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Breast Masses in Children and Adolescents: Radiologic-Pathologic Correlation¹

CME FEATURE

See accompanying test at http://www.rsna.org/education/rg_cme.html

LEARNING OBJECTIVES FOR TEST 6

After reading this article and taking the test, the reader will be able to:

- Identify an age-appropriate differential diagnosis for breast enlargement or a mass in a child or adolescent.
- Recognize the features of each of the common breast masses in children and describe how to distinguish one from another.
- Discuss the differences in evaluation and management of breast masses in children and adults.

TEACHING POINTS

See last page

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The spectrum of breast lesions in children and adolescents varies markedly from that for adults, with the former lesions being overwhelmingly benign. A breast mass in a young boy or girl may arise from normal and abnormal breast development. Other causes of masses include infection, trauma, and cyst formation. After onset of puberty, most cases of breast enlargement arise from benign fibroadenoma in girls and gynecomastia in boys. These conditions have specific imaging appearances, although juvenile (often giant) fibroadenoma cannot be distinguished from phyllodes tumor, which can be benign or malignant. In children, both conditions usually appear as well-circumscribed, hypoechoic masses at sonography and show diffuse enhancement except for nonenhancing septations at magnetic resonance imaging. A diagnosis of juvenile papillomatosis (a benign lesion) portends later development of breast cancer, and patients with this condition should be closely monitored. Malignant lesions of the breast in children are rare. The most common malignant lesions are metastases and are usually associated with widespread disease. The most common primary breast malignancy is malignant phyllodes tumor. Primary breast carcinoma is exceedingly rare in the pediatric age group, but its imaging appearance in children is the same as seen in adults and is different from that of almost all benign lesions. In girls, diagnostic interventions may injure the developing breast and cause subsequent disfigurement. Given this risk and the low prevalence of malignant disease in this population, a prudent course should be followed in the diagnosis of breast lesions. Imaging findings are very helpful for selecting patients for further diagnostic procedures. Although malignancy is rare, lesions with suspicious imaging findings or progressive growth should be subjected to cytologic or histologic examination.

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Introduction

Discovery of breast masses in children and adolescents often causes tremendous parental and physician concern because of the high prevalence of breast cancer in the adult population. Knowledge of the spectrum of pathologic conditions that affect the pediatric breast allows the radiologist to play an important role in providing an age-appropriate differential diagnosis. The vast majority of conditions that cause breast masses or breast enlargement in children and adolescents are benign. Bilateral enlargement most commonly occurs because of normal or abnormal development. These conditions are usually self-limited and do not require therapy, but, occasionally, inappropriate breast development may be a sign of a more serious condition, such as a hormonally active gonadal or adrenal tumor that causes feminization. Developmental lesions may be asymmetric or, uncommonly, unilateral, but unilateral enlargement or a palpable mass more often arises from a cystic lesion or the very common benign fibroadenoma. The natural history of the typical fibroadenoma is to regress; however, the juvenile type of fibroadenoma tends to grow rapidly and is radiologically indistinguishable from phyllodes tumor, which may be malignant. Surgical resection of a juvenile fibroadenoma is generally indicated. Malignant lesions of the breast in children are rare, and most of them represent metastases. Because of the low prevalence of breast cancer in the pediatric population and the risk of injuring the developing breast bud from diagnostic procedures, knowledge of the unique differential diagnosis of breast masses in children and adolescents can help to direct appropriate management.

In this article, the differential diagnosis of breast masses in the pediatric population is explored, and the clinical, pathologic, and imaging features of these conditions are reviewed and correlated.

Evaluation of the Pediatric Breast

Breast lesions in children and adolescents are managed differently compared with those in adults. First, the initial breast imaging study performed in pediatric patients is sonography, whereas mammography is reserved for selected cases. Advantages of sonography over mammography include lack of ionizing radiation in a susceptible population and greater sensitivity in the relatively dense fibroglandular tissue of young girls (1–3).

Mammography has a role in the evaluation of microcalcifications and of suspicious discrete masses in older adolescents. Computed tomography (CT) is usually not used to assess breast masses in children because of the risks of ionizing radiation. The role of magnetic resonance (MR) imaging for breast evaluation in adult women is still being elucidated; however, in children, MR imaging may be valuable for those patients with breast masses that involve deeper structures, such as vascular malformations or chest wall lesions.

Second, identified breast masses in pediatric and adult patients are managed quite differently. The prevalence of breast cancer in the pediatric age group is extremely low compared with that in the adult population (4–6), whereas the risk of intervention—including fine-needle aspiration cytologic analysis and core needle biopsy—to the developing breast is much greater than that to the mature breast (7–9). Consequently, a conservative approach of clinical and sonographic follow-up is more commonly adopted in children.

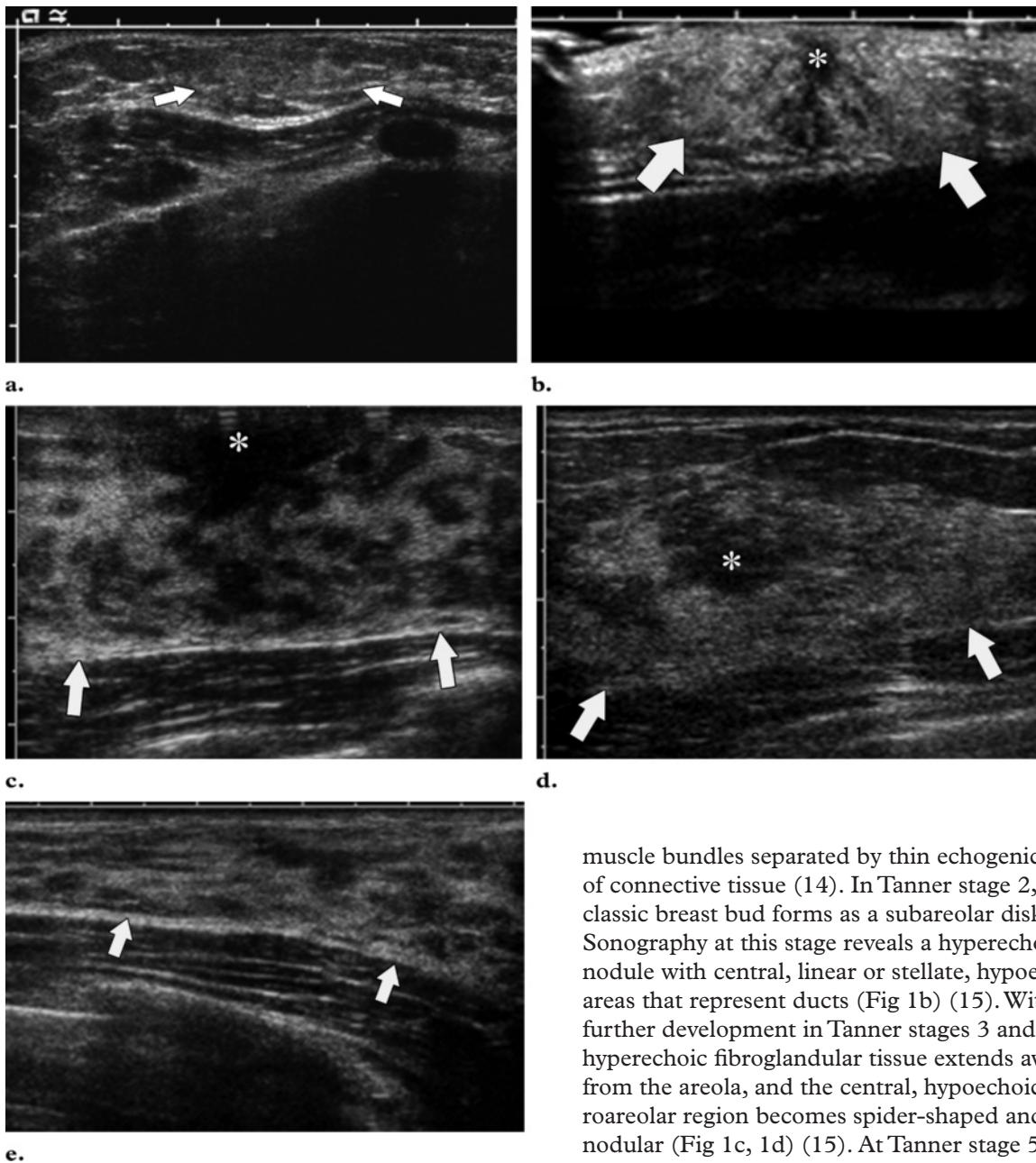
Normal Breast Development

In the 5th–6th week of fetal life, breast development begins when epidermal cells invaginate toward the deeper mesenchyme and form the primary mammary ridges or milk lines. These ridges extend from the axilla to the groin, but, normally, the cranial and caudal portions involute, which leaves only the portion at the fourth intercostal space to develop into the breast (10).

In prepubertal children, the breasts are composed of epithelial-lined ducts surrounded by a connective tissue stroma (10,11). These ducts are often enlarged at birth in both male and female full-term infants because of the effects of maternal hormones. Bilateral subareolar palpable nodules are common and may persist for the first 6–12 months of life (11,12).

In girls, a second phase of breast development begins at puberty. The onset of pubertal breast development is called *thelarche*, which normally occurs after age 8–9 years and before 13 years of age (10). Under the influence of estrogen, progesterone, and other hormones, the ducts begin to elongate and branch, leading to lobular differentiation and the development of terminal duct-lobular units (13). Pubertal breast development is divided into five phases called *Tanner stages* (10). Upon completion of this process, the mature female breast is composed of fatty tissue and glandular elements supported by a framework of fibrous connective tissue (Cooper ligaments).

Figure 1. Five Tanner stages of normal pubertal breast development. **(a)** Sonogram of Tanner stage 1 breast tissue in a 6-year-old girl shows a small area of ill-defined echogenic tissue in the retroareolar region (arrows). **(b)** Sonogram of Tanner stage 2 breast tissue in a 13-year-old girl reveals an echogenic nodule with a retroareolar, stellate, hypoechoic focus (*). **(c)** Sonogram of Tanner stage 3 breast development in a 13-year-old girl demonstrates more echogenic, glandular tissue (arrows) with a central spider-shaped hypoechoic focus (*). **(d)** Sonogram of Tanner stage 4 breast development in a 16-year-old girl shows more echogenic fibroglandular tissue (arrows) with a central hypoechoic nodule (*). Note also the increased subcutaneous fat anterior to the glandular tissue compared with earlier stages. **(e)** Sonogram of mature (Tanner stage 5) breast tissue in a 16-year-old girl demonstrates echogenic fibroglandular tissue (arrows) without a central hypoechoic focus.



In Tanner stage 1 (ie, before thelarche), sonography of the breast demonstrates mildly heterogeneous retroareolar subcutaneous tissue anterior to the pectoralis muscle (Fig 1a). The muscle is characterized by linear orientation of

muscle bundles separated by thin echogenic septa of connective tissue (14). In Tanner stage 2, the classic breast bud forms as a subareolar disk (10). Sonography at this stage reveals a hyperechoic nodule with central, linear or stellate, hypoechoic areas that represent ducts (Fig 1b) (15). With further development in Tanner stages 3 and 4, the hyperechoic fibroglandular tissue extends away from the areola, and the central, hypoechoic retroareolar region becomes spider-shaped and then nodular (Fig 1c, 1d) (15). At Tanner stage 5, the breast is mature and sonographically manifests as echogenic fibroglandular tissue without the central hypoechoic region seen in earlier stages (15). Hypoechoic fat is seen anteriorly, and pectoralis muscle posteriorly (Fig 1e). In the retroareolar region, hypoechoic ducts are seen (14).

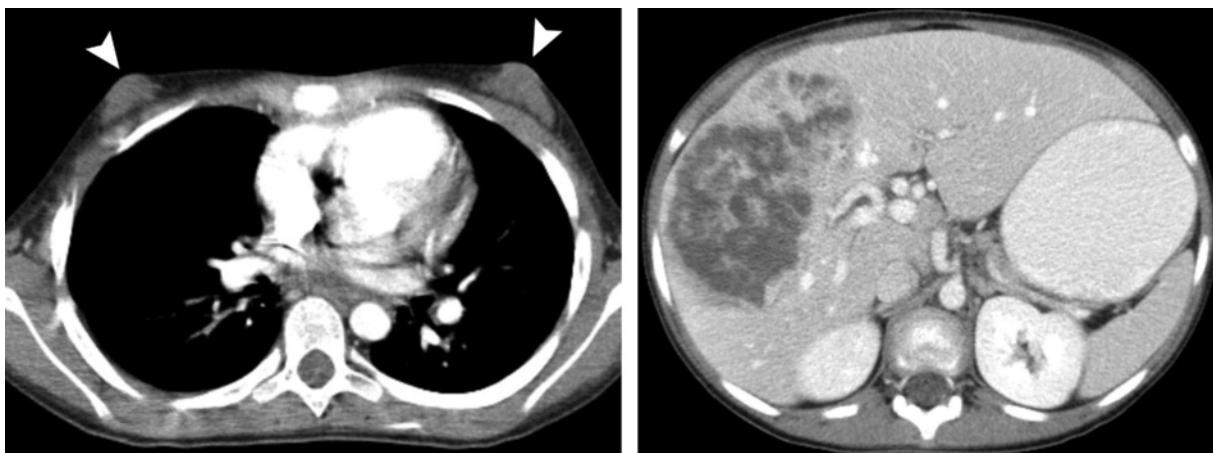
**a.****b.**

Figure 2. Gynecomastia in a 15-year-old boy with fibrolamellar carcinoma. (a) Axial CT image of the chest obtained after intravenous administration of iodinated contrast material shows bilateral, triangular areas of soft tissue in the subcutaneous fat in the expected location of the nipples (arrowheads). (b) CT image obtained at a lower level than a shows a large mass in the liver that enhances less than the normal parenchyma.

