rare lesions involving the cervix include leiomyomas, endometriomas, cervical mucoceles, Gartner’s duct cysts, cervical pregnancy, and cervical stenosis, which may present as masses and have a variable appearance on MRI de-
FIGURE 12–11. Endometrial carcinoma (stage IIB) in a 68-year-old woman with recurrent vaginal bleeding. A and B, On T2-weighted axial and sagittal images, a significant increase in the thickness of the endometrium can be demonstrated, which cannot be visualized on the T1-weighted unenhanced image (C). The tumor invades the cervix, prolapsing into the upper vagina (arrow). After contrast administration, the tumor is depicted as an area of lower signal intensity compared with the myometrium (D), and no fluid retention within the uterine fundus is visible.
FIGURE 12–12. Endometrioid carcinoma of the ovary associated with endometrial carcinoma in a 72-year-old woman. A, The sagittal T2-weighted image shows thickening of the endometrium consistent with stage IIA endometrial cancer with infiltration of the cervix. A large mass with inhomogeneous high signal is also noted dorsal to the uterus (arrow) originating from the ovary. B, On T1-weighted contrast-enhanced imaging, the solid mass dorsal to the uterus has inhomogeneous contrast uptake, whereas the endometrial carcinoma is hypointense compared with the myometrium, with an infiltration depth less than 50% of the myometrial thickness.

Cervical carcinoma is the third most common gynecologic malignancy and the most common malignancy in women younger than 50 years. It is second to ovarian carcinoma in mortality. Invasive cervical cancer is thought to develop over time from a noninvasive precursor lesion to a cervical intraepithelial neoplasia. Seventy-five to 85% of cervical carcinomas histologically are squamous-epithelial carcinoma; the remainder are adenocarcinoma (10%-15%) or adenosquamous carcinomas (2%-5%). Cervical carcinoma commonly arises at the squamocolumnar junction, which marks the junction between the endo- and ectocervix. Patients usually present with vaginal bleeding or discharge; however, this clinical presentation often already represents advanced disease. Cervical carcinoma spreads by invading through the cervical stroma and into the upper vagina, parametria, or myometrium. Extension into the lymphatic channels of the parametria produces nodal spread along the obturator, iliac, and para-aortic nodal chains. Direct invasion of adjacent structures, including the bladder (Fig. 12-14), ureters, sigmoid colon, and pelvic side wall, may be present. Prognosis and initial choice of therapy depend on the size and stage of tumor at presentation, its histologic grade, depth of stromal invasion, adjacent tissue extension, and presence of lymph node metastases.

Because of increased soft tissue contrast, MRI surpassed CT in the evaluation of cervical carcinomas and has been shown to be an excellent modality for staging cervical cancer. T1-weighted sequences demonstrate the neoplasm as an abnormal area of high signal intensity, distinct from the normal lower-signal-intensity cervical stroma (see Fig. 12-14). MRI may be used for assessing tumor volume and extent within the cervical stroma, into the parametrium, and into the vagina. On T1-weighted images, the tumor within the cervical stroma may not be differentiated from the stroma, but tumor extension into the parametrium may be better appreciated because of the tumor’s slightly higher signal intensity than the parametrium. On T2-weighted sequences,
Cervical carcinoma with infiltration of the bladder wall in a 41-year-old woman. The cervical carcinoma was staged before surgery. 

**A.** A sagittal T₂-weighted image shows an inhomogeneous hyperintense tumor of the cervix, which infiltrates the upper third of the vagina. The low signal intensity of the bladder wall is interrupted at the area of the tumor (arrow).

**B.** On a sagittal T₁-weighted image, no fat plane between the bladder and cervix is visible. 

**C and D.** After contrast administration, the tumor has irregular enhancement, and solid enhancing areas protruding into the bladder can be demonstrated.
FIGURE 12-15. Cervical carcinoma. A, In this patient, the sagittal T2-weighted image shows a localized cervical cancer in the posterior labium of the cervix (arrow) with early infiltration of the posterior fornix. B, In another patient, the T2-weighted sagittal image shows infiltration of the upper third of the vagina (arrow) along the ventral wall.

however, the parametrium often increases in signal intensity to the same extent as that of tumor. Extension into the lower uterine isthmus or the vagina is optimally seen on both sagittal and coronal imaging planes (Fig. 12-15); the transverse images are used to complement the findings from the other two planes. For assessing primary cervical tumor, sagittal and transverse planes of imaging are optimal; for parametrial extension, an additional oblique transverse plane angled perpendicular to the long axis of the cervix may be helpful.

