

# Ultrasonography of the Adrenal Gland

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With appropriate techniques and using liver, spleen or kidney as an acoustic window, normal adrenal gland and adrenal lesions can be delineated by ultrasonography. The right adrenal gland is usually evaluated by transverse oblique scans and coronal scans, respectively, through the anterior and middle axillary line, while the left adrenal gland is investigated by an oblique coronal scan mainly through the posterior axillary line. For adrenal lesions, ultrasonography has a sensitivity of 74–97%, a specificity of 61–96%, and an accuracy of 70–97%. The diagnostic accuracy depends on the scanning technique and expertise of the operator, the body status of the patient, the size and functional status of the lesion, and the ultrasonographic quality. Small adrenal nodules, ileus, obesity, fatty liver, and large body status account for most of the reasons for decreased accuracy. Small adrenal nodules less than 3 cm in diameter mainly comprise functioning cortical adenomas, nonfunctioning cortical adenomas, nodular hyperplasia, and metastases. Most small adrenal masses are homogeneous and hypoechoic, and the echo patterns are nonspecific. Large adrenal masses greater than 3 cm in diameter mainly include primary adrenocortical carcinoma, lymphoma, metastasis, lymphoma, and pheochromocytoma. The echogenicity of a large adrenal mass may be hyperechoic and heterogeneous because of the higher incidence of necrosis and hemorrhage. Other uncommon adrenal masses are myelolipoma, hematoma, granulomatous lesions, hemangioma, and adrenal cysts of various origins. The differential diagnoses of a hyperechoic adrenal mass include neuroblastoma, myelolipoma, and tumor with central necrosis or heterogeneity. Calcification is encountered in both benign and malignant processes. It is sometimes difficult to differentiate benign adrenal masses from malignant lesions. Dynamic computed tomography, magnetic resonance imaging, and positron emission tomography play critical complementary roles in such an instance.

**KEY WORDS** — adrenal gland, adrenal lesions, ultrasonography

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## Introduction

Normal adrenal glands are a pair of small, thin organs located superior and medial to the kidneys

in the perirenal space of the retroperitoneum [1–4]. Because of the spine at the back, ribs at the posterior and lateral spaces, and the anterior presence of gastrointestinal gas, it is relatively difficult to

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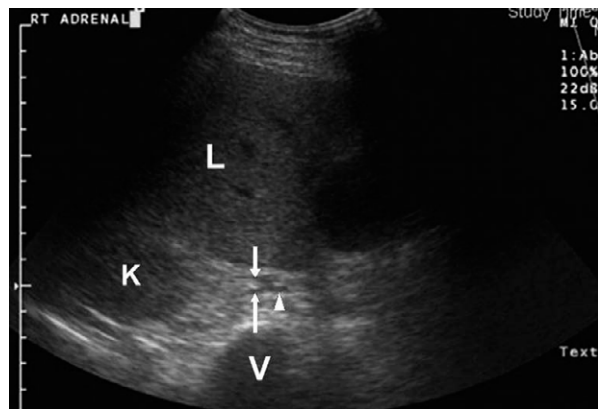
delineate the adrenal glands or adrenal lesions by ultrasonography (US), as compared with other imaging modalities such as computed tomography (CT) and magnetic resonance imaging. With the advent of the high-resolution real-time scanner, as well as the convex or sector scanner for application to the intercostal spaces, it has become easier to assess the glands, and lesions as small as 0.6 cm in diameter can be delineated by US [2].

US has the advantages of noninvasiveness, low cost, use of non-ionizing irradiation, and high portability [5]. The majority of functioning adrenal tumors are benign and small in size, and the lesions can be treated by surgical excision or image-guided intervention, such as radiofrequency. Thus, early detection of adrenal lesions is important for adequate patient management. Successful evaluation of the adrenal glands depends on a number of factors, including appropriate scanning technique, the body status of the patient, size and functional status of the lesion, the operator's knowledge of the anatomy and pathology of the glands, as well as the limitations of adrenal scanning [5,6].

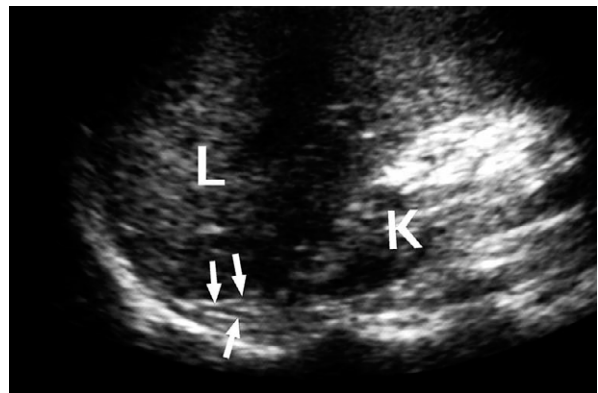
### Normal Adrenal Glands

Normal adrenal glands are a pair of small, thin and flat organs that consist of a superoantero-medial ridge and two inferoposterolateral wings (Figs. 1–3) [1–4]. The two wings of the adrenal glands are not symmetrical. The medial wing is more prominent superiorly and small or absent inferiorly, and vice versa for the lateral wing [7]. The right gland is somewhat triangular, while the left gland is semilunar [8,9]. Normally, the glands are 0.3 to 0.6 cm in thickness, 4 to 6 cm in length, and 2 to 3 cm in width [8,10]. The glands, particularly the left gland, are not really located in the suprarenal area; rather, they are anteromedial to the upper pole of the kidneys, with 10% of the left gland extending inferiorly to the level of the renal hilum. The adrenal mass may also be located anteriorly to the kidney (Figs. 4 and 5) [11].

Because of its specific morphology and scanning plane, the adrenal gland may appear variable in shape. It is usually linear or curvilinear superiorly, inverted Y- or inverted V-shaped in the middle section, and L- or reverse L-shaped inferiorly (Figs. 1–3) [1,2,4,9]. In adults, the gland is hypoechoic owing to the presence of surrounding hyper-echoic fat (Figs. 1–3). Echogenic medulla may sometimes be seen in normal and hyperplastic glands [7].