Thelarche can be asymmetric or unilateral, and the normal breast bud may be mistaken for a mass. Sonographic evaluation is helpful for demonstrating normal developing breast tissue in which there is no discrete mass.

Congenital and Developmental Abnormalities

Anomalous Nipple and Breast Development

Polythelia, or supernumerary nipple, is a common anomaly that is found in 1%–2% of the population (10). The finding is usually unilateral, and 95% of supernumerary nipples are found along the milk line (11). Polymastia (the presence of more than two breasts) occurs less frequently than polythelia. Accessory breast tissue is most often found in the axilla, although it may be located as far caudad as the vulva (11). Amastia (absence of the breast) is rare and may be associated with the Poland syndrome of unilateral pectoral muscle aplasia (11).

Premature Thelarche

Premature thelarche is the onset of female breast development before age 7–8 years. In general, thelarche occurs earlier in African Americans girls than in white girls; thus, breast development is considered premature before age 7 years in the former group and prior to 8 years of age in the latter. As with age-appropriate thelarche, premature thelarche may be asymmetric or unilateral, in which case it may arouse clinical concern for



Figure 3. Unilateral gynecomastia proved after excisional biopsy in a 17-year-old adolescent who admitted frequent use of marijuana. Sonogram shows a biconvex focus of decreased echogenicity (arrow) compared with adjacent subcutaneous fat, deep to which is the pectoralis muscle with hypoechoic muscle bundles separated by linear echogenic fascial bands (arrowhead).

a neoplasm. At sonography, premature thelarche appears as normal developing breast tissue without a discrete lesion (14).

Premature thelarche may occur as an isolated event or as part of precocious puberty. Isolated premature thelarche generally occurs in girls aged 1–3 years and is nonprogressive. Reassurance is all that is required. However, if the patient has clinical evidence of other forms of sexual maturation, such as axillary and groin hair growth or vaginal bleeding, a work-up for precocious puberty should be pursued. Radiologic evaluation for suspected precocious puberty should include a bone age assessment and abdominal and transvaginal pelvic sonography to look for evidence of maturation of

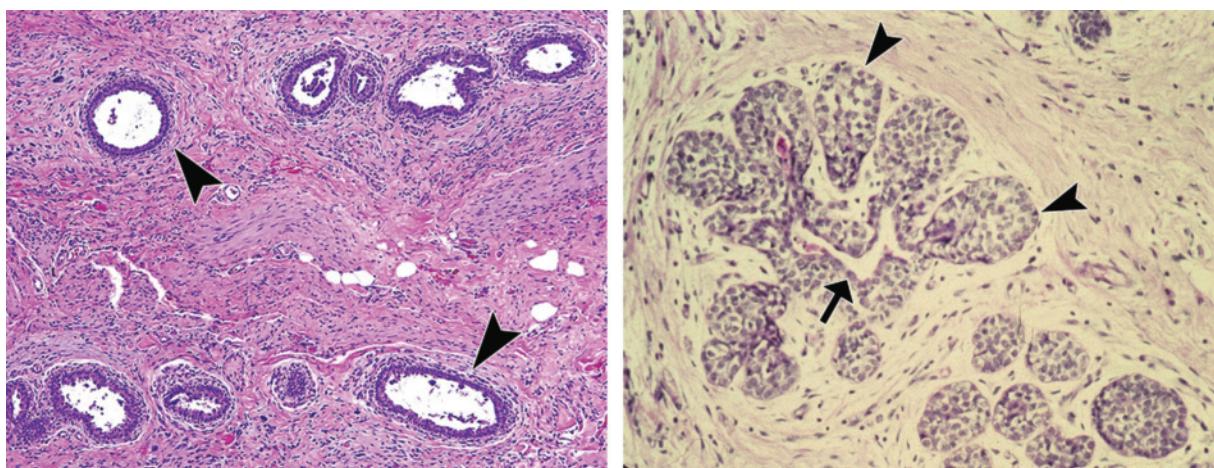
**a.****b.**

Figure 4. (a) Photomicrograph (original magnification, $\times 40$; hematoxylin-eosin [H-E] stain) of a biopsy specimen from a patient with juvenile hypertrophy shows dense connective tissue surrounding ducts (arrowheads) and absence of lobular development. (b) Photomicrograph (original magnification, $\times 100$; H-E stain) of a normal terminal-duct lobular unit shows the epithelial-lined terminal duct (arrow) that drains multiple lobules (arrowheads).

the uterus and ovaries. In addition, the ovaries and adrenal glands should be evaluated for estrogen-producing lesions, including functioning ovarian cysts, juvenile granulosa cell tumors of the ovary, and rare feminizing adrenal cortical tumors.

Gynecomastia

Gynecomastia is excessive development of the male breast and clinically manifests as tender, firm subareolar nodules. In children, gynecomastia often occurs during the neonatal period and puberty. Bilateral enlargement of the breasts is common in neonates because of the influence of maternal hormones. At puberty, two-thirds to three-fourths of boys have some degree of breast enlargement, which peaks at age 13–14 years and usually resolves within 2 years (10,16). The condition is usually bilateral but may be unilateral, and it may be familial. The etiology of gynecomastia is thought to be a decrease in the ratio of testosterone to estrogen. Excessive body fat may lead to increased conversion of testosterone to estrogen. Excessive gynecomastia or development of gynecomastia in a prepubertal boy suggests the presence of an endocrinopathy or other underlying disease. Uncommon causes of gynecomastia include estrogen-producing tumors of the testis, such as Sertoli or Leydig cell tumors; rare, feminizing adrenal cortical tumors; gonadotropin-secreting tumors, such as hepatoblastoma and fibrolamellar carcinoma (Fig 2) or choriocarcinoma; prolactinomas; liver disease; Klinefelter syndrome; testicular feminization syndrome; and neurofibromatosis type 1. In addition, use of drugs such as marijuana, anabolic steroids, corticosteroids, cimetidine, digitalis,

and tricyclic antidepressants can cause male breast development (10).

At sonography, increased subareolar tissue similar to the appearance of early breast development is seen, usually without a discrete mass (Fig 3) (9,14). At CT, dense fibroglandular tissue is noted (Fig 2) (17).

Juvenile Hypertrophy

Juvenile hypertrophy, which is also known as virginal hypertrophy or macromastia, is excessive female breast enlargement that occurs in a relatively short period of weeks to months. Juvenile hypertrophy often begins shortly after menarche but may occur during pregnancy. Usually both breasts are symmetrically, diffusely enlarged, but the condition may be asymmetric or even unilateral.

The pathologic appearance of juvenile hypertrophy shares features with gynecomastia. There is no discrete mass, and the cut surface of lesions appears homogeneous grayish tan to yellow. Histologic evaluation reveals an irregular distribution of ducts, with varying degrees of cystic dilatation and intraductal hyperplasia within a dense hypocellular stroma (Fig 4). No lobular units are seen in the areas of hypertrophy (11,12).

Patients are often very symptomatic, but surgery should be avoided in girls with ongoing breast growth. These patients are generally treated with anti-estrogen agents, such as tamoxifen. After growth has stabilized, surgical options include reduction mammoplasty and mastectomy with reconstruction (18).

Teaching Point

Cystic Lesions

Mammary Duct Ectasia

Ductal ectasia develops in infants or young children in rare cases. Most often, the retroareolar ducts are involved and the patient presents with bloody nipple discharge (10,16). Less frequently, patients may present with tender or nontender palpable masses caused by secondary inflammation (16). Stasis of secretions can lead to bacterial infection with *Staphylococcus aureus* or *Bacteroides* species (10). At sonography, ectatic mammary ducts are seen as subareolar, anechoic tubular structures (Fig 5), which may contain debris (9,16). Ectatic mammary ducts may resolve with cessation of breast feeding or with antibiotic therapy. Surgical excision may be required in patients with persistent or recurrent drainage (10,16).

Galactoceles

Galactoceles usually develop in lactating women, but they may occur in infants of either gender or in older boys in the absence of endocrinopathy (12). Galactoceles typically appear as enlarging painless masses. They may be unilateral or bilateral. At pathologic analysis, galactoceles are smooth-walled cysts that are lined by simple cuboidal to columnar apocrine-type epithelium and filled with milky fluid.

At sonography, the appearance of galactoceles depends on the relative proportions of fat and water content of the fluid. The water component is hypoechoic, whereas the fat component is hyperechoic; thus, the resulting appearance may be that of a complex cyst (Fig 6) (16). On MR images, galactoceles show enhancement of only the wall and septations (16). A fat-fluid level may be seen on a true lateral mammogram and is a specific finding of galactoceles (Fig 6) (9). A patient's clinical history may suggest the diagnosis, but in cases with a complex imaging appearance, cyst aspiration that yields a milky substance may be required for definitive diagnosis. Aspiration is also therapeutic (9,10,19).

Retroareolar (Montgomery) Cysts

In adolescent girls, the glands of Montgomery at the edge of the areola may become obstructed. Clinical symptoms of local inflammation are noted in about two-thirds of patients, whereas another one-third present with a painless mass (20). The

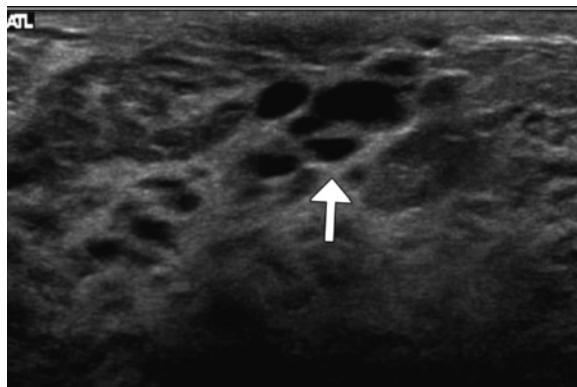


Figure 5. Retroareolar duct ectasia in a young pregnant woman. Sonogram demonstrates dilated anechoic ducts (arrow) seen in cross section deep to the areola.

diagnosis is usually made on clinical grounds, but it may be confirmed at sonography, which generally shows single or multiple, retroareolar, thin-walled, unilocular cysts that may contain some echogenic debris. The cysts measure 2 cm or less in diameter and are frequently bilateral (20). Most retroareolar cysts resolve completely or partially with conservative management (20).

Abscess and Mastitis

Mastitis most commonly affects lactating women, but it also occurs in young infants and adolescents of both sexes. The underlying cause may be mammary duct obstruction or ectasia, cellulitis, an immunocompromised state, or nipple injury (6,9,10). Patients with a suppurative infection present with a tender, indurated, erythematous breast and possibly with fever (6,11). *S aureus* is the most common pathogen (11,12). At histologic analysis, acute and chronic inflammatory infiltration is noted, as well as fibrosis and occasional multinucleated giant cells (11). At sonography, a hypoechoic complex mass, often with a thick wall and color Doppler flow at only the periphery, is seen (14). Sonography may be used to guide needle aspiration of the abscess.

Hematomas

Hematomas most commonly result from sports or iatrogenic trauma (10,14). At sonography, hematomas appear as complex cystic masses, with the internal echotexture varying with the age of the hematoma. Acute hematomas are hyperechoic and become progressively more anechoic as they resolve (14). Mammography demonstrates a mass with architectural distortion (17). At CT,

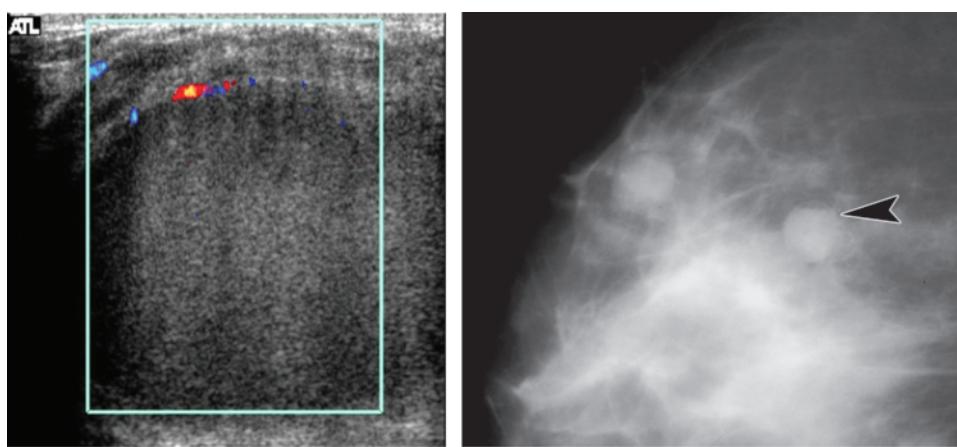


Figure 6. Galactocele in a 15-year-old girl that was confirmed by aspiration of milky fluid. (a) Color Doppler sonogram reveals a well-circumscribed, round cystic structure with homogeneous internal echogenicity, posterior acoustic enhancement, and flow to the cyst wall only. (b) True lateral mammogram of another patient shows the fat-fluid level (arrowhead), which is a specific finding for galactocele.

acute hematomas appear hyperattenuating, and the margins may be ill-defined. Reactive changes of healing may produce a spiculated margin (17).

