Adrenal Masses: CT and MR Approach, Spectrum of Imaging Findings and Histologic Correlation

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Learning objectives

- To summarize the appropriate imaging approach of adrenal masses.

- To illustrate and to describe the imaging features of the wide spectrum of adrenal lesions on computed tomography (CT) and magnetic resonance (MR) with histologic correlation.
Background

**Adrenal glands** are a common site of disease.

The detection of adrenal masses has increased with the expanding use of cross-sectional imaging.

**Adrenal incidentalomas** are asymptomatic masses discovered on imaging studies performed for reasons unrelated to adrenal disease, and have a prevalence in the general population of 3% to 7%.

The **majority** of incidental adrenal masses are **benign** and are most commonly adenomas.

However, **adrenal gland** is also a common site of **metastases**. Additionally, **primary malignant adrenal neoplasms** can also occur.

Once an **adrenal lesion is detected**, the goal of adrenal imaging is to characterize and to **differentiate** the benign "leave-alone" lesions from masses that **require treatment**.

**Imaging plays** an essential role in the characterization of adrenal lesions, **suggesting** their **benign or malignant nature**, and should **always be integrated** with patient oncologic background.

In the **imaging workup** of adrenal lesions several morphologic aspects assess the **risk of malignancy** such as the identification of intracellular lipid, macroscopic fat, hemorrhage, cystic changes, vascularity (namely washout values), calcifications, shape, size and change in size. The **clinical context** is also crucial in the interpretation of these lesions, particularly with regard to patient history of malignancy.

**Benign** adrenal masses generally are homogenous low density lesions, that present smooth margins, and that usually remain stable in size.

Certain adrenal lesions have **specific benign imaging features** that are diagnostic at detection and do not warrant further workup, like adrenal **myelolipomas** (easily recognized by the presence of macroscopic fat), and **adrenal cysts** (simple cyst without enhancement after contrast administration).
Certain imaging features are suspicious for malignancy, such as large size, growth, irregular margins, heterogeneous attenuation and central necrosis.

In patients without history of malignancy, the main concern for a large adrenal mass is adrenal cortical carcinoma, although it is rare in the general population.

Usually, adrenal masses larger than 4 cm are surgically resected in patients without history of malignancy, unless a definitive benign diagnosis, such as myelolipoma, adrenal cyst, typical adenoma, or hemorrhage, can be established.

Patient history of malignancy is one of the most important aspects in the workup of incidental adrenal lesion. It is extremely rare for an incidental adrenal mass to be metastatic disease of unrecognized primary malignancy.

Characterization of incidental adrenal lesions in patients with cancer is essential to predict prognosis of the primary disease, to assess staging, and to direct therapy.

CT and MRI are the most commonly used imaging studies for evaluating an incidental adrenal mass. These techniques reflect physiologic differences distinguishing adenoma from malignant masses, by evaluating intracytoplasmic lipid content and contrast washout pattern.

On CT, the distinction between benign from malignant adrenal masses is based on density measurement on unenhanced CT and on the determination of their different contrast washout characteristics.

Density measurement on unenhanced CT is based on the fact that adrenal adenomas have a varying amount of intracytoplasmic lipid (mainly cholesterol, fatty acids, and neutral fat), and an inverse relationship exists between the lipid content of the adenoma and its density measurement on CT. Approximately 70% of adenomas have sufficient intracytoplasmic lipid to be diagnosed on unenhanced CT, and the threshold of 10 HU allow the diagnosis of adenoma with 71% sensitivity and 98% specificity, being currently the standard threshold used to diagnose a lipid-rich adenoma on CT.

Conversely, almost all nonadenomatous lesions are low intracytoplasmic lipid content, and their CT attenuation is consequently higher.

Up to 30% of adenomas are lipid poor and have an attenuation value greater than 10 HU on unenhanced CT scans, as do almost all malignant lesions. Therefore, these lesions require further evaluation to be characterized.
Contrast washout characteristics also permit to differentiate adenoma from other lesions.

After enhancement with intravenous contrast, adenomas enhance rapidly and also show a rapid loss of contrast medium, a phenomenon termed "contrast washout"; despite malignant lesions also enhance rapidly, they usually show a slower washout of contrast medium due to leaky capillaries.

The ratio of attenuation values on the washout-delayed scan, after 15 minutes, when compared with the initial dynamic contrast-enhanced study can help to accurately characterize adrenal lesions.

