Imaging the adrenal glands

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Learning objectives

1. To present the normal adrenal gland appearance on ultrasound (US), computed tomography (CT) and magnetic resonance imaging (MRI).
2. To review and illustrate imaging findings in a wide spectrum of usual and unusual adrenal diseases.
3. To systematize the evaluation of incidentally detected adrenal masses.

Background

Adrenal gland imaging is usually performed either for the investigation of abnormal biochemistry pointing to adrenal pathology or the characterization of an adrenal mass discovered incidentally.

Adrenal masses are seen at autopsy in 2-10% of all patients and metastases are found post-mortem in the adrenal glands in up to 26% of patients in oncologic setting. Hence, it is not surprising that is a very frequent incidental finding during abdominal imaging. However, even in an oncologic patient, many adrenal lesions are benign, mostly non-hyperfunctioning adenomas.

Thus, imaging studies play a central role not only in the detection of adrenal abnormalities but also in characterizing them as benign or malignant.

Anatomic considerations

The adrenal glands are paired retroperitoneal organs that lie in a suprarenal location and are enclosed within the perinephric fascia together with the kidneys and a variable amount of fat. Each gland comprises two discrete anatomic and functional units: the adrenal cortex and the medulla. The cortex is derived from the mesoderm and is responsible for synthesis and secretion of cortisol, aldosterone, and adrenal androgens. The medulla, which is derived from the neural crest, is the site for synthesis of the catecholamines epinephrine and norepinephrine.

The right adrenal gland usually presents a linear, comma or V shape. It lies between the right lobe of the liver and the right crura of the diaphragm, posterior to the inferior
cava vein (ICV) at the level where the ICV enters the liver and located anteromedial and superior to the upper pole of the right kidney. The left adrenal gland is triangular or Y-shaped. This gland is more closely applied to the kidney, lying just medial and anterior to the upper pole of the left kidney, posterior to the pancreas and splenic vessels, and lateral to the left crura of the diaphragm.

Both glands have a medial and a lateral limbs extending posteriorly from a central ridge. The limbs are 4 to 6 cm in length, 2 to 3 cm in width and 5 to 7 mm in thick, with concave and sharply margined contours.

The blood supply of the adrenals is derived from branches of the inferior phrenic artery, the right renal artery, and the aorta. Each adrenal is drained by a single central vein. On the right, this vein is short (1 to 1.5 cm long), runs transversely, and joins the lateral aspect of the inferior vena cava. The left adrenal vein is longer than the right adrenal vein and runs somewhat obliquely from the inferomedial aspect of the gland to enter the left renal vein.

Imaging evaluation

Ultrasound

Ultrasonography is often the first imaging study performed in the newborn or young infant. It is safe and easy to perform without sedation. The adrenal glands are infrequently seen in adults.

The adrenal gland cortex is less echogenic than the surrounding perirenal fat, whereas the medulla is evident as a highly echogenic central linear structure. The echogenic linear medulla is most prominent in the fetus and the newborn.

When possible, long-axis and transverse images of the adrenal glands should be obtained. The shape and size of the gland should be documented as well as the presence of haemorrhage, solid and/or cystic components of the masses and vascular involvement.
Computed Tomography (CT) Technique

In patients with known adrenal disease, CT is the imaging modality of choice.

CT is also the primary method for excluding metastatic disease in the adrenals. Frequently, however, the radiologist is confronted with incidentally detected adrenal lesions and is challenged to develop diagnostic strategies for differentiating benign from malignant lesions.

CT of the adrenal glands should be performed with thin slices (3mm or less) for detection of small endocrine tumors and correct measurements of CT attenuation.

Unenhanced CT
The adrenal glands are of uniform soft tissue density. Precontrast attenuation value is about 25 - 40 HU.

Unenhanced CT can give clues to the diagnosis, as well as indicate the likelihood of lesion malignancy:

1. Size
   - Lesions greater than 5cm in diameter tend to be either metastases or primary adrenal carcinomas.
   - Rapid change in size suggests malignancy, on the other hand, benign lesions are slow-growing lesions
   - Size alone is poor at discriminating between adenomas and non-adenomas. A 3.0 cm cut-off had been described with 79% specificity and 84% sensitivity.

