Benign Renal and Adrenal Tumors

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Benign Renal Tumors

Introduction

Benign tumors of the kidney and adrenal constitute a heterogeneous group with different clinical and radiological implications depending on the organ of origin.

In the kidney, benign neoplasms are rare relative to malignant ones. However, in some cases such as angiomyolipoma and multilocular cystic nephroma, an imaging diagnosis is possible.

In the adrenal, benign tumors are the majority and a daily challenge in clinical practice. Again, imaging is capable in many cases to achieve a definitive diagnosis differentiating them from malignancy, particularly metastasis, both in the kidney and adrenal knowledge of the underlying pathology is helpful in understanding the key imaging findings.

Angiomyolipoma

Definition

Angiomyolipoma is a neoplasm consisting of three tissue elements: blood vessels, smooth muscle and fat, hence the name ***angiomyolipoma*** [1].

Pathology

On gross examination, most angiomyolipomas are smoothly rounded or ovoid and circumscribed but lack a tumor capsule (Fig. 1A). The size ranges from less than a centimeter to over 20 cm. The tumor compresses and distorts the renal parenchyma and collecting system but does not invade it. It is not uncommon that a large portion of the mass projects into the perirenal space with only a small intrarenal component. Intratumoral hemorrhage and necrosis are common.

Although every angiomyolipoma is composed of all three cellular constituents, their relative amounts vary tremendously. Those composed primarily of fat will be yellow, while those composed primarily of muscle will be tan or gray.

Small angiomyolipomas are a common finding in the kidney at autopsy or as an incidental finding on computed tomography, ultrasonography, and magnetic resonance imaging. These small angiomyolipoma usually are clinically silent, and do not distort the kidney.

Histologically aggregates of abnormal thick-walled vessels are admixed with varying amounts of adipose tissue and smooth muscle. Fat cells vary considerably in size but otherwise resemble normal adipose tissue. The smooth muscle component is pleomorphic, but mitotic figures are uncommon. The vascular component is the most characteristic feature of the angiomyolipoma (Fig. 1B). The smaller arteries are devoid of elastica. Smooth muscle forms a collar about the periphery of a vessel often exhibiting a perpendicular orientation to the vessel lumen. This abnormal morphology may result in the aneurysms.

Because of the frequency of hemorrhage, perirenal extension and pleomorphism of the myomatous elements, these tumors may lead to an erroneous pathologic diagnosis, usually liposarcoma, leiomyosarcoma, or spindle cell carcinoma. Although there have been case reports of angiomyolipomas engulfing adjacent lymph nodes and extending into the inferior vena cava, distant metastases are extremely rare.

Clinical Setting

Most angiolipoma occur as an isolated finding and not associated with tuberous sclerosis. In the majority of these cases, the angiomyolipoma is clinically silent. Discovery often occurs during the radiological evaluation of the abdomen for unrelated symptoms. Less commonly, patients may present with pain, hematuria and or a mass. Hemorrhage within or around the tumor may produce flank pain, hypotension, and hematuria. Angiomyolipoma is discovered in women more often than in men. Most symptomatic angiomyolipomas occur as, a solitary renal mass in otherwise normal individuals. Lesions larger than 4 cm in diameter may hemorrhage more frequently than smaller tumors. Approximately 80 percent of patients with tuberous sclerosis have angiomyolipoma which are usually multiple and bilateral.

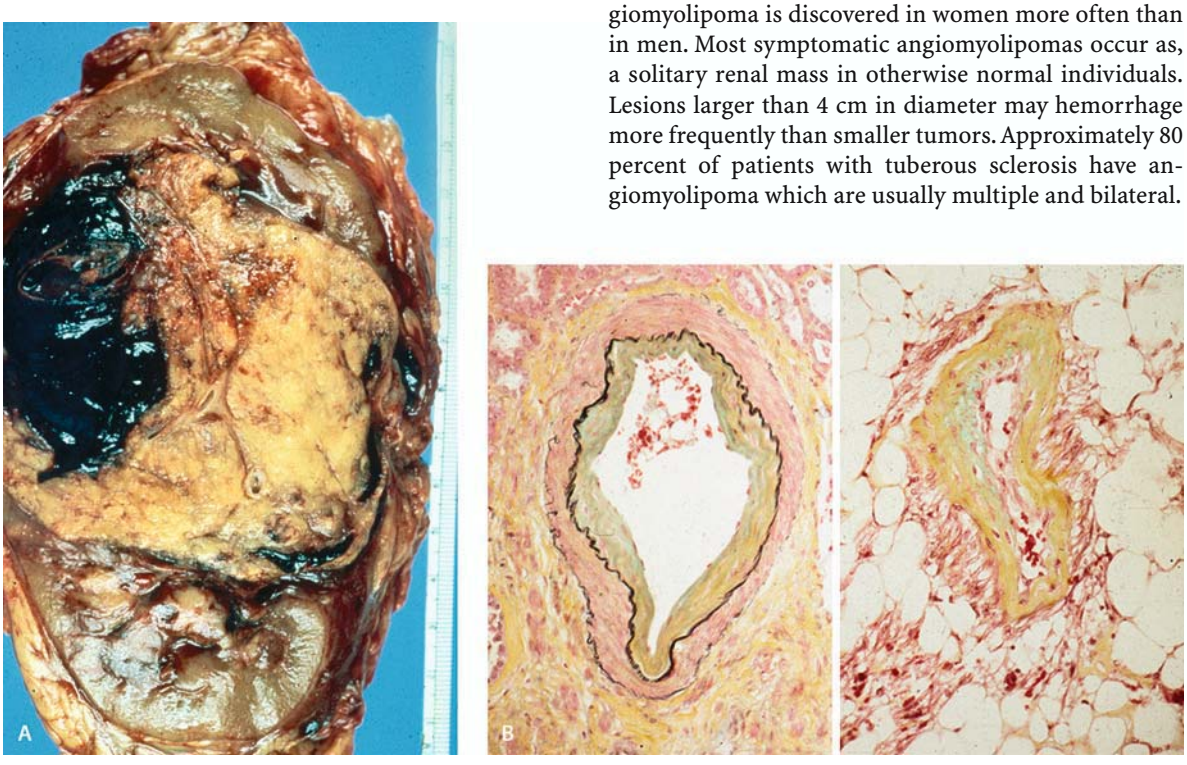


Fig. 1A, B. Angiomyolipoma pathology. **A** Gross specimen. The tumor measures 9 cm and compresses the kidney. The yellow area represents intratumoral fat. A large area of hemorrhage is conspicuous. **B** Normal vessel *left*, angiomyolipoma *right*. The vessel is devoid of elastica. The smooth muscle forms a collar about the periphery of the vessel exhibiting a perpendicular orientation to the vessel lumen

Radiologic Findings

■ **Overview.** The presence of a fatty renal mass is *very suggestive* of angiomyolipoma. The best radiologic techniques to detect this fat are computed tomography and magnetic resonance imaging [2, 3]. Unfortunately this finding is not specific, as renal cell carcinoma *very rarely* will also contain fat.

■ **Excretory Urography.** In sporadic cases, angiomyolipoma causes a unilateral, unifocal renal mass. When associated with tuberous sclerosis, there are typically multiple, bilateral masses. Rarely the angiomyolipoma will demonstrate a radiolucency within the mass when a large component of fat is present. This lucency is significant only on films obtained before administration of contrast material, since any radiolucency seen within a tumor following contrast material more likely represents necrosis or diminished perfusion rather than fat. This fat-related radiolucency on the KUB is an infrequent radiographic observation, being reported in less than 10 per cent of patients. Other urographic features of angiomyolipoma are related to the mass effect of the lesion.

■ **Computed Tomography.** Fat in a renal tumor is a finding that is very suggestive of angiomyolipoma (Fig. 2). As the angiomyolipoma may be largely extrarenal, the fatty component may be easily confused with a primary retroperitoneal tumor such as liposarcoma. Computed tomography is extremely valuable in detecting the nephrographic defect that indicates the true renal origin of the mass. Sagittal and coronal images are especially useful for tumors, which arise, in the upper or lower pole. Intermixed with the fat are muscle and blood vessels, with attenuation values similar to those of renal parenchyma. Large aneurysms can occasionally be recognized as foci of intense enhancement similar to the renal artery. Recent hemorrhage can be recognized by higher attenuation values. Computed tomography is also of value in documenting perinephric blood, which may be massive, and life threatening. It there is a small fatty component; pixel mapping may be very helpful in establishing the diagnosis (Fig. 3). If the fatty component is not detectable, the computed tomographic findings are those of other solid tumors (e.g. renal cell carcinoma). Calcification is uncommon in angiomyolipoma.

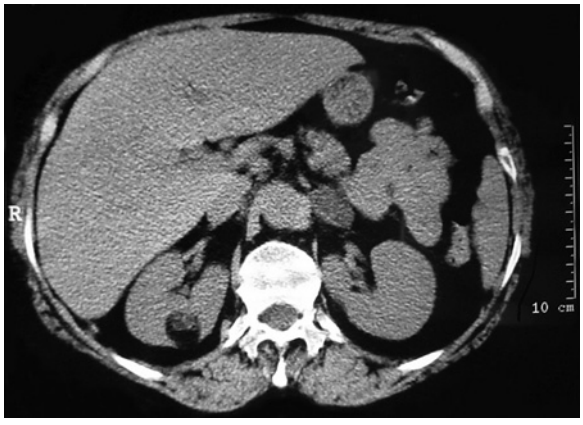
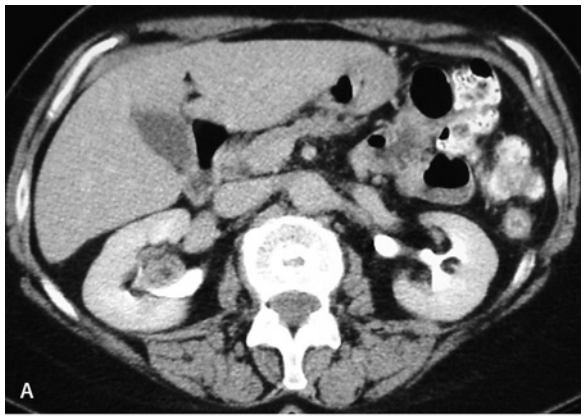


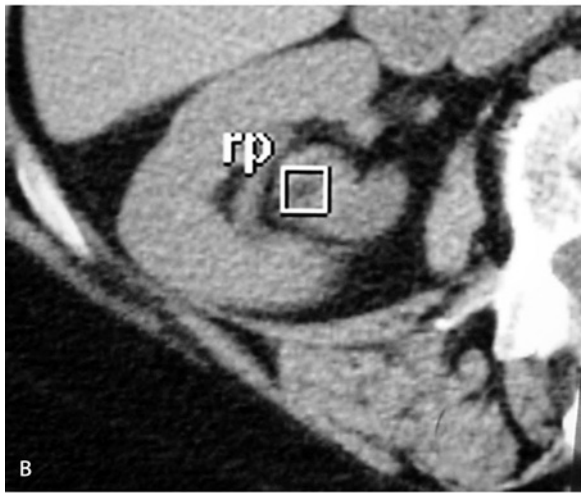
Fig. 2. Angiomyolipoma, CT findings. Computed tomogram, unenhanced. There is a 1.5 cm fatty mass with a density similar to adjacent retroperitoneal fat. The ventral portion of the tumor is of tissue density and probably represents hemorrhage or myomatous elements

■ **Ultrasonography.** The typical angiomyolipoma has an echogenicity similar to that of perirenal or renal sinus fat (Fig. 4). As a result of the hyperechogenicity, small angiomyolipomas may be quite conspicuous. It is to be emphasized, however that this finding of an echogenic renal mass is not specific to angiomyolipoma, since adenocarcinoma may yield a similar image When the fatty component is minimal, or obscured by hemorrhage, the angiomyolipoma is typically less echogenic than the renal sinus fat and may be isoechoic with the renal parenchyma. Especially if small, these nonfatty angiomyolipomas are more difficult to detect and impossible to differentiate from other renal tumors. Most of the angiomyolipoma may be extrarenal and simulate a retroperitoneal soft tissue origin rather than a renal origin.