Vagina

T1-weighted sequences delineate the vagina from surrounding structures equally as well as T2-weighted sequences. However, in most cases, T1-weighted sequences are essential and the optimal imaging plane is transverse. On T2-weighted sequences, the high-signal-intensity center represents the vaginal epithelium and mucosa, and the lower signal intensity surrounding the high-signal-intensity center represents the vaginal wall.

The most common benign masses of the vagina, often found incidentally on MRI, are Bartholin’s cysts. They are caused by retained secretions within the vulvovaginal glands and are typically located in the posterolateral aspect of the lower third of the vagina. In most cases they are asymptomatic. Depending on its fluid content, the cyst is usually of medium or high signal intensity on T1-weighted images and high signal intensity on T2-weighted sequences.

Primary malignant neoplasms of the vagina are rare, accounting for less than 2% of gynecologic cancers. They usually are squamous cell carcinomas (90%) or adenocarcinomas, and patients present with bleeding, discharge, or pain and fistula formation. Primary tumors in most cases cannot be differentiated from metastatic lesions on MRI, nor can inflammatory disease be separated from a neoplasm.

On T1-weighted sequences, primary vaginal neoplasms are imaged with medium signal intensity like the normal vagina, and their presence can be appreciated only when they are large enough to alter the vaginal contour (Fig. 12-16). On T2-weighted scans, a medium-to high-signal-intensity mass can be appreciated and its location and extent accurately assessed. The main role of MRI in evaluating malignant tumors of the vagina is not in making the primary diagnosis but rather in staging vaginal tumors and evaluating the extent of the tumor in adjacent tissue.

Ovary

Normal Anatomy

Currently, sonography is the method of choice for evaluating ovarian masses. MRI serves as a problem-solving technique after the sonographic study of adnexal abnormalities. Most ovarian masses are benign cysts, such as physiologic follicular cysts, corpus luteum cysts, serous cystadenomas, mucinous cystadenomas, and dermoids.

The normal ovaries are seen as low- or medium-signal-intensity structures on T1-weighted sequences. Occasionally, the ovaries may blend with surrounding bowel loops. On T2-weighted sequences, the signal intensity of the ovaries increases and has components of signal intensity equal to or greater than those of fat, depending on the field strength of the magnet used. The transverse and coronal imaging planes are ideal for evaluating the ovaries, and normal ovaries are demonstrated on MRI in up to 96%.

Ovarian Tumors

Figure 12-17 gives a brief overview about adnexal masses in MRI. Figure 12-18 summarizes differential diagnosis of nongynecologic masses in the female pelvis.
**Figure 12–16.** Vaginal carcinoma in a 72-year-old woman. Magnetic resonance imaging was performed for staging purpose. A, and B, T2-weighted axial images show an ill-defined, infiltrating hyperintense mass arising from the vagina that infiltrates the pelvic side wall (arrow) as well as parts of the levator muscle. C and D, On T1-weighted unenhanced images, no fat planes between the tumor and the pelvic side wall and muscular structures can be visualized, indicating infiltrative growth.

**Figure 12–17.** Magnetic resonance imaging classification of adnexal masses.
Cystic Benign Ovarian Lesions

Benign macroscopic cysts of the ovary include follicular cysts, corpus luteum cysts, theca lutein cysts, and simple cysts. Follicular and corpus luteum cysts are usually solitary and may contain hemorrhage. Both resolve without treatment. Theca lutein cysts result from high levels of human chorionic gonadotropin (hCG) or an increased sensitivity of theca cells to hCG. They typically are bilateral and multiple and, in the case of high levels of hCG, resolve when the cause of hyperstimulation is removed.