2. Attenuation value
   - Adenomas have a high intra-cellular lipid content, which lowers their attenuation value. In clinical practice, 10 HU is the most widely used threshold attenuation value for the diagnosis of an adrenal adenoma.
   - Acute to subacute hematomas can have a high attenuation value that usually ranges from 50 to 90 HU.
   - Up to 30% of benign adenomas, as well as malignant lesions, have an attenuation value greater than 10 HU and are considered to be lipid poor.

**Contrast-enhanced CT**

The use of contrast material may be useful in characterizing an adrenal lesion in respect to the presence, degree, and pattern of enhancement. It can also help determine the organ of origin of a mass when it is unclear from the unenhanced study.

Imaging scanner may be acquired at different time intervals after contrast injection:

**Arterial phase** (25-35seconds after intravenous contrast injection)
   - Although useful for distinguish adrenal lesion from adjacent structures, it is not necessary once enhanced phases are acquired
   - It is generally accepted that early contrast enhancement is not contributive to the differential diagnosis of benign and malignant disease
   - This phase is not routinely acquired.
Parenchymal phase (60-90 seconds after intravenous contrast injection)

- Is the phase where the mean attenuation difference between adenomas and nonadenomas is higher, due to the faster wash-out of adenomas

Delayed phase (15 minutes after intravenous contrast injection)

- Required to determine lesions’ wash-out, a very useful tool in the differentiation of the lipid-poor adenomas.

**Fig.**: Normal adrenal glands on CT, before and after intravenous contrast administration.

**References**: A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

**Magnetic Resonance Imaging Technique**

Because of its superiority for estimating the fat content of the lesion, MRI offers great potential, especially for the differentiation of benign and malignant enlargement of the adrenals.

**Conventional Spin-echo Imaging**

On T2 sequences, adrenals are isointense or slightly hypointense compared with the liver and hypointense compared with the spleen.

T2-weighted spin-echo images were initially promising on the basis that hypercellular and high fluid content lesions like the malignant and metastatic ones would be hyperintense, while adenomas would be homogeneously iso- or hypo-intense compared with the normal adrenal gland. However, considerable overlap between the lesions exits, and some remain indeterminate.
Fig.: Normal adrenal glands on a coronal T2-wi.

References: A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

Gadolinium-enhanced Magnetic Resonance Imaging

- The accuracy of MRI in differentiating benign from malignant masses can be improved after intravenous gadolinium injection on gradient echo sequences.
- However, there is considerable overlap in the characteristics of benign and malignant masses, limiting the clinical applicability of this technique to distinguish adenomas from malignant masses.
In addition, adenomas often show a thin rim of enhancement in the late phase of gadolinium-enhanced images.

Metastases frequently have heterogeneous enhancement.

**Chemical-shift Imaging**

The ability to detect and characterize intracellular lipid makes chemical shift MR an ideal imaging technique for evaluating adrenal masses and distinguishing between metastatic disease and benign cortical adenomas.

Chemical shift imaging is performed with in-phase and out-of-phase spoiled gradient-recalled-echo (GRE) sequences. The SI on an in-phase image is derived from the signal of water plus fat protons, if water and fat are present in the same pixel. On out-of-phase sequences, the SI is derived from the difference of the signal intensities of water and fat protons. Therefore, adenomas that contain intracellular lipid lose SI on out-of-phase sequence compared with in-phase images, whereas metastases that lack intracellular lipid remain with unchanged SI.

**Fat saturation**

Fat-saturation MR is used to demonstrate macroscopic fat seen in adrenal myelolipomas. Macroscopic fat shows a loss of signal intensity on fat-saturation images compared to pulse sequences of the same technique without fat saturation.