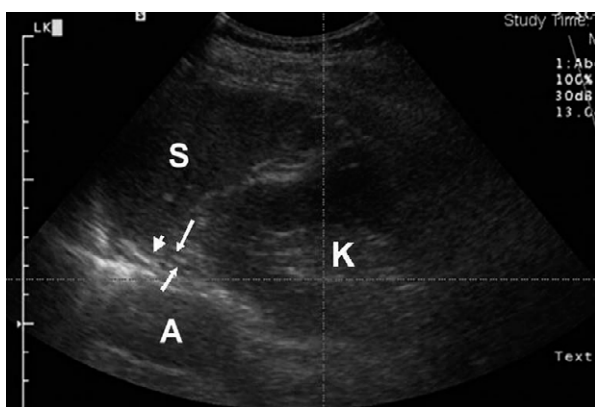
**Fig. 1.** Transverse oblique scan of the right upper abdomen through the right anterior axillary line and liver shows the horizontal Y-shaped hypoechoic adrenal gland (arrows and arrowhead), which is located in the area among the upper pole of right kidney (K), right liver lobe (L), and vertebrae (V). Note the anteromedial ridge (arrowhead) and posterolateral wings (arrows).



**Fig. 2.** Coronal scan of the right upper abdomen through the midaxillary line shows that the hypoechoic right adrenal gland (arrows) is a horizontally inverted Y-shape. K = right kidney; L = right liver lobe.

## Scanning Technique

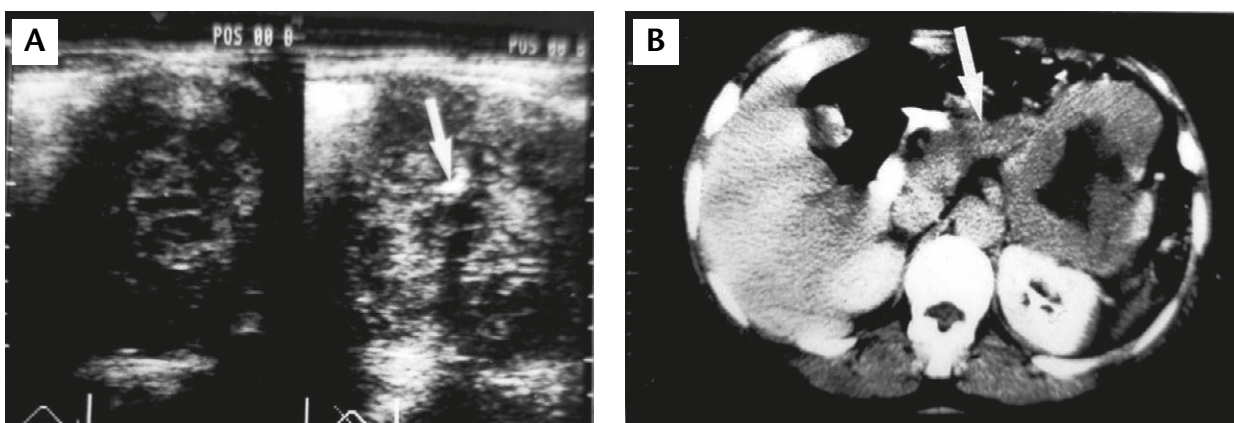
There are several approaches to scanning adrenal glands. It is usually difficult to assess the glands by posterior scanning because of obscuration by the ribs or the transverse process of the spine. The left adrenal gland is usually obscured by the stomach or bowel gas when it is scanned from the anterior abdominal wall. However, the right gland may be delineated through the liver, with its medial portion located posteriorly to the inferior vena cava



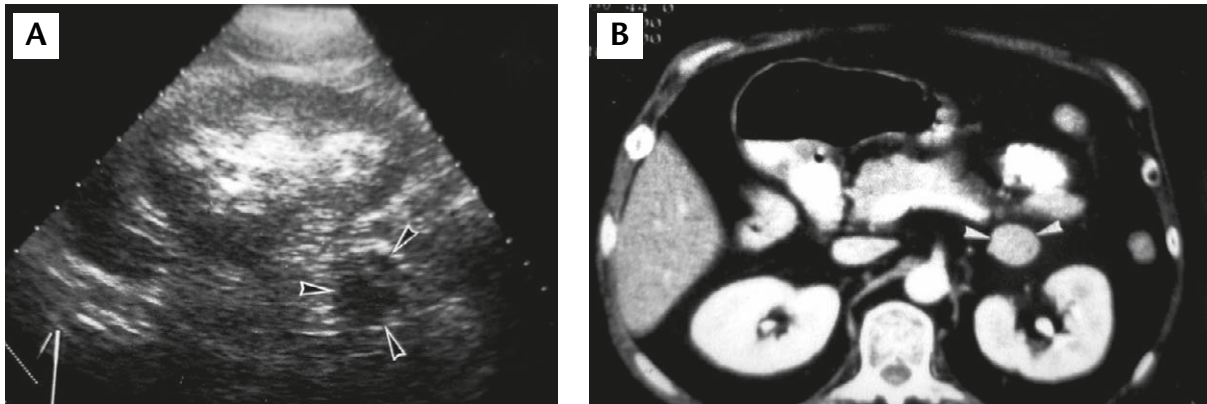
**Fig. 3.** Oblique coronal scan of the left upper abdomen through the posterior axillary line shows a normal left adrenal gland (arrows), which is hypoechoic and a horizontal Y-shape. It is confined by the spleen (S), left kidney (K), and abdominal aorta (A). Note the anteromedial ridge (short arrow) and posterolateral wings (long arrows).

[1,2,4–7], and is usually seen at the level of the porta hepatis in patients with normal-sized livers [7]. A larger adrenal mass can be investigated from the anterior abdominal wall (Fig. 6). However, it is sometimes difficult to assess whether the lesion is of adrenal origin if the mass is too large (Fig. 4). Right adrenal lesions can also be assessed in a coronal scanning plane through the right kidney and aorta or the inferior vena cava [7].