■ **Magnetic Resonance Imaging.** As with CT, it is the identification of the fatty component on MR that enables confident diagnosis. The fatty components of angiomyolipoma have a similar signal to that of renal sinus and retroperitoneal fat. Fat-suppressed images are extremely helpful and demonstrate signal loss within the mass (Fig. 5). Areas if muscle, blood vessel and hemorrhage will have a less characteristic signal. If fat cannot be identified with certainty, a presumptive diagnosis of angiomyolipoma cannot be made. In exophytic tumors, especially those arising from the upper or lower pole, coronal or sagittal images may be of value in differentiating an angiomyolipoma from a primary retroperitoneal tumor. As the fat within an angiomyolipoma is adipose tissue and not intracellular lipid, chemical shift imaging is not definitive in the MR diagnosis of angiomyolipoma.

■ **Angiography.** Typically, the angiomyolipoma is hypervascular. Suggestive features include one dominant feeding artery with a circumferential arrangement of vessels around the tumor and multiple aneurysms. Unlike renal cell carcinoma, arteriovenous shunting is typically absent. Since these angiographic features are nonspecific and may be seen in renal adenocarcinoma, angiography is not used for diagnosis. The primary utility of angiography is in preoperative embolization, and in those cases with active tumoral bleeding.





	165	166	167	168	169	170	171	172	173	174	175
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316	-6	1	-26	-3	-11	-50	-33	-24	-17	-10	15
317	-14	-11	-31	-35	-34	-43	-19	-30	-38	-7	45
318	-23	-13	-18	-37	-58	-50	-31	-33	-8	35	41
319	-15	-10	-7	-35	-43	-8	3	18	22	20	9
320	11	2	-26	-1	19	11	-12	17	26	21	47
321	4	9	-10	9	10	-9	-31	2	34	47	49
C	6	15	10	20	35	18	6	26	23	9	27

Fig. 3A–C. Value of pixel mapping in angiomyolipoma with a small amount of fat. **A** Contrast-enhanced computed tomogram. There is a well-defined mass compressing the renal pelvis. Although the mass is heterogeneous, fat is not clearly apparent. **B** Computed tomogram, unenhanced. Individual pixels within the square will be displayed. **C** Quantitative values for each pixel. Note that the center of the mass has values indicative of fat (–58, –50 and –43 Hounsfield units). Case courtesy Brent Wagner, M.D. Reading, PA

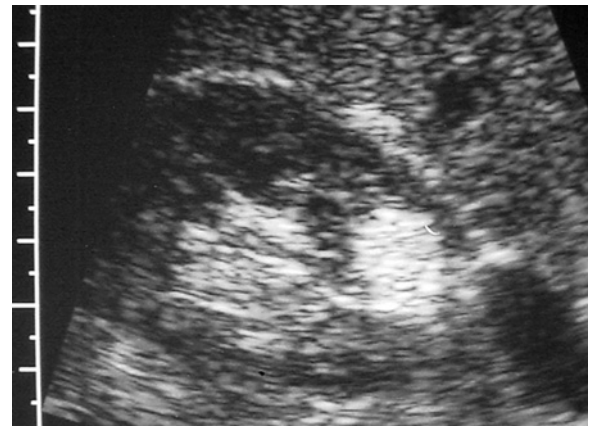


Fig. 4. Angiomyolipoma, ultrasound features. Longitudinal sonogram through the right kidney. The hyperechoic mass is very suggestive, although not diagnostic for angiomyolipoma

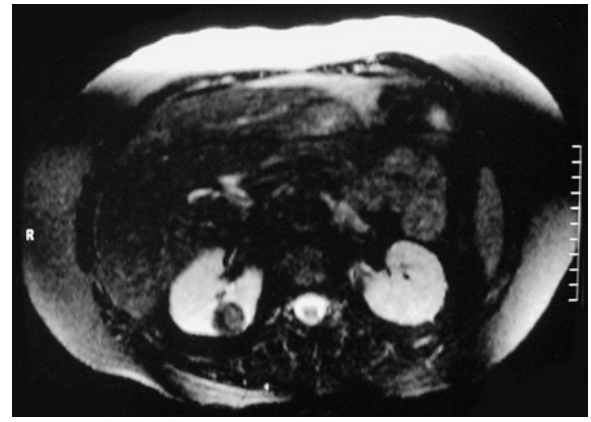


Fig. 5. Angiomyolipoma, MR findings. T2 weighted, fat suppressed scan. There is a 2 cm angiomyolipoma in the right kidney with the same signal of that of adjacent retroperitoneal fat which is black

Multilocular Cystic Nephroma

Definition

Multilocular cystic nephroma is an uncommon, nonfamilial renal neoplasm composed of a well circumscribed encapsulated mass that contains multiple, noncommunicating fluid-filled locules [2, 4]. It is usually although not invariably benign.

Pathology

On gross examination, the multilocular cystic nephroma is well circumscribed by a thick capsule. Typically the tumor compresses the adjacent renal parenchyma.

These tumors can vary from several centimeters to greater than 30 cm. The average size in one large series was 10 cm [5]. Extension of the mass through the renal capsule into the perinephric space is frequent.

On cut sections, the individual locules are variable in size, contain nonhemorrhagic fluid and do not communicate with each other (Fig. 6A) Most locules vary in size from several millimeters to 2.5 cm. Occasionally, however, an individual locule may measure 8 cm in diameter. The locules are separated by thin, translucent septa. Hemorrhage and necrosis are uncommon. Occasionally a portion of the tumor will herniate into the renal pelvis and may obstruct portions of the collecting system.

Microscopically multilocular cystic nephroma is well circumcised by a dense fibrous capsule composed of collagen. The cysts are lined by flattened or cuboidal epithelial cells. In many cases this epithelium projects into the lumen of the locule to create "hob-nail" or "teardrop" appearance (Fig. 6B). The septal stroma is composed of small spindle cells with sparse cytoplasm.

Very rarely the multilocular cystic nephroma will have a stroma that is sarcomatous. Metastases may be histologically similar to the stromal component of the renal lesion. The epithelial elements are not present in the metastases.

Clinical Setting

Multilocular cystic nephroma has a biphasic age and sex distribution: One peak in prevalence occurs in infants and young children with a second peak in middle-aged adults. In children, boys are more commonly affected than girls. In the adult, the multilocular cystic nephroma is more common in women. In infants this lesion is usually discovered as a palpable mass. In the adult most present with pain, a palpable mass or with hematuria (especially those with pelvic herniation). Occasionally the multilocular cystic nephroma is discovered incidentally when imaging is being performed for unrelated symptoms.

Radiologic Findings

■ **Overview.** The multiloculated appearance is readily identifiable on CT, ultrasound, or MRI (Fig. 7). Although the findings of pelvic herniation and lack of hemorrhage and venous invasion favor its diagnosis, the multilocular cystic nephroma is indistinguishable from cystic renal cell in the adult and cystic Wilms tumor in the child. The ultimate differentiation is microscopic.

■ **Excretory Urography.** The typical case demonstrates a large renal mass that distorts the renal contour and the collecting system. Curvilinear or punctate calcification may be detectable in the walls of the locules. Faint linear opacification within the mass may be detectable because of the contrast in the vascularity of the septa. The interface between the lesion and the adjacent renal tissue is sharply defined confirming the renal origin. Herniation of one or more locules into the pelvis presents as a well-defined, nonopaque filling defect. Obstruction of the collecting system may occur. Rarely there is nonvisualization of the collecting system secondary to extensive pelvic herniation.

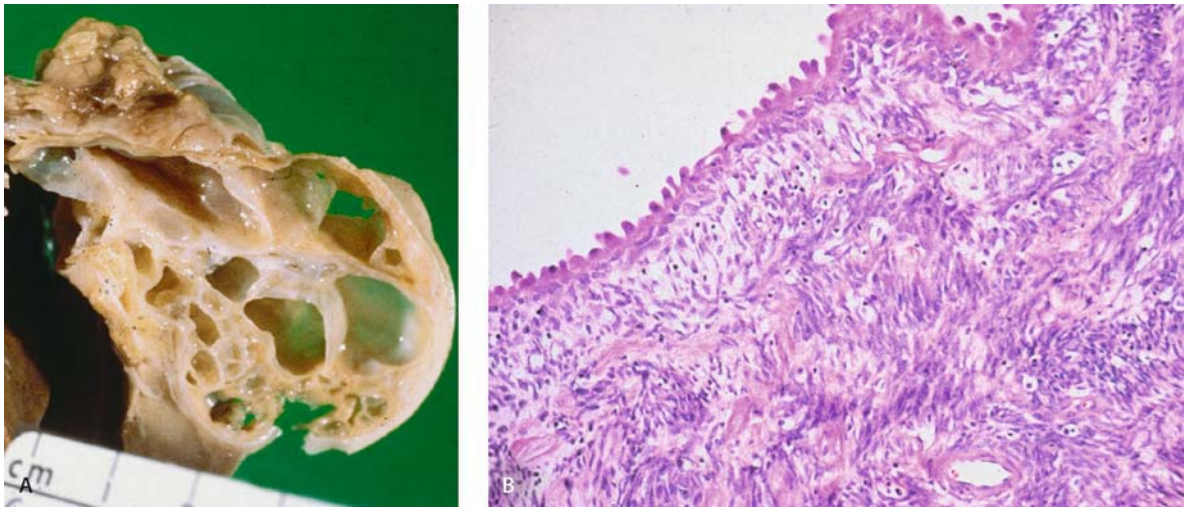


Fig. 6A, B. Multilocular cystic nephroma, pathology. **A** Cut gross specimen. The individual locules vary in size and do not communicate with one another. **B** Photomicrograph. The epithelial cells project into the lumen of the locule ("hob-nail" appearance). The stroma is composed of small spindle cells with sparse cytoplasm

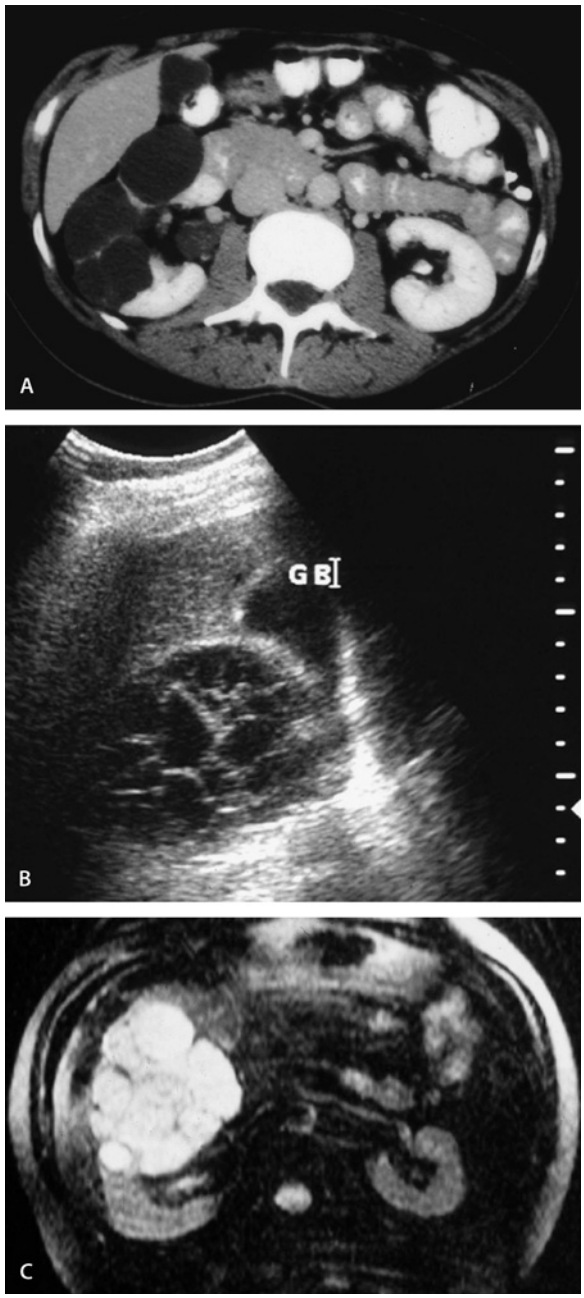


Fig. 7A–C. Multiloculated mass, typical imaging features. **A** Computed tomogram, contrast medium enhanced. There is a large multiloculated mass arising from the right kidney. Each locule is of water density. The septa show prominent enhancement. **B** Longitudinal sonogram, right upper abdomen. Typically the tumor will consist of larger echo free cysts separated by echogenic septa. **C** T2-weighted, fat suppression MR scan of the right kidney. Typically the tumor will consist of high signal, fluid-filled locules and low signal septa

■ **Computed Tomography.** On computed tomographic images (Fig. 7A), multilocular cystic nephroma is a well-defined mass arising from the kidney. The locules vary greatly in size, with variation in attenuation values from that of water to slightly higher. The portion of the tumor that has prolapsed into the pelvis may be identified by the adjacent contrast material in the collecting system. The enhancing septa are much more apparent after contrast material is administered. The fluid-filled locules do not enhance. Computed tomography detects calcium in the septa much more often than does the plain abdominal film.