Adenomas can be distinguished from nonadenomas by:

Absolute percentage washout (APW) is calculated by a formula (see Fig. 1)

An APW value of 60% or greater at 15 minutes is diagnostic of an adenoma.

In the absence of unenhanced series, a relative percentage washout (RPW) is calculated by a formula (see Fig. 1)

An RPW value greater than 40% is diagnostic of adenoma.

Contrast washout is independent of the amount of lipid content and allows accurate diagnosis of both lipid-rich and lipid-poor adenoma.

<table>
<thead>
<tr>
<th>Percentage Washout</th>
<th>Formula</th>
<th>Washout Values (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>APW</td>
<td>((E-D)/(E-U) \times 100)</td>
<td>Adenoma: &gt;60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Malignancy: &lt;60</td>
</tr>
<tr>
<td>RPW</td>
<td>((E-D)/E \times 100)</td>
<td>Adenoma: &gt;40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Malignancy: &lt;40</td>
</tr>
</tbody>
</table>

Fig. 1: Percentage Washout Formulas for 15-minute Delayed Contrast-enhanced CT Scans: These threshold percentage washout values can be used to accurately differentiate adenoma from malignancy. APW = absolute percentage washout, RPW = relative percentage washout D= delayed enhanced value, E= enhanced attenuation value, U= unenhanced attenuation value.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT
In general, a combination of unenhanced CT and washout characteristics correctly discriminates nearly all adrenal adenomas from malignant lesions.

On MR technique, the principle of adrenal evaluation is based on chemical shift imaging which is obtained as dual-echo breath-hold gradient echo acquisition. As CT density measurement, this technique also depends on the presence of intracytoplasmic lipid in adenomas to distinguish them from nonadenomas.

Chemical shift MRI (CS-MR) is based in the different resonant frequency rates of protons in fat and water molecules, with fat protons resonating at a slower frequency. By choosing the "correct" TE (echo time), the signal from lipid will oppose that from water, causing signal drop-off in voxels containing both lipid and water on opposed-phase imaging.

Most adrenal adenomas contain sufficient amount of lipid and lose signal (become darker) on the opposed-phase images imaging when compared with in-phase images. With CS-MR, adenomas are differentiated from metastasis with sensitivity and specificity of 81% to 100% and 94% to 100%, respectively.

The paired in-phase and opposed-phase images can be analyzed using quantitative methods such as signal intensity index or chemical shift ratio.

Although, simple visual analysis is as effective and easier to use, being more commonly used in clinical practice.

Occasionally, heterogeneous signal suppression may be seen in an adenoma because of a heterogeneous population of lipid-rich cells.
<table>
<thead>
<tr>
<th>Incidental Adrenal Lesions</th>
<th>Frequency (%)</th>
<th>Size (cm)</th>
<th>Growth Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenoma</td>
<td>About 50-80 (common)</td>
<td>1-4</td>
<td>Stable or very slow</td>
</tr>
<tr>
<td>Metastasis</td>
<td>Uncommon unless patient has cancer</td>
<td>Variable, usually &lt;3</td>
<td>Variable, slow to rapid</td>
</tr>
<tr>
<td>Myelolipoma</td>
<td>5-10</td>
<td>1-5</td>
<td>Stable to slow</td>
</tr>
<tr>
<td>Carcinoma</td>
<td>&lt;5 (rare)</td>
<td>Usually &gt;4</td>
<td>Variable, usually slow</td>
</tr>
<tr>
<td>Pheochromocytoma</td>
<td>5</td>
<td>Variable</td>
<td>Slow</td>
</tr>
<tr>
<td>Hematoma</td>
<td>1</td>
<td>Variable</td>
<td>Rapid</td>
</tr>
<tr>
<td>Cyst</td>
<td>1</td>
<td>Variable</td>
<td>Usually stable</td>
</tr>
<tr>
<td>Neuroblastoma</td>
<td>Rare, more common in children</td>
<td>Variable, but often large</td>
<td>Variable, slow to rapid</td>
</tr>
<tr>
<td>Ganglioneuroma</td>
<td>Very rare</td>
<td>Variable</td>
<td>Variable, slow to rapid</td>
</tr>
<tr>
<td>Hemangioma</td>
<td>Very rare</td>
<td>Variable</td>
<td>Usually slow</td>
</tr>
</tbody>
</table>

**Fig. 2:** Morphologic and Imaging Characteristics of Incidental Adrenal Lesions. 
**References:** Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