Simple ovarian cysts are thin walled with a smooth lining, contain serous fluid, and may reach 10 cm in diameter. Most adnexal cysts are asymptomatic. Occasionally, however, they may cause pelvic pain, pressure, or discomfort. Cysts may bleed, undergo torsion, or rupture, causing hemoperitoneum. On MRI, simple ovarian cysts are well-circumscribed homogeneous masses with a smooth interface (Fig. 12-19). If peripherally located, the cyst has a smooth and almost imperceptible wall. On T₁-weighted sequences, they are of low signal intensity, often similar to that of urine or slightly greater than urine. On a T₂-weighted sequence, the cyst has high signal intensity, in most cases higher than that of fat.

Ovarian hemorrhagic cysts are also well-circumscribed homogeneous structures with smooth walls of various thickness. The wall is seen as a low-signal-intensity line surrounding the ovarian lesion and corresponds to ovarian tissue or a pseudocapsule. Hemorrhagic cysts have high signal intensity on both T₁- and T₂-weighted sequences as a result of blood degradation products.

Polycystic ovarian disease results from a poorly understood derangement of reproductive endocrine function. It is characterized by the clinical triad of secondary menstrual abnormality (oligomenorrhea or amenorrhea), hirsutism, and obesity. Follicle-stimulating hormone (FSH) is produced by the pituitary gland and stimulates ovarian follicles, but there is no midcycle surge of luteinizing hormone (LH), and ovulation and menstruation do not occur. The ovaries in these patients are generally enlarged and contain numerous immature follicles around the periphery of the ovary. The unruptured follicles are typically 5 to 15 mm in diameter and may vary in size. The characteristic MRI appearance of polycystic ovarian disease consists of multiple small peripheral cysts adjacent to abundant low-signal-intensity central stroma.

Cystadenomas are benign neoplasms arising from the surface epithelium of the ovary. They may occur at any age, but most are found in women 20 to 44 years old. Serous cystadenomas constitute about 22% of benign ovarian neoplasms and are often between 5 and 10 cm in size. They are usually smooth, unilocular or multilocular cysts filled with serous fluid. Occasionally, papillary projections may be obvious. The signal intensity of the cyst fluid in MRI varies with the cyst contents. In the presence of mucin or hemorrhage, cysts may demonstrate increased signal intensity on T₁- and T₂-weighted images, and layering and fluid-fluid levels may be noted.

Mucinous cystadenoma accounts for about 15% to 20% of benign ovarian tumors. They are also smooth, but more frequently they present as multilocular cysts ranging in size, with a tendency to be larger than serous cystadenomas. The majority measure 15 to 30 cm in diameter at diagnosis. If rupture occurs, the tumor cells may implant on the peritoneum and result in pseudomyxoma peritonei. This is more commonly associated with malignant or borderline tumors. The MRI appearance of mucinous cystadenoma may be identical to that
of serous cystadenoma. The presence of thick septa and the more multicocular appearance may be used as differentiating features.

Solid Benign Ovarian Lesions

Ovarian fibromas account for about 5% of ovarian tumors. They are part of the sex cord-stromal tumors that include granulosa-theca tumors, Sertoli-Leydig tumors, lipid cell tumors, and gynandroblastomas. About 80% of these tumors produce hormones, although fibromas do not. Fibromas usually arise in postmenopausal women and are mostly asymptomatic until they cause pelvic pressure or produce torsion. Ascites is seen in 40% to 50% of patients with fibromas larger than 5 cm in diameter. Meigs’ syndrome represents the rare triad of fibroma, ascites, and pleural effusion.

On MRI fibromas are usually well-defined solid tumors that demonstrate low signal intensity on both T1- and T2-weighted images. Because of hyalinization and myxomatous changes, irregular areas of high signal intensity on T2-weighted images may occasionally be noted.

Pelvic Inflammatory Disease

Pelvic inflammatory disease is an ascending infection of the uterus, fallopian tubes, and broad ligaments. Pelvic inflammatory disease may be either acute or chronic, and tubo-ovarian abscess is a potential complication. Patients present with a history of abdominal pain and tenderness. In the case of a tubo-ovarian abscess, MRI will demonstrate an adnexal mass that is ill defined and inhomogeneous and that usually contains fluid because of abscess formation. Increased vascularity within the pelvis associated with the inflammatory response may be noted. After administration of Gd chelates, the abscess wall and surrounding inflammatory tissue typically enhance on T1-weighted images, whereas the central abscess cavity remains of low signal intensity.