**Imaging findings OR Procedure details**

Primary adrenal disease can be systematized according to its cortical or medullar origin:

**Adrenal Cortical Disease**

1. Adrenal hyperplasia
2. Adrenocortical adenoma
3. Cushing syndrome (adrenal hyperproduction of corticosteroids)
4. Conn syndrome (primary hyperaldosteronism)
5. Adrenogenital syndrome
6. Adrenocortical carcinoma

**Adrenal Medullary Disease**

1. Neuroblastoma
2. Ganglioneuroblastoma
3. Ganglioneuroma
4. Pheochromocytoma

In this pictorial review, adrenal disease will be described focusing on its behaviour as endocrine syndrome, benign and malignant disease.

**ADRENAL ASSOCIATED ENDOCRINE SYNDROMES**

1. Cushing syndrome
2. Conn syndrome
3. Addison disease
4. Adrenogenital syndrome
5. Pheocromocytoma

**1. Cushing syndrome**

Cushing syndrome is caused by excessive amounts of hydrocortisone and corticosterone. Patients typically present the known signs glucocorticoids, such as truncal obesity, hypertension, fatigability and weakness, easy bruisability, osteoporosis and broad violaceous cutaneous striae.

Adrenal hyperplasia is the most common (70%) cause of noniatrogenic Cushing syndrome. Benign adrenal adenomas are the causative agent in 20% of cases, while adrenal carcinoma the remaining 10%.*

**2. Conn syndrome**
Aldosteronism is a syndrome associated with hypersecretion of mineralocorticoid aldosterone. Patients present with diastolic hypertension, representing 1 to % of systemic causes of this problem. In primary form of aldosteronism the cause of the excessive aldosterone production resides in the adrenal gland. A solitary adrenal, benign, hyperfunctioning adrenal adenoma is the cause of 80% of cases, while the other 20% are due to adrenal hyperplasia.*

3. Addison disease

Addison disease represents a primary adrenocortical insufficiency and occurs only after 90% of the adrenal cortex is destroyed. The most common cause is idiopathic (60%), but tuberculosis, histoplasmosis, infarction, fungal infection, lymphoma and metastatic disease are also be contributing agents.

Adrenals are shrink and may not be detectable with imaging methods.

4. Adrenogenital syndrome

Adrenogenital syndrome is a congenital autosomal recessive adrenal hyperplasia characterized by an enzymatic disorder (21-hydroxylase deficiency) in the cortisol synthesis leading to an increase of the other adrenal steroids, generally causing adrenal hyperandrogenism. Both adrenal adenomas and carcinomas may be a cause of masculinizing and feminizing syndrome in older patients.*

*Adrenal hyperplasia and adenomas will be exposed and illustrated in the next section: benign adrenal diseases.

5. Pheochromocytoma

Paragangliomas are tumors composed of chromafin cells that may secrete catecholamines, and can occur anywhere from the bladder to the brain. When specifically located at the adrenal glands they arise from the pheochromocytes, the predominant cells of the adrenal medulla, are called pheochromocytomas.

Pheochromocytomas have been called the "ten percent tumor": about 10% are bilateral, 10% are extra-adrenal (paragangliomas of the retroperitoneum, mediastinum, or urinary bladder), 10% occur in children, and 10% are malignant. Not rarely is the radiologist and not the pathologist who determines whether the primary tumor is benign or malignant based on the presence or absence of metastatic disease.

Pheochromocytomas can occur sporadically or a part of a hereditary syndrome such as multiple endocrine neoplasia (MEN) type IIA, von Hippel-Lindau disease, neurofibromatosis, and isolated familial pheochromocytoma.
**Imaging findings:**

Pheochromocytomas are usually 3cm or larger well-circumscribed lesions.

Tumor varies from purely solid to complex to predominantly cystic lesions. Small tumors are generally homogeneous but heterogeneity predominates in the larger ones due to intratumoral haemorrhage, necrosis with consequent cyst formation, and the presence of calcifications.

**Computed tomography**

Calcification is rare, but when present has an "egg-shell" configuration.

Traditionally, literature advises not to administrate intravenous contrast media in patients with suspected pheocromocitoma because of a presumed risk of precipitating adrenergic crisis. However, more recent experiences support a high level of safety with non-ionic contrast media.