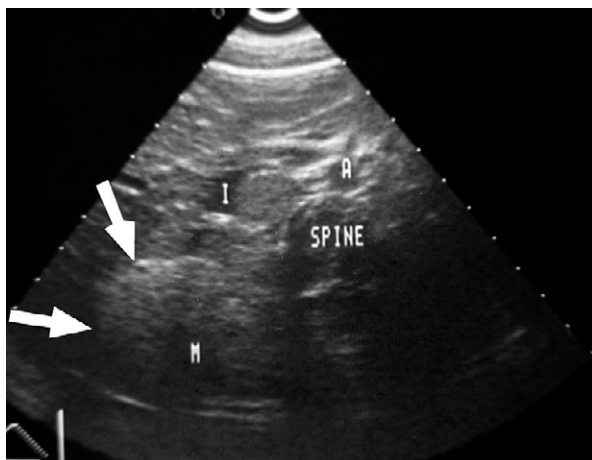
By using a 3.5 MHz sector or phase array probe, the best approach for viewing the right adrenal gland is to scan from the right flank region through the intercostal space (Figs. 1 and 2), while the best approach for the left gland is to scan from the posterior axillary line (Fig. 3). Through the anterior axillary line and liver, the right adrenal gland can be assessed in a transverse oblique scan. The gland in such a scan is confined to an area surrounded by the liver, inferior vena cava, upper pole of the right kidney, spine, and the diaphragmatic crus (Fig. 1). In a coronal scan through the mid-axillary line, the right gland is located lateral to the diaphragmatic crus and superior to the right kidney (Fig. 2) [1,2,4–7]. Since the spleen is relatively small compared with the liver, the left adrenal gland is investigated with an oblique coronal scan through the posterior axillary line using the spleen or left kidney as an acoustic window. In such an approach, the



**Fig. 4.** A case of left adrenal pheochromocytoma that was misinterpreted as peritoneal in origin on sonogram. (A) Transverse sonogram of the left upper abdomen shows a 9-cm heterogeneous and hyperechoic mass associated with calcification (arrow). (B) Computed tomogram shows that the pancreas (arrow) is displaced anteriorly, suggesting a retroperitoneal origin of the mass.



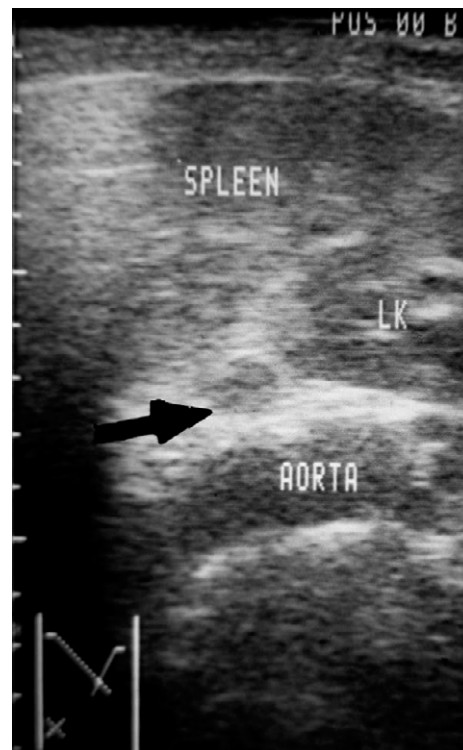
**Fig. 5.** A case of primary pigmented nodular adrenal hyperplasia with adrenal nodule located at the left renal hilum. (A) Sagittal sonogram of the left upper abdomen scanned from the back shows a 3-cm hypoechoic nodule (black arrowheads) near the left renal hilum. (B) Computed tomogram confirms that the left adrenal nodule (white arrowheads) extends downward and is located anteromedially to the renal hilum.



**Fig. 6.** Transverse oblique scan of the right upper abdomen shows a hyperechoic mass at the right adrenal area due to neuroblastoma (M; arrows); it is located on the right, posterior to the vertebrae (SPINE), and displaces the inferior vena cava (I) anteriorly. A = aorta.

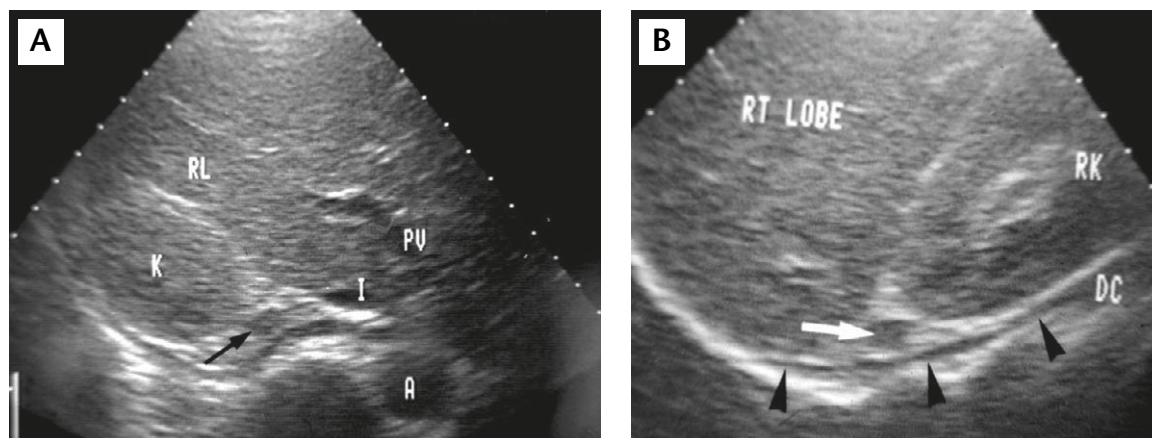
left adrenal gland is usually confined to the area that is surrounded by the spleen, aorta, and upper pole of the left kidney (Fig. 3) [1–4,7].

The visualization of normal adrenal glands depends on several factors, including the quality of equipment, scanning approach, skill of the ultrasonographer, and the effort of scanning. Using a real-time scanner, in our experience, successful visualization of the normal adrenal gland is 90% on the right side and 50% on the left [5]. The corresponding figures in the literature are 92–97% and



**Fig. 7.** A case of left adrenal aldosteronoma. Sonogram shows the homogeneously hypoechoic cortical adenoma (arrow) surrounded by the spleen, left kidney (LK), and aorta.

71–90%, respectively [2,12,13]. The visualization rate is higher in newborn infants by using a higher frequency transducer, giving successful visualization rates of 97–100% and 83–96% on the right and left sides, respectively [14,15].



**Fig. 8.** A case of idiopathic hyperaldosteronism with bilateral adrenal hyperplasia. (A) Transverse oblique sonogram of the right upper abdomen shows a 1.2-cm adrenal nodule (arrow) in the area confined by the kidney (K), right liver lobe (RL), and inferior vena cava (I). (B) Coronal sonogram shows that the nodule (arrow) is located lateral to the diaphragmatic crus (DC; arrowheads). A = aorta; PV = portal vein; RK = right kidney; RT LOBE = right liver lobe.