<table>
<thead>
<tr>
<th>Incidental Adrenal Lesions</th>
<th>Shape</th>
<th>Texture</th>
<th>Unenhanced CT Attenuation (HU)</th>
<th>15-minute CT Washout (%)</th>
<th>MR SI Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adenoma</td>
<td>Smooth, round</td>
<td>Homogeneous</td>
<td>&lt;10 in 70%</td>
<td>RPW&gt;40; APW&gt;60</td>
<td>SI drop off on opposed-phase images</td>
</tr>
<tr>
<td>Metastasis</td>
<td>Variable</td>
<td>Heterogeneous when larger</td>
<td>&gt;10</td>
<td>RPW&lt;40</td>
<td>May show increased SI on T2-weighted images</td>
</tr>
<tr>
<td>Myelolipoma</td>
<td>Smooth, round</td>
<td>Variable, with macroscopic fat</td>
<td>&lt;0, often &lt;50</td>
<td>-</td>
<td>Variable SI drop off on opposed-phase images</td>
</tr>
<tr>
<td>Carcinoma</td>
<td>Variable</td>
<td>Variable</td>
<td>&gt;10</td>
<td>RPW&lt;40</td>
<td>Intermediate SI</td>
</tr>
<tr>
<td>Pheochromocytoma</td>
<td>Variable</td>
<td>Variable</td>
<td>&gt;10, rarely &lt;10</td>
<td>RPW&lt;40</td>
<td>High SI on T2-weighted images</td>
</tr>
<tr>
<td>Hematoma</td>
<td>Smooth</td>
<td>Variable</td>
<td>&gt;10, sometimes &gt;50</td>
<td>-</td>
<td>Variable SI</td>
</tr>
<tr>
<td>Cyst</td>
<td>Smooth, round</td>
<td>Homogeneous</td>
<td>&lt;10</td>
<td>Does not enhance</td>
<td>High SI on T2-weighted images</td>
</tr>
<tr>
<td>Neuroblastoma</td>
<td>Variable</td>
<td>Variable</td>
<td>&gt;10</td>
<td>RPW&lt;40</td>
<td>Variable if necrotic</td>
</tr>
<tr>
<td>Ganglioneuroma</td>
<td>Variable</td>
<td>Variable</td>
<td>&gt;10</td>
<td>-</td>
<td>Usually intermediate SI</td>
</tr>
<tr>
<td>Hemangioma</td>
<td>Variable</td>
<td>Variable</td>
<td>&gt;10</td>
<td>-</td>
<td>Usually intermediate SI</td>
</tr>
</tbody>
</table>

**Fig. 3:** Morphologic and Imaging Characteristics of Incidental Adrenal Lesions. APW, absolute percentage washout; RPW, relative percentage washout; SI, signal intensity. 
**References:** Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

**Adrenal Biopsy**
The number of **imaging-guided biopsies** necessary to **diagnose** an adrenal mass has decreased, with the recent advances in their characterization.

However, they may still be necessary to **exclude** or **confirm metastases** if **imaging findings** are **inconclusive**, or to **evaluate enlarging adrenal masses**.

Adrenal biopsy is usually performed with CT guidance and has been shown to be safe, with a 85% to 96% diagnostic accuracy and 3% to 9% complication rate.

**Plasma-free metanephrine level** should be **obtained prior to biopsy**, if there is any **suspicion of a pheochromocytoma**, because this procedure may **induce a hypertensive crisis** in that situation.

**Diagnostic Algorithm of Incidental Adrenal Lesions**

Recently, White Paper of the American College of Radiology (ACR) Committee on Incidental Findings presented an adrenal imaging algorithm.

According to this, in:

- An incidental adrenal mass of **any size** that has **diagnostic features** of a **benign lesion**, such as a myelolipoma, cyst, or a lipid-rich adenoma, a specific benign **diagnosis can be made** and **no additional imaging is needed**.

- Adrenal masses **smaller than 4 cm** with **no diagnostic imaging features** for which prior imaging is available and that have **been stable for at least a year** are **likely benign** and do **not need follow-up imaging**.

- Enlarging lesions, **biopsy or resection** should be considered because they **may be malignant**.

- Patients with **no history of cancer**, if **no prior CT or MRI** is available for comparison and the lesion has **benign imaging features** (low density, homogeneous with smooth margins), then the mass can be **presumed to be benign** and a **follow-up unenhanced CT or CS-MR in 12 months** may be considered.