■ **Ultrasonography.** The ultrasonographic appearance is that of a well-defined, sharply marginated complex cystic mass. (Fig. 7B) The larger cysts are echo free while the septa are echogenic. Extremely small cysts, each too small to be individually resolved, may be imaged as an echogenic foci which paradoxically appear to be solid portions of the mass.

■ **Magnetic Resonance Imaging.** Signal intensity of the fluid within the locules is similar to that of water, (hypointense on T1-weighted images and hyperintense on T2-weighted images) (Fig. 7C). As with enhanced CT, the septations enhance after gadolinium administration are more apparent than on the nonenhanced images. Increased signal intensity within one or more locules, most likely represents increased protein content or less likely hemorrhage within the locule.

■ **Angiography.** Angiography is seldom required, but may reveal neovascularity traversing the septa and around the mass. The septa can be seen during the nephrographic phase as bands of radiodensity coursing through and surrounding radiolucent, the fluid-filled locules. These angiographic findings are indistinguishable from neovascularity in other tumors.

Oncocytoma

Definition

Renal oncocytoma, a subgroup of renal adenoma, is a benign neoplasm that arises from tubular epithelial cells of the kidney [1, 2]. The renal oncocytoma is unrelated to oncocytomas in other organ systems.

Pathology

Oncocytomas are usually solitary, occasionally multiple, and rarely bilateral. They may be familial. They may coexist with renal cell carcinoma in the same kidney. Rarely, a single renal mass will be comprised predomi-

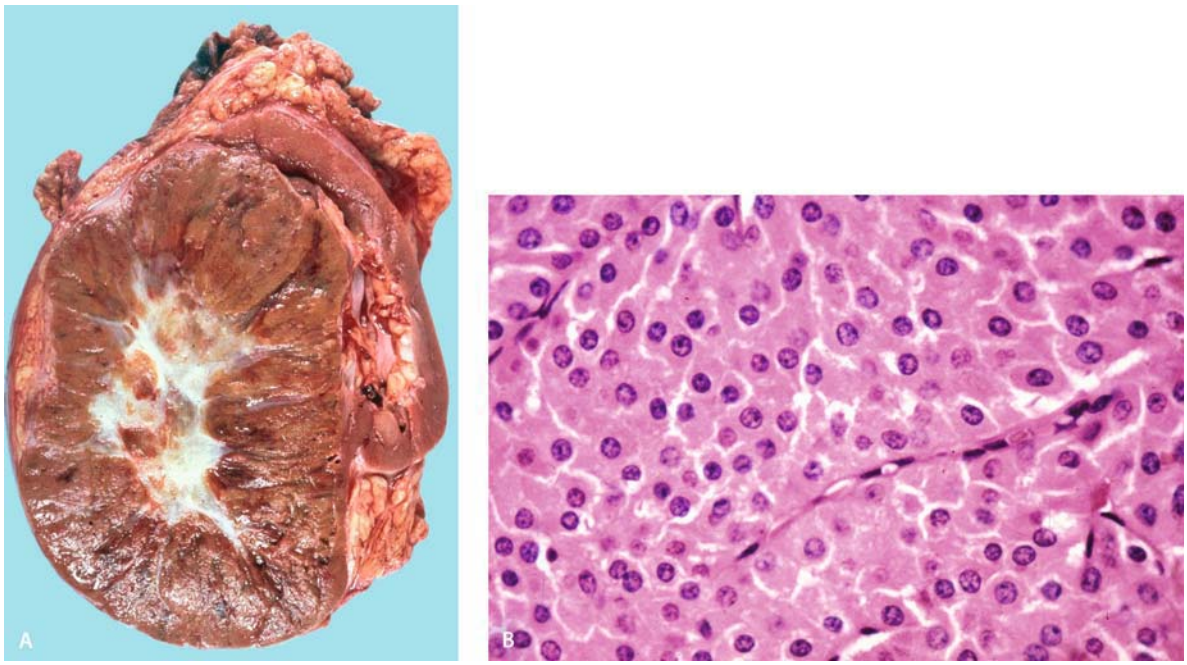


Fig. 8A, B. Oncocytoma, pathology. **A** Cut gross specimen. The tumor is well circumscribed with a color similar to normal kidney. Centrally there is a prominent stellate scar. **B** Photomicrograph. The cells exhibit intense, uniform eosinophilic staining. The nuclei are small without nuclear pleomorphism or mitotic figures

nantly of oncocytes yet have a small focus of renal cell carcinoma.

Oncocytomas may grow to a large size and are usually, but not invariably homogeneous in consistency. On cut surface, they are well circumscribed and have a uniform mahogany brown or beefy red color. The central portion of the cut surface frequently shows a characteristic whitish stellate scar (Fig. 8A). Necrosis, hemorrhage and vascular invasion are very uncommon.

Although this gross is very suggestive of oncocytoma, the diagnosis is made utilizing light microscopy. The tumor is characterized by uniform finely granular eosinophilic cytoplasm and-round-to oval, small nuclei (Fig. 8B). The intense eosinophilic staining is a result of the large number of mitochondria typically present Nuclear pleomorphism is either absent or present focally. Very few mitotic figures are present. Cells near the stellate scar form small nests, which are separated by loose, hyalinized, edematous stroma. Peripherally, cells are arranged in solid sheets with delicate fibrovascular stroma. Dystrophic calcification is uncommon, but may occur.

Clinical Setting

Oncocytomas are usually seen in middle and old age. Men are more commonly affected than women (ratio 1.7:1). Most are detected as an asymptomatic renal mass. Oncocytomas may grow to a size large enough to be palpable, painful, and cause gross or microscopic hematuria.

Radiologic Findings

■ **Overview.** Although historically it was felt that radiologic diagnosis of oncocytoma was possible by detecting the central scar, or a "spoke wheel" arterial supply, it has been found that all of these findings are nonspecific [6]. Confident differential from renal cell carcinoma is impossible [7].

■ **Excretory Urography.** Urographic features of oncocytoma are related to the mass effect of the mass. Depending upon size, there may be alteration of the renal contour with or without displacement or dilatation of the collecting system. Calcification is uncommon, but may be seen in the region of the central scar.

■ **Computed Tomography.** An oncocytoma appears as a focal, ball-shaped, homogeneous mass. On noncontrast enhanced scans, the area isodense or very slightly less dense than normal renal tissue. Contrast enhancement is usually homogeneous and less than that of the normal renal parenchyma.

The most suggestive feature of oncocytoma is a central, stellate area, representative of a central scar (Fig. 9).

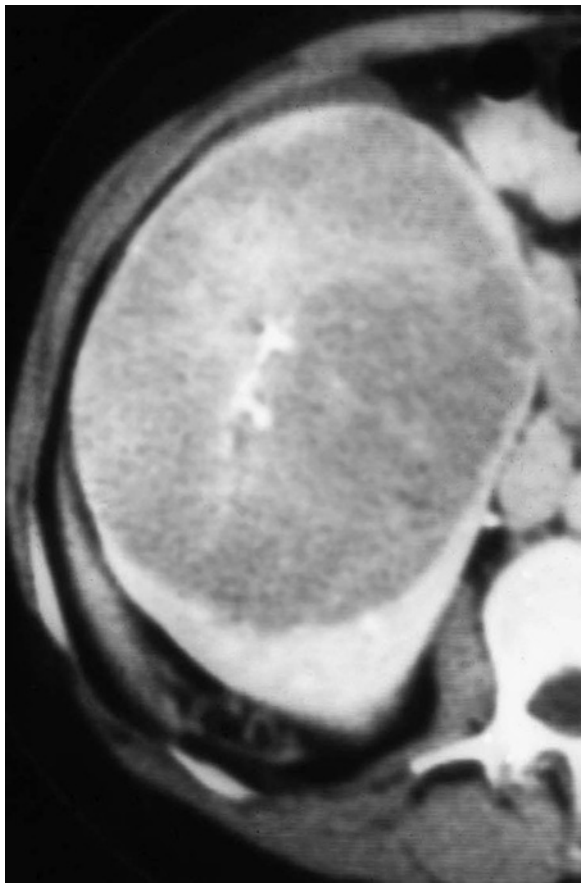


Fig. 9. Renal cell carcinoma. Computed tomogram, contrast medium enhanced. There is a large right renal mass with a well-defined central density which resembles the scar of an oncocytoma. Oncocytoma cannot be confidently differentiated radiologically from renal cell carcinoma

Unfortunately, this pattern overlaps the appearance of central necrosis seen with some adenocarcinomas, and cannot be used as a reliable indicator for the diagnosis of oncocytoma.

The presence of a homogeneous mass without a scar cannot be distinguished from nonnecrotic renal cell carcinoma (Fig. 10). An even less suggestive appearance of the oncocytoma is that of a heterogeneous mass on unenhanced and /or enhanced CT scans. This pattern is clearly indistinguishable from that of renal cell carcinoma.

■ **Ultrasonography.** The typical oncocytoma will be recognized as an evenly echogenic solid mass. The central scar has been described both as an area of increased or decreased echogenicity. In either case the sonographic appearance is not specific enough to confidently distinguish it from a malignant tumor.

■ **Magnetic Resonance Imaging.** The most suggestive features of oncocytoma are a homogeneously enhancing solid tumor with a central scar. The scar may be either hyperintense or hypointense. The absence of hemorrhage, necrosis, adenopathy, or venous tumor thrombus is noteworthy, but do not distinguish an oncocytoma from a renal cell carcinoma or other malignancies.

■ **Angiography.** Oncocytoma is usually a vascular, encapsulated mass that has neovascularity and a homogeneous nephrogram. The scar is typically avascular and may be seem in the angiographic nephrogram. There is no characteristic arrangement of the feeding arteries

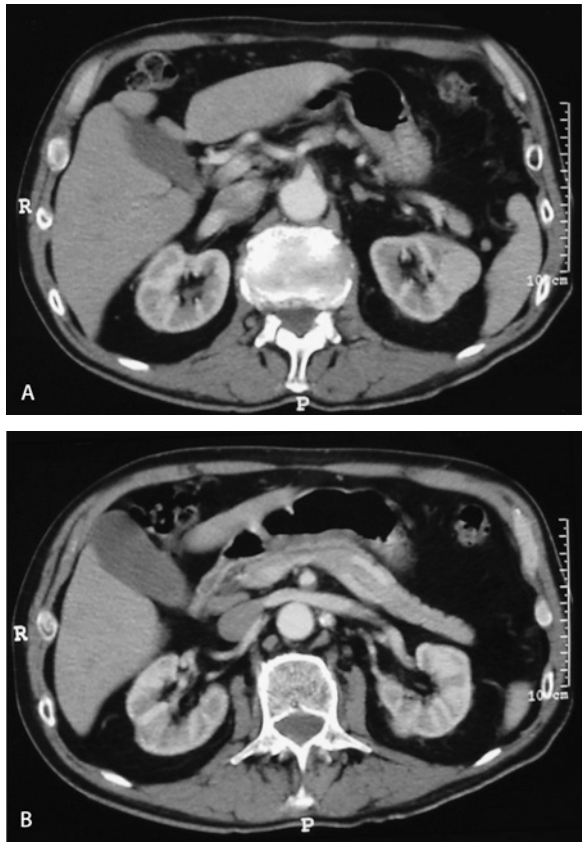


Fig. 10A, B. Coexistent oncocytoma and renal cell kidney in the same kidney. **A** Computed tomogram, contrast medium enhanced. There is a well-defined, homogeneous 2 cm mass, which enhanced 68 Hounsfield units. **B** Section through the lower pole shows a 1.2 cm mass. The larger mass was an oncocytoma, the smaller mass a renal cell carcinoma

that distinguishes this tumor from other tumors. Arterial encasement, arterio-venous shunting, and venous invasion are absent.