Pheochromocytomas are hypervascular tumors, presenting marked enhancement after intravenous administration of contrast material with very poor wash out.

**Magnetic Resonance**

Most pheochromocytomas demonstrate homogeneous high signal intensity on T2-weighted images, the "light bulb sign". However, with refined MR techniques they may show heterogeneous low, intermediate and high SI on T2-WIs and thus this sign should not be used as a feature to suggest or exclude pheochromocytoma. They typically show intense enhancement after the administration of contrast material.

Pheochromocytomas do not contain a substantial amount of cytoplasmic lipid, and, therefore, they maintain their signal intensity on out-of-phase GRE chemical shift images.

Hereditary forms of the disease such as Von Hippel-Lindau disease and MEN type IIA should be suspected when bilateral pheochromocytomas are revealed, as well as CT may reveal masses in the pancreas, kidney, and spinal cord.
**Fig.** Left adrenal pheochromocytoma. In-phase(A) and opposed-phase(B) T1-wi reveal a small adrenal mass (arrow) of low signal intensity that does not lose signal on opposed-phase. Corresponding T2-wi axial(C) and sagital images(D) ashows the "light bulb sign".

**References:** A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL
**Fig.**: Right heterogeneous adrenal pheochromocytoma. T1-w (A) and T2-w (B) images depict a heterogeneous adrenal mass, with high signal on both sequences, corresponding to a hemorrhagic focus. After intravenous contrast administration, obvious enhancement is seen (C), with no apparent washout on late phase (D).

**References:** A. Frias Vilaça; Imagiologia, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

**BENIGN ADRENAL LESIONS**

1. Adrenal hyperplasia
2. Adrenal adenoma
3. Adrenal myelolipoma
4. Adrenal haemorrhage
5. Adrenal cyst

1. Adrenal hyperplasia
Adrenal hyperplasia is the cause of 70% cases of Cushing syndrome and 20% cases of Conn syndrome.

Its differentiation from adrenal adenoma as etiologic agent is of primary importance once it is medically treated, while surgical removal of the hyperfunctioning adenoma may be curative.

**Imaging findings**

Diffuse hyperplasia presents with adrenal limbs longer than 5cm and exceeding 10mm in thickness.

Uncommonly, hyperplasia may appear nodular and mimic solitary or multiple adenomas.
Fig.: Adrenal hyperplasia in a patient with Cushing syndrome. Left adrenal gland present thickened limbs.

References: A. Frias Vilaça; Imagioologia, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

2. ADRENAL ADENOMAS

Adrenocortical adenomas are benign neoplasms of the adrenal cortex, found in 3% of cases at autopsy.

They might be functioning or non-functioning lesions. Nonfunctioning adrenal adenomas are the most common adrenal incidentaloma. However, functioning adenomas are usually associated with a specific clinical syndrome (Cushing or Conn syndrome). Neither CT nor MR findings allow the differentiation between both.

Cushing adenomas are usually larger than the Conn's syndrome, measuring 2-5cm and <2cm respectively, and surgical treatment is the option. Nevertheless, both syndromes can also course with bilateral adrenal hyperplasia being managed medically and not surgically.

One cannot forget that although adrenal Cushing syndrome is most commonly attributable to adenoma it can as well result from adrenal cortical carcinoma or primary adrenal hyperplasia.

Diagnostic imaging is based on:

- Intracellular lipid content (histological criteria)
- Vascular behavior after contrast administration (physiological criteria).

Note: Both lipid-rich and lipid-poor adenomas behave similarly, independently of their lipid content.

Imaging findings

Computed tomography

Low attenuation values (< 10 Hounsfield Units (HU)) on unenhanced CT imaging suggests benign, adenomatous lesion.
**Fig.**: Right adrenal adenoma. The adrenal mass presents with 2HU mean value.