- The cases where **suspicious imaging features** are present, **unenhanced CT or CS-MR could be performed**. If these are **not diagnostic** of an **adenoma**, then adrenal **CT protocol with washout analysis** may be helpful. If the lesion does **not have imaging and washout features of a benign lesion**, then **biopsy** may be appropriate.
- **Oncologic patients**, if the adrenal mass does **not have imaging features diagnostic of a benign lesion** and **no prior imaging** is available to establish stability, **unenhanced CT**, **CS-MR**, or **PET/PET-CT** can be considered. If these studies do **not confirm** the mass to be an **adenoma**, then adrenal **CT with washout analysis** may be helpful. If these imaging studies are **not diagnostic of a benign lesion**, then **biopsy** should be considered.

- An adrenal mass **larger than 4 cm without a definitive benign diagnosis** is usually **resected** in patients **without history of cancer**, because there is concern for an adrenal cortical carcinoma. In patients with a **history of cancer**, **PET/PET-CT** or **biopsy** is recommended because the large adrenal mass could represent a metastasis.

![Fig. 4: Recommended algorithm for management of incidental adrenal masses.](image)

\[
\text{↓} = \text{decreased}; \ APW = \text{absolute percentage washout}; \ CS-MR = \text{chemical shift MRI}; \ HU = \text{Hounsfield unit}; \ RPW = \text{relative percentage washout}; \ a \text{ If patient clinical signs or symptoms of adrenal hyperfunction, consider biochemical evaluation.} \\
\text{b Consider biochemical testing to exclude pheochromocytoma.} \\
\text{c Benign imaging features: homogeneous, low density, smooth margins.} \\
\text{d Suspicious imaging features: heterogeneous, necrosis, irregular margins.}
\]
Imaging findings OR Procedure details

Imaging findings

**Adrenal Adenoma**

Adrenal adenomas are the most common adrenal lesions.

Functioning adenomas (Cushing syndrome, Conn syndrome) are uncommon and usually can be confirmed by means of biochemical evaluation in the presence of an adrenal mass.

There are no specific morphologic features that permit adenoma characterization, because the majority is small, smooth, and homogeneous when detected.

However, most can be characterized by using lipid-sensitive or washout CT techniques or chemical shift MR techniques.

**CT findings:**

Adenomas are typically well-defined, often homogeneous and may have the same density as normal adrenal tissue.

Most adenomas contain large amounts of intracytoplasmic lipid, therefore many have a low density, often near that of water, on unenhanced examinations (see Fig. 5).

Intralesional calcifications are rare.

The degree of enhancement of adenomas after intravenous administration of contrast medium does not differ significantly from that of other adrenal tumors, although adenomas show more rapid washout of contrast medium than adrenal metastases.

Rarely, an adenoma can be hemorrhagic, usually in a patient receiving anticoagulant therapy. The presence of hemorrhage results in regions of higher attenuation and heterogeneity.
Fig. 5: Left adrenal nonfunctioning adenoma. (a) Axial and (b) coronal unenhanced CT images shows a well-defined left adrenal mass with attenuation of 5 HU. (c) T1-weighted gradient-echo in-phase images, of the same patient, shows adrenal signal intensity (arrow) slightly higher than the spleen (internal reference organ). T1-weighted gradient-echo opposed-phase image (d) shows marked signal intensity loss of the left adrenal lesion with signal intensity markedly lower than of the spleen (*). (e) On histologic examination adrenal cortical adenoma composed of clear cells with abundant intracytoplasmic lipid droplets, forming cords, mimicking the adrenal zona fasciculata.  

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

MR findings:

The most important characteristic feature of adrenal adenoma is the presence of intracellular lipid. So, MR imaging chemical shift imaging is the most reliable technique for its diagnosis. Most adrenal adenomas demonstrate a loss of signal intensity on out-of-phase images when compared with in-phase images (see Fig. 5). A decrease in signal intensity of more than 20% is considered diagnostic of an adenoma.

Uniform enhancement on immediate contrast material-enhanced images is also typical of adenomas.

Small, rounded foci of altered signal intensity may be seen within an adenoma due to cystic changes, hemorrhagic component, or variation in vascularity.

Simple Cyst
Adrenal cysts are **uncommon** lesions resulting from endothelial proliferation, prior hemorrhage, or parasitic disease.

Adrenal cysts show a 3:1 female predilection.

**Four types** of cysts are recognized on the basis of pathologic classification: endothelial, epithelial, parasitic, and posttraumatic pseudocysts.