Mesoblastic Nephroma

Definition

Mesoblastic nephroma a rare benign renal neoplasm that usually presents in the neonate and is composed primarily of connective tissue [1, 8].

Pathology

The typical tumor is a solid, yellow-tan, unencapsulated mass of 8–30 cm replacing most of the kidney parenchyma. The cut surface has a whorled appearance resembling a uterine leiomyoma. The tumor is unencapsulated with its margins blending imperceptibly with normal renal parenchyma (Fig. 11A). Hemorrhage and necrosis are uncommon. Typically the tumor does not invade the renal pedicle, extend into the renal pelvis or metastasize.

Two types of cysts may be present. There may be discrete areas of cystic degeneration (pseudocyst). There may be small fluid-filled epithelial-lined cysts located near the junction of the tumor and uninvolved parenchyma ("trapped nephrons" vs. benign epithelial differentiation).

Microscopically the tumor consists of interlacing bundles of benign mesenchymal cells. At the renal interface, the spindle cells grow between intact nephrons (Fig. 11B). Within the tumor small numbers of tubules and nephrons may be discovered.

Clinical Findings

The mesoblastic nephroma is the most common solid renal mass discovered in the newborn or neonate. There is no predilection for race or gender. Mesoblastic nephroma is rarely discovered in older children or adults.

Mesoblastic nephroma is usually discovered either in utero during an obstetric sonographic examination or in the newborn as a large, nontender abdominal mass. Polyhydramnios, which may be acute and give rise to premature labor, is a well-recognized complication of mesoblastic nephroma. The large size of the mass in the fetus may also cause dystocia.

Radiologic Findings

■ **Overview.** Mesoblastic nephroma is best evaluated utilizing ultrasonography.

■ **Excretory Urography.** Although seldom utilized, the urographic features of mesoblastic nephroma include large, non-calcified renal mass with distortion of the remaining parenchyma.

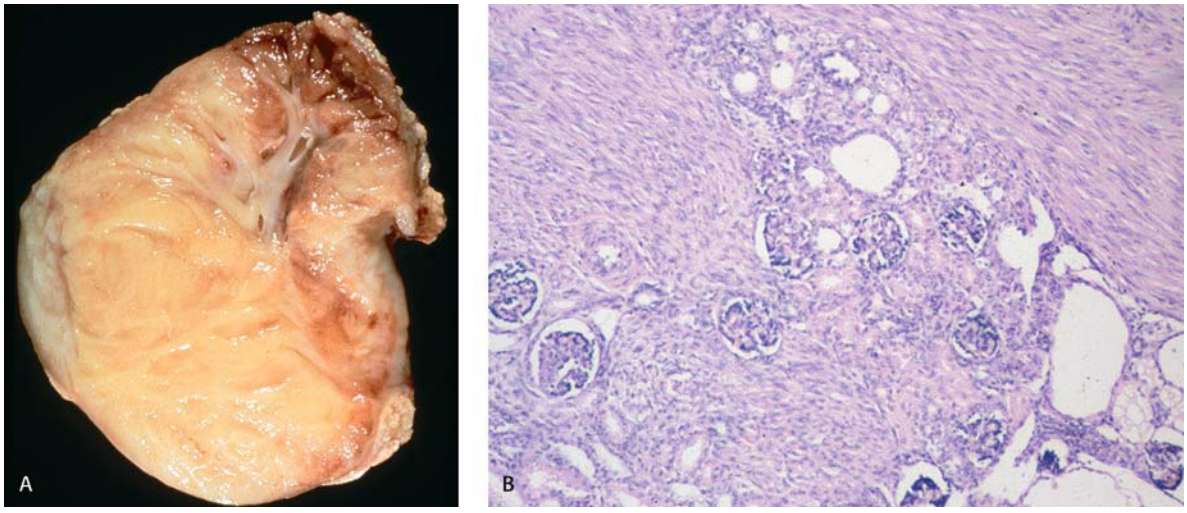


Fig. 11A, B. Mesoblastic nephroma replacing the right kidney. **A** Cut gross specimen. The tumor replaces almost the entire right kidney. The reniform shape is maintained. **B** Photomicrograph. The tumor is comprised of interlacing bundles of benign mesenchymal cells, which infiltrate between intact nephrons

■ **Computed Tomography.** Mesoblastic nephroma is characteristically large and of homogeneous tissue attenuation both before and after contrast material enhancement. Like other renal masses enhancement is less than normal renal tissue. Hemorrhage, necrosis, cyst formation, and calcification are uncommon.

■ **Ultrasonography.** Mesoblastic nephroma is usually typically evenly echogenic with low-level echoes. Cystic areas within the tumor may be identified as small, dilated, fluid-filled structures. Necrosis, although uncommon, is seen as focal hypoechoic areas within the echogenic mass. In utero diagnosis is suggested with the combination of polyhydramnios and a solid abdominal mass (Fig. 12).

■ **Magnetic Resonance Imaging.** Mesoblastic nephroma is usually imaged as a large reniform mass, which enhances less than normal renal parenchyma (Fig. 13).

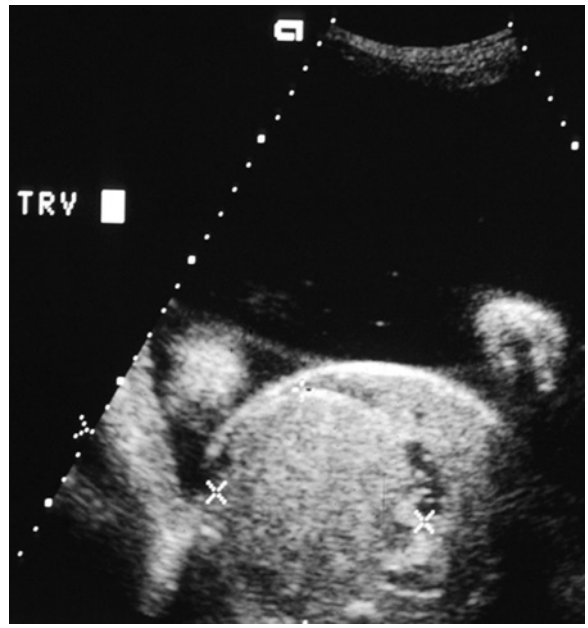


Fig. 12. Mesoblastic nephroma detected on a maternal sonogram. Transverse scan through the fetal abdomen demonstrates a 7.5 cm solid, echogenic mass. Note also the presence of polyhydramnios

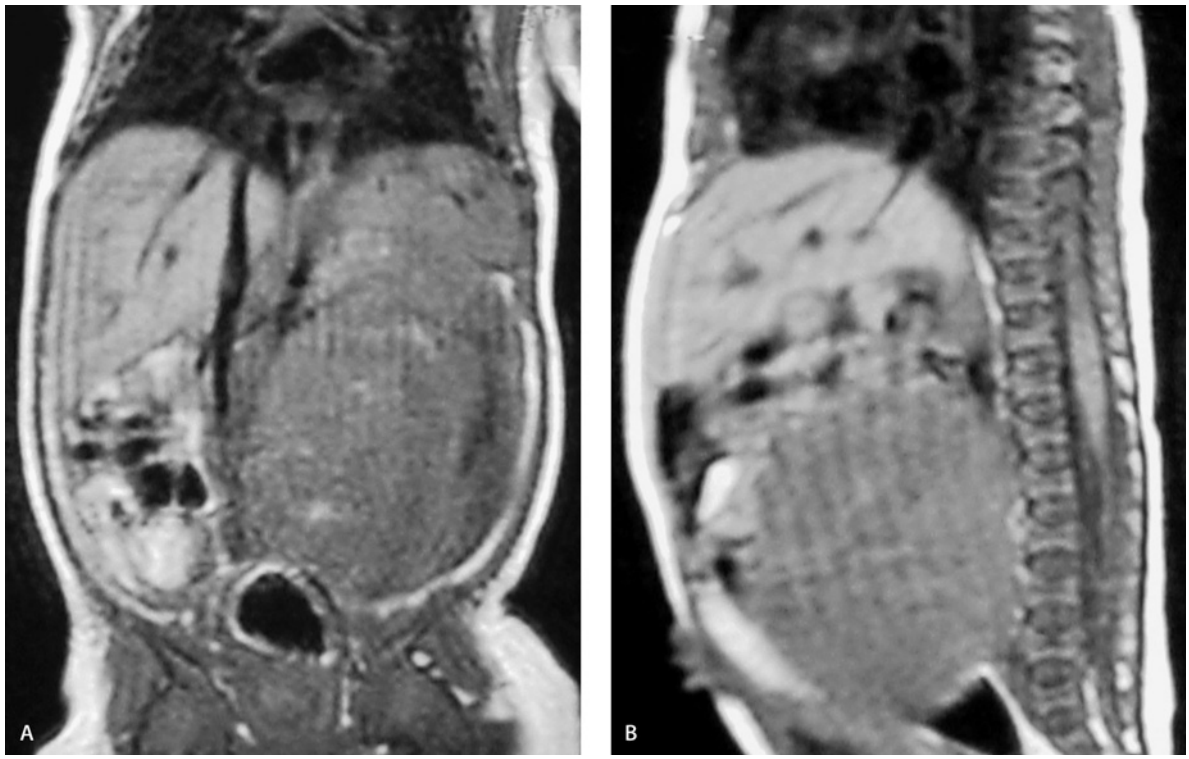


Fig. 13A, B. Mesoblastic nephroma. T1-weighted coronal (**A**) and sagittal (**B**) scans show a large solid mass within the left kidney. Note that the reniform shape is maintained

Juxtaglomerular Tumor

Definition

Juxtaglomerular tumor is a benign renal tumor, which secretes renin and is rare but curable cause of significant hypertension [1, 9].

Pathology

The tumor is usually small, solitary, and confined to the kidney. The average tumor size is small, usually because affected patients come to medical attention because of their symptoms. Most are located just beneath the renal capsule. On gross inspection, the juxtaglomerular cell tumor is usually tan or gray, sharply marginated, and often demarcated from the surrounding parenchyma by a pseudocapsule (Fig. 14A). Small foci of hemorrhage within the tumor are common. Like other peripherally located renal tumors, they may present with massive perinephric hemorrhage.

Microscopically, these tumors are composed of sheets and/or cords of cells associated with numerous blood vessels. The cells resemble smooth muscle cells and form eddies about minute vascular channels. The media of small arteries may be composed of numerous cells identical to those of the tumor, thus recapitulating the morphology of the juxtaglomerular apparatus (Fig. 14B). Cytoplasmic granules can be demonstrated with PAS or Bowie stains. The tumor may contain 30,000 times as much renin as the adjacent renal cortex.

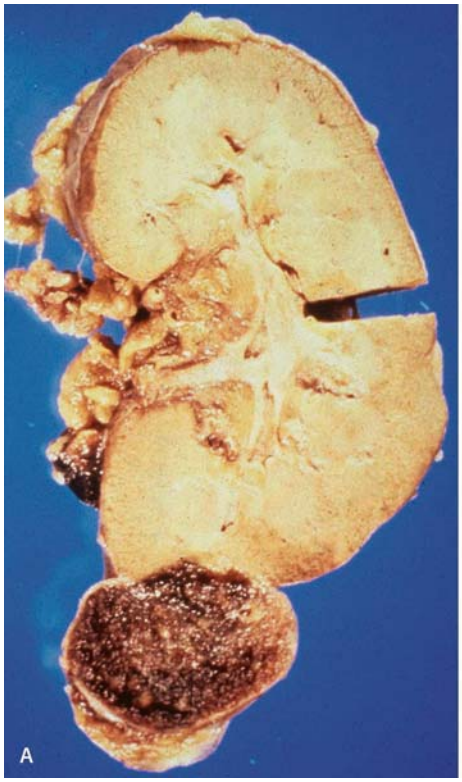
Clinical Setting

Juxtaglomerular tumor often presents in teenagers or young adults and women are more frequently involved than men. The most frequent presenting symptoms include moderate to severe headache (hypertension), polydipsia polyuria, including enuresis (kaliopenic nephropathy), and intermittent neuromuscular complaints (hypokalemia). Hypertension, frequently moderate to severe, is invariably present and may be accompanied by retinopathy. Hypertension is often present for many years, uncontrolled by antihypertensive medication. An abdominal or flank bruit is absent.