**References**: A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

Lesion’s intracellular lipid content can be evaluated by the calculation of the absolute percentage enhancement wash-out can be calculated with lesion attenuation values obtained in pre-contrast, and 60seconds (early phase) and 15minutes (delay phase) acquisitions after contrast injection:

\[
% \text{washout} = \frac{\text{HU early} - \text{HU delay}}{\text{HU early} - \text{HU pre}} \times 100
\]

Frequently in clinical practice, only post-contrast images are available. In these patients, relative percentage enhancement wash-out can be calculated with lesion attenuation values obtained 60seconds (early phase) and 15minutes (delay phase) acquisitions after contrast injection:

\[
% \text{washout} = \frac{\text{HU early} - \text{HU delay}}{\text{HU early} - \text{HU pre}} \times 100
\]
A cut-off of 60% for absolute wash-out and 40% for the relative wash-out allows identification of an adenoma with high specificity and sensitivity. Attention might be made to the fact that washout values are only applicable to relatively homogeneous masses without large areas of necrosis or haemorrhage.

**Fig.** Non adenomatous adrenal lesion. On pre-contrast image (A), adrenal mass presents 35HU attenuation. After intravenous contrast administration, on early phase (B), has 67 HU, and on late phase 50 HU. The calculated absolute wash-out revealed to be 53% (inferior to 60%).

**References:** A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

**Magnetic Resonance**

Adenomas are homogeneously iso- or hypo-intense compared with the normal adrenal gland.

Optical loss of signal intensity on MRI chemical-shift imaging sequences is diagnostic of cortical adenoma. However, quantitative analysis can be made through the chemical shift index, with signal intensity values obtained on both in-phase (IP) and opposed-phase (OP) sequences, as follows:

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A chemical shift index >0.15 has high specificity and positive predictive value for adenoma.
Fig.: Chemical shift imaging characterization of an adrenal adenoma. In-phase (A) and opposed-phase (B) T1-wi show a small left adrenal lesion that looses signal in B, indicating the presence of intracellular lipid.

References: A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

If CT or MRI imaging establishes a diagnosis of a cortical adenoma and clinical evaluation does not reveal signs, symptoms, or laboratory findings of adrenal hyperfunction, variable approaches have been proposed. Most specialists recommend removing any non-functioning adrenal lesion larger than 5cm unless the radiographic appearance of the lesion is diagnostic of a cyst or myelolipoma. Smaller tumors should be followed with imaging at 4 and 12 months after the initial presentation, but some authors recommend "ignoring" the lesion and not obtaining follow-up imaging.

3. Myelolipoma

Myelolipoma is a rare, benign encapsulated tumor composed of hematopoietic (myeloide and erythroide) tissue and variable amounts of mature adipose tissue.

Most myelolipomas are asymptomatic, non-functioning and incidentally found tumors, to which conservative follow-up is enough when a definitive diagnosis can be established with imaging. When presenting with symptoms, they are generally due to mass effect, tumor necrosis, or haemorrhage.

Imaging findings

Detection and characterization of macroscopic fat within an adrenal mass establishes a diagnosis of myelolipoma with high diagnostic certainty.
Myelolipomas can be categorized into three main groups on the basis of their composition:

- Fat predominant
- Mixed fatty and myeloid elements
- Myeloid cells predominance

As the imaging findings vary with its composition, the differential diagnosis range from adenomas and lipomas in the fat-dominant lesions to liposarcomas and renal angiomyolipomas in the ones with more important myeloid component.

**Computed tomography**

In most cases CT reveals a well-defined suprarenal mass with a fine capsule and containing areas of fat. Attenuation values usually range from -30 to -115 HU, significantly lower than the attenuation of cortical adenomas (generally >-10HU).

Enhancement is observed in the soft-tissue component of myelolipomas after intravenous administration of contrast material and may mask the fat attenuation.

After bleeding, the tumor may show high- or low-attenuation fluid collections depending on the age of the blood.

Calcification occurs in up to 20% of cases and may be related to previous haemorrhage.
**Fig.**: Adrenal myelolipoma. Left adrenal mass has large central area of fat density identical to surrounding retroperitoneal fat.

**References:** A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

**Magnetic Resonance**

The fatty component of this tumor is hyperintense on non-fat-suppressed T1-weighted images.

The presence of macroscopic fat is demonstrated by the loss of signal intensity on fat-saturated images when compared with an identical sequence obtained without fat saturation.