Endometriosis

Endometriosis is a condition of unknown pathogenesis in which endometrial glands and stroma are found in an ectopic site outside the uterine cavity and musculature. This condition occurs usually in premenopausal women; the postmenopausal population comprises only 2% to 4% of cases. It is found in up to 15% of women undergoing laparoscopy and affects as many as 30% to 40% of infertile women. The most common sites of involvement for implants of heterotopic endometrial tissue are, in decreasing order of frequency, the ovary, the uterine ligaments, the cul-de-sac, and the pelvic peritoneal surfaces.

Endometriomas are internal hemorrhages within an area of endometriosis resulting in endometrial cysts. As mentioned, they most commonly involve the ovary and are bilateral in one third of cases. They may partially or completely replace the normal ovarian tissue. The cyst wall usually contains endometrial glands and stroma and is often surrounded by a dense fibrous capsule with adhesions to adjacent structures. The cysts most often contain chocolate-colored material but may also contain subacute hemorrhage with clot and watery fluid. The two most common clinical presentations are pelvic pain and infertility. Less common manifestations include pleurisy, cyclic hemoptysis, and headaches.

Endometriosis has many different appearances on MRI. The most common is similar to that of a hemorrhagic ovarian cyst (Fig. 12-20). Lesions are often heterogeneous and composed of a variety of tissues, including a hemorrhagic fluid component, hemorrhagic solid components, and fibrotic tissue. Whereas MRI has been shown to be helpful in detecting implants in the vaginal fornix, rectovaginal ligaments, urinary bladder, and presacral region, including the cul-de-sac, mesenteric endometrial implants are, in most cases, not readily demonstrable. Although the MRI appearance is variable, several findings suggestive of endometrioma have been reported, including a distinct low-signal-intensity zone on both T1- and T2-weighted images surrounding a cyst containing hemorrhage and prominent low-signal-intensity shading in a cyst on T1-weighted images (Fig. 12-21).

Teratoma

Three types of teratomas exist: mature benign teratomas, immature malignant teratomas, and monodermal or highly specialized teratomas, which include struma ovarii and carcinoid. The majority of teratomas consist of the cystic and mature forms, which are also referred to as dermoid cysts. They comprise approximately 90% of teratomas and 10% to 25% of all ovarian neoplasms. Teratomas most commonly occur during the reproductive years, although they may be seen at any age from infancy to senescence. Characteristically, dermoid cysts (Fig. 12-22) are unilocular cysts that contain ectodermal, mesodermal, and endodermal structures and often a solid protuberance, the so-called Rokitansky or dermoid plug. The plug often contains fat, hair, bone, or even well-formed teeth. Complications of cystic teratomas include torsion, rupture, infection, or even malignant transformation (in 2%). On MRI the key to diagnosis of a dermoid cyst is the identification of fat within an adnexal mass. Chemical shift imaging, applying T1-weighted fat-suppressed images, is the most definitive way to differentiate fat within a dermoid cyst from hemorrhagic adnexal lesions, which may also show high signal intensity on T1-weighted images. Other patterns that may be observed include fluid-fluid levels, floating debris, and mural nodules with areas of signal void representing bone or teeth formation within a mature teratoma. MRI is less sensitive than CT in detecting these calcifications.