The peripheral renin level is usually elevated, with evidence of secondary aldosteronism that persists even if the hypertension is controlled medically. Renal function is usually normal unless complicated by hypertensive nephropathy.

Radiologic Findings

■ **Overview.** The radiologic findings of juxtaglomerular cell tumor are nonspecific. Like other hormone secreting tumors, the diagnosis is made clinically and the radiologic findings are confirmatory.



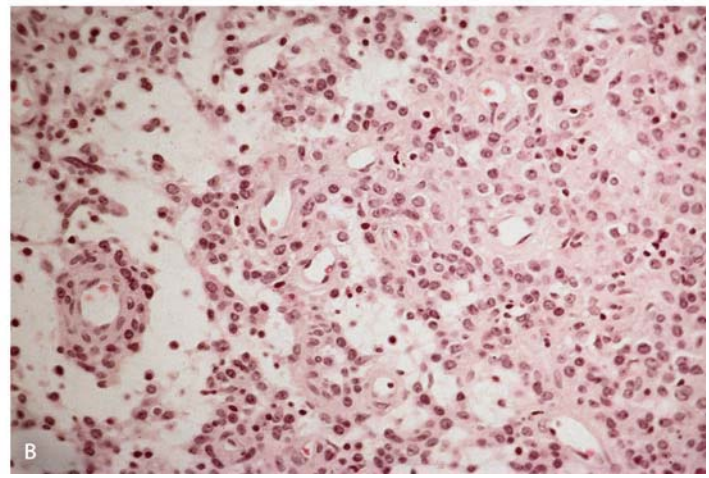


Fig. 14A–C. Juxtaglomerular tumor arising from the lower pole of the left kidney. **A** Gross specimen. A 4 cm mass arises exophytically from the lower pole of the kidney. **B** Photomicrograph. The walls of blood vessels are composed of tumor cells. **C** Excretory urogram, left posterior oblique. There is a 4 cm mass originating from the lower pole of the left kidney

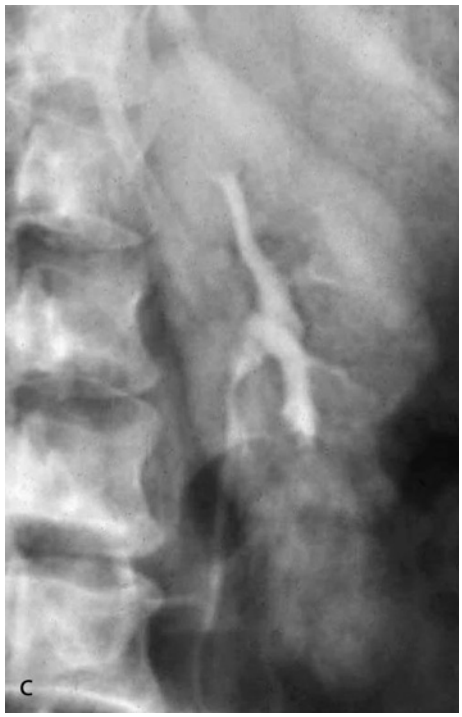


Fig. 14C

■ **Excretory Urography.** The excretory urogram may demonstrate a small, well-defined mass that is often peripheral (Fig. 14C). Because the mass is frequently small, the urogram is often normal.

■ **Computed Tomography.** The juxtaglomerular cell tumor is usually hypodense or isodense with normal renal parenchyma. Especially when the tumor is small it may not be detected on unenhanced scans and be very subtle on enhanced scans. CT may also be helpful in identifying the extent of the tumor as well as detecting intratumor hemorrhage or necrosis.

■ **Ultrasonography.** The juxtaglomerular cell tumor is usually more echogenic than normal renal parenchyma, possibly because of the numerous interfaces between the juxtaglomerular cells and the abundant small vascular channels within the tumor. Hemorrhage and necrosis may are typically hypoechoic areas within the mass. Less commonly, a hypoechoic solid tumor without evidence of necrosis is encountered.

■ **Angiography.** In some cases of juxtaglomerular cell tumor patients are misdiagnosed clinically as renal vascular stenosis. The former will have normal renal arteries whereas the latter will have renal artery stenosis.

When a case of suspected renal artery stenosis has normal renal arteries, careful evaluation for juxtaglomerular cell tumor is warranted. Despite the presence of abundant microscopic vascular spaces within the tumor, arteriography demonstrates a hypovascular mass since the vessels are so small.

Mesenchymal Tumors

Definition

Mesenchymal tissue gives rise to fibroma, lipoma, myoma, angioma, and lymphangioma [2].

Pathology

Tumors of mesenchymal origin are usually small and do not distort either the internal architecture or the contour of the kidney. They are most often incidental findings at nephrectomy or autopsy. Less commonly they present as a large intrarenal mass (Fig. 15). Microscopically they are identical to similar tumors elsewhere in the body.

Clinical Setting

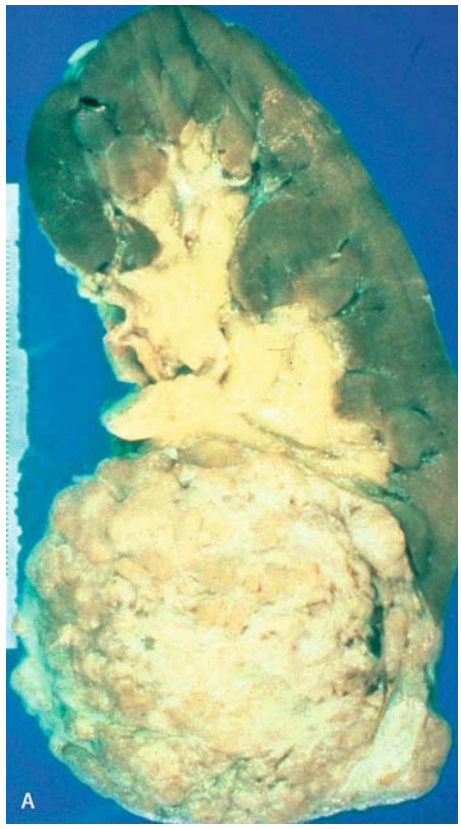
Benign mesenchymal tumors of the adult kidney become symptomatic only when they grow large enough to cause pain or hematuria, or both. Those which are small often escape clinical detection and are discovered at autopsy or when there is a nephrectomy for another disease.

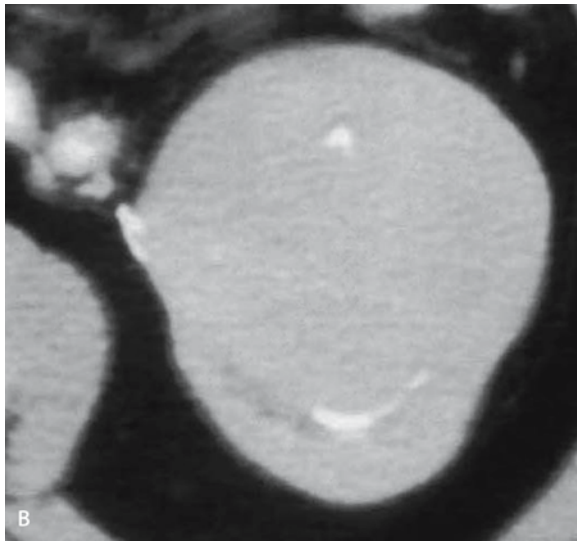
Radiologic Findings

■ **Overview.** A specific radiologic diagnosis of mesenchymal tumors is impossible. Even a rare renal lipoma cannot be distinguished from the more common angiomyolipoma. The radiologic findings are nonspecific. Confident differential from other benign or malignant tumors is impossible.

■ **Excretory Urography.** Urographic features of mesenchymal tumors are the same as those of any other solid tumor, either benign or malignant, and are related to the mass effect of the lesion. These include focal collecting system attenuation and displacement or focal caliectasis due to local pressure on a draining infundibulum.

■ **Computed Tomography and Magnetic Resonance Imaging.** Mesenchymal tumors usually are homogeneous expansive masses that enhance following administration of contrast material, Like other renal tumors, the enhancement is less than surrounding normal renal parenchyma (Fig. 15).





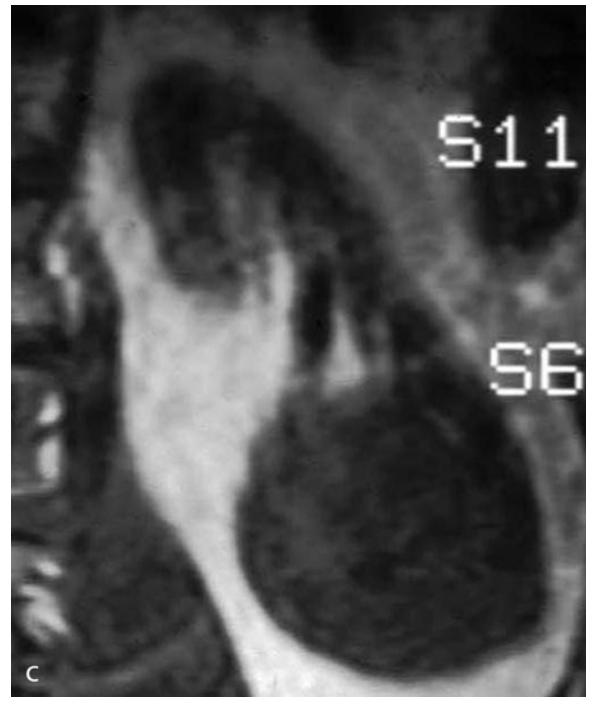


Fig. 15A–C. Large leiomyoma originating from the lower pole of the left kidney. **A** Gross specimen. A 7 cm nonnecrotic tumor arises from the lower pole of the left kidney. **B** Computed tomogram, contrast medium enhanced, pyelographic phase. The tumor is homogeneous, ball-shaped and distorts the collecting system and contour. **C** Coronal MR image, T1-weighted. The mass is homogeneous and has a signal similar to the kidney

■ **Ultrasonography.** Most mesenchymal tumors are echogenic solid masses either deep within the parenchyma or on the surface of the kidney.

■ **Angiography.** Mesenchymal neoplasms of the kidney are usually hypovascular. Angiography could provide valuable information for surgical planning if nephron-sparing surgery is to be performed.

Benign Adrenal Tumors

Adenoma

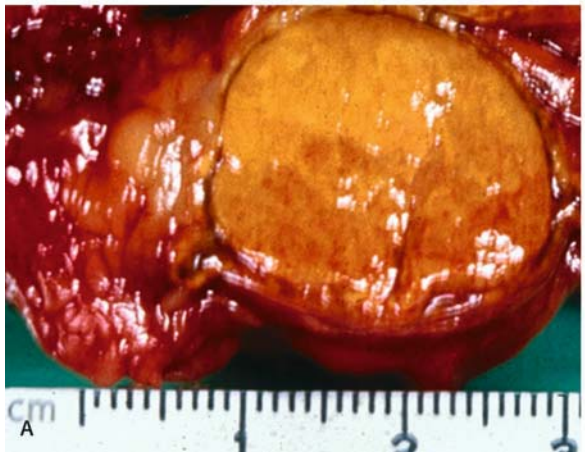
Definition

Adrenal cortical adenoma is a benign neoplasm arising from adrenal cortical cells that resemble normal adrenal cells histologically.