Fibrocystic Change

Fibrocystic changes in the breast are usually physiologic alterations that are very common in the 3rd decade of life, although such changes may be seen to some extent in late adolescence. Patients present with cyclically tender breasts that are nodular at palpation (10).

A spectrum of histologic findings is included under the designation of fibrocystic change. In children, solitary cysts are more common than multiple cysts. Fibrosis, or fibrous mastopathy, was the most common lesion in a series of 113 lesions in adolescents (the study excluded patients with fibroadenoma and gynecomastia) (12). Fibrous mastopathy manifests as a solid white mass that consists of dense hypocellular to moderately cellular fibrous tissue surrounding scattered terminal duct-lobular units. Some pathologic findings in the spectrum of fibrocystic change, such as atypical duct hyperplasia, are considered risk factors for subsequent breast cancer, but these changes are generally confined to the adult population (12). The findings of fibrocystic change at sonography are nonspecific and include multiple cysts of varying sizes, dilated ducts, and echogenic foci representing fibrous tissue that may cause posterior sound attenuation (3,14).

Benign Masses

Fibroadenoma

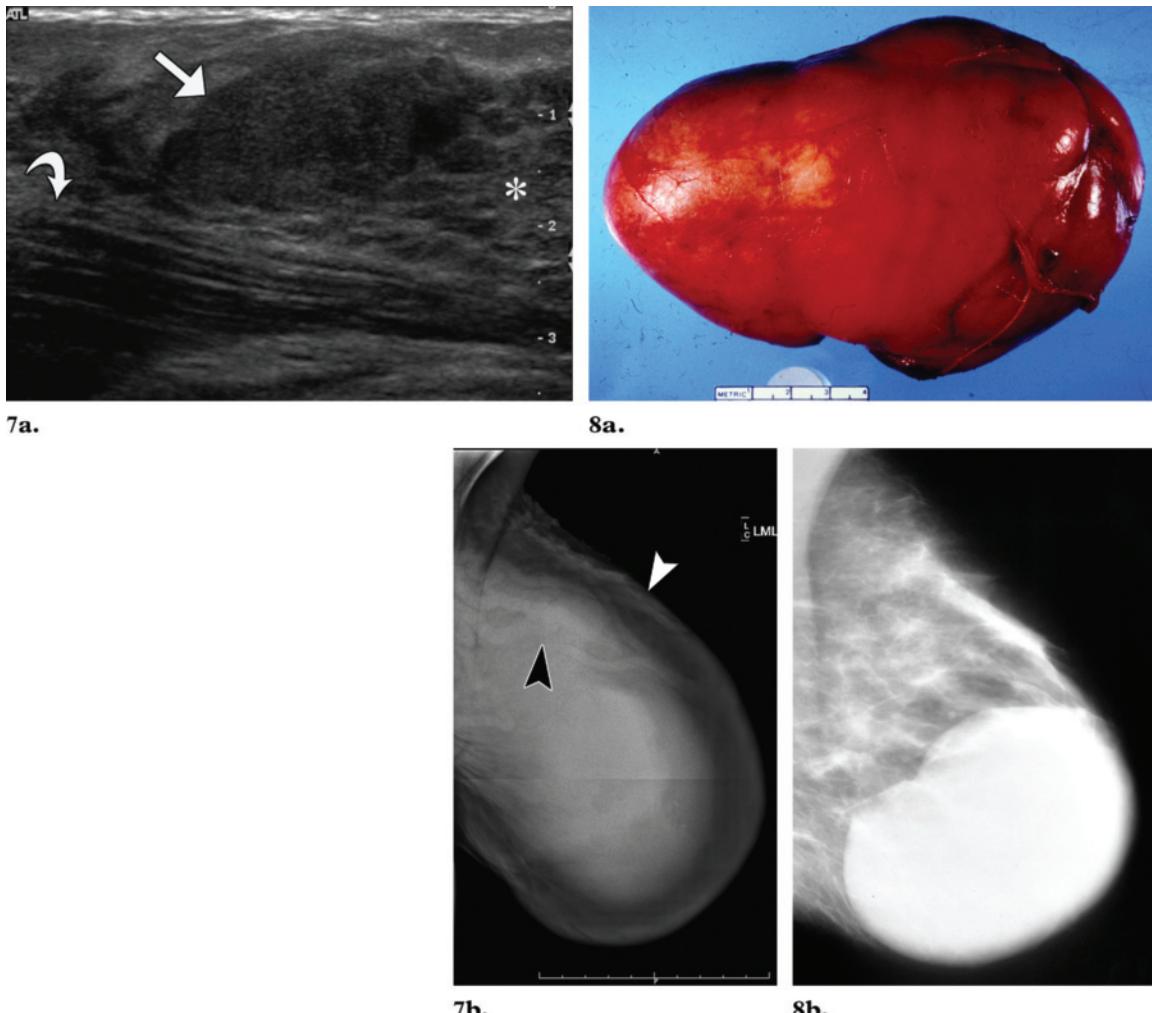
Fibroadenoma is a benign fibroepithelial tumor and is the most common breast mass in girls younger than 20 years of age, accounting for well over half of tumors in surgical series (6,11,21).

Teaching Point

Clinical Presentation.—The mean patient age at diagnosis is 15–17 years (11). Most patients present with a slowly enlarging, painless mass that causes breast asymmetry. At physical examination, the mass is well-circumscribed, rubbery, and freely movable; it is most often located in the upper outer quadrant (4,6,22). Fibroadenomas are estrogen-sensitive and may grow faster during pregnancy (23), although they usually do not vary in size during the menstrual cycle (21). Fibroadenomas in males have been reported but are rare because males have no terminal duct-lobular units (4).

Juvenile or cellular fibroadenoma is an uncommon histologic variant of fibroadenoma that frequently undergoes markedly rapid growth. A fibroadenoma over 5–10 cm in diameter is termed a *giant fibroadenoma*. Although most giant fibroadenomas are of the cellular subtype, not all cellular fibroadenomas are giant. Juvenile fibroadenomas constitute approximately 7%–8% of all fibroadenoma subtypes (11,24) and most

Figures 7, 8. (7) Bilateral juvenile fibroadenomas in a 13-year-old African-American girl who presented with left breast enlargement. **(a)** Sonogram of the smaller right breast shows a well-circumscribed, homogeneously hypoechoic mass (straight arrow) within the fibroglandular breast tissue (*), with the pectoralis muscle deep to the mass (curved arrow). **(b)** Mediolateral oblique mammogram of the left breast shows a large mass that occupies much of the breast and dilated veins (arrowheads). (8) Juvenile fibroadenoma in a 14-year-old girl. **(a)** Photograph of the gross resected specimen shows the smooth contour and pseudocapsule of the lesion. Scale is in centimeters. **(b)** Corresponding mediolateral oblique mammogram shows the dense mass with its smooth borders.



often occur in African American adolescent girls (4,12,25). Approximately 10%–25% of patients with juvenile fibroadenomas have multiple or bilateral tumors at presentation (4,25), and multiple and bilateral tumors are more likely to affect African American girls (12). Patients with a juvenile fibroadenoma typically present with a rapidly enlarging breast. Skin ulceration or prominent, distended superficial veins may be noted (Fig 7) (11).

Pathologic Features.—Fibroadenomas are well-circumscribed, smooth, or mildly lobulated masses (Fig 8). Most measure 2–5 cm in diameter, and the cut surface appears bulging, uniform gray white, and gelatinous or mucoid (Fig 9). The mass typically does not possess a true capsule but has a well-demarcated interface between the stroma and uninvolved parenchyma of the breast (4).

The juvenile or cellular subtype of fibroadenoma is usually larger than 5–10 cm in diameter. The surface is typically multilobulated or bosselated (11,12). Some tumors have cleftlike

Figure 9. Juvenile fibroadenoma in a 13-year-old girl. **(a)** Photograph of a sectioned gross specimen shows a mucoid-appearing surface with multiple clefts. Scale is in centimeters. **(b)** Axial T1-weighted image shows a well-circumscribed, round mass (arrowhead) in the right breast that is hypointense relative to fat and slightly hypointense relative to fibroglandular tissue. **(c)** On a sagittal fat-saturation T2-weighted image, the mass appears lobulated and hyperintense with hypointense septations (arrow), findings that reflect the pathologic features. **(d)** Axial T1-weighted image obtained 5 minutes after intravenous administration of gadolinium contrast material demonstrates diffuse intense enhancement of the tumor except for the septations (arrow). **(e)** Enhancement curve shows the characteristic benign (type 1) pattern of progressive enhancement. **(f)** On a computer-aided detection image, the tumor appears blue, a color assignment that corresponds to the type 1 enhancement pattern of progressive wash-in characteristic of benign tumors. Red corresponds to early wash-in and rapid wash-out of contrast material as seen in the heart and descending aorta. When seen in a tumor on computer-aided diagnostic images, red suggests malignancy.

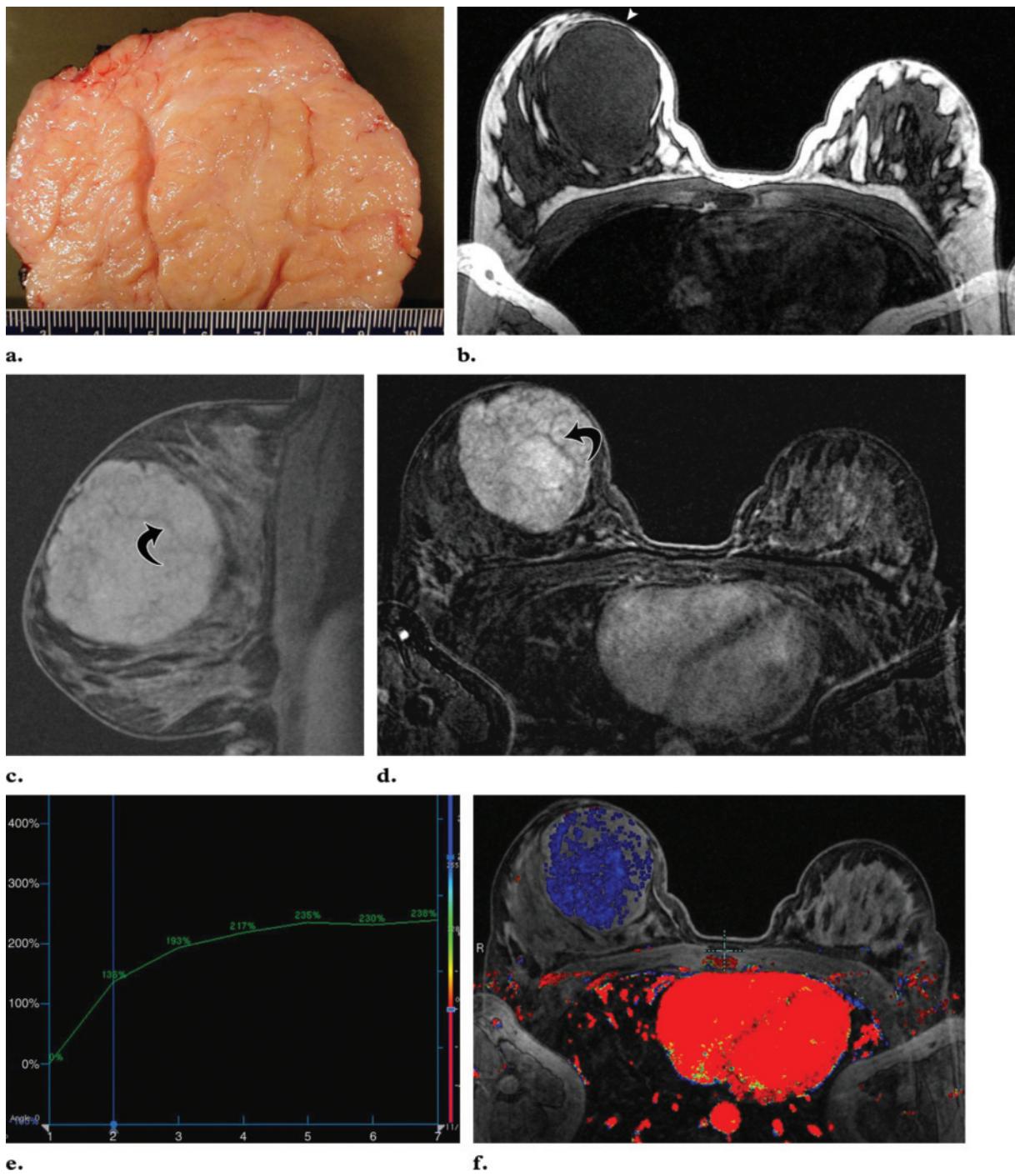
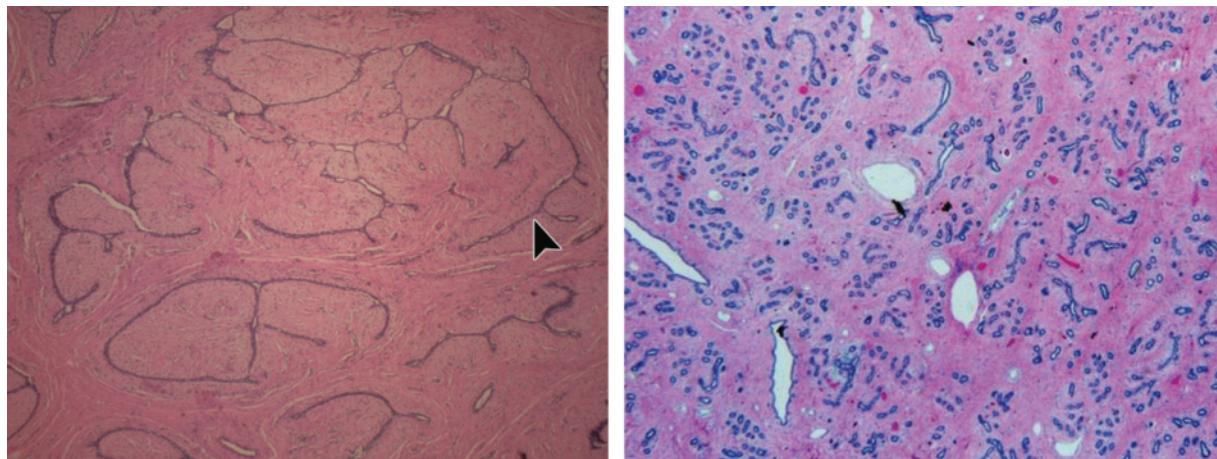