In contrast to the much more common mature cystic teratoma, immature malignant teratomas are composed of immature or embryonal tissue derived from the three germ cell layers. These tumors are rather rare and comprise less than 1% of ovarian teratomas. They occur most commonly in the first two decades of life. At presentation, they are usually large and bulky and tend to form adhesions to surrounding structures or invade locally (Fig. 12-23). Typically, they grow rapidly, and fat

Text continued on page 375
FIGURE 12–20. Endometriosis of the ovary in a 33-year-old woman. A, On T2-weighted axial imaging, a septated, partially hypointense mass can be seen in the left ovary (arrow); however, the typical shading of blood degradation products is not visible. B, The corresponding T1-weighted image shows high signal intensity (SI) of these areas, indicating hemorrhage. C, The T1-weighted fat saturated image after contrast administration does not show suppression of the high SI hemorrhagic areas as it does for fat.
FIGURE 12-21. Endometriosis of the ovary in a 29-year-old woman. A tumor of the right ovary was found on routine sonography. A, On the T2-weighted axial image, a round lesion of the right ovary (arrow) with inhomogeneous signal intensity is demonstrated, displaying a shading of the signal from the more anterior to the more posterior parts. On T1- (B) and fat saturated T1-weighted (C) images, the lesion has a high signal consistent with hemorrhage.
Figure 12–22. Dermoid cyst (cystic mature teratoma) of the ovary in a 16-year-old girl with sudden increase of abdominal girth and discomfort of the lower abdomen. A, On sagittal T2-weighted imaging, a huge septated lesion with large areas of high signal intensity (SI) is demonstrated. The cranial part of the lesion shows a more solid component. Some small areas of low signal represent Rokitansky's protuberance (arrow). T1-weighted axial (B) and sagittal (C) imaging show partial high SI areas within the lesion consistent with fat; the more caudal parts consist mainly of simple fluid. D, After contrast administration (T1-weighted fat suppressed contrast enhanced), the cranial, more solid component shows some contrast uptake, whereas the signal from fat is clearly suppressed. Again, small areas of low SI can be noted in this solid area, which represented teeth formation.
FIGURE 12-23. Malignant, immature teratoma of the ovary in a 9-year-old girl. The patient presented with a large palpable pelvic mass causing protrusion of the abdomen. A large inhomogeneous partially cystic mass can be seen on coronal (A) and axial (B and C) T2-weighted images. D, On T1-weighted unenhanced imaging, the lesion again shows an inhomogeneous signal intensity with areas of hemorrhage and fluid within cysts that show a high protein content. E and F, The main part of the lesion is solid and has inhomogeneous contrast uptake on T1-weighted fat saturated images. In the caudally located part, a papillary solid vegetation of the wall protrudes into a cystic area. Both kidneys show dilatation of the renal pelvis as a result of a compression of both ureters by the large tumor.
may occasionally be seen in parts of the lesion. Immature teratomas usually have an inhomogeneous appearance on T2-weighted images with solid, cystic, and fatty areas. Solid parts of the lesions typically show enhancement on T1-weighted images after injection of Gd chelates.

Malignant Ovarian Lesions

Ovarian cancer is the leading cause of death resulting from genital cancer in the United States. Malignant ovarian tumors are principally classified according to the ovarian component from which they arise: (1) surface epithelial tumors; (2) germ cell tumors; and (3) sex cord and stromal tumors.

Approximately 85% of ovarian malignancies originate from the epithelium of the ovary. Because there is no true capsule of the ovary and because the ovary is covered only by the visceral peritoneum, ovarian cancer often is already metastatic by the time it is discovered. Clinical symptoms are nonspecific. Ovarian carcinoma has a strong tendency for extension outside the ovary. Routes of spread include direct invasion of adjacent structures such as the uterus, sigmoid colon, urinary bladder, and small bowel. Peritoneal seeding to the small bowel, pelvis, and omentum also occurs frequently. Lymphatic dissemination is primarily to pelvic and para-aortic lymph nodes. Hematogenous spread occurs only very late to the liver, lung, or pleura. The prognosis of ovarian cancer depends on the presence of residual tumor after surgery, histologic type of the tumor, FIGO stage at initial diagnosis, and tumor grade.