### Focal Adrenal Mass and Nodule

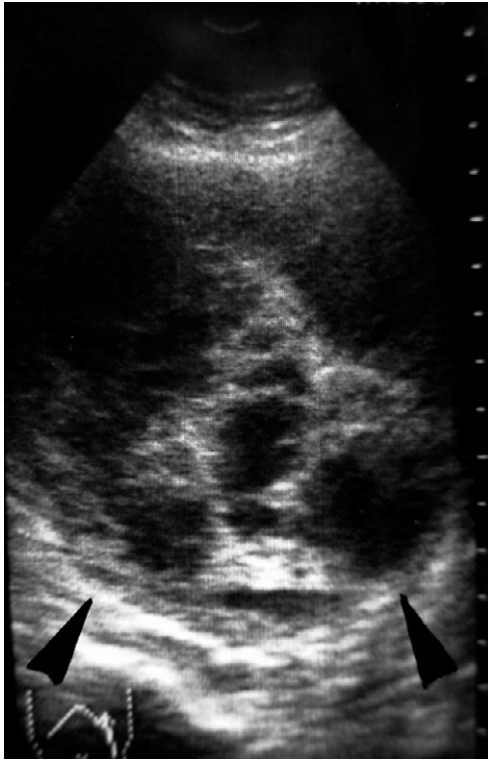
Lesions involving the adrenal gland can be either focal or diffuse, and unilateral or bilateral. Focal masses are much more common than diffuse lesions and can be round, oval or irregular in shape.

1. Adrenal nodules of less than 3 cm in diameter include: (1) benign nodules in cases of functioning or nonfunctioning cortical adenoma (Fig. 7), pheochromocytoma, or primary pigmented nodular adrenocortical disease (PPNAD) (Fig. 5) [5,6], and most nonfunctioning cortical adenomas are less than 3 cm in size [5,6,16], but may be as large as 10 cm in diameter [17]; (2) malignancies, with lung cancer being the most common, followed by cancers of other origins, including breast, kidney and lymphoma [6,7]; and (3) bilateral adrenal hyperplasia in cases of Cushing's syndrome, hyperaldosteronism (Fig. 8), adrenogenital syndrome, and rare diseases such as PPNAD [18]. In bilateral hyperplasia, the glands may be diffusely enlarged or nodular (Fig. 8), and the nodule may be either singular or multiple, micronodular (smaller than 0.8 cm) or occasionally macronodular (0.8 cm to 7 cm) [7,19].
2. For adrenal masses that are larger than 3 cm in diameter, it is easier to detect them using anterior (Fig. 6), lateral and posterior approaches. However, it is relatively difficult to differentiate an

adrenal mass from a retroperitoneal tumor adjacent to the adrenal gland. The adrenal mass may be round but is also frequently oval because of its restriction in the narrow fat space [7]. In cases of large adrenal masses, the kidney may be displaced laterally and/or inferiorly, and the inferior vena cava may be compressed. The left adrenal mass may displace the stomach, pancreas, and splenic vein anteriorly (Fig. 4). Occasionally, a large adrenal mass may be located anteriorly to the kidney at the hilar level without renal displacement (Fig. 4) [20]. This occurs more on the left side by a frequency of 10% (Fig. 5). A larger adrenal mass is more likely to have necrosis or hemorrhage (Fig. 9), which have similar features on sonogram. An adrenal mass with focal hemorrhage, blood, and necrosis without liquefaction may appear hyperechoic, while necrosis and hematomas with liquefaction may be hypoechoic or anechoic. The wall of a necrotic or hemorrhagic adrenal tumor is variable in appearance and may be smooth, irregular, thick or thin [20]. A larger adrenal mass is commonly found in cases of pheochromocytoma (Figs. 4 and 9), adrenocortical carcinoma, metastases (Fig. 10), and lymphoma [6]. Other cases include adrenal hyperplasia [19], granulomatous disease [21,22], hemangioma [23], and myelolipoma [24].

## Multiple Adrenal Masses

Multifocal adrenal lesions, whether unilateral or bilateral, can be either benign or malignant. These

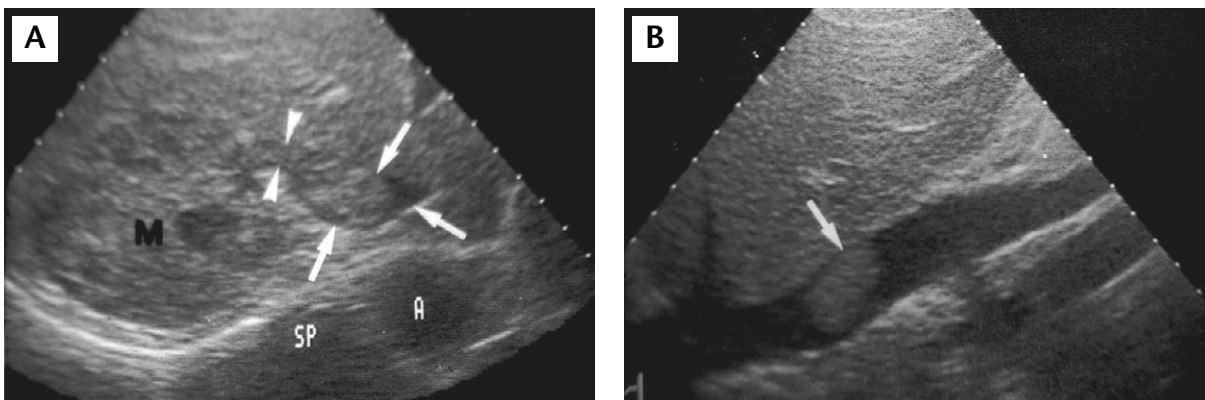


**Fig. 9.** Sonogram of the left upper abdomen shows a complex mass (arrows) due to pheochromocytoma of the left adrenal gland that is 10 cm in diameter.

lesions include: (1) pheochromocytoma, since 10% of pheochromocytomas can be bilateral with a familial tendency [25,26]; (2) adrenal nodular hyperplasia, with the nodules mostly being less than 1 cm in diameter, though hyperplasia up to 7 cm in diameter has been reported [19]; and (3) inflammatory granulomatous disease [6,21]. Malignancies may involve bilateral adrenal glands and include: (1) primary or secondary malignant lymphoma, mainly of a non-Hodgkin's disease type; and (2) metastases, with lung cancer being the most common primary [7]. Multinodular hyperplasia in a unilateral gland can be found in cases of primary hyperaldosteronism and Cushing's disease.