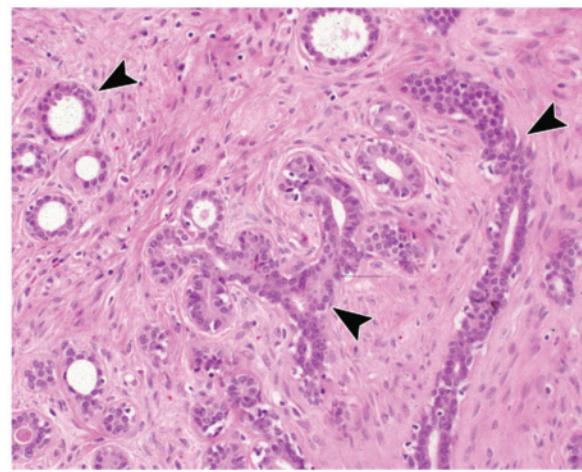
Figure 10. Histologic patterns of fibroadenoma in three different patients. **(a)** Photomicrograph (original magnification, $\times 40$; H-E stain) shows the intracanalicular pattern with nodular configuration. The stromal cells are compressing the ducts into branching strands (arrowhead). **(b)** Photomicrograph (original magnification, $\times 40$; H-E stain) shows the pericanalicular pattern. The acinar arrangement of the round and ovoid tubules is preserved and surrounded by the stromal component. **(c)** Photomicrograph (original magnification, $\times 400$; H-E stain) shows that the stroma surrounding the ducts (arrowheads) is cellular, consistent with the juvenile subtype of fibroadenoma.

**a.****b.**

depressions and tiny cysts similar to those seen in phyllodes tumors (Fig 9) (12).

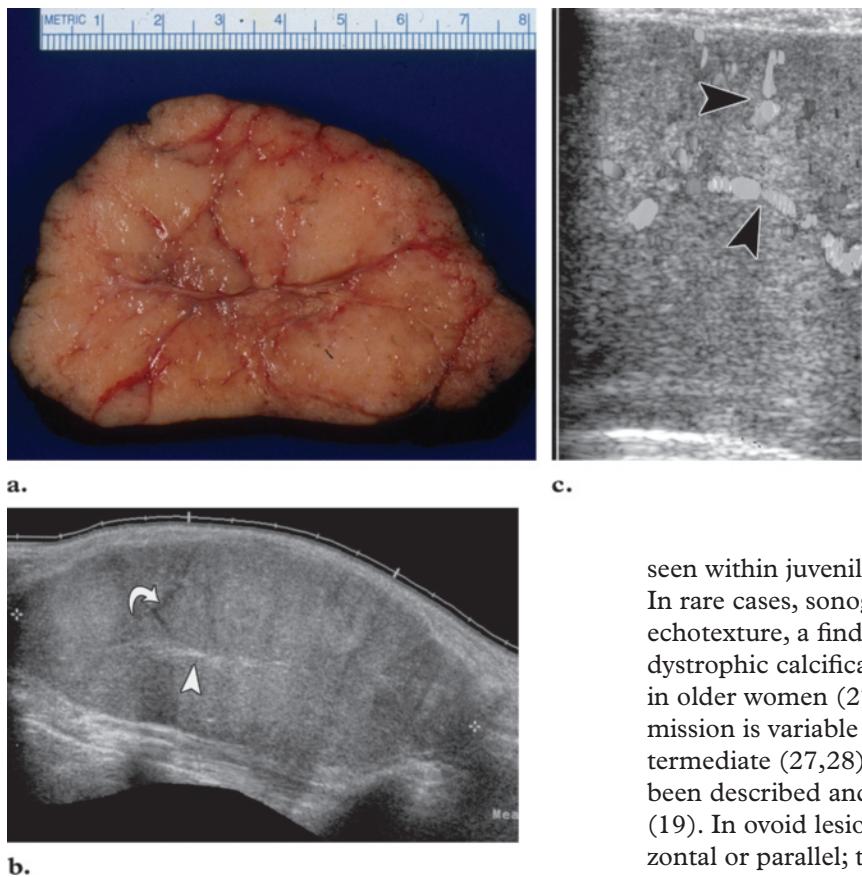
Histologic Features.—Fibroadenoma is a benign tumor with multiphasic histologic characteristics, exhibiting proliferation of the epithelial, stromal, and myoepithelial elements of the terminal duct-lobular unit (19). Several distinct histologic patterns are recognized, based on variations in the stromal and epithelial components. Some subtypes carry prognostic significance for future development of breast cancer.

In typical fibroadenomas, the glandular epithelial component of fibroadenoma exhibits an intracanalicular or a pericanalicular pattern or a mixture of the two. These histologic patterns have no prognostic implications. The intracanalicular pattern demonstrates a hypocellular myxomatous stroma that surrounds and compresses the epithelial-lined ducts into anastomosing strands or slits (Fig 10a). The stromal cells have a spindle to stellate configuration (11,25). The pericanalicular configuration preserves the acinar or glandular arrangement of the epithelial component, which appears round or oval in cross section (Fig 10b), and the stromal component is limited to some collagen deposition in an edematous background (11,25).

**c.**

Juvenile or cellular fibroadenomas are histologically distinguished by a hypercellular stromal proliferation associated with the pericanalicular or intracanalicular patterns (Fig 10c). The stromal component dominates and is composed of compact spindle cells with myxoid stroma in less cellular areas. The epithelial component may feature networks of elongated, ramifying clefts lined with hyperplastic epithelium that create an appearance reminiscent of phyllodes tumor. In the past, juvenile or cellular fibroadenomas have been diagnosed as benign phyllodes tumor (4,12,22,26). If mitoses are found, they are few and are confined to the stroma around the epithelial-lined clefts (12).

Figure 11. Juvenile fibroadenoma in a 15-year-old girl. **(a)** Photograph of sectioned gross specimen demonstrates a central fibrous septation and multiple smaller reddish grooves or clefts. Scale is in centimeters. **(b)** Extended-field-of-view sonogram shows the hyperechoic septation (arrowhead) and smaller anechoic clefts (arrow) within a homogeneously hypoechoic, well-margined mass with posterior acoustic enhancement. **(c)** Color Doppler image (shown in black and white) reveals internal vascularity (arrowheads).



The epithelial component of fibroadenoma may exhibit a wide range of typical hyperplastic features, especially in adolescent girls (26). Epithelial features of sclerosing adenosis, apocrine metaplasia, epithelial calcification, and cysts greater than 3 mm collectively characterize the so-called complex fibroadenoma, which is considered a harbinger of subsequent development of breast cancer (4).

Imaging Appearance.—Sonography is very sensitive in the detection of fibroadenomas (27). The typical sonographic appearance of a fibroadenoma is a well-circumscribed, round, oval (Fig 7), or macrolobulated mass with fairly uniform hypoechoogenicity (19,24). These masses may appear almost anechoic with low-level internal echoes (27,28). Slender, fluid-filled clefts may be

seen within juvenile fibroadenomas (Fig 11) (28). In rare cases, sonography reveals a heterogeneous echotexture, a finding that represents necrosis or dystrophic calcification, which is more common in older women (27,28). Posterior acoustic transmission is variable and is usually enhanced or intermediate (27,28), but posterior shadowing has been described and may be related to infarction (19). In ovoid lesions, the growth pattern is horizontal or parallel; that is, the long axis of the mass is parallel to the chest wall (Fig 7) (22,27–29). During a color Doppler evaluation, these lesions may appear avascular or may demonstrate some central vascularity (Fig 11).

At mammography, a fibroadenoma appears as a well-defined, round or oval, macrolobulated mass (Figs 7, 8). Calcification may be noted as small, peripheral, punctate densities that coalesce into popcornlike calcifications (22).

CT is typically not used to evaluate breast masses in children, but fibroadenomas are common and may be found serendipitously on CT scans obtained for other indications. They appear as well-demarcated, round, ovoid, or smoothly lobulated, noncalcified masses (17).

Fibroadenomas have a variable appearance at MR imaging. In a series of 23 fibroadenomas in 21 patients, Hochman et al (30) found that

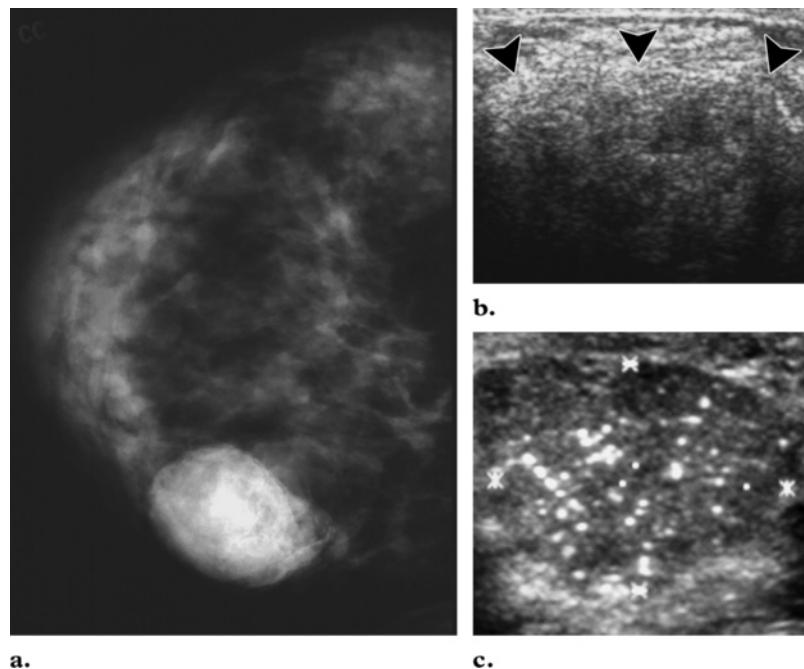


Figure 12. Lactating adenoma. **(a)** Mediolateral oblique mammogram of a 17-year-old girl shows a posterior, dense, well-circumscribed mass. **(b)** Corresponding sonogram shows a heterogeneously echogenic mass (arrowheads) with posterior shadowing. **(c)** Sonogram of another patient shows small hyperechoic foci within a mass, findings that represent the fat in the milk produced by the tumor.

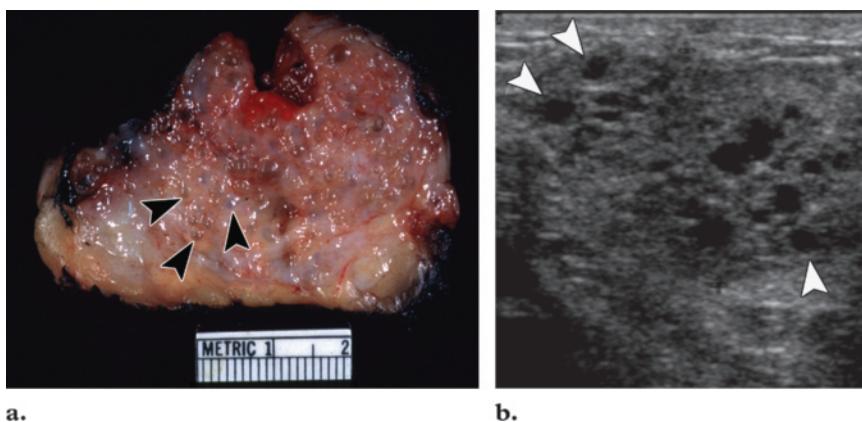
about half of the lesions demonstrated T2 hyperintensity and enhancement and almost as many demonstrated low T2 signal intensity and no enhancement. T2 hypointensity was observed in the lesions of older patients, a finding that was associated with more sclerotic stroma at histopathologic analysis. Of the lesions that enhanced, some had internal septations (Fig 9) that appeared to correlate with collagenous bands seen in histopathologic specimens (30). Wurdinger et al (31) compared the MR imaging characteristics of 81 fibroadenomas and 24 phyllodes tumors. Most fibroadenomas were round or lobulated with smooth margins. Half were homogeneous and half heterogeneous in signal intensity. Most showed no septations, although 30% had septations (Fig 9), which typically did not enhance. Fibroadenomas were low in signal intensity on T1-weighted images and hyperintense on T2-weighted images (Fig 9). Most fibroadenomas demonstrated a benign enhancement pattern, with slow initial enhancement and delayed wash out (Fig 9). The authors concluded that, because of overlapping features, fibroadenoma could not be differentiated from phyllodes tumor at MR imaging.