The role of MRI in the evaluation of patients with suspected adnexal neoplasms lies in lesion detection, characterization, staging, and follow-up. On MRI, the manifestation of ovarian carcinoma is variable and depends on the tumor type. Lesions are usually large (>4–5 cm) and may be solid, cystic, or mixed. Solid masses usually demonstrate a low to intermediate signal intensity on T1-weighted images and high signal intensity on T2-weighted images (Fig. 12-24). However, these findings may vary depending on the amount of hemorrhage or necrosis within the tumor. In cystic ovarian neoplasms, as with solid lesions, the MRI appearance varies and depends on the cyst contents. In cystic ovarian carcinomas that contain proteinaceous or hemorrhagic material, high signal intensity on both T1- and T2-weighted sequences may be seen. Cystic neoplasms may demonstrate thick walls or septations and contain solid vegetations or regions of nodularity (Fig. 12-25). Both findings are best demonstrated on either T2-weighted or Gd chelate-enhanced T1-weighted images. Extent of disease within the pelvis may also be determined using MRI, demonstrating involvement of the uterus, bladder, and rectosigmoid. Outside the pelvis, MRI may detect ascites, peritoneal implants, presence of omental cake, and mesenteric disease. MRI characterizations of a malignant lesion include size larger than 4 cm, solid or predominantly solid lesions, wall thickness greater than 3 mm, vegetations or solid nodules, and necrosis. Other findings that are found in malignant lesions include pelvic side wall or organ involvement, ascites, adenopathy, and omental disease.

In summary, the primary role of MRI for ovarian imaging is to act as a problem-solving modality after sonography and CT have been performed. MRI is more accurate than ultrasonography for tissue characterization in differentiating simple fluid from that of more complex fluids. MRI may supplement the ultrasonographic examination by defining the nature of an adnexal mass and its extent and determining the presence of blood or fat components. However, MRI still may not provide a specific diagnosis in certain cases of an adnexal mass.

MALE PELVIS

MRI is emerging as a valuable imaging tool in evaluation of the male pelvis. It has several advantages over other cross-sectional imaging modalities. MRI provides direct multiplanar images and superb soft tissue contrast. Currently, the most common indication for MRI in the evaluation of the prostate gland is preoperative staging of patients with biopsy-proven prostatic carcinoma. However, it is generally accepted that MRI is currently not suitable as a primary imaging modality for detection of prostate carcinoma. In imaging of the seminal vesicles, MRI is useful in evaluating a number of abnormalities, including suspected congenital anomalies, male infertility, primary or secondary neoplastic involvement, infection, and hemorrhage.

Prostate

The mature prostate is composed of both glandular and nonglandular tissue. Historically, the prostate was divided anatomic into different lobes. However, during the past 30 years, the concept of zonal anatomy has gradually replaced this previously described lobar anatomy.

The zonal anatomy of the prostate divides the gland into three major zones: peripheral, central, and transitional. A small amount of glandular tissue is also present in the periurethral glands. The zonal differentiation is clinically significant because most prostate carcinomas arise in the peripheral zone, whereas benign prostatic hyperplasia usually originates in the transitional zone. The urethra and the anterior fibromuscular stroma represent nonglandular tissue within the prostate. MRI of the prostate has evolved with the development in MRI coils and MRI pulse sequences. The use of phased-array coils and endorectal surface coils greatly improves the signal-to-noise ratio. The combination of both types of coils allows homogeneous signal within a large field of view and very high anatomic resolution. This has led to an overall improved accuracy in image interpretation of the prostate gland. In general, imaging of the prostate gland is performed using T1- and T2-weighted sequences. For high-resolution images, fast spin echo imaging has replaced conventional spin echo sequences. Imaging of the prostate gland is customarily performed in all three orthogonal planes; the relationships between the prostate and adjacent structures are best demonstrated on transaxial and sagittal images. The normal prostate gland demonstrates a homogeneous intermediate signal intensity on T1-weighted images. On
FIGURE 12–24. Ovarian carcinoma in a 32-year-old woman with a large, mainly solid pelvic mass on ultrasonography. A and B, Sagittal and axial T2-weighted images demonstrate a large inhomogeneous tumor displacing the uterus and bladder. The ovaries cannot be identified. On T1- (C) and fat suppressed T1-weighted (D) images, again inhomogeneous SI within the lesion can be noted with areas of hemorrhage. E, after contrast administration, the fat suppressed T1-weighted image demonstrates slight enhancement of the solid parts of the tumor.
T2-weighted sequences, the peripheral zone is of high signal intensity, equal to or greater than that of adjacent periprostatic fat, whereas the central zone has low signal intensity. The prostatic capsule is composed of fibrous and muscular elements and can be visualized as a low-signal-intensity line on T2-weighted images closely surrounding the peripheral zone of the gland.