Pathology

Adrenal adenomas show considerable variation in gross appearance. They vary in size from barely visible to 10 cm. Larger adenomas more commonly seen in patients with virilizing syndromes where the average size is 5 cm. Adenomas which have abundant intracellular lipid (lipid-rich) are typically yellow (Fig. 16A). Those with less intracellular lipid (lipid-poor) may be red, brown or black (Fig. 16B). Tumor necrosis is uncommon. Approximately 70% of adenomas are lipid-rich.

Microscopically, the cells tend to be fairly uniform. Pleomorphism is uncommon. Tumor necrosis is un-



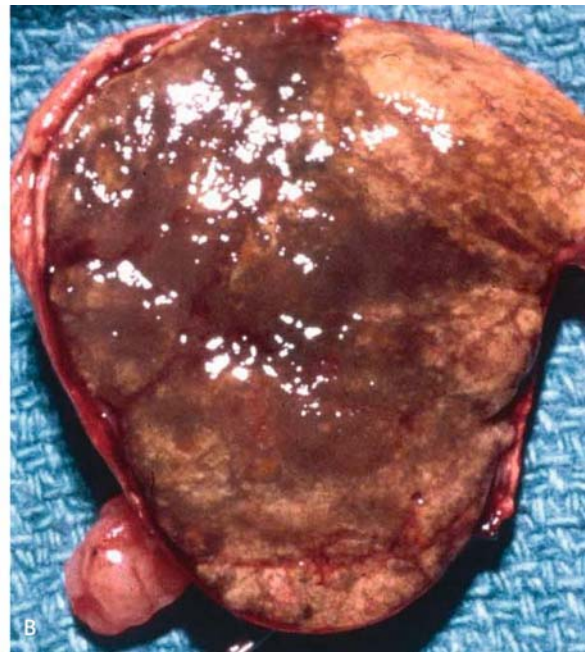


Fig. 16A, B. Adrenal adenoma, pathology. **A** Lipid rich adrenal adenoma, gross specimen, cut section. The yellow color results from the abundant lipid within the tumor. The tumor measures 2 cm, is sharply circumscribed and is nonnecrotic. **B** Lipid poor adrenal mass, gross specimen, cut section. The tumor is brownish-red color is more typical of an adenoma which does may contain abundant lipid. The adenoma is well-defined and nonnecrotic

common and often a complication of thrombosis. Adenomas causing the adrenogenital syndrome are the most difficult to separate from malignancy, especially when the tumor is large. Features that favor malignancy include nuclear pleomorphism, mitotic activity and tumor necrosis.

Clinical Setting

Adrenal adenomas may produce hormones resulting in hypercortisolism, hyperaldosteronism, masculinization and feminization. More commonly, however, cortical adenomas do not hyperfunction and are detected as an incidental mass (incidentaloma). Cortical hormones are synthesized but not in excessive quantities, hence, the term non***hyper***functioning rather than nonfunctioning adenoma. . Functioning and nonfunctioning tumors often have an identical gross and radiologic appearance Functioning adenoma may suppress normal adrenal function result in some degree of atrophy of normal adrenal tissue. Nonhyperfunctioning adenomas greater than 3 cm in diameter occur in approximately 3 per cent of autopsied. Prevalence increases with age.

An increased prevalence of adenoma has been reported in patients with diabetes, hypertension, renal adenocarcinoma, and hereditary colonic adenomatosis.

Radiologic Findings

■ **Overview.** The identification of adenoma in a patient with adrenal hyperfunction (e.g. hypercortisolism, hyperaldosteronism) is usually straightforward. The most challenging task of adrenal imaging is to distinguish the nonhyperfunctioning adenoma from metastasis. This is best accomplished by detecting intracellular lipid (CT or MR) or by evaluating the CT washout dynamics after administration of contrast media [10–12].

■ **Computed Tomography.** Lipid-rich adenomas will appear as a homogeneous mass, with a diameter less than 5 cm, and an attenuation value between –5 and +10 Hounsfield units on an unenhanced scans (Fig. 17A).

Lipid-poor adenomas are typically homogeneous, less than 5 cm but have an attenuation value of greater than 10 Hounsfield units on an unenhanced scan (Fig. 17B). In these cases, adrenal washout is very helpful in differentiating adenoma from metastasis.

Upon immediate administration of intravenous contrast material (60 s), adrenal adenomas and metastases will have nearly identical attenuation values. However, adenomas will lose their enhancement more quickly than metastases. This rapid wash out of enhancement can be measured and can be used to confidently differentiate adenomas from metastases. An attenuation cut-

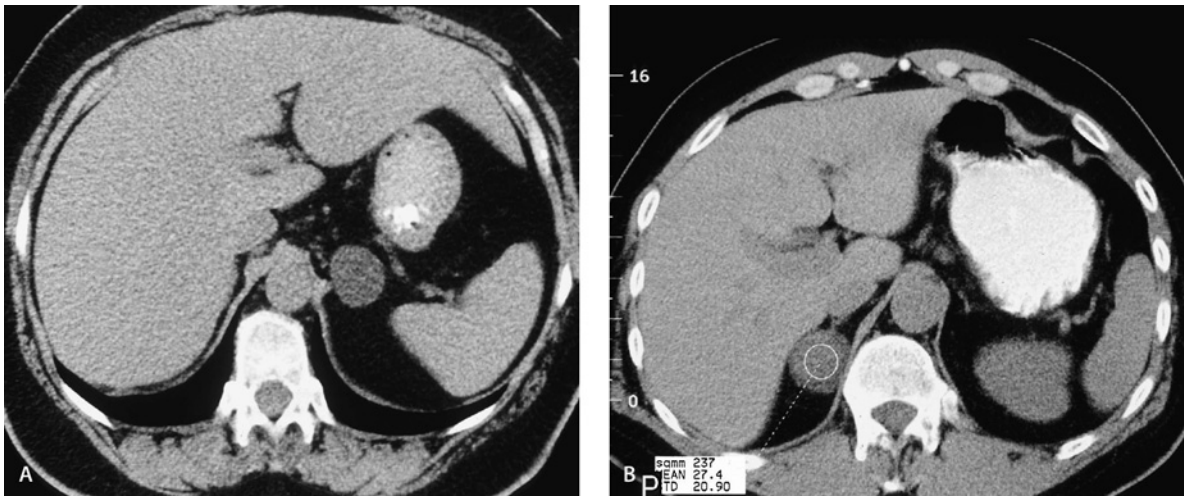


Fig. 17A, B. Adrenal adenoma spectrum of CT findings. **A** Lipid rich. CT scan, nonenhanced. There is a well-defined, homogeneous, 3 cm left adrenal mass, which measures–7 Hounsfield units. **B** Lipid poor. CT scan, nonenhanced. There is a well-defined, homogeneous, 3 cm right adrenal mass that measures 27 Hounsfield units. This appearance is nonspecific and may represent an adenoma, a pheochromocytoma or a metastasis. In these cases, adrenal washout may be helpful

off of 24 HU on enhanced CT performed 12 to 18 minutes after contrast administration can differentiate adenomas (24 HU) from metastases (>24 HU) with a very high sensitivity and specificity [10].

A delayed CT attenuation value can be used to calculate the percentage of relative enhancement washout, which can also be used to differentiate adenomas from metastases.

Percentage of relative enhancement washout = [(E-D)/E] × 100, where E is the enhanced attenuation value and D is the delayed enhanced value. A threshold value of more than 50% contrast washout on 15-minute delayed CT has been used to differentiate adenomas from metastases with a sensitivity and specificity near 100% [10, 13](Fig. 18).

If both of these techniques produce an intermediate result, and if differentiation is critical for patient management, biopsy may be required. This is especially true in patients with a known primary tumor, in which management would be altered if an adrenal metastasis were present.

■ **Magnetic Resonance Imaging.** An adenoma is typically isointense or mildly hypointense to liver on T1- and T2-weighted spin-echo sequences. On an opposed-phase gradient-echo scan, the lipid-rich adenoma demonstrates signal dropout relative to spleen (Fig. 19). This technique is very sensitive at differentiating adenoma from metastasis. The lipid-poor adenoma typically will not demonstrate signal dropout. In these cases, CT adrenal washout should be performed [14].

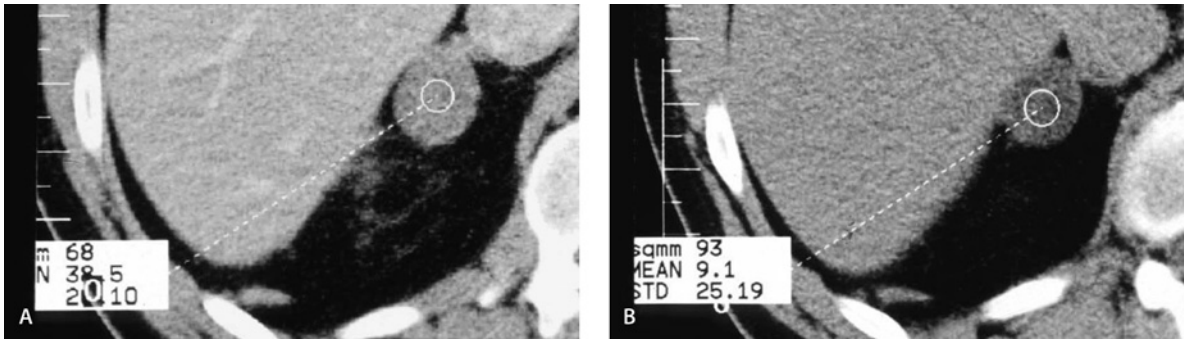


Fig. 18A, B. Adrenal washout study. This study may be very helpful in evaluating adrenal masses which measure greater than 10 Hounsfield units on an nonenhanced scan, or in those cases performed only with a contrast material enhanced scan. **A** On the immediate enhanced scan a well-defined adrenal mass measures 38.5 Hounsfield units. **B** On the delayed scan the mass measures 9.1 Hounsfield units. The washout is 76%, which is indicative of adenoma. Note that on the delayed scan the mass measures less than 10 Hounsfield units, confirming that the mass is a lipid rich adenoma

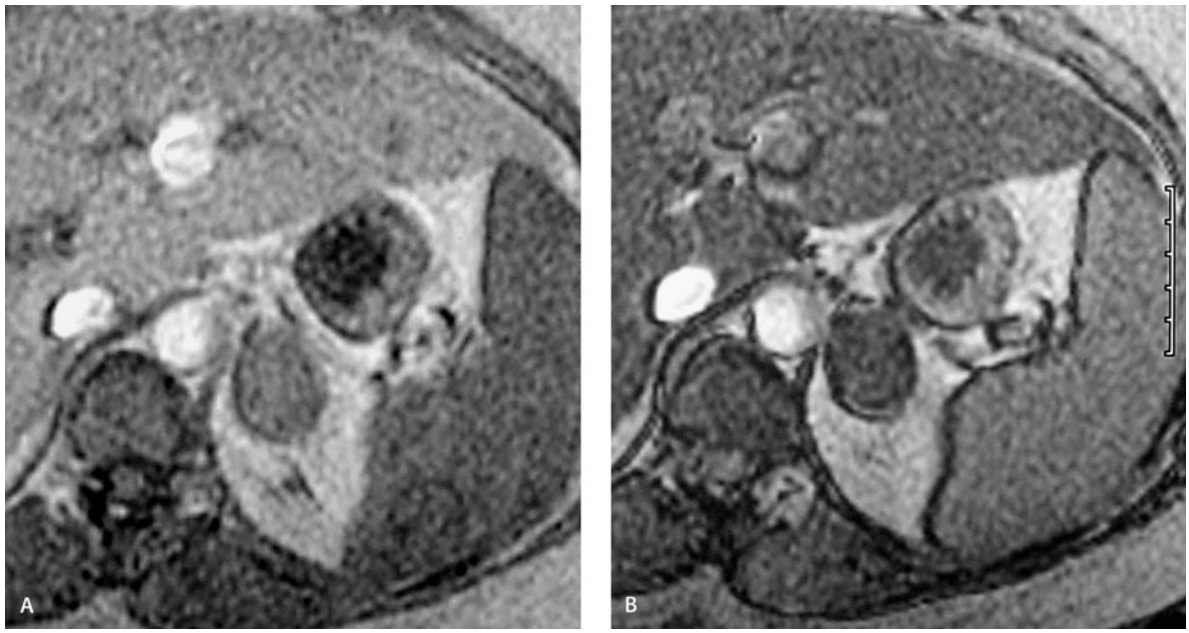


Fig. 19A, B. Opposed-phase gradient-echo scan. **A** On the in-phase scan, the left adrenal mass has a similar signal to that of spleen. **B** On the out-of-phase scan, the adrenal mass demonstrate signal dropout and is of lower signal than the spleen. This signal dropout indicates the presence of intracellular lipid, thus a lipid rich adenoma

Pheochromocytoma

Definition

Pheochromocytoma is a neoplasm of the adrenal medulla composed of paraganglionic cells. Most tumors produce catecholamines. The term pheochromocytoma should be restricted to tumors that arise within the adrenal gland. The same tumor arising outside the adrenal gland should be referred to as a paraganglioma rather than an extra-adrenal pheochromocytoma.