**CT and MR findings:**

They **usually** demonstrate the expected **cystic CT and MR imaging features** (see Fig. 6) but **some** have **higher attenuation values at CT**. **Usually**, these lesions have **thin** (<3-mm-thick) **walls** and may contain **internal septa**, both of which can **enhance** or **contain calcifications**.

**Fig. 6:** Left adrenal simple cyst. Coronal unenhanced (a) and contrast-enhanced (b) CT scan images shows a left adrenal mass with hydric attenuation (16 HU). Axial T1-weighted gradient-echo in-phase (c), and axial T2-weighted MR images obtained without (d) and with (e) fat suppression images shows an oval, well-circumscribed, left adrenal cyst, with a thin wall. The cyst has a typical appearance, showing low signal intensity at T1-weighted imaging and high signal intensity at T2-weighted imaging.

**References:** Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

**Myelolipoma**
Myelolipoma is an uncommon benign tumor composed of mature adipose tissue and hematopoietic tissue.

Myelolipomas do not produce hormones, so most are detected as incidental findings. Occasionally, large tumors or those undergoing tumor necrosis or spontaneous hemorrhage may cause flank pain.

These tumors can arise in the adrenal gland or, much less frequently, from an extraadrenal location.

Large myelolipomas can be confused with other retroperitoneal lipomatous tumors such as liposarcoma.

CT findings:

CT shows a well-defined mass with variable quantities of fat and soft tissue. The amount of recognizable macroscopic fat varies from almost 100% to none. However, the presence of even the slightest macroscopic fat is very suggestive of a myelolipoma (see Fig. 7).

Elements of a soft-tissue density are found in varying amounts (see Fig. 7).

Calcification is seen in up to 20% of the cases.

MR findings:

The appearance of a myelolipoma on MR imaging reflects the proportion of fat and of bone marrow elements in the tumor.

The use of fat suppression can help the diagnosis by demonstrating a loss of signal intensity within the fatty component (see Fig. 7). Fat has a high signal intensity on both T1- and T2-weighted sequences, which is reduced on fat-suppression images.

The bone marrow elements have a low signal intensity on T1-weighted images and moderate signal intensity on T2-weighted images (see Fig. 7).
Fig. 7: Left adrenal myelolipoma. Axial (a) and coronal (b) unenhanced CT scans show a left adrenal mass composed of soft tissue, fat and a small calcification (arrow). In another patient, axial T2-weighted MR images obtained without (c) and with (d) fat suppression show a well-circumscribed, heterogeneous, right adrenal mass that as at the right side a small macroscopic fatty component that shows a decrease in signal intensity on the fat-suppressed image (d). The same adrenal mass on axial T1weighted gradient-echo in-phase MR image (e) show on the left side a crescentic area that on T1-weighted gradient-echo opposed-phase MR image (f) shows loss of signal intensity (*). (g) On histologic imaging, myelolipoma is characterized by a mixture of mature adipose tissue and hematopoietic elements.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

Hemangioma

Adrenal hemangioma is a rare benign tumor.

Hemangiomas are composed of closely adjacent vascular channels lined with a single layer of endothelium.
These benign tumors do not produce adrenal hormones, and most are large when found as an incidental finding.

**CT findings:**

On CT, hemangiomas are seen as large well-defined masses. They have a **soft-tissue density on unenhanced images** and exhibit **inhomogeneous persistent enhancement on delayed images** (see Fig. 8). Most hemangiomas are calcified, either from phleboliths in the tumor or from **previous hemorrhage** (see Fig. 8).

**MR findings:**

The MR findings associated with hemangiomas include a **hypointense appearance relative to the liver on T1-weighted sequences**. Central hyperintensity may be seen because of hemorrhage. On **T2-weighted images**, hemangiomas are hyperintense (see Fig. 8). **Peripheral enhancement that persists on delayed images** is characteristic.

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**Fig. 8:** Left adrenal hemangiomas. Axial precontrast (a), portal venous phase (b) and late venous phase (c) CT scans shows a large, well-defined left adrenal mass, with soft tissue density on unenhanced images, that presents inhomogeneous and globular enhancement over time, with some calcifications. In another patient, axial T2-weighted MR images obtained without (d) and with (e) fat suppression show a well-circumscribed, heterogeneous left adrenal mass, predominantly hyperintense, with a posterior hypointense area. On axial T1-weighted gradient-echo in-phase MR image (f) it appears predominantly hypointense, with a posterior hyperintense area. This lesion corresponded to a left adrenal hemangioma with a posterior area of subacute hemorrhage. (g) On histologic examination, hemangiomas consist on benign neoplasm
composed of multiple vascular channels, with blood content, lined by CD34/CD31+ endothelial cells.