## Diffuse Adrenal Enlargement

Diffuse enlargement of the adrenal gland can originate from a variety of causes, including: (1) neoplasms, most commonly seen in cases of lymphoma (Fig. 11), and adrenal metastases from lung cancer, renal cell carcinoma, or an unknown primary [27]; (2) hemorrhage; (3) granulomatous disease such as tuberculosis (Fig. 12) and histoplasmosis [21,22,28]; and (4) bilateral adrenal hyperplasia, which may occur in cases of stress, Cushing's syndrome, hyperaldosteronism, adrenogenital syndrome, and PPNAD [18].



**Fig. 10.** A case of metastatic lung cancer in the right adrenal gland with invasion to the inferior vena cava. (A) Transverse oblique and (B) coronal sonogram of the right upper abdomen shows a right adrenal mass (M) with invasion (arrowheads) to the inferior vena cava (arrows). The tumor thrombus in the inferior vena cava (arrows) is well delineated. SP = spine; A = aorta.

## Calcification in Adrenal Gland

Calcification may occur in both benign (Figs. 4 and 13) and malignant lesions. Of the malignancies, calcification is most frequently observed in neuroblastomas, followed by adrenocortical carcinoma and mucin-producing metastases. The benign adrenal lesions that may be associated with calcification include cyst, adenoma, myelolipoma, Conn's

adenoma, hemangioma, hematoma, tuberculosis, histoplasmosis, cryptococcosis, Wolman's disease, amyloidosis, dermoid cyst, herpes simplex, and lesions with unknown etiology [6,29,30]. Calcification may also be found in benign and malignant pheochromocytomas (Fig. 4).

## Functioning Adrenal Lesions

The adrenal gland is composed of the adrenal cortex and medulla, which perform different endocrine functions. Abnormal endocrine function may occur in adrenal hyperplasia, cortical adenoma, adrenocortical carcinoma, pheochromocytoma, and other diseases.

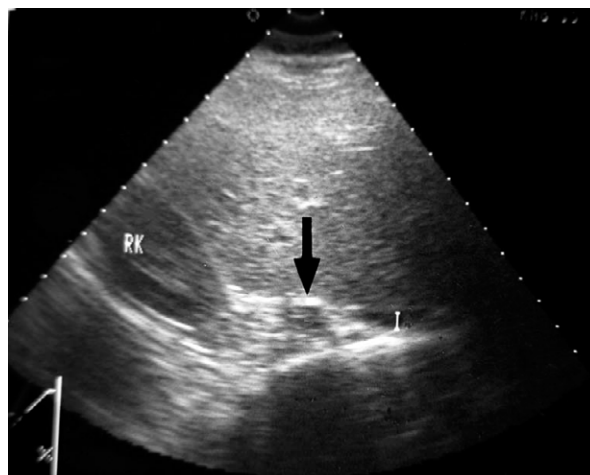
1. **Hypercortisolism:** This common syndrome or disease due to adrenocortical hyperfunction is summarized in the Table [31–36].
2. **Pheochromocytoma:** This tumor is caused by hyperfunction of pheochromocytes in the adrenal medulla, which secrete potent hormones such as norepinephrine or epinephrine. This hyperfunction results in various clinical manifestations, including paroxysmal hypertension, facial flushing, tachycardia, sweating, pallor, headache, and increased metabolism. In cases



**Fig. 11.** A case of diffuse enlargement of the right adrenal gland due to lymphoma. Sonogram reveals an enlarged right adrenal gland (black arrowhead) associated with intrahepatic lymphoma (white arrowhead), and enlarged nodes (arrows) in the retrocrural space.



**Fig. 12.** Coronal sonogram of the left upper abdomen shows left pleural effusion (arrow) and diffusely enlarged left adrenal gland due to tuberculosis (arrowhead).



**Fig. 13.** Transverse oblique sonogram of the right upper abdomen reveals calcification (arrow) of the right adrenal gland in a patient with Addison's disease. I = inferior vena cava; RK = right kidney.

**Table.** Comparison of the three common syndromes due to adrenocortical hyperfunction [31–36]

	Cushing's disease*	Primary hyperaldosteronism	Adrenogenital syndrome
Excess hormone	Cortisol	Mineralocorticoid aldosterone	Androgen or estrogen
Clinical manifestations	Truncal obesity, buffalo hump, fatigue, weight gain, puffy face, muscle wasting, weakness, abdominal striae, acne, glycosuria, hypertension, hirsutism, anxiety, insomnia, osteoporosis	Polyuria, diastolic hypertension, hypokalemia, hypernatremia	Feminization in male almost always due to adenoma or cortical carcinoma, pseudohermaphroditism in small girls, virilization in female, precocious puberty in boys
Laboratory data	↑ glucocorticoid	Hypokalemia, ↓ plasma renin,	↑ sex hormone
Etiology or adrenal pathology	80% corticotropin-dependant (hyperplasia): Cushing disease, 70% Ectopic corticotropin syndrome, 10% 20% corticotropin-independent: Adenoma, 10% Cortical carcinoma, 8% Bilateral nodular hyperplasia, 2%	Adenoma, 70% (Conn's syndrome); 90% < 2.5 cm, 20% < 1 cm Hyperplasia, 30% Adrenocortical carcinoma, < 1%	Congenital adrenal hyperplasia in 80%, the others include adenoma, adrenocortical carcinoma, ovarian or testicular tumors 21-hydroxylase deficiency accounts for about 95% of congenital adrenal hyperplasia

\*In Cushing's disease, 30% of patients may have normal-sized adrenal glands, the mean width of the adrenal limbs positively correlated with the circulating cortisol and ACTH levels. The adrenals are larger in patients with ectopic ACTH syndrome [33].



of biochemical evidence of a catecholamine-secreting tumor or pheochromocytoma, the next objective in the work-up is to localize and characterize the tumor. The early detection and diagnosis of this tumor is important as it is lethal if left untreated, while a cure is possible if the tumor is excised. However, one must be aware that manipulation or interventional procedures may induce a hypertension crisis.