Differential Diagnosis.—The main consideration in the differential diagnosis of fibroadenoma is phyllodes tumor, a fibroepithelial neoplasm that may be malignant. **The histopathologic and imaging features of the cellular subtype of fibroadenoma and phyllodes tumor overlap considerably, such that they are indistinguishable at imaging.** The finding of peripheral cysts at sonography suggests phyllodes tumor (28), but definitive diagnosis requires tissue sampling.

Juvenile hypertrophy and giant fibroadenoma both manifest with rapid breast enlargement, and distinguishing between the two may be difficult, especially because the large size of giant fibroadenoma renders it harder to appreciate clinically and sonographically as a discrete mass. However, juvenile hypertrophy is usually bilateral.

Treatment and Prognosis.—The natural history of fibroadenoma is one of slow growth and eventual regression (4,11). Early reports suggested the possibility of rare malignant transformation in adults, but the risk is quite low (32). Fibroadenomas in adolescents are not regarded as premalignant, although women with complex fibroadenomas have an increased long-term risk for developing breast cancer (6,10,11). Given this natural history and the potential for iatrogenic injury to the developing breast,

Teaching Point



a.

b.

Figure 13. Juvenile papillomatosis in a 16-year-old girl. (a) Photograph of the sectioned gross specimen shows multiple tiny cysts (arrowheads). Scale is in centimeters. (b) Sonogram shows a slightly hypoechoic mass that contains multiple, small anechoic cysts (arrowheads), findings that correspond to those of the pathologic examination.

many authors advocate that pediatric patients with typical clinical and sonographic findings be managed conservatively with clinical and sonographic follow-up (24,33). Fine-needle aspiration or core needle biopsy may be used for patients for whom confirmation of the diagnosis is desired (34). Surgical excision is indicated for symptomatic or rapidly growing masses (11).

The biologic behavior of the juvenile or cellular subtype of fibroadenomas is benign, but metachronous lesions are not uncommon (11). In contrast to typical fibroadenomas, juvenile fibroadenomas are generally treated with excision because of their rapid growth (35).

Lactating Adenoma

True adenomas are cellular epithelial proliferations without a prominent stromal component. Lactating adenomas predominantly consist of lobules with lactational changes that develop in late pregnancy or during lactation (11). At sonography, lactating adenomas usually have benign features, such as well-defined margins, smooth lobulations, homogeneous echotexture, and posterior acoustic enhancement, with their long axis parallel to the chest wall (Fig 12). However, some of these tumors have features, including irregular or angulated margins or posterior acoustic shadowing, suggestive of malignancy (36,37). Small central hyperechoic foci, which represent fat in the milk produced by the tumor, may be seen (Fig 12) (19). Lactating adenomas usually resolve at delivery or upon cessation of lactation.

Intraductal Papilloma

Intraductal papilloma is an epithelial proliferation into the lumen of a mammary duct and is

uncommon in children (10–12). These masses have rarely been reported in boys (5). They are usually solitary, arise in the large subareolar ducts, and manifest with serous or serosanguinous nipple discharge. Intraductal papillomas are bilateral in 25% of cases (10) and are histologically similar to juvenile papillomatosis. At sonography or MR imaging, they may appear elongated or they may be surrounded by a dilated duct filled with anechoic fluid. Papillomas are treated with simple surgical excision.

Juvenile Papillomatosis

Juvenile papillomatosis is a localized, proliferative disorder of young women and older adolescents. The mean patient age at diagnosis is 19 years (11). Patients present with a firm, well-defined, mobile mass in the periphery of the breast and without nipple discharge (11,38). At gross examination, the resected mass appears well circumscribed and contains multiple small cysts (<2 cm) within a dense fibrous stroma (Fig 13), an appearance that has given rise to the term *swiss cheese disease* (11,38,39). Yellowish calcifications are common (11). Tumors vary in size, ranging from 1 to 8 cm (38,39). At histologic analysis, multiple macrocysts and dilated ducts are apparent within a fibrous stroma that blends into adjacent normal breast tissue (11,12,38).

The imaging appearance of juvenile papillomatosis is characteristic although not specific. At sonography, juvenile papillomatosis appears as an ill-defined mass with multiple small cysts, especially at the periphery, findings that reflect the gross pathologic features (Fig 13) (19,40,41).

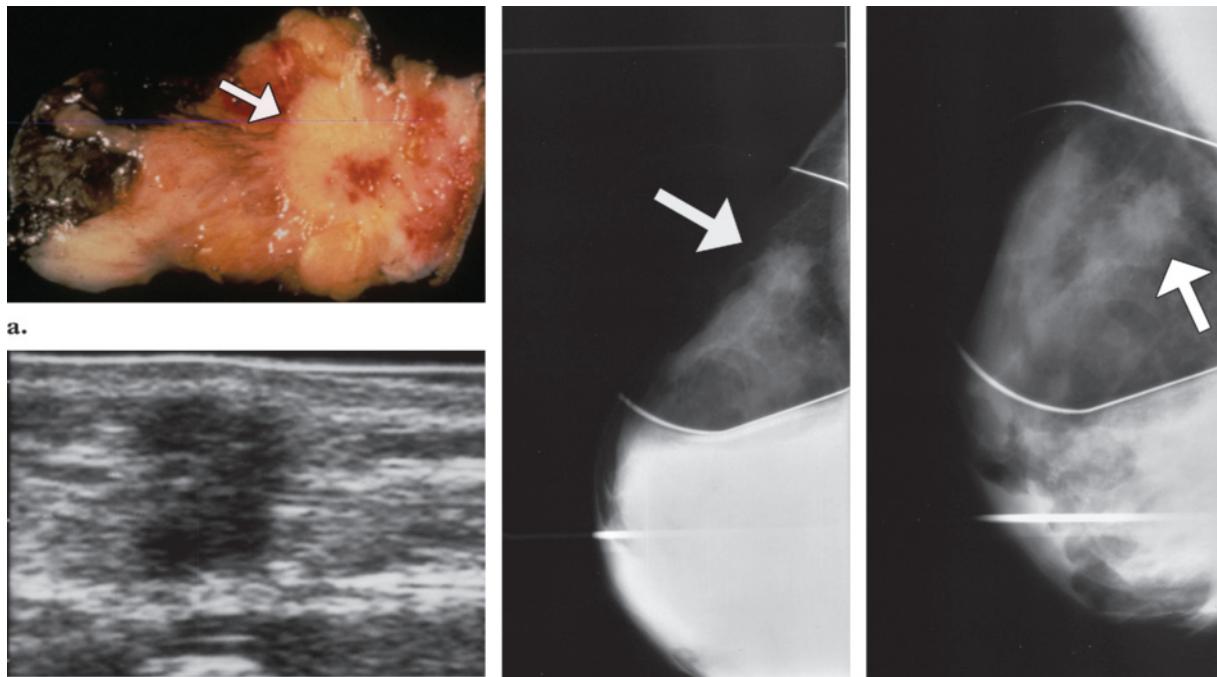


Figure 14. Granular cell tumor in an 18-year-old woman. **(a)** Photograph of a sectioned gross specimen reveals a white-tan tumor with invasive borders (arrow). **(b)** Sonogram reveals a mass with ill-defined borders and antiparallel orientation. These sonographic features are suggestive of malignancy. No posterior shadowing is seen. **(c, d)** Spot compression craniocaudal **(c)** and mediolateral oblique **(d)** mammograms demonstrate a round mass with ill-defined, slightly spiculated margins (arrow).

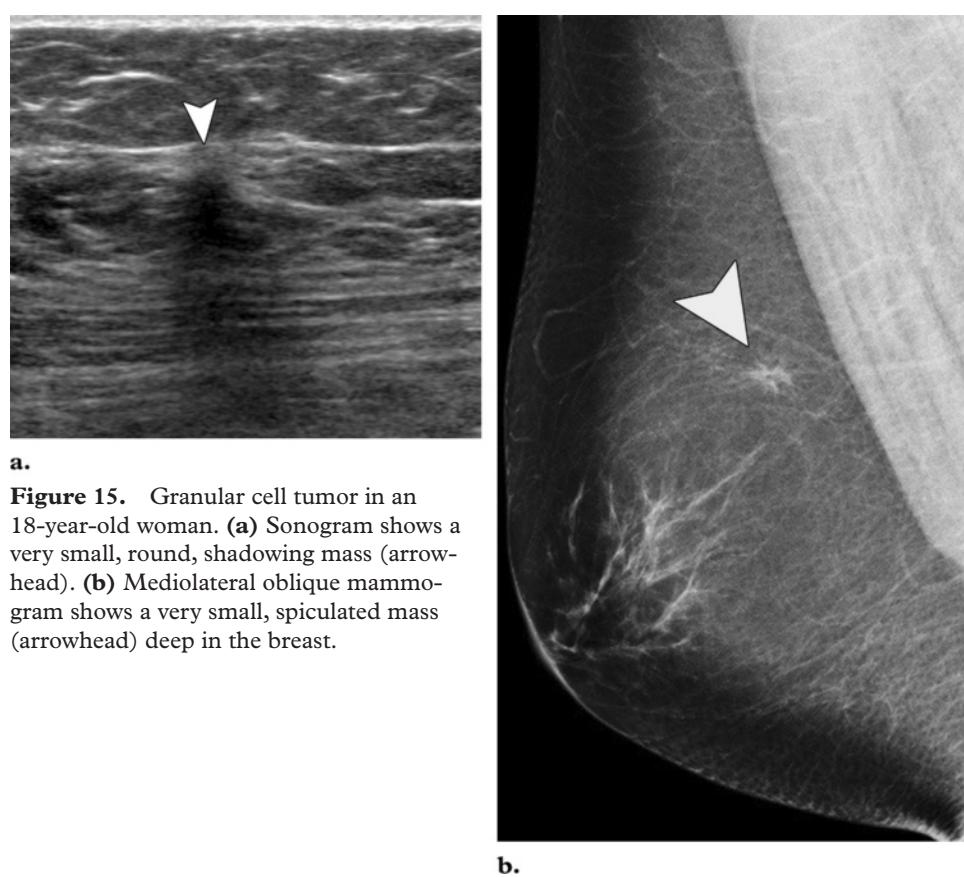


Figure 15. Granular cell tumor in an 18-year-old woman. **(a)** Sonogram shows a very small, round, shadowing mass (arrowhead). **(b)** Mediolateral oblique mammogram shows a very small, spiculated mass (arrowhead) deep in the breast.

Microcalcifications may be seen at sonography (19). Although results of mammography are usually negative, occasionally mammograms may reveal microcalcifications or asymmetric density (19,41). At MR imaging, juvenile papillomatosis has been described as a lobulated mass with small internal cysts, which are seen best with T2-weighted sequences, and that demonstrates marked enhancement with a benign enhancement profile (42).

Although juvenile papillomatosis is a benign condition, it is considered a marker for familial breast cancer. Patients with this diagnosis have a high rate of positive family history of breast cancer (33%–58% of cases). About 5%–15% of patients have concurrent breast cancer (38,39). In the single case in the literature of concurrent carcinoma associated with juvenile papillomatosis occurring in an adolescent, secretory carcinoma was found in the opposite breast (39). Treatment is generally complete surgical excision with negative margins to prevent recurrence. Patients with bilateral and recurrent disease and a family history of breast cancer are at risk of developing subsequent breast cancer and should be closely monitored (39).

Granular Cell (Myoblastoma) Tumor

Granular cell tumor is usually a benign neoplasm that most commonly arises in the skin and tongue but may occur in any site (43).

Approximately 5%–6% of these tumors arise in the breast, most often in premenopausal African American women (43). Granular cell tumors are uncommon in children, accounting for less than 1% of breast lesions in this population. When initially described, these tumors were thought to originate from muscle cells (hence, the designation *myoblastoma*), but they are now believed to originate from perineural cells (43).

Granular cell tumors manifest clinically as palpable, firm masses. Most are superficial, and skin retraction and fixation may be noted (44). At gross inspection, granular cell tumors are grayish white to yellow, gritty masses with ill-defined borders (Fig 14) (11). They measure 1–2 cm in size. At histologic analysis, they are composed of large polygonal cells with abundant, pale eosinophilic, granular cytoplasm arranged in sheets and nests interspersed with branching thin-walled blood vessels (11). These tumors tend to form cords that extend into the adjacent normal breast

parenchyma, a characteristic that simulates the growth pattern of infiltrating carcinoma (43).