**References:** Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

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**Hemorrhage**

Adrenal hemorrhage can be **bilateral** or **unilateral**.

**Bilateral** adrenal hemorrhage is usually associated with anticoagulation therapy or a blood dyscrasia; less commonly, it is associated with the stress of surgery, sepsis, or hypotension; and rarely, it is caused by trauma.

**Unilateral** adrenal hemorrhage is usually caused by blunt abdominal trauma and involves the right gland more often than the left. Adrenal vein thrombosis may also cause unilateral adrenal hemorrhage.

If spontaneous, an **underlying adrenal tumor** should be considered, and **follow-up imaging** or **biopsy** is required.

**CT findings:**

On CT, **acute or subacute adrenal hemorrhage** typically has an **increased unenhanced attenuation value** of 50-90 HU. **Follow-up studies** show **reduction in size of the adrenal mass** with a **gradual decrease in the attenuation value** (see Fig. 9).

The high attenuation value of a recent adrenal hemorrhage is usually readily apparent on unenhanced CT, but is indistinguishable from a solid adrenal neoplasm on contrast-enhanced CT.

Detection of an adrenal mass on contrast-enhanced CT after trauma is usually assumed to result from a hematoma, but an **unrelated adrenal neoplasm** can be **excluded only** by **unenhanced CT or serial follow-up CT**.

**MR findings:**

MR imaging is the most sensitive and specific modality for diagnosing adrenal hemorrhage.

**MR imaging features** depend on the **age of the hemorrhage**: in **acute phase** (less than 7 days after onset) it has **hypointensity** on T1- and T2-weighted images because of the presence of intracellular deoxyhaemoglobin; in the **subacute phase** (7 days to
7 weeks after onset) the lesion is **hyperintense on T1- and T2-weighted images** due to the paramagnetic effect of free methaemoglobin (see Fig. 9); in the **chronic phase**, the lesion periphery exhibits **low signal intensity on T1- and T2- weighted images**, because of the presence of hemosiderin and fibrous capsule or calcifications.

**Fig. 9**: Right subacute adrenal hemorrhage in a preterm newborn that suffered from postpartum stress. Axial T1-weighted gradient-echo in-phase MR image (a) and T1-weighted gradient-echo out-of-phase MR image (b) shows a right adrenal lesion that is hyperintense and as no loss of signal intensity on the out-of-phase MR image(arrows) (b). On axial (c) and coronal (d) T2-weighted MR images without fat suppression this mass still present a high signal intensity. (d) Right adrenal gland ultrasound done at the same day as the MR study, and (f) at four months later shows reduction of the size of the right adrenal mass (arrows). (g) On histologic examination, there is a massive intra-adrenal hemorrhage, without any evidence of tumoral cells.

**References:** Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

**Pheochromocytoma**

Pheochromocytoma is a **rare catecholamine-secreting tumor**.
This neoplasm had been called the **10% tumor**. This designation is based on the fact that approximately **10%** of pheochromocytomas are **bilateral**, **10%** are **extraadrenal**, **10%** occur in **children**, **10%** are **detected incidentally** and **10%** are **malignant**.

The diagnosis of pheochromocytoma results from the detection of an adrenal mass in the **appropriate clinical** and **biochemical setting**.

**Imaging appearances** are **variable**.

**Nonfunctioning pheochromocytomas** tend to be **larger** than functioning tumors.

**CT findings:**

Most pheocromocytomas appear as a smooth, round well-defined mass with a density near that of soft tissue. Larger lesions may be heterogeneous because of tissue necrosis or internal hemorrhage (see Fig. 10). **Macroscopic fat** can **rarely** be **identified**.

These tumors have **marked enhancement after intravenous contrast medium administration**, reflecting their vascularity, and have washout **characteristics typically similar** to those of **malignant adrenal lesions, regardless** of whether the pheochromocytoma is **malignant or benign** (see Fig. 10).

**Uncommonly** these lesions may show washout values consistent with benign disease, low attenuation at unenhanced CT, or poor enhancement after intravenous administration of contrast medium.

**MR findings:**

Up to **70%** of pheochromocytomas demonstrate **high signal intensity on T2-weighted images** (light bulb sign); this finding is probably caused by a **cystic component** (see Fig. 11).

However, **30%** of lesions demonstrate **low signal intensity on T2-weighted images** and may be **confused with other adrenal disease**.