Benign prostatic hyperplasia is one of the most common abnormalities affecting the prostate gland. Benign prostatic hyperplasia develops predominantly within the transitional zone. As it enlarges, it causes compression of the surrounding central zone as well as the urethra, resulting in varying degrees of bladder outlet obstruction. The appearance of benign prostatic hyperplasia on MRI depends on whether stromal or glandular hyperplasia occurs. Glandular benign prostatic hyperplasia is characterized by nodular areas of heterogeneous increased signal intensity on T2-weighted images (Fig. 12-26), whereas stromal benign prostatic hyperplasia is of more intermediate signal intensity.

In cases of acute prostatitis, usually no imaging studies are needed because the diagnosis is made clinically. In MRI of acute prostatitis, most commonly diffuse enlargement of the gland can be noted. If a prostatic abscess develops, the abscess is seen as an area of increased signal intensity on T2-weighted images.

Congenital anomalies of the prostate gland are frequently found in the context of other anomalies of the genitourinary system. Congenital cysts of the prostate gland are either midline or lateral in location. Midline congenital cysts include prostatic utricle cysts and müllerian duct cysts. Both result from abnormal regression of the müllerian system. However, whereas utricle cysts are generally associated with other anomalies like hypospadias, ambiguous genitalia, or undescended testis, müllerian duct cysts are not associated with other genital anomalies and thus are usually diagnosed in adulthood as a result of clinical symptoms. Lateral congenital prostatic cysts are rare acquired cystic lesions of the prostate that include retention cysts and ejaculatory duct cysts. Typically, these cysts have low signal intensity on T1-weighted images and a high signal intensity on T2-weighted sequences. If the cysts contain hemorrhage or proteinaceous fluid, the signal intensity on T1-weighted
Benign prostatic hyperplasia in a 74-year-old man with bladder outlet obstruction. A–D, Axial and sagittal T2-weighted images show the bladder to be elevated, and a suprapubic catheter can be identified in the T2-weighted sagittal image. The bladder wall shows irregularities but no solid thickening, and bladder diverticula (arrows) are present. The prostate is quite symmetrically enlarged with nodular high signal intensity (SI) enlargement of the inner gland.
FIGURE 12–26 Continued. E and F. On T1-weighted images, there is a small area with accumulation of protein-rich fluid that shows a high SI. Otherwise, the prostate shows well-defined borders. G and H. After contrast administration, T1-weighted images show an inhomogeneous enhancement of the prostate with hypointense cystic areas.
Prostatic carcinoma is the second leading cause of cancer-related death in men. Accurate preoperative staging of disease is imperative because the mode of therapy depends on the clinical stage of the condition. It is of special interest to differentiate disease confined to the prostate gland from disease that has extended beyond the prostate because treatment may vary depending on capsular extension (Fig. 12-27). Patients with cancer confined to the prostate gland alone may be candidates for radical prostatectomy. This procedure is potentially curative. Patients with disease extension beyond the confines of the prostate are generally not surgical candidates and may be offered an alternative therapeutic approach. Tumor invasion into the seminal vesicles can be detected on MRI by analysis of the size, configuration, and signal intensity of each vesicle.

Whereas on T₁-weighted images prostatic carcinoma may be hypointense or hyperintense relative to adjacent prostatic tissue, this tumor is generally detected on T₂-weighted sequences as a low-signal-intensity lesion within the high-signal-intensity peripheral zone. Tumors arising outside the peripheral zone are usually not detectable on MRI because the inhomogeneous signal pattern of the transitional zone prevents differentiation of prostatic tumor from benign prostatic hyperplasia. Similarly, a normal-appearing prostate gland does not exclude the presence of a carcinoma. Hemorrhage within the prostate gland that occurs because of a previous biopsy may lead to impaired tumor detection on MRI.