The imaging characteristics of granular cell tumors are quite variable and may suggest malignancy. At sonography, this tumor may appear as an ill-defined solid mass with posterior acoustic shadowing (43,44) or as a circumscribed mass with posterior acoustic enhancement (Figs 14, 15) (43,45). A hyperechoic rim is often identified (44). At mammography, granular cell tumors may appear as round well-demarcated masses, indistinct densities, or spiculated masses similar to carcinomas (Figs 14, 15). Microcalcifications are not a feature of granular cell tumors (43–45). At MR imaging, they have been described as a homogeneously enhancing mass on T1-weighted images obtained after intravenous administration of gadolinium and as having a hyperintense rim on T2-weighted images (46). In another report, a granular cell tumor showed slightly hypointense signal relative to normal breast tissue and irregular margins (47). Rapid peripheral enhancement, a finding suggestive of malignant growth, has also been observed on MR images (47,48).

A preoperative diagnosis is desirable because, despite their sometimes malignant appearance, granular cell tumors are almost always benign. Thus, they are treated with wide excision rather than with mastectomy.

Pseudoangiomatous Stromal Hyperplasia

Pseudoangiomatous stromal hyperplasia (PASH) is a benign, hormonally stimulated myofibroblastic proliferation that is usually found in premenopausal women, but it has been described in patients in the late 2nd decade of life (21,49). In addition, PASH can mimic fibroadenoma clinically and radiologically. Focal areas of histologic changes that are typical of PASH are commonly found in biopsy and mastectomy specimens, but tumors composed solely or predominantly of PASH are rare (50,51). Young patients generally present with a painless, firm, rubbery, movable mass, clinical findings similar to those of fibroadenoma (49,52). PASH tumors may grow rapidly in adolescents (53). The condition has been reported in males with gynecomastia (50).

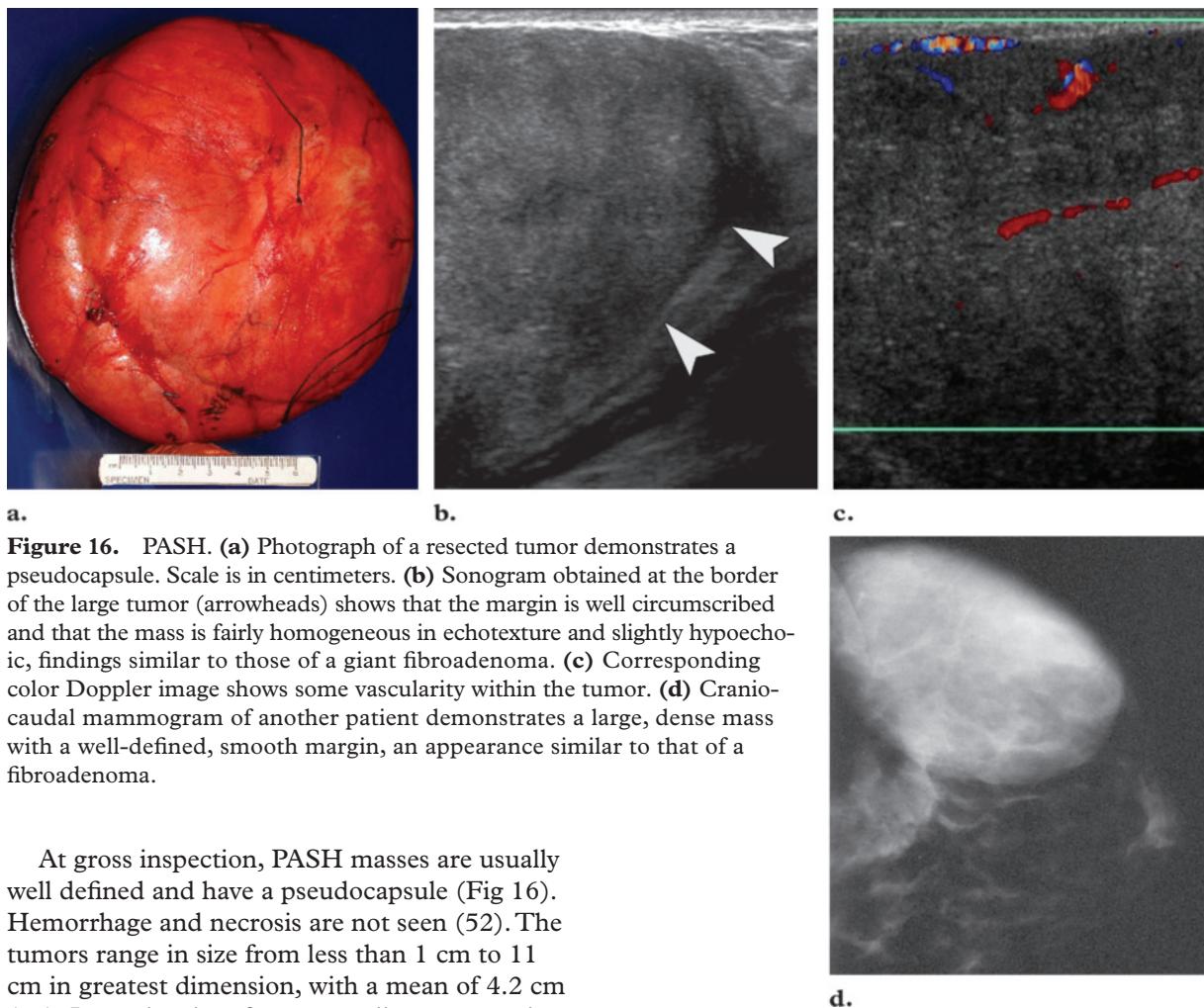


Figure 16. PASH. (a) Photograph of a resected tumor demonstrates a pseudocapsule. Scale is in centimeters. (b) Sonogram obtained at the border of the large tumor (arrowheads) shows that the margin is well circumscribed and that the mass is fairly homogeneous in echotexture and slightly hypoechoic, findings similar to those of a giant fibroadenoma. (c) Corresponding color Doppler image shows some vascularity within the tumor. (d) Cranio-caudal mammogram of another patient demonstrates a large, dense mass with a well-defined, smooth margin, an appearance similar to that of a fibroadenoma.

At gross inspection, PASH masses are usually well defined and have a pseudocapsule (Fig 16). Hemorrhage and necrosis are not seen (52). The tumors range in size from less than 1 cm to 11 cm in greatest dimension, with a mean of 4.2 cm (50). In a minority of cases, no discrete mass is found (51). The characteristic histologic feature of PASH is anastomosing slitlike spaces or channels lined with sparse, flat, myofibroblastic cells that resemble endothelial cells surrounded by a dense collagenous stroma (Fig 17). These anastomosing channels resemble vessels but contain no red blood cells.

The imaging features of PASH are nonspecific. The sonographic appearances are quite variable, but most PASH tumors appear as solid, circumscribed, hypoechoic, ovoid masses with their long axis parallel to the chest wall, findings similar to those of fibroadenomas (Figs 16, 17) (49,50,54–56). A significant proportion of these tumors lack circumscribed margins (50). Posterior acoustic phenomena are variable but usually absent. At mammography, a dense noncalcified mass is almost always detected, and in adult women, such a mass is often the presenting sign (Fig 16) (49,50). The margins of PASH tumors usually appear well or partially circum-

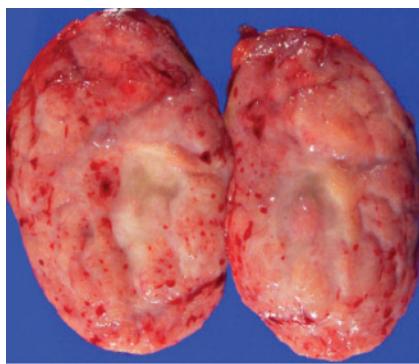
scribed on mammograms, but in rare cases, they are spiculated (54,56).

PASH tumors are generally treated with simple surgical excision because of their tendency to enlarge slowly (53,54,56). These tumors are benign, but a recurrence rate of up to 18% has been reported (49,51,52). Spontaneous regression has also been described (51). Lesions that are diagnosed with image-guided core needle biopsy but are not resected have shown clinical and radiologic stability (49,50). Surgery is indicated for symptomatic or growing masses (49).

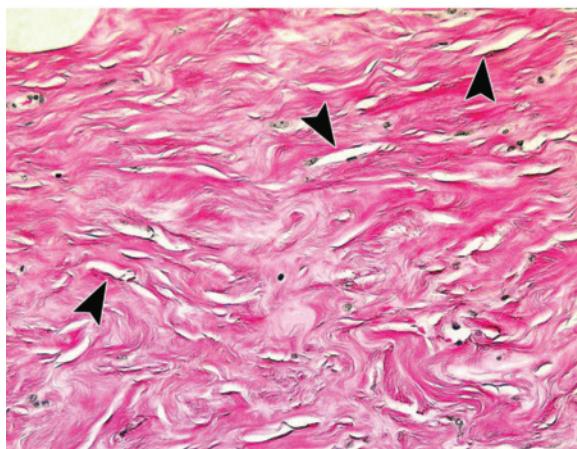
Benign Vascular Lesions

Vascular tumors that involve the breast in children are usually benign. Hemangiomas and vascular malformations may involve the chest wall and, in rare cases, the breast itself in children (5,12).

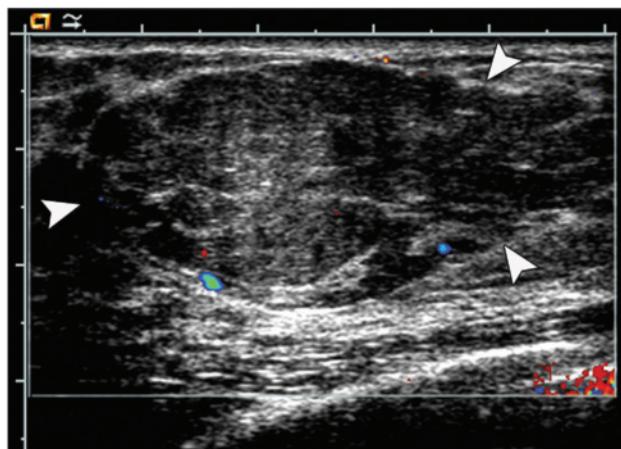
Infantile or capillary hemangioma is the most common neoplasm of infancy and usually manifests in the first few months of life as a growing mass and, if the overlying skin is involved, with



a.



b.



c.

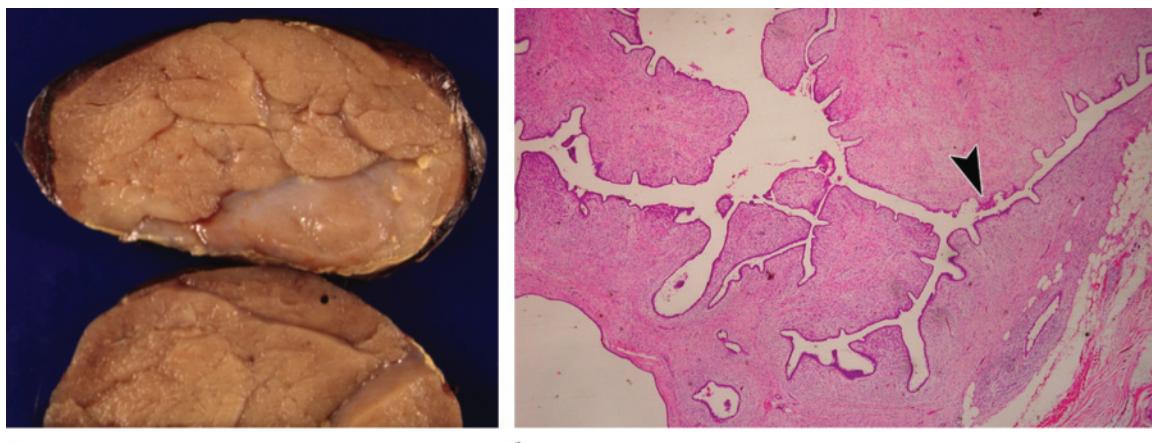
Figure 17. PASH. (a) Photograph of a sectioned gross specimen shows that the mass has a somewhat variegated surface. (b) Photomicrograph (original magnification, $\times 400$; H-E stain) shows slender spaces or clefts (arrowheads) that are lined by flat spindle cells and surrounded by a dense collagenous stroma. There are no red blood cells in the spaces. (c) Sonogram shows a well-circumscribed, predominantly hypoechoic mass (arrowheads) with its long axis parallel to the chest wall.

the characteristic appearance of a strawberry nevus. Infantile hemangiomas have a typical clinical course of initial growth until the child is 11–12 months old, followed by a slow involution that may last for years. About half of the patients have lesions elsewhere (12,57). Infantile hemangiomas are multilobular masses with histologic features similar to those of hemangiomas in other anatomic sites. In the proliferating phase, small vascular spaces are surrounded and even compressed by densely packed, plump endothelial cells arranged in lobules divided by fibrous septa. In the involuting phase, the endothelial cells become more spindle-shaped and the vascular spaces become more conspicuous. The stroma is collagenized and may be partially replaced by fat (58).

At sonography, a hemangioma usually manifests as a superficial, discrete parenchymal mass, an appearance that distinguishes this lesion from a vascular malformation. Hemangiomas may be hyperechoic or hypoechoic relative to surrounding soft tissue, or they may have mixed echotexture, with sharp or indistinct borders. Vascular channels may be seen at the periphery or center of the mass (57,59,60). At MR imaging, a dis-

crete mass is identified that is usually isointense relative to muscle with T1-weighted sequences and fairly homogeneously hyperintense with T2-weighted sequences. Hemangiomas typically appear lobulated with dark fibrous septa. Flow voids may be seen on spin-echo images, and MR angiograms may reveal high-flow vessels at the periphery or in the center of the mass. These masses usually enhance intensely. Involuting hemangiomas may have hyperintense foci on T1- and T2-weighted images due to fatty replacement of stroma, or they may have hypointense foci on T2-weighted images due to fibrosis (57,61).