Most lesions show **intense enhancement** after the administration of contrast material (see Fig. 10).

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** (see Fig. 10).
Because manipulation of pheochromocytomas may induce a hypertensive crisis, diagnosis or exclusion of this entity should be achieved as noninvasively as possible.

**Fig. 10:** Left adrenal pheocromocytoma. (a) Axial precontrast CT scan shows a large, well delineated, heterogeneous left adrenal mass, with central calcifications and necrotic areas, and peripheral soft tissue density, that displaces the left kidney inferolaterally (*). On axial (b) and coronal (c) enhanced portal venous phase CT scans this lesions shows enhancement of the soft tissue component and peripheral calcifications. On axial T2-weighted MR images (d) this mass as high signal intensity, with central necrotic areas and peripheral solid component. On MR dynamic study images (e) this lesion as early enhancement of the peripheral solid component. On the axial T1-weighted gradient-echo in-phase MR images (f) and out-of-phase MR images (g) this mass shows no loss of signal intensity. (h) On histologic examination, we found a tumor with an alveolar pattern, composed of cells with a granular basophilic cytoplasm, without atypia or mitoses, with areas of hemorrhage and with a prominent eosinophilic stroma.

**References:** Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT
Fig. 11: Bilateral adrenal pheocromocytoma. (a) Axial T1-weighted gradient-echo in-phase MR images show bilateral well delineated, heterogeneous hypointense adrenal masses. On axial (b) and coronal (c) T2-weighted MR images these masses have high signal intensity, with hyperintense central necrotic areas and peripheral solid component. (d) On axial T2-weighted MR images obtained with fat suppression they show no macroscopic fat component.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

Adrenal Carcinoma
Adrenal carcinoma is a rare tumor.

The peak prevalence of this disease occurs in patients 30-70 years of age.

Adrenocortical carcinoma can manifest as a hyperfunctioning mass causing Cushing syndrome or Conn syndrome. Other manifestations include an abdominal mass and abdominal pain.

Most lesions tend to be very large at presentation.

CT findings:

The CT appearance of an adrenal carcinoma is that of a heterogeneous and irregular large mass (see Fig. 12). Central necrosis is common (see Fig. 12 and 13), and calcifications are seen in 20-30% of the cases. Enhancement is heterogeneous after intravenous administration of contrast material and CT washout values are consistent with those of other malignant diseases.

Venous extension of tumor is common and can usually be identified on contrast-enhanced images.

MR findings:

On MR imaging, carcinomas are usually heterogeneously hyperintense on both T1- and T2-weighted images (see Fig. 12), reflecting the frequent internal hemorrhage and necrosis.

Hemorrhagic byproducts, principally methaemoglobin, 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 (see Fig. 12 and 13).

Adrenocortical carcinoma can contain foci of intracytoplasmic lipid, which results in a loss of signal intensity on out-of-phase images (see Fig. 12).

Enhancement is also heterogeneous, revealing nodular areas of intense enhancement and other areas with no enhancement.

Intravenous extension of tumor is also well depicted on MR imaging because data sets can be projected into multiple planes.
Fig. 12: Left adrenal carcinoma. Axial precontrast CT scan (a) shows a large, well-defined heterogeneous left adrenal mass, predominantly of soft tissue density, presenting central necrotic areas. On axial portal venous phase (b) and late venous phase (c) CT scans this lesion shows early heterogeneous enhancement of the soft tissue component. Axial T2-weighted MR images obtained without (d) and with (e) fat suppression show a well-circumscribed, heterogeneous left adrenal mass, with central necrotic areas, and no macroscopic fat component. On axial T1-weighted gradient-echo in-phase MR images (f) and T1-weighted gradient-echo out-of-phase MR images (g), this lesion shows small foci of loss of signal intensity (arrows) that correspond to small intracellular fatty foci. (h) On histologic examination, this neoplasia presented a diffuse architecture (>33%), high nuclear grade (Fuhrman criteria), less than 25% of tumor is composed of clear cells and with necrosis and vascular, sinusoidal and capsular invasion (these last 4 not seen is this picture). These morphological aspects, along with the location, favor the diagnosis of adrenal cortical carcinoma.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT
Fig. 13: Right adrenal carcinoma. Coronal (a) and axial T2-weighted MR images obtained without (b) and with (c) fat suppression show a well-circumscribed, shows an heterogeneous right adrenal mass (arrows), with an abundant central necrotic area, a peripheral solid component, without macroscopic fat component. Axial T1-weighted gradient-echo in-phase MR image (d) is consistent with the anterior description.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

Large adrenal carcinomas tend to invade the adrenal vein and inferior vena cava.