The three types of myelolipomas present as follows:
• homogeneous, hyperintense masses on T1-weighted images with intermediate signal intensity on T2-weighted images, findings that are suggestive of lesions that are predominantly composed of fat;
• heterogeneous masses containing foci with the same signal intensity as that of fat intermixed with focal high-signal-intensity areas on T2-weighted images and contrast-enhanced T1-weighted images, findings that are indicative of mixed fatty and myeloid elements; and
• nodules that are hypointense relative to liver on T1-weighted images and hyperintense relative to liver on T2-weighted images and that enhance after administration of gadolinium chelate contrast material, resulting in an appearance of focal masslike areas primarily composed of myeloid cells.

The unusual complication of peritumoral hemorrhage will appear as high SI on T1-WIs that persists with fat saturation secondary to the T1-shortening effects of methemoglobin.

4. Adrenal hemorrhage

Adrenal hemorrhage is the most frequent adrenal lesion in neonates. When present in a septic patient, it can become an abscess may develop. In adulthood it’s a rare finding and usually seen in the context of severe hypoperfusion, hypotension, shock, burns, anticoagulation therapy and after trauma. Traumatic hemorrhage is mostly unilateral and right sided, probably due to direct compression of the gland by the spine and liver from blunt abdominal trauma, shearing of small vessels perforating the adrenal capsule by deceleration forces, and short term rise in intra-adrenal venous pressure due to compression of the inferior vena cava.

In the presence of bilateral hematomas, signs and symptoms of adrenal failure (Addison’s disease) might be depicted, which often is not diagnosed, resulting in unnecessary morbidity and mortality.

Imaging findings

Such lesions commonly manifest as a round to ovoid adrenal mass, but diffuse irregular hemorrhage obliterating the gland and uniform adrenal enlargement may also be seen.
Fig.: Adrenal hemorrhage. Mixed echogenic mass is seen adjacent to the kidney, in adrenal topography.

References: A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

Computed tomography

Hematomas vary in attenuation depending on their age. Acute to subacute hemorrhage can be diagnosed with confidence and present high attenuation values (ranging from 50 to 90 HU). With increasing delay between the bleeding and CT examination, lesions gradually diminish in size, as well as decrease its attenuation values. Calcifications may develop a few months later.

Periadrenal hemorrhage may be present and an ill-defined adrenal margin, periaxial stranding, and asymmetric thickening of the diaphragmatic crura may be detected.

Contrast enhancement is not seen.

Magnetic Resonance

MR imaging is the most sensitive and specific modality for diagnosing adrenal hemorrhage, and its features vary according to the age of the hematoma.
The specific MR imaging finding of a subacute hematoma is the presence of a high SI rim sign, indicating the presence of methemoglobin within the periphery of the hematoma.

5. Adrenal cyst

This is a rare entity and might have endothelial, epithelial, parasitic or pseudocystic origin.

Imaging findings

Cysts are uncomplicated and benign when they have thin walls (maximum 3mm) with or without calcification, internal water density /signal, do not enhance and do not exceed 5-6cm.

Ultrasound

Thin-walled anechoic cyst that may be septated.

Computed tomography

Cystic lesion with smooth, uniform and thin wall.

MRI

Uncomplicated cysts present uniform low-intensity contents on T1-wi and uniform high-intensity contents on T2-wi.
**Fig.**: Adrenal uncomplicated cyst. Adrenal lesion shows hyperintense signal on T2-w images without (A) and with fat saturation (B), hypointense signal on T1-wi and no enhancement after intravenous contrast administration (D). Internal septa are better depicted on T2-wi.

**References:** A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

**Magnetic Resonance**

The fatty component of this tumor is hyperintense on non-fat-suppressed T1-weighted images.

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The unusual complication of peritumoral hemorrhage will appear as high SI on T1-WIs that persists with fat saturation secondary to the T1-shortening effects of methemoglobin.