Vascular malformations are abnormalities of morphogenesis and consist of dilated, endothelial-lined, vascular channels of varying size and histologic type. Those malformations that involve the chest wall may consist of dilated lymphatic channels (lymphangioma, cystic hygroma) or venous channels. In contrast to hemangioma, which is a high-flow neoplasm, vascular malformations have no associated parenchymal mass, tend to traverse fascial planes,



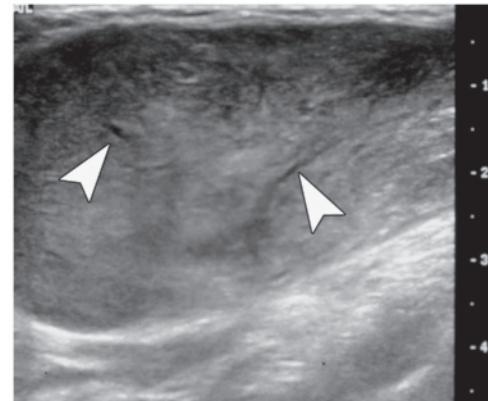
a. **b.**

Figure 18. Benign phyllodes tumor. **(a)** Photograph of a sectioned specimen from a patient with a benign phyllodes tumor demonstrates multiple clefts on the surface. **(b)** Photomicrograph (original magnification, $\times 40$; H-E stain) of a phyllodes tumor in another patient shows that the epithelial component forms elongated, branching leaflike structures (arrowhead) within the cellular stroma. **(c)** Sonogram of a benign phyllodes tumor in a 25-year-old woman reveals a fairly homogeneously hypoechoic, sharply circumscribed mass with posterior acoustic enhancement and anechoic linear clefts (arrowheads). These findings are similar to the appearance of a juvenile fibroadenoma.

and have slow or absent flow within their channels. At sonography, anechoic spaces of varying size are identified. In lymphatic malformations, echogenic debris from prior hemorrhage may be seen, but no flow is seen at color Doppler imaging. In venous malformations, slow flow or a shadowing phlebolith may be detected in the cystic spaces. At MR imaging, no discrete mass is identified. Cystic spaces of T2 hyperintensity with dark intervening septa are noted. In lymphatic malformations, fluid-debris levels from prior hemorrhage may be observed. In venous malformations, these cystic spaces may enhance with intravenous administration of contrast material, whereas in lymphatic malformations, there may be no contrast enhancement or enhancement of only the walls and septa (57,61).

Intramammary Lymph Node

Intramammary lymph nodes are most often found in the upper outer quadrant of the breast. The nodes are readily identified because of their characteristic sonographic appearance as a well-delineated ovoid structure with a hilar notch or central echogenic fat.



c.

Malignant Masses

Phyllodes Tumor

Phyllodes tumor, or cystosarcoma phyllodes, is a rare fibroepithelial neoplasm that accounts for only 1% of breast lesions in children and adolescents, but it is the most common primary mammary malignancy in this age group (6,11,12). Its peak age of prevalence is in the 4th decade of life, but about 5% of phyllodes tumors occur in girls younger than 20 years of age. Phyllodes tumor shares many clinical, pathologic, and imaging features with juvenile fibroadenoma. Phyllodes tumors demonstrate a wide spectrum of biologic behavior, and some have the potential for invasive growth, recurrence, or metastasis in rare cases (4,11). Most phyllodes tumors in adolescents are histologically benign.

Clinical Presentation.—Most patients present with a painless, rapidly growing, movable, rubbery mass, findings that simulate those of juvenile fibroadenoma (11,62). Most phyllodes tumors in children are larger than 6 cm at presentation (4).

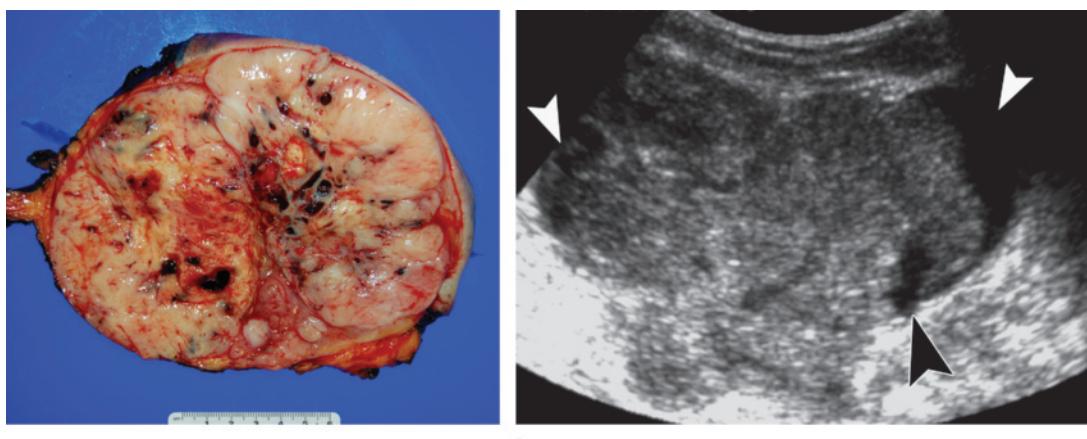
**a.****b.**

Figure 19. Malignant phyllodes tumor. **(a)** Photograph of the sectioned tumor specimen reveals a somewhat lobulated surface with small foci of hemorrhage, findings that suggest malignancy. Scale is in centimeters. **(b)** Sonogram of a different, 22-year-old patient reveals a partially circumscribed hypoechoic mass with posterior sound enhancement and anechoic foci (arrowheads), some of which are round and others are curvilinear.

If the tumor is very large, the overlying skin may be shiny or tense and dilated veins may be seen, as with juvenile fibroadenoma (10).

Pathologic Features.—Phyllodes tumors vary greatly in size, ranging from 1 to 20 cm (63), but most are 8–10 cm (10). They are generally soft, fleshy masses that may contain clefts that produce a bosselated surface (Fig 18). Alternatively, the surface may be homogeneously smooth. The findings of foci of hemorrhage or necrosis suggest malignancy (Fig 19).

Histologic Features.—The histologic hallmarks of phyllodes tumors are stromal cellularity and mitotic activity. Dispersed within the cellular stroma are branching epithelial-lined spaces or clefts that create an appearance similar to that seen in cellular fibroadenoma (Fig 18) (11). Mitoses are seen throughout the stroma, rather than being confined to the region around the epithelial-lined clefts as in cellular fibroadenoma.

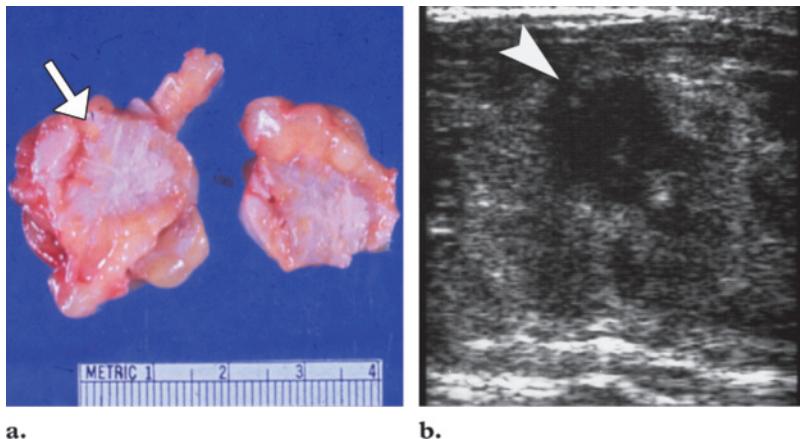
Phyllodes tumors are classified on the basis of histologic appearance into one of three categories that correspond to clinical outcome: benign, intermediate, and malignant. No single feature allows differentiation of phyllodes tumors with indolent behavior from those with the potential to metastasize. However, prognostically favorable features include a size less than 4 cm, pushing (vs infiltrative) borders, lack of necrosis, and fewer than three mitoses per high power field (4,64). The most unfavorable histologic feature is high-grade sarcomatous stromal overgrowth (4,11).

Mitotic rate is the single most important feature for predicting metastatic behavior (65).

Imaging Appearance.—The sonographic appearance of phyllodes tumor is similar to that of fibroadenoma. A well-circumscribed, round, ovoid, or macrolobulated hypoechoic mass is identified, often with posterior acoustic enhancement (Fig 18) (63,66,67). The internal echotexture is frequently heterogeneous, an appearance that is less commonly observed in fibroadenoma. Anechoic cysts or clefts, findings that reflect the gross pathologic appearance of phyllodes tumors, are very suggestive of this diagnosis but are not pathognomonic as they can also be seen in juvenile fibroadenoma (Figs 18, 19) (3,28,68). The imaging findings of benign and malignant tumors overlap significantly, and tissue sampling of suspect lesions is necessary for definitive diagnosis (63,67).

At mammography, a phyllodes tumor appears as a nonspecific, large, dense mass without calcifications (63,67,69). At MR imaging, phyllodes tumor has been described as a well-circumscribed, round or lobulated mass similar to a fibroadenoma. A minority of both phyllodes tumors and fibroadenomas demonstrate suspicious contrast material enhancement patterns (31). Phyllodes tumors are hypo- to isointense relative to breast tissue on T1-weighted images, and they have variable signal intensity on T2-weighted images (31,70,71). Phyllodes tumors are more likely

Figure 20. Invasive ductal carcinoma in a 22-year-old woman. (a) Photograph of the resected specimen shows a gritty white tumor with irregular margins (arrow) within surrounding fat. Scale is in centimeters. (b) Sonogram reveals a hypoechoic mass (arrowhead) with irregular borders and an anti-parallel growth pattern.



a.

b.

than fibroadenomas to have heterogeneous internal signal intensity with nonenhancing internal septations and peritumoral high signal intensity on T2-weighted images, but the appearances of the two tumors overlap, such that they cannot be differentiated on the basis of MR imaging (31).

Yabuuchi et al (72) compared 30 benign, intermediate, and malignant phyllodes tumors and found that tumors that were hypo- to isointense relative to normal breast parenchyma on T2-weighted images or that had low apparent diffusion coefficient signal on diffusion-weighted images were more likely to demonstrate the unfavorable histologic feature of stromal hypercellularity. The finding of irregular cyst walls corresponded to necrosis and was not seen in any benign tumor. T1 hyperintensity was found to correspond to hemorrhagic infarction and also suggested malignancy (72).

Treatment and Prognosis.—Most often, the prognosis for phyllodes tumor is favorable after complete surgical excision alone, but some of these tumors have the potential to recur or even metastasize. Phyllodes tumors with infiltrative borders or positive surgical margins are the most likely to recur (65). Both histologically benign and malignant tumors may recur (65). The recurrence rate in adolescents is about 10% and lower than in adults (65). Local recurrence does not alter the prognosis. In the pediatric population, 5%–24% of phyllodes tumors are histopathologically judged to be malignant (62,65,69). Metastases are rare in adolescents and spread hematogenously, most frequently to the lungs (62,65). Local disease and recurrence are treated with complete excision. Patients with malignant tumors should be closely monitored (62).

Carcinoma

Breast cancer is exceedingly rare in children, accounting for less than 1% of breast lesions (12). The age-adjusted incidence of carcinoma in 2004 was 0.03 cases per 100,000 in patients younger than 20 years of age (73). Among patients older than 25 years of age, the prevalence increases sharply (11). Boys are rarely affected (5,74,75).

Secretory (juvenile) carcinoma is the main subtype that occurs in children and adolescents and carries a favorable prognosis (6,12,76). Breast cancer in young patients may be related to inherited family cancer syndromes, particularly *BRCA1* and *BRCA2* gene mutations (11). In addition, breast carcinoma is known to occur as a secondary malignancy in patients who were treated for childhood cancer and to manifest at a younger age in these patients than in the general population (8,10,11).

Patients present clinically with a painless, firm mass separate from the breast bud (74,76). Secretory carcinomas are less than 3 cm in diameter (11,12) and are circumscribed with a pseudocapsule (76). Sectioned specimens reveal a grayish white tumor that is separated into lobules by prominent fibrous bands (11). At histologic examination, tumor nodules have a multicystic appearance because of collections of extracellular secretions of eosinophilic mucin that stains positive with periodic acid Schiff and of mucopolysaccharide-containing materials (74,75). Diffuse intracellular secretions and vacuolization are also noted (4,11).

Other less frequent histologic types that have been described in children include medullary, inflammatory (76), infiltrating lobular and ductal, and anaplastic (11) carcinoma. These subtypes are much more aggressive, and advanced disease carries a poor prognosis in children, equal to that in adults (76).