The multiplanar imaging evaluation of disease progression by cephalad extension or invasion of adjacent vascular structures is essential on surgical management.

Neuroblastoma
Neuroblastoma can occasionally be seen in adults, although it usually occurs in childhood, representing the third most common malignant tumor in this age group. These tumors may be found anywhere along the paravertebral sympathetic plexus.

Neuroblastomas that affect adults typically show less calcifications and are more metastatic at the time of diagnosis. Their imaging findings are also hard to differentiate from other malignant diseases, and biopsy is usually required.

CT and MR findings:

The imaging findings of neuroblastoma in adults are similar to those in children. The lack of specificity of imaging features (see Fig. 14) and more frequent disseminated involvement make lymphoma or metastatic disease likely possibilities in these patients.

![Fig. 14: Left adrenal gland stage 4 neuroblastoma. (a) Axial precontrast CT scan image show a large, well delineated, heterogeneous left adrenal mass, predominantly of tissue density, with central necrotic areas and some calcifications, it displaces the left kidney inferolaterally (*) and the abdominal aorta to the right and crosses the midline(+) (f) (g). (b) On coronal enhanced portal venous phase CT scan images this](image)
lesions shows enhancement of the solid component. (c) On the axial T1-weighted gradient-echo in-phase MR images the same lesion presents predominant low signal intensity, with central areas of more hypointense signal intensity necrotic areas. On axial (d) and coronal (e) T2-weighted MR images this mass as high signal intensity, with more hyperintense necrotic central areas. On MR dynamic study images this lesion as an heterogeneous early enhancement. (h) Typically a small blue cell tumor (minimal cytoplasm, hyperchromatic round nuclei), with poorly defined cytoplasmic borders, here with pronounced pleomorphism due to previous chemotherapy.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

Ganglioneuroma

Ganglioneuroma is a rare benign tumor composed of Schwann cells and ganglion cells.

Although it can arise in the adrenal medulla, in 20%-30% of the cases, the majority is extraadrenal, located along the paravertebral sympathetic plexus.

These lesions are usually detected incidentally because they do not secrete hormones.

CT findings:

On CT, ganglioneuromas appear as a solid adrenal mass ranging from 4 to 22 cm in diameter, without specific imaging features (see Fig. 15). The density of the lesion on unenhanced images is often less than that of muscle. Contrast-enhanced images show homogeneous or mildly heterogeneous enhancement.

MR findings:

On MR imaging, the signal intensity of a ganglioneuroma is less than that of the liver on T1-weighted sequences. Greater heterogeneity is seen on T2-weighted images than on enhanced CT images (see Fig. 15).

Although the tumor may surround blood vessels, encroachment on their lumen is rare.
Fig. 15: Right adrenal gland ganglioneuroblastoma. (a) Axial in-phase T1-weighted MR image shows a heterogeneous mass (arrows) with predominant low signal intensity involving the right adrenal gland. On axial (b) and coronal (c) T2-weighted MR images this mass as heterogeneous high signal intensity. We can also see that this lesion as contra lateral involvement. (d) Axial T2-weighted MR images obtained with fat suppression show no macroscopic fat component in this lesion. On MR dynamic study images this lesion as an heterogeneous moderate enhancement. (e) On histological evaluation, this tumor is composed of numerous collections of abnormal but fully mature ganglion cells.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

Metastasis

Metastases are the most common malignant lesions involving the adrenal gland. Adrenal metastases are found in up to 27% of patients with malignant epithelial tumors at autopsy.
Common primary sites of tumors that metastasize to the adrenal glands include the lung, breast, melanoma, bowel and pancreas.

Metastases are usually bilateral but may also be unilateral, either small or large.

**CT and MR findings:**

The CT and MR imaging features are nonspecific.

Small metastases are often homogeneous on contrast-enhanced CT, whereas large metastases often have local regions that appear heterogenous as a result of necrosis, hemorrhage, or both (see Fig. 16 and 17).

Intralesional calcifications are rare.

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**Fig. 16:** Right adrenal metastasis of a renal cell carcinoma. Axial precontrast phase (a), axial (b) and coronal (c) arterial phase and late venous phase (d) contrast-enhanced CT scans shows a right adrenal hypervascular mass (arrows). (e) On histological examination, we see a lesion that as mixture of clear