Pathology

Most pheochromocytomas measure from 3–5 cm in diameter. They are typically round to ovoid. Large tumors are demarcated from the normal adrenal by a pseudocapsule of compressed adrenal tissue (Fig. 20A). Small tumors are not encapsulated (Fig. 20B). The tumor is gray pink and has a soft consistency. Multiple tumors are not uncommon (Fig. 20B) Hemorrhage, necrosis and cyst formation are common in large tumors.

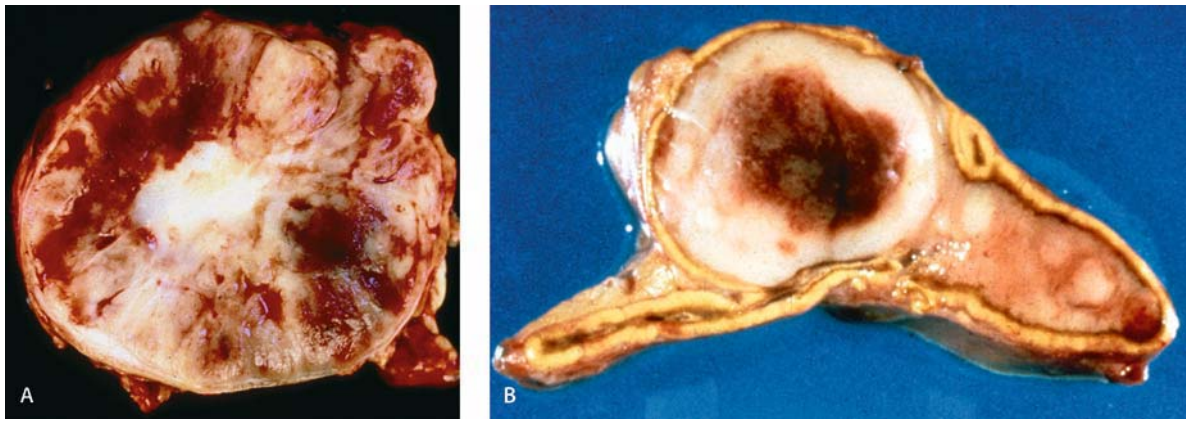


Fig. 20A, B. Pheochromocytoma, gross pathology, two different cases. The tumor may be large (**A**) or small (**B**). Large tumors are often hemorrhagic and necrotic with prominent cystic areas. There are at least four distinct tumors in the specimen (**B**)

Microscopically, the pheochromocytoma resembles normal adrenal medullary tissue and is composed of pheochromocytes. Adjacent groups of tumor cells are separated by a rich fibrovascular stroma. The walls of areas of cystic necrosis may be calcified. The nuclear pleomorphism that may be present in some tumors does not correlate with biologic behavior.

Clinical Setting

Excess catecholamine production causes hypertension (labile or sustained) combined with episodes of palpitations, perspiration, and anxiety. The 24-hour urine vanillylmandelic acid (VMA) level is elevated in 90 per cent of patients. The presence of free norepinephrine in a 24-hour urine specimen is a sensitive indicator of functioning paraganglioma. A urine assay is more sensitive than plasma catecholamine measurement. Approximately 10 per cent of cases are associated with extra-adrenal paragangliomas or are bilateral.

Pheochromocytoma may be associated with Type IIA and Type IIB multiple endocrine neoplasia (MEN) syndromes, neurofibromatosis, von Hippel-Lindau disease and Carney's triad. Patients with MEN syndromes frequently have asymptomatic pheochromocytoma.

Radiologic Findings

■ **Overview.** The radiologic findings of pheochromocytoma are nonspecific, but correlate with the tumor's variable gross pathologic findings. Like other hormone secreting tumors, however, the diagnosis is made clinically and the primary role of imaging is to localize and to determine if there are multiple tumors [1, 11, 14].

■ **Computed Tomography.** Computed tomography has a high sensitivity (>90 per cent) in the detection of pheochromocytoma. Contrast material is rarely required but if nonionic contrast material is utilized, no subsequent increase in epinephrine or norepinephrine levels has been demonstrated. Small tumors are usually homogeneous, whereas large tumors often contain areas of diminished attenuation reflecting necrosis. Those with extensive cystic necrosis may be confused radiologically with a complex adrenal cyst, hemorrhage or abscess (Fig. 21A).

There are, however, several limitations of computed tomography. It is impossible to distinguish pheochromocytoma from other adrenal tumors by computed tomography alone. Computed tomography is less reliable than magnetic resonance imaging studies for very small nodules and less sensitive than magnetic resonance and radionuclide studies for extra-adrenal tumors and metastatic disease. Despite these limitations, computed tomography is the most commonly utilized technique for initial evaluation of a patient with clinical evidence of a catecholamine-producing tumor.

■ **Magnetic Resonance Imaging.** Magnetic resonance imaging is especially useful: (1) in detecting extra-adrenal paragangliomas, especially those arising in the wall of the bladder and paracardiac region; (2) in evaluating the postoperative patient; (3) in patients with hypertension and only mildly elevated catecholamine levels; (4) and in evaluating patients at increased risk for developing paraganglioma (e.g., von Hippel-Lindau syndrome).

On T1-weighted images pheochromocytoma typically has a signal intensity that is lower than or equivalent to that of liver, kidney, or muscle. In many cases the signal intensity is high on T2-weighted images (Fig.

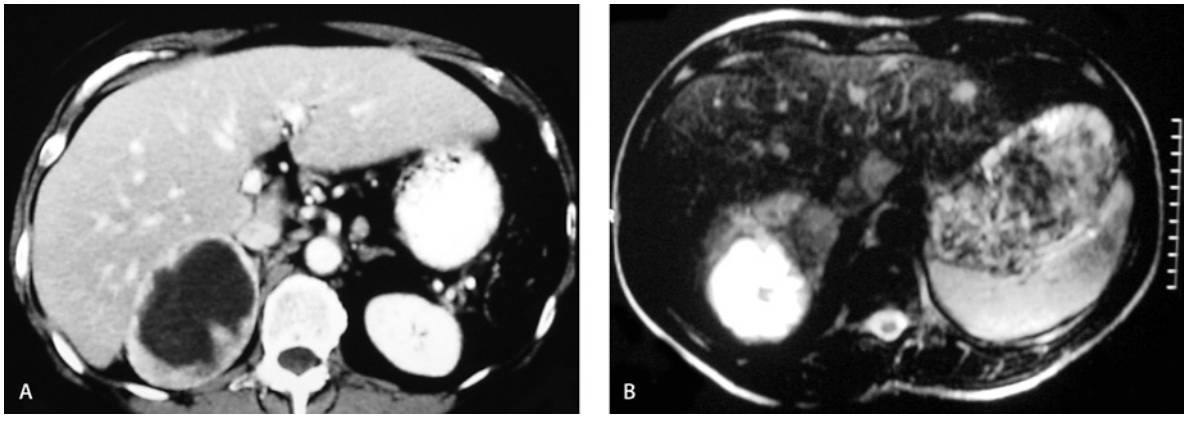


Fig. 21A, B. Pheochromocytoma, 2 different cases. **A** Computed tomogram, contrast material enhanced. There is a 7 cm thick-walled, cystic mass which originated above the right kidney. **B** T 2-weighted axial MR scan with fat saturation. A portion of the tumor has a very high signal (compare to adjacent CSF)

21B). These signal characteristics support the diagnosis of pheochromocytoma but are in no way pathognomonic.

Less commonly, however, a pheochromocytoma may demonstrate atypical signal characteristics, which emphasizes the importance of correlating radiologic abnormalities with clinical and laboratory findings.

■ **Nuclear Medicine.** Metaiodobenzylguanidine (MIBG) is a norepinephrine analogue accumulates at sites of norepinephrine synthesis. It may be especially helpful in detecting medullary hyperplasia, recurrence, metastases, or extra-adrenal paragangliomas. MIBG has the advantage of imaging the entire body with one dose. Disadvantages of MIBG include limited availability, poor spatial resolution, and the length of the procedure (1 to 3 days). MIBG imaging is not specific and may be positive in cases of neuroblastoma, carcinoid, medullary thyroid carcinoma, choriocarcinoma, and atypical schwannoma.

Myelolipoma

Definition

Myelolipoma is an uncommon, benign, metabolically inactive tumor composed of mature fat and bone marrow.

Pathology

On gross examination, the myelolipoma is usually pale yellow with areas of red or pink that represents hematopoietic components and hemorrhage (Fig. 22). Occasionally the hemorrhage is massive. Large lesions are often lobulated. The myelolipoma may be multiple and bilateral.

Microscopically, the lesion is composed of mature fat and proliferating hematopoietic tissue. The hematopoietic tissue resembles bone marrow and contains the cell lines in different stages of maturation. Foci of hemorrhage and calcification are common.

Clinical Setting

Myelolipoma is usually detected as an incidental finding in adults undergoing a radiologic examination for unrelated clinical indications. Autopsy prevalence is less than 0.2 per cent and there is an equal sex distribution. Most adrenal myelolipomas originate in the adrenal cortex and are 10 cm in diameter or larger. Approximately 10 per cent of cases are bilateral. Myelolipomas contain fat as adipose tissue and bone marrow elements in variable proportions. Most have sufficient fat to be detected by computed tomography or magnetic resonance imaging.

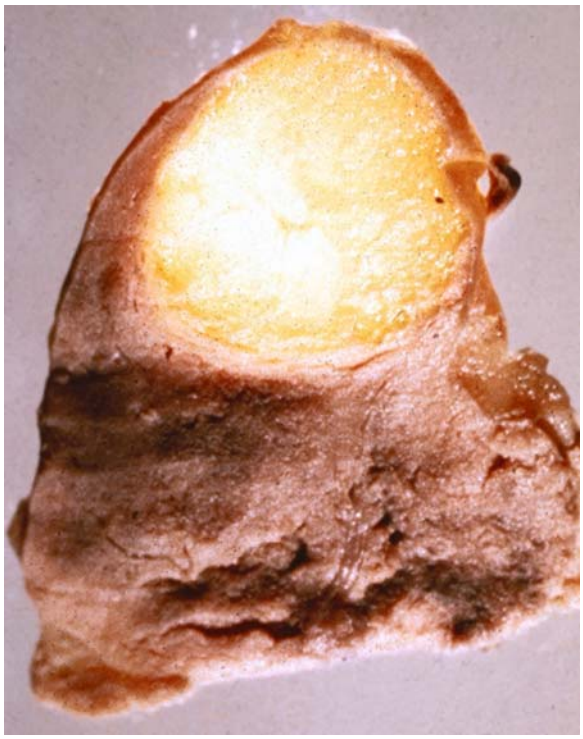


Fig. 22. Myelolipoma, gross pathology. The tumor is well defined and sharply marginated. Its yellow color is a result of the abundant adipose tissue

The vast majority of patients have otherwise normal adrenal glands. Myelolipoma can coexist with Cushing's syndrome, congenital adrenal hyperplasia, and nonhyperfunctioning adenoma. Very rarely, a myelolipoma arises in an extra-adrenal site, such as the retroperitoneum, thorax, or pelvis. Hemorrhage is a significant complication of myelolipoma; spontaneous bleeding can cause acute flank pain or rarely hypovolemic shock.