Fig.: Adrenal myelolipoma. Right adrenal mass behaves like subcutaneous fat tissue on T2-w (A) and T1-w (B) images. Chemical-shift imaging in out-of-phase (C) reveals...
no significant loss of signal intensity. Fat suppressed T1-w shows lesions content to parallel the subcutaneous fat, depicting the presence of macroscopic fat.

**References:** A. Frias Vilaça; Imagiologia, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

**MALIGNANT ADRENAL LESIONS**

1. Adrenal metastases
2. Adrenal carcinoma
3. Neural crest tumors

**1. Adrenal metastases**

The adrenal gland is a common site of metastatic disease. Primary tumors that commonly metastasize to the adrenal gland include lung, breast, melanoma, gastrointestinal and renal cell carcinomas. Because adrenal metastases are so common in lung cancer, and they may be the only site of metastasis, the glands should be included in the CT examination of all patients presenting with a lung cancer.

However, even in patients with lung cancer, about one third of adrenal masses are benign. Thus, imaging evaluation is very helpful to make the correct diagnosis and a baseline examination might be of primary importance.

CT is the most cost-effective method for screening and following patients with malignancies. MRI can be valuable in cases in which CT could not be performed.

**Imaging findings**

Adrenal metastases can vary considerably on both CT and MRI.

A normal appearance does not absolutely exclude metastasis, especially with lung cancer, but most often careful examination will reveal some focal bulge of the adrenal contour. Lesions may be unilateral or bilateral, and size can range from less than a centimeter to extremely large. When small, they commonly are fairly well circumscribed, round or oval. They may have smooth or irregular, lobulated contours.

The different physiological perfusion patterns of adenomas and metastases are the basis of imaging interpretation after contrast material injection: adenomas enhance rapidly after contrast administration and also demonstrate a rapid loss of contrast medium - "contrast washout", and metastases also enhance rapidly but show a slower washout of contrast medium.

**Computed tomography**
Small lesions are solid tumors and usually have homogeneous soft tissue attenuation values, similar to or higher than that of muscle on noncontrast scans. Larger metastases may develop central necrosis and thus become heterogeneous. If hemorrhage occurs, slightly high density areas may be seen on noncontrast scans.

Metastases frequently have heterogeneous enhancement.

Calcifications are rare but occur in mucin-producing tumors.

Fig.: Right adrenal metastatic lesion in a patient with known lung neoplasm.

References: A. Frias Vilaça; Imagiologia, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

Magnetic Resonance

On T1-weighted images, metastases usually have signal intensity similar to or lower than that of normal liver tissue, not distinctly different from that of adenomas. On T2-weighted images they are usually hyperintense compared with normal liver, often similar to or of higher intensity than fat, unlike the typical adenoma.

Because they do not produce lipid, there is no decrease in signal on opposed phase images.

After intravenous administration of gadolinium these lesions exhibit exuberant and heterogeneous enhancement that persists for several minutes.
Fig.: Metastatic lesions in the liver, right adrenal and spleen.

References: A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

2. Adrenocortical Carcinoma

Primary carcinoma of the adrenal gland is a rare tumor. There is a bimodal age distribution of adrenocortical carcinomas with an initial peak in the pediatric population and second peak in the fourth to fifth decades of life. Adrenocortical carcinoma can manifest as a hyperfunctioning lesion causing Cushing syndrome or Conn syndrome. Other manifestations include an abdominal mass and abdominal pain.

Complete surgical resection offers the only chance for cure.

Imaging findings

Imaging objectives are to detect adrenocortical carcinomas, localize the masses to the adrenal gland, and evaluate for local extension and metastatic disease.

In general, the tumor is large (> 6 to 8cm) at diagnosis and heterogeneous due to regressive changes (necrosis and haemorrhage).

Distinction between benign and malignant disease is almost impossible if no signs of metastatic disease are seen.

Findings as large size of tumor, necrosis and haemorrhage suggest malignancy.

Computed tomography
Large carcinomas are heterogeneous masses with irregular margins. Solid components show marked contrast enhancement. Calcifications may be present.