There are "rules of 10" for pheochromocytoma, including that 10% of tumors arise outside the adrenal gland, 10% of extra-adrenal tumors are extra-abdominal, around 10% of tumors are malignant, and about 10% of cases have multiple masses. Paraganglioma is the preferred term for extra-adrenal pheochromocytoma [32]. Unlike other tumors, benign pheochromocytomas may become very large and tend to be necrotic and hemorrhagic, even if they are small [37] (Figs. 4 and 9). Multiple pheochromocytomas are often benign [20,32]. Extra-adrenal pheochromocytomas are more likely to be malignant, with a prevalence of 40%. They may occur in the sympathetic nervous system, organ of Zuckerkandl, or in the wall of the urinary bladder, with only around 1% of the tumors occurring in the chest. The tumor may also be found in patients with type 2A and type 2B multiple endocrine neoplasia and can be associated with von Hippel-Lindau disease in about 10% of cases and with neurofibromatosis in less than 1% of cases [38]. It is reported that in the detection of pheochromocytoma, <sup>131</sup>I-metaiodobenzylguanidine has a sensitivity and specificity of 80–90% and 90%–100%, respectively, and is particularly useful in detecting paraganglioma or residual tumor after surgery [32].

## Incidentaloma

An incidentaloma is a tumor found by coincidence without clinical symptoms and suspicion. In an autopsy series, the prevalence of previously undiagnosed adrenal masses ranged from 1.4 to 2.9% [16]. The prevalence of adrenal incidentaloma

approaches 3% in middle age, and increases to as much as 10% in the elderly. Advances in imaging and the availability of imaging technology may reveal a higher incidence, making the management of incidentaloma a challenge for modern medicine. The etiology of incidentalomas is as follows: adenoma 41%, metastases 19%, adrenocortical carcinoma 10%, myelolipoma 9%, pheochromocytoma 8%, with other mostly benign lesions, such as adrenal cysts, comprising the remainder. In lung cancer patients, adrenal masses were detected in 4.0%. A quarter of these corresponded to benign adenomas, whereas the rest were metastases [16].

The diameters of nonfunctioning cortical adenomas range from 1–6 cm (mean 2.4 cm), with 50% of the tumors being less than 2 cm in diameter. These tumors can be found at autopsy with a frequency of 2.8% [39,40] and are commonly observed in aged women and in patients with hypertension, diabetes mellitus or cancer.

In patients with malignancies, it is difficult to differentiate between incidentaloma and metastasis. Detecting such a difference is important for accurate staging and management of cancer patients. In a series of 330 patients with non-small cell carcinoma, 32 were associated with adrenal nodules without evidence of metastasis elsewhere in the abdomen. Of these 32 nodules, 8 were proven to be metastases, and 17 were shown to be nonfunctioning cortical adenomas. The mean diameter of the metastases was 4.3 cm, and 60% of the metastatic tumors were larger than 3 cm in diameter [41].

## Benign Adrenal Lesions

### Adrenal cysts

Adrenal cysts are usually seen in patients between 40 and 60 years of age. Sixty percent of adrenal cysts are subclassified pathologically as lymphangiomatous, epithelial or infectious types; the remaining 40% are pseudocysts secondary to cystic change of adrenal lesions, such as infections, tumors and hematoma [31,32]. The adrenal cysts are usually anechoic. They may exhibit high echogenicity,

casting an acoustic shadow if there is calcification, which occurs in 15% of adrenal cysts [42]. In contrast to calcified renal cysts, which have a high incidence of carcinoma, calcified adrenal cysts are usually benign [4].

**Myelolipoma**

Myelolipoma is a rare, benign, nonfunctioning tumor with an incidence of 0.08–0.20% at autopsy and is usually seen in 30- to 60-year-old patients [31,32]. Because of a mixed content of fat and bone marrow cells, the tumor is characteristically hyperechoic [24] and simulates renal angiomyolipoma (Fig. 14). Thus, one should carefully differentiate between adrenal myelolipoma and renal angiomyolipoma when scanning.

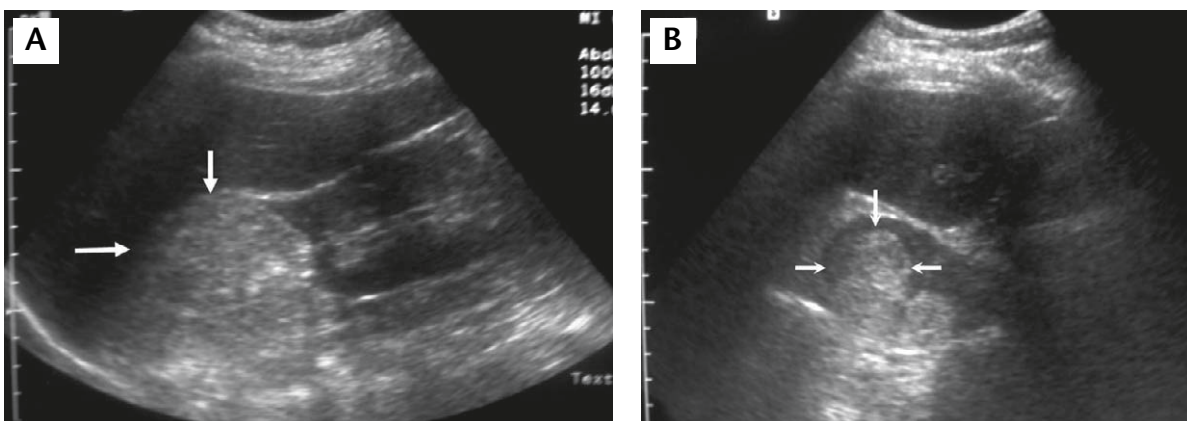
**Inflammatory disease**

Tuberculosis and histoplasmosis are the two main inflammatory lesions of the adrenal glands that may lead to Addison’s disease and are often associated with granulomatous infection in other organs [22,43]. The key imaging findings are diffuse enlargement or nodules of the glands in the acute phase, and calcification in the chronic stage. Image-guided intervention may be of help in establishing an accurate diagnosis. Nonspecific chronic inflammation of the adrenal fibrofatty tissue may also lead

to mass-like lesions and shows as indistinct hyperechoic masses on sonograms [20]. Bacterial infection or abscess of the gland is rare; it may occur in the postpartum period or as a complication of adrenal cysts, necrotic tumors, and chorioamnionitis [44].