Seminal Vesicles

The seminal vesicles are seen posterior and superior to the prostate on sagittal images and posterior on trans-
FIGURE 12–28. Seminal vesicle cyst associated with ipsilateral renal agenesis in a 34-year-old man with nonspecific clinical symptoms of the lower urinary tract. A–C, Sagittal and coronal T2-weighted images demonstrate a large cystic lesion located dorsally to the bladder with clearly visible shading of the signal from ventral to dorsal. Additionally, a tubular, fluid-filled structure (arrow) is displayed that follows the route of the normal ureter and enters the cystic lesion. On sonography, agenesis of the right kidney was noted. The tubular fluid-filled structure represents a rudimentary ectopic ureter that enters the seminal vesicle cyst. D and E, On axial T2-weighted imaging, the cyst can be seen in the seminal vesicles, and the dilated ectopic ureter is displayed in the pelvic side wall. F, After contrast administration, there is only discrete contrast uptake in the wall. No solid component can be found. (Courtesy of Dr. M. Uder, Hamburg.)
verse images, with low signal intensity in relation to the fat on $T_1$-weighted sequences. On a $T_2$-weighted sequence, there is a relative increase in signal intensity because of the fluid within the seminal vesicles, and the wall is seen as low intensity. Often the signal intensity is greater than that of the surrounding retroperitoneal fat.

Seminal vesicle cysts are the most common congenital anomalies of the seminal vesicles. They are most frequently unilateral and can either be unilocular or multilocular. Whereas small cysts are mainly found incidentally, large cysts can often be symptomatic. In MRI the signal intensity of a seminal vesicle cyst depends on the fluid composition. Because blood or high proteinaceous content may be present, frequently cysts have high signal intensity on both $T_1$- and $T_2$-weighted sequences (Fig. 12-28) or high signal intensity on $T_1$-weighted images and low signal intensity on $T_2$-weighted images. Otherwise, seminal vesical cysts have low signal intensity on $T_1$-weighted images and high signal intensity on $T_2$-weighted sequences. In rare cases, seminal vesicle cysts may be found in association with ipsilateral renal agenesis or dysplasia (see Fig. 12-28). The corresponding congenital abnormality in female patients is the didelphian uterus with Gartner’s duct cyst and renal agenesis. Embryologically, these congenital anomalies represent developmental anomalies of the wolffian and müllerian ducts, respectively.

**Testis and Scrotum**

Ultrasonography is the imaging modality of choice because of its superb capabilities for displaying the scrotal anatomy and characterization of intratesticular and paratesticular lesions. However, MRI of testicular lesions may demonstrate in great detail the anatomy of the scrotum and inguinal region and is sensitive in demonstrating testicular abnormalities, especially on $T_2$-weighted images. MRI currently complements sonographic studies and is used when further evaluation is necessary.

The normal testis on MRI is a sharply defined oval structure of homogeneous intermediate signal intensity on a $T_1$-weighted image and higher signal intensity on a $T_2$-weighted image. A low-intensity 1-mm-thick layer demonstrated around the testis represents the tunica albuginea and the tunica vaginalis. The mediastinum testis, which arises from the tunica, is seen as a region of lower signal intensity than the testis on a $T_2$-weighted sequence and measures approximately 1 to 3 cm in length. Both $T_1$- and $T_2$-weighted sequences are necessary for evaluating the testis and intrascrotal contents. The coronal plane allows visualization of the testis, epididymis, and spermatic cord. This plane allows comparison of the right and left hemiscrotum. The bare area of the testis and the inguinal canal are best seen in the sagittal plane. The transverse plane allows comparison of the right and left structures and complements the coronal plane.

Testicular cysts are seen as smooth, round lesions on MR images. On $T_1$-weighted scans, these cysts have low signal intensity compared with the surrounding testicular tissue. On $T_2$-weighted scans, the cysts are of high signal intensity, similar to that of testicular tissue, and nearly isointense with the normal testicular parenchyma.

Testicular tumors are seen as areas of inhomogeneous signal intensity equal to or lower than the intensity of the normal testis on $T_1$-weighted sequences and markedly lower on $T_2$-weighted sequences. The margination and extent of the tumor, as well as the effect on the normal testicular size and shape, can be clearly demonstrated on MRI.