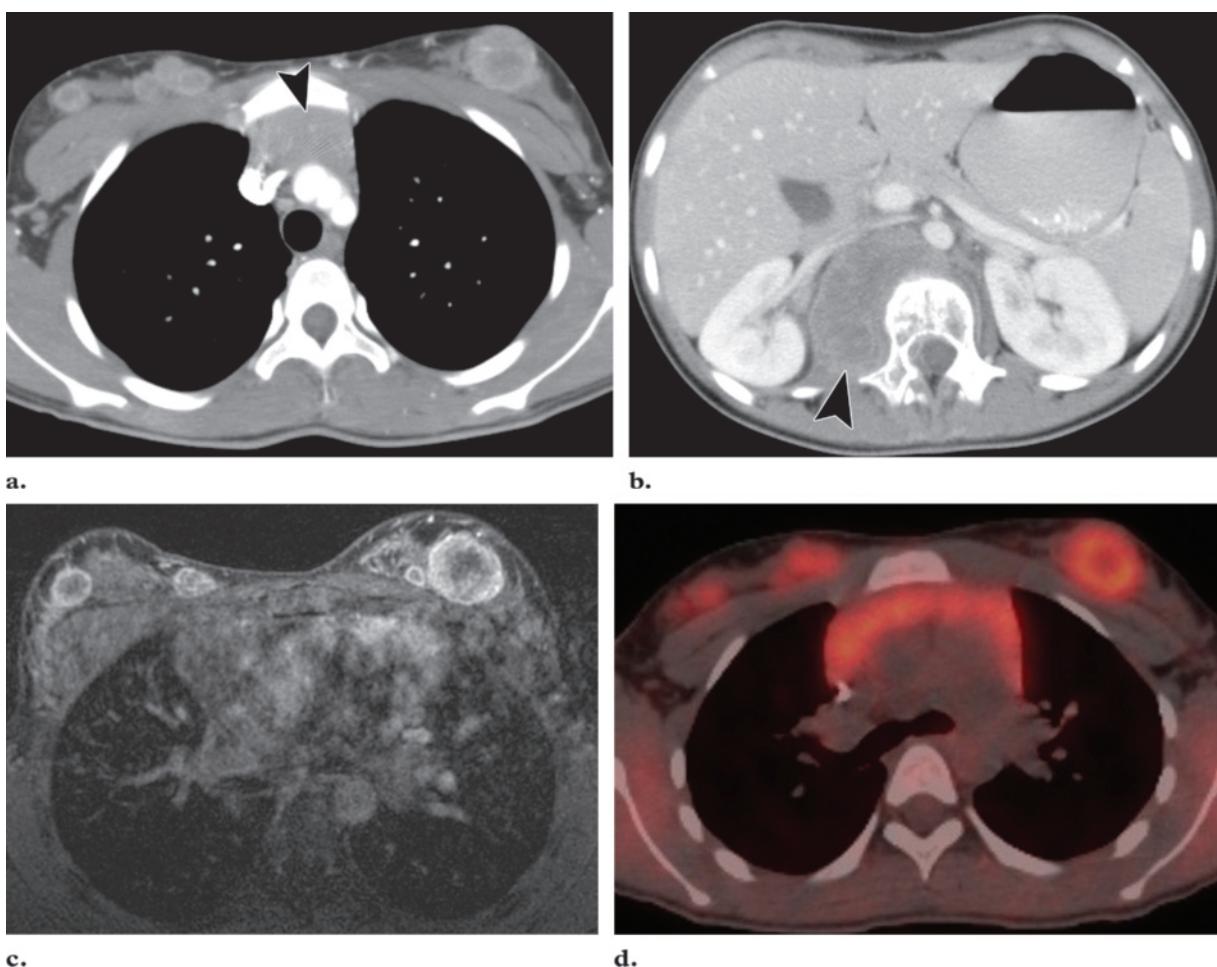


Figure 21. Metastatic alveolar rhabdomyosarcoma in a 14-year-old girl. **(a)** Axial CT scan obtained after intravenous administration of iodinated contrast material demonstrates bilateral rim-enhancing breast masses. In addition, an anterior mediastinal mass (arrowhead) is noted. **(b)** CT scan obtained at a lower level than **a** reveals a right paraspinous mass (arrowhead) with extension into the spinal canal and deviation of the spinal cord to the left. **(c)** T1-weighted MR image obtained after intravenous administration of gadolinium contrast material again shows the bilateral rim-enhancing breast lesions. **(d)** Axial fused positron emission tomographic-CT image obtained after intravenous administration of fluorine 18 fluorodeoxyglucose shows foci of abnormal metabolism in both breasts and the anterior mediastinum.

Teaching Point

The sonographic characteristics of carcinoma are variable and nonspecific. At sonography, carcinoma typically appears as a hypoechoic mass with irregular margins, inhomogeneous internal echoes, a long axis perpendicular to the chest wall, and variable posterior acoustic shadowing; these features are similar to those seen in an adult (Fig 20) (3,77).

Metastatic Disease and Hematologic Malignancy

The most prevalent malignant tumors of the breast in children and adolescents are metastatic or disseminated tumors, most commonly rhabdomyosarcoma, neuroblastoma, and hematolym-

phoid malignancies (6,8,11,12,78). Breast metastases occur much more often in girls but can develop in boys (79). Rhabdomyosarcoma is one of the most common tumors to metastasize to the breast in children, occurring in 6% of patients with rhabdomyosarcoma (80), particularly those with the alveolar subtype and primary tumor in the extremity (7,80–82). Alveolar rhabdomyosarcoma may manifest with disseminated disease (Fig 21) and diffuse lymphadenopathy, a clinical presentation that suggests lymphoproliferative disorder. Rhabdomyosarcoma rarely primarily occurs in the breast (8,11).

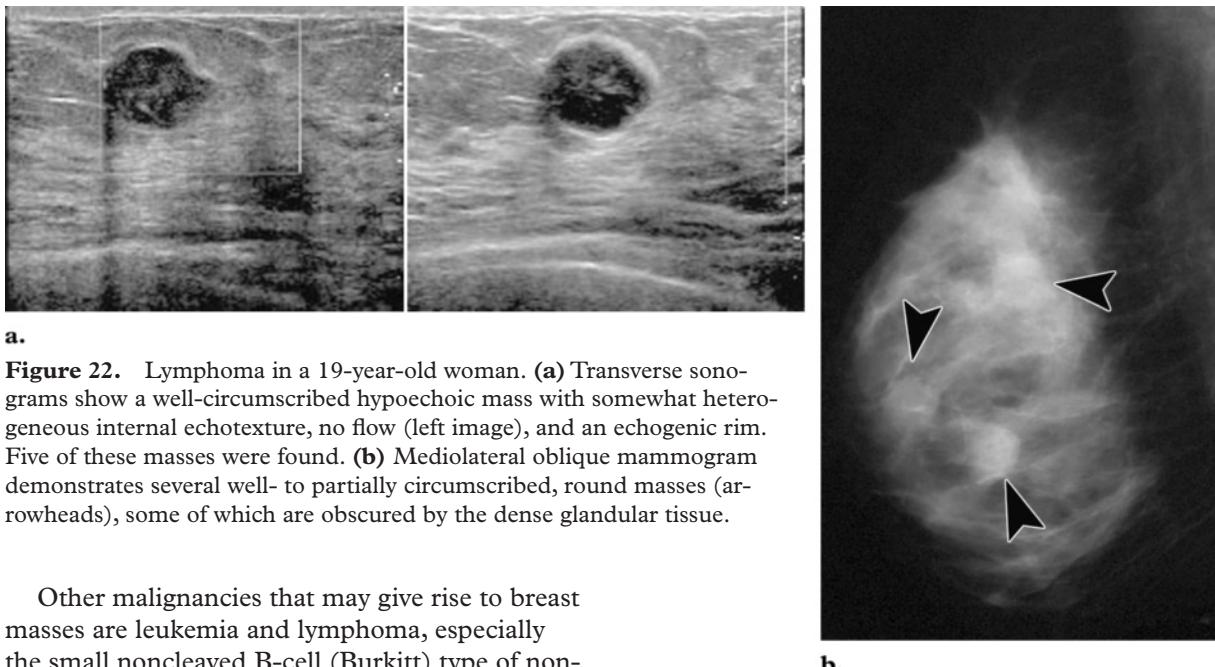


Figure 22. Lymphoma in a 19-year-old woman. **(a)** Transverse sonograms show a well-circumscribed hypoechoic mass with somewhat heterogeneous internal echotexture, no flow (left image), and an echogenic rim. Five of these masses were found. **(b)** Mediolateral oblique mammogram demonstrates several well- to partially circumscribed, round masses (arrowheads), some of which are obscured by the dense glandular tissue.

Other malignancies that may give rise to breast masses are leukemia and lymphoma, especially the small noncleaved B-cell (Burkitt) type of non-Hodgkin lymphoma (11). An increased number of such tumors develop during pregnancy and lactation (11,79). Diffuse adenopathy may suggest the diagnosis. In rare cases, lymphoproliferative disease, usually non-Hodgkin lymphoma, may involve the breast primarily (8,12,82). Other primary tumors that may metastasize to the breast include Ewing sarcoma, primitive neuroectodermal tumors, malignant melanoma, and renal cell carcinoma (11,12,78).

Metastases are frequently multiple and bilateral (Fig 21) (11), but they are more commonly large, solitary tumors (7,78,81). They clinically manifest as well-margined, movable, rapidly enlarging masses that may be painful (79,82,83).

The sonographic appearances of breast metastases are variable, but most demonstrate lobulated or irregular margins and heterogeneous, hypoechoic internal echotexture with hyperechoic foci (14,78,82). Posterior acoustic shadowing or lack of enhancement is typically seen (78). Leukemia and lymphoma usually appear as well- or ill-defined hypoechoic solid masses (Fig 22) (82). Metastatic neuroblastoma has been described as multiple hypoechoic masses (84).

Mammography demonstrates nodular, diffuse increased density (78) or circumscribed to partially circumscribed, dense masses without calcifications (Fig 22) (82). Diffuse edema or axillary adenopathy may be seen with leukemia and lym-

phoma (82). CT is typically not used to evaluate breast masses in children, but breast metastases may be first noted on surveillance CT scans in children with known primary cancer. Metastases may manifest as well- or ill-defined masses with swelling of the breast tissue (Fig 21). Adenopathy and chest wall invasion may be observed, particularly with lymphoma (17). MR imaging features include T2 hyperintensity and rapid ring-enhancement of the lesions (Fig 21) (82,83).

In a patient with known malignancy, any enlarging breast mass, even one with a reassuring sonographic appearance, should be investigated promptly (6,9), initially with fine-needle aspiration or core needle biopsy (7,78). Breast metastases or localizations are usually associated with disease elsewhere, and the prognosis is generally poor (8,85).

Angiosarcoma

Angiosarcoma is a rare tumor of the breast in adult women, but the low-grade form has been observed in children in the 2nd decade of life (4,86). Angiosarcoma has been reported in patients previously treated for breast cancer and Hodgkin disease (87). Most patients present with a painless mass (88). A bluish or reddish discoloration of the skin may be seen (87,88). As with phyllodes tumor, angiosarcomas are histologically graded. Low-grade tumors demonstrate a sinu-

soidal pattern with anastomosing vascular channels, whereas high-grade tumors demonstrate additional findings of papillary formations, solid and spindle cell foci, mitoses, so-called blood lakes, and necrosis (86).

At mammography, one or more noncalcified masses or focal asymmetry may be seen (87,88). Up to one-third of angiosarcomas are mammographically occult (88). The sonographic features of angiosarcoma are variable. About one-half are hypoechoic, but they may be hyperechoic or mixed (87,88). Posterior acoustic shadowing is not a feature, and a minority show posterior enhancement. Margins are typically circumscribed, but they may be lobulated or indistinct. Diffuse abnormal mixed echogenicity without a discrete mass may be observed. Angiosarcomas are hypervascular on color Doppler images (87). At MR imaging, angiosarcomas manifest as large, lobular, heterogeneous masses that are hypointense with T1-weighted sequences and hyperintense with T2-weighted sequences, with rapid intense contrast enhancement and washout typical of a malignant tumor (87–89). Blood-containing cystic spaces and feeding vessels have been observed at sonography and MR imaging (88–90).

Conclusions

The histologic spectrum of breast masses in children and adolescents is quite different from that in adults and overwhelmingly consists of benign entities. Imaging findings are very helpful in the selection of patients for diagnostic interventions. Knowledge of the clinical, pathologic, and imaging features allows the radiologist to guide appropriate management of these patients.

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Breast Masses in Children and Adolescents: Radiologic-Pathologic Correlation

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At puberty, two-thirds to three-fourths of boys have some degree of breast enlargement, which peaks at age 13–14 years and usually resolves within 2 years (10,16).

Page 913

Fibroadenoma is a benign fibroepithelial tumor and is the most common breast mass in girls younger than 20 years of age, accounting for well over half of tumors in surgical series (6,11,21).

Page 918

The histopathologic and imaging features of the cellular subtype of fibroadenoma and phyllodes tumor overlap considerably, such that they are indistinguishable at imaging.

Page 921

Although juvenile papillomatosis is a benign condition, it is considered a marker for familial breast cancer. Patients with this diagnosis have a high rate of positive family history of breast cancer (33%–58% of cases). About 5%–15% of patients have concurrent breast cancer (38,39).

Page 927

The sonographic characteristics of carcinoma are variable and nonspecific. At sonography, carcinoma typically appears as a hypoechoic mass with irregular margins, inhomogeneous internal echoes, a long axis perpendicular to the chest wall, and variable posterior acoustic shadowing; these features are similar to those seen in an adult (Fig 20) (3,77).