**Adrenocortical insufficiency**

Adrenocortical insufficiency is a clinical diagnosis based on clinical and biochemical findings. Primary adrenocortical insufficiency or Addison’s disease occurs when 90% or more of the adrenal cortex is destroyed. The disease more frequently occurs in granulomatous disease than in cases of adrenal neoplasm, hemorrhage and other infection [32,45]. Addison’s disease due to metastasis is typically associated with systemic metastases. Secondary adrenal insufficiency most commonly results from the suppression of the hypothalamic-pituitary axis by exogenously administered steroids, but may also result from panhypopituitarism. Idiopathic atrophy is probably an autoimmune disease and is the most common cause of subacute and chronic adrenal insufficiency in developed countries [32]. Acute adrenal insufficiency most often results from the rapid withdrawal of steroids from patients with adrenal atrophy caused by chronic steroid use. Fulminant hemorrhagic destruction of both adrenal glands, usually associated with overwhelming



**Fig. 14.** A case of right renal hamartoma or angiomyolipoma. (A) Coronal sonogram of the right upper abdomen shows a hyper-echoic hamartoma (arrows) of the right kidney that extends to the suprarenal area; the differential diagnoses include adrenal myelolipoma, retroperitoneal lipoma, fibrous lipoma, and liposarcoma. (B) Right renal sonogram confirms that the tumor (arrows) is of renal origin.

septicemia, is another cause of acute adrenocortical insufficiency. Calcification of small adrenal glands is more frequently observed in tuberculosis (Fig 13) [32].

### **Adrenal hemorrhage**

The causes of adrenal hemorrhage include trauma, stress, coagulopathy, underlying adrenal tumors, and idiopathic diseases such as adrenal venous lesions [46]. Spontaneous hemorrhage is usually associated with septicemia (Waterhouse-Friderichsen syndrome), surgery, burn injury or an adrenal neoplasm [31]. The disease is bilateral in up to 20% of patients. On sonograms, acute hemorrhage is mildly hyperechoic, while subacute hemorrhage (i.e. 1–2 months or older) may appear hypoechoic or anechoic [47–49]. The characteristic finding is progressive shrinkage of adrenal size during a 6-month period of observation.

### **Other unusual benign lesions**

These include ganglioneuroma, ganglioneuroblastoma, extramedullary plasmacytoma, neurilemoma, teratoma, collision tumor, primary malignant melanoma, angiosarcoma, and others. Except for fat-containing tumors, the imaging features of these masses are usually nonspecific [50–52]. Ganglioneuroma is a benign form of neuroblastoma. This is a rare tumor that can be seen in children or adults. Neuroblastoma may sometimes mature spontaneously into benign ganglioneuroma.

## **Adrenal Malignancies**

### **Primary adrenocortical carcinoma**

Primary adrenocortical carcinoma mostly occurs in patients aged 45 to 60 years with around 22% being nonfunctioning and 78% being functioning. Of the functioning tumors, 50% present with Cushing's syndrome, 20% with adrenogenital syndrome, 4% with hyperaldosteronism, and 4% with Cushing's and virilizing syndrome. If the tumor is nonfunctioning, it may become very large (> 6 cm in diameter). Survival of the patient is frequently

shorter than those with a functioning tumor because of the nonfunctioning tumor's invasiveness and the presence of widespread metastases to the liver, lung, bone, and peritoneal cavity. Eighty-one to ninety percent of nonfunctioning tumors are larger than 6 cm in diameter and usually show heterogeneity and high echogenicity due to the presence of necrosis, hemorrhage, and calcification. Functioning tumors range from 3–6 cm in diameter and present as homogeneously hypoechoic on sonograms [53].

### **Adrenal metastases**

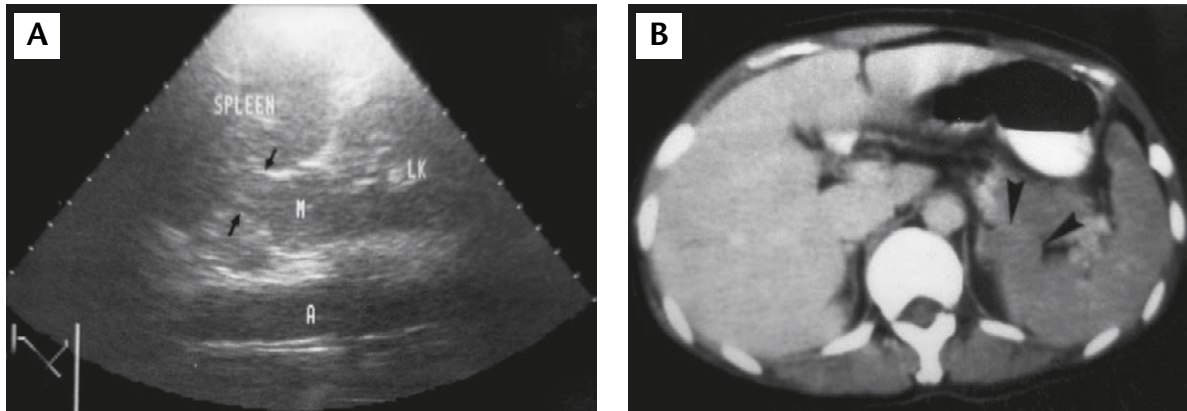
The most common primaries of adrenal metastases are the lung (Fig. 10) and breast; other origins include kidney, gastrointestinal tract, thyroid, pancreas, and skin. In an autopsy series, 76% of lung cancers and 54% of breast cancers were associated with adrenal metastases. Forty percent of adrenal metastases are bilateral [4,20].