Radiologic Findings

■ **Overview.** The presence of a fatty adrenal mass is *very suggestive* of myelolipoma. The best radiologic techniques to detect this fat are computed tomography and magnetic resonance imaging [15, 16]. Differentiation from angiomyolipoma is dependent upon determination of tumor origin. Theoretically, a well-differentiated supra-renal liposarcoma could not be distinguished from a large myelolipoma.

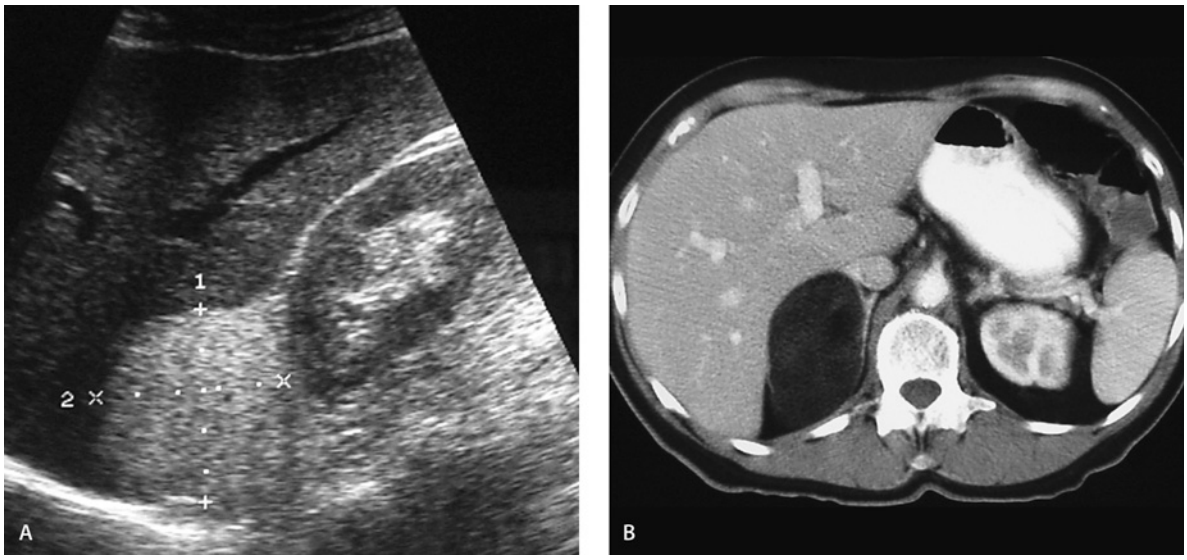


Fig. 23A, B. Myelolipoma, ultrasound and computed tomographic findings. **A** Longitudinal sonogram, right upper abdomen. There is a 4.8 cm by 4.6 cm mass in the region of the right adrenal. **B** Computed tomogram, contrast material enhanced. The tumor measured –40 Hounsfield units, indicative of adipose tissue, hence a myelolipoma

■ **Computed Tomography.** Fatty areas within the tumor will have attenuation values less than –30 Hounsfield units (Fig. 23). Hemorrhage and marrow elements will be recognized as foci of soft tissue density within the tumor. The margins of a hemorrhagic myelolipoma may be irregular, owing to blood dissecting into the adjacent retroperitoneal fat. Very rarely the hemorrhage is so extensive that it obliterates all of the fat. Confident diagnosis in these cases is impossible. Calcification is readily apparent and commonly seen on computed tomography.

■ **Magnetic Resonance Imaging.** As with CT, it is the identification of the fatty component on MR that enables confident diagnosis. The fatty components of myelolipoma have a similar signal to that of renal sinus and retroperitoneal fat. Fat-suppressed images are extremely helpful and demonstrate signal loss within the mass. As the fat within a myelolipoma is adipose tissue and not intracellular lipid, chemical shift imaging is not helpful in MR diagnosis. Bone marrow elements and hemorrhage will have a variable and a less characteristic signal. Coronal or sagittal images are valuable in differentiating a myelolipoma from an upper pole angiomyolipoma.

Ganglioneuroma

Definition

Ganglioneuroma is a benign neoplasm composed of sympathetic ganglion cells with variable numbers of Schwann cells, and collagen.

Pathology

There is considerable variation in size. They are typically sharply marginated, but not encapsulated. On cut section, the ganglioneuroma is gray-white and firm thus resembling a leiomyoma (Fig. 24A). There may be extensive areas of cystic degeneration. They may be bilateral. Very rarely, ganglioneuroma is discovered with pheochromocytoma or with a peripheral nerve sheath tumor.

On microscopic examination, the ganglion cells are often clustered within the tumor mass. Less commonly, they are distributed diffusely throughout the tumor. The stroma may appear edematous or compact. Schwann cells are often arranged in bundles within the ganglioneuroma.

Clinical Setting

Ganglioneuroma occurs at all ages and is typically asymptomatic. Ganglioneuroma is rarely associated with hypertension despite the fact that levels of urinary catecholamines and their metabolites may be elevated. Rarely a patient with ganglioneuroma will present with watery diarrhea, hypochlorhydria, and alkalosis (WDHA), the Verner-Morrison syndrome. This condition results from the secretion of a vasoactive intestinal polypeptide by the tumor. Likewise, very rarely, ganglioneuroma may result from the maturation of a neuroblastoma or a ganglioneuroblastoma.

Radiologic Findings

■ **Overview.** Ganglioneuroma can be suggested in a nonhypertensive patient with an adrenal mass and an elevated level of catecholamine and/or catecholamine metabolites or with Verner-Morrison syndrome. In asymptomatic patients, specific diagnosis requires either biopsy or surgical removal (Fig. 24) [1, 11].

■ **Excretory Urography.** A large ganglioneuroma may compress and displace the upper pole of the kidney. Calcification is uncommon.

■ **Computed Tomography.** On the unenhanced scan, a ganglioneuroma has attenuation slightly less than that of muscle. There may be faint enhancement.

■ **Magnetic Resonance Imaging.** On T1-weighted magnetic resonance images, the tumor is homogeneous with low signal intensity. On T2-weighted images the tumor is heterogeneous with predominantly high signal intensity.

Very Rare Benign Adrenal Tumors

Mesenchymal tumors, such as leiomyoma, and hemangioma are very rare. Affected patients present as a large adrenal mass with normal adrenal function. Although the presence of phleboliths and contrast material pooling on angiography has been reported with hemangioma, an accurate diagnosis is rarely made prospectively. Likewise, a specific radiologic diagnosis is rarely possible in cases of other mesenchymal adrenal tumors [2].

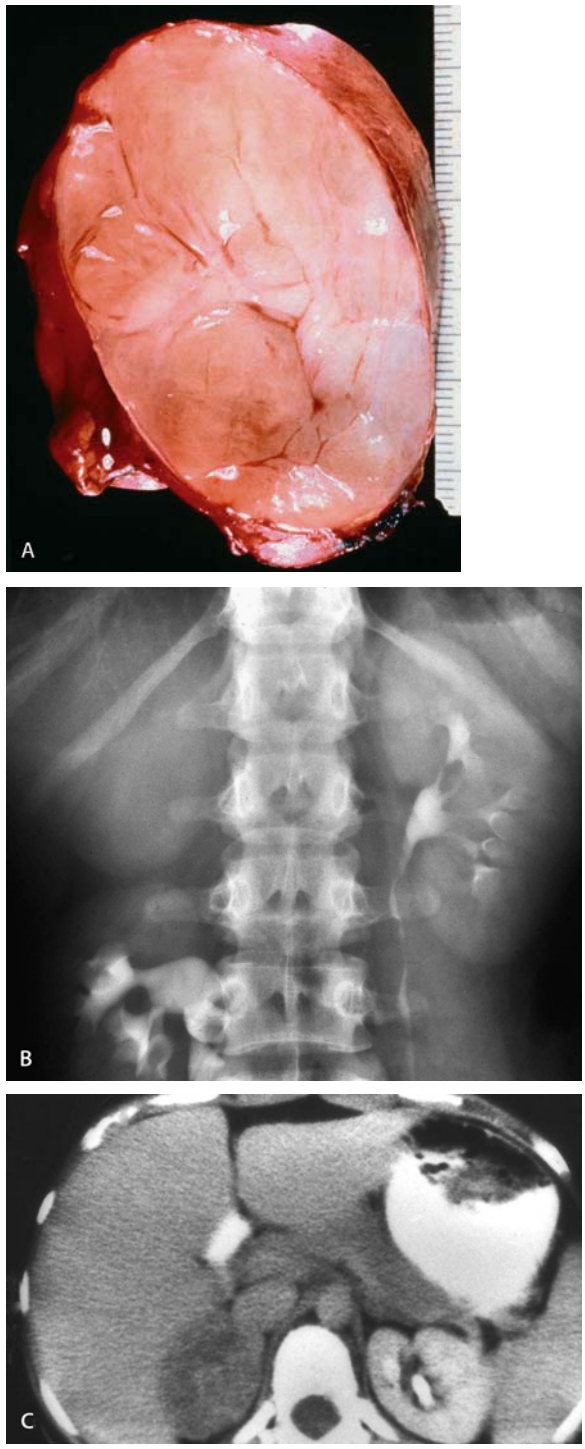


Fig. 24A–C. Ganglioneuroma. **A** Gross pathology, cut section. The tumor is sharply marginated and nonnecrotic. **B** Excretory urogram, pyelographic phase. There is a large mass displacing the right kidney inferiorly. **C** Computed tomogram, contrast material enhanced. The mass is well defined and has a density slightly less than adjacent muscle

References

1. Hartman DS (2000) Benign renal and adrenal tumors. European Radiology 10 (Supplement 2) 5221–5230
2. Davidson AJ, Hartman DS, Choyke PL, Wagner BJ (1999) Davidson's radiology of the kidney and genitourinary tract, Third Edition. W B Saunders Company, Philadelphia
3. Wagner BJ, Wong-You-Cheong JJ, Davis CJ, Jr (1997) Adult renal hamartomas. RadioGraphics 17:155–169
4. Agrons GA, et al (1995) Multilocular cystic renal tumor in children: radiologic-pathologic correlation. RadioGraphics 15:653–669
5. Madewell JE, Stanford MG, Davis CJ Jr et al (1983) Multilocular Cystic Nephroma: A radiographic-pathologic correlation of 58 patients : Radiology 146: 309–321
6. Quinn MJ, Hartman DS, Friedman AC et al (1984) Renal Oncocytoma: new observations: Radiology 153: 49–53
7. Davidson et al (1993) Renal oncocytoma and carcinoma: Failure of differentiation with CT. Radiology 186:693–696.
8. Hartman DS, Lesar MSL, Madewell JE et al (1981) Mesoblastic Nephroma: Radiologic-pathologic correlation of 20 cases: AJR 136:69–74
9. Dunnick NR, Hartman DS, Ford KK et al (1983) The radiology of juxtaglomerular tumors: Radiology 147: 321–326
10. Dunnick NR, Korobkin M (2002) Imaging of adrenal incidentalomas: current status. AJR 179:559–568.
11. Kawashima A, Sandler CM, Fishman EK, et al (1998) Spectrum of CT findings in nonmalignant disease of the adrenal gland. RadioGraphics 18: 393–412.
12. Szolar DH, Kammerhuber FH (1998) Adrenal adenomas and nonadenomas: assessment of washout at delayed contrast-enhanced CT. Radiology 207:369–375
13. Peña CS et al (2000) Characterization of indeterminate (lipid poor) adrenal masses: use of CT washout characteristics at contrast enhanced CT. Radiology 217: 798–802
14. Krebs TL, Wagner BJ (1998) MR imaging of the adrenal gland: radiologic-pathologic correlation. RadioGraphics 18: 1425–1440
15. Kenney PJ, Wagner BJ, Rao P, Heffess CS (1998). Myelolipoma: CT and pathologic features. Radiology 208:87–95.
16. Rao P, Kenney PJ, Wagner BJ, Davidson AJ (1997) Imaging and pathologic features of myelolipoma. RadioGraphics 17: 1373–1385