![Adrenal carcinoma. A large left adrenal mass with areas of central necrosis and irregular enhancement. Renal vein invasion and inferior cava vein is evident.](image)

**Fig.** Adrenal carcinoma. A large left adrenal mass with areas of central necrosis and irregular enhancement. Renal vein invasion and inferior cava vein is evident.

**References:** A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

**Magnetic Resonance**

They appear heterogeneous on both T1- and T2-weighted images owing to the presence of internal haemorrhage and necrosis. Hemorrhagic byproducts, principally methemoglobin, can result in areas of high signal intensity within the lesion on T1-weighted images; areas of necrosis have high signal intensity on T2-weighted images.

Adrenocortical carcinoma can contain foci of intracytoplasmic lipid, which results in a loss of signal intensity on out-of-phase images and reflects the tumor’s origin from the adrenal cortex. This should not create confusion with an adrenal adenoma because adrenocortical carcinomas are usually large (>5 cm), heterogeneous, and have only small foci of lipid.

Large adrenal carcinomas tend to invade the adrenal vein, inferior vena cava and/or right atrium, and thrombus can be detected by both imaging methods.

**3. Neural crest origin tumors**

Neural crest tumors can range from the benign ganglieneuroma to the highly malignant neuroblastoma.
**Ganglioneuromas** are uncommon benign neurogenic tumors that arise from sympathetic ganglia and are localized in the adrenal in about 40% of cases. They occur predominantly in third to fifth decade.

**Neuroblastoma** is the fourth most common pediatric malignancy, usually affecting children under the age of 4 years. It arises from undifferentiated neural tissue in the adrenal medulla or along sympathetic chain, being found anywhere from the cervical region to the pelvis. This tumor has been associated with genetic diseases, including neurofibromatosis, Beckwith-Wiedemann syndrome, and trisomy. Neuroblastoma tends to metastasize early, specially to bone, liver and lymph nodes.

**Ganglioneuroblastomas** are seen in children under 10 years of age and have a degree of differentiation that is intermediate between those of neuroblastomas and ganglioneuromas, being potentially malignant.

**Imaging findings**

The goal of imaging is to stage local extent and metastasis, for which MRI is the current imaging modality of choice owing to its higher soft-tissue contrast resolution.

Neuroblastoma presents a heterogeneous tumor matrix with areas of necrosis and hemorrhage. Ganglioneuroblastoma tends to be smaller and more well-defined than neuroblastoma at diagnosis.

Since the imaging characteristics of ganglioneuroma overlap with those of ganglioneuroblastoma and neuroblastoma, differentiation on imaging is not possible unless metastatic disease is present.

Local staging is based on tumor size, prevertebral extension across across the midline, intraspinal extension, renal invasion or infarction, vascular encasement, hepatic skeletal metastasis, and supradiaphragmatic involvement and can be depicted by both CT and MRI.

**Computed tomography**

The tumor enhances moderately, less than that of surrounding tissues, after intravenous administration of contrast material.

Calcifications are frequent (about 80%), finely stippled and linear or ring shaped.

**Magnetic Resonance**
The tumor shows heterogeneous low signal intensity on T1-weighted images, high signal intensity on T2-weighted images and heterogeneous moderate enhancement after administration of contrast material. Areas of intratumoral hemorrhage typically have high signal intensity on T1-weighted images. Cystic changes have high signal intensity on T2-weighted images.

**Fig.**: Ganglioneuroma in a 42 years old female. A large well-defined, heterogeneous right adrenal mass is seen. It presents hyperintensity on T2-wi (A) and relative hipointensity on T1-wi (B), and enhances moderately after contrast administration (C).

**References**: A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

The following figure summarises the principal differentials diagnosis in the presence of an adrenal lesion:
Fig.

References: A. Frias Vilaça; Imagiology, Hospital de São Sebastião, Santa Maria da Feira, PORTUGAL

Conclusion
Although the adrenal gland is involved by a range of diseases, including primary and metastatic malignant tumors, the most common lesion detected is the incidental benign adrenal adenoma.

In patients with known adrenal disease, CT is the imaging modality of choice. Though MR is playing a more and more important role in the characterization of adrenals masses, it is still mostly used when CT findings are not conclusive.

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**References**