### **Lymphoma**

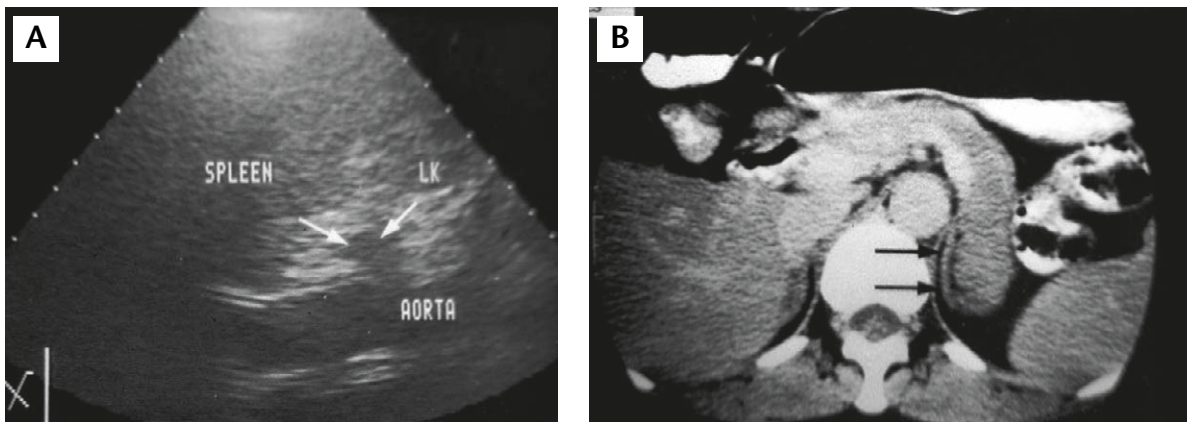
Primary adrenal lymphoma is rare. This tumor is usually a non-Hodgkin's type and is most frequently associated with retroperitoneal or ipsilateral renal lymphoma. One to four percent of patients with systemic lymphoma may have adrenal involvement; of these, nearly 50% are bilateral and may be diffuse or focal [31]. The tumors are usually homogeneous and hypoechoic (Fig. 11).

### **Neuroblastoma**

Neuroblastoma is a neuroendocrine tumor arising from a neural crest element of the sympathetic nervous system. The tumor is the most common extracranial solid cancer in infancy and childhood with frequent metastasis to the bone, nodes, liver, and skin; 50% of victims are younger than 2 years old, and 80% are younger than 5 years old. Two-thirds of the tumors are located in the abdomen, and two-thirds of the abdominal tumors are of adrenal origin. Some patients may present with hypertension due to increased secretion of catecholamine. Because of frequent necrosis or hemorrhage and the presence of calcification, the mass is



**Fig. 15.** A case of left adrenal pseudonodule on sonogram caused by medial tubercle of the spleen. (A) Oblique coronal sonogram of the left adrenal area shows a nodule (M) at the left suprarenal area surrounded by the left kidney (LK), spleen, and aorta (A); the nodule (M) is isoechoic and contiguous (arrows) to the spleen. (B) Computed tomogram shows that the left adrenal pseudo-nodule on sonogram is caused by the medial tubercle of the spleen (arrowheads).



**Fig. 16.** Pitfall of left adrenal sonography. (A) Sonogram of the left upper abdomen shows a hypoechoic nodule (white arrows) surrounded by the spleen, aorta, and left kidney (LK). (B) Computed tomogram reveals that the pseudonodule shown on sonogram is a pancreatic tail located lateral to the left adrenal gland (black arrows).

characteristically hyperechoic or heterogeneously echogenic [54]. Calcifications may be found in 50% of patients. The major differential diagnosis of the tumor is Wilms' tumor, which arises from the kidney.

### Sonographic Characterization of Adrenal Lesions

Adrenal masses or nodules are usually hypoechoic to surrounding fat on sonograms. A final accurate diagnosis depends on the clinical manifestation, laboratory findings, biopsy or surgery. However,

pheochromocytoma should be considered first in cases of complex mass or cystic change in a solid nodule. The differential diagnoses of hyperechoic mass include myelolipoma, neuroblastoma (Fig. 6), pheochromocytoma (Fig. 4), and primary or secondary carcinoma with necrosis and heterogeneous content. Differentiation of small nodules between adrenal hyperplasia and functioning adrenal adenoma is of importance, since the latter requires surgical removal, whereas bilateral hyperplasia with or without nodules may need only conservative treatment, unless a pituitary tumor or some other ACTH-producing tumor is found.

## Differentiation of Benign and Malignant Lesions and the Roles of Other Imaging Modalities

Except for pheochromocytoma, lesions larger than 4 cm in diameter are more likely to be malignancies, which include metastasis, lymphoma, and primary adrenal carcinoma. Progression in lesion size is a useful indicator of malignancy, because adenomas are frequently a fixed size [32]. Other suggestive findings of malignancy include masses associated with an indistinct or irregular outline, invasiveness to the surrounding organs or vessels (Fig. 10), coexistent contralateral adrenal masses, or metastases elsewhere [5,6] (Fig. 11).

It is essential to differentiate an incidentaloma from a metastatic nodule that occurs most frequently in cases of lung cancer. A nonfunctioning cortical adenoma is usually less than 3 cm in diameter and of a fixed size. It is more likely to have an attenuation value of 10 Hounsfield units or less and a contrast washout of 60% or greater on a 15-minute delayed CT scan. Another specific sign of adenoma is loss of signal intensity on opposed-phase gradient-echo T1-weighted imaging [31,32,55,56]. With combined unenhanced and delayed enhanced CT, 96% of adrenal masses can be correctly categorized as adenomas or non-adenomas [57]. In a series of 175 adrenal masses in 150 patients, positron emission tomography (PET) scanning using a standard uptake cutoff value of 3.1 yielded a sensitivity, specificity, and accuracy of 99%, 92%, and 94%, respectively; combined PET/CT data yielded corresponding values of 100%, 98%, and 99% [58].

## Accuracy and Limitation of Adrenal US

Various structures in the vicinity of the adrenal glands may be misinterpreted as adrenal lesions on US. These include protruded masses from the liver, pancreas, or upper kidney (Fig. 14), as well as primary retroperitoneal tumors, accessory spleen, medial tubercle of spleen (Fig. 15), gastric fundus, small

bowels, enlarged nodes, pancreatic tails (Fig. 16), engorged vessels, and collaterals. The sensitivity, specificity and accuracy of US in adrenal lesions are 74–97%, 61–96% and 70–97%, respectively [2,5,6,10,59]. Small lesion size, patient obesity, fatty liver, ileus, and large body status are major factors that decrease the sensitivity of US [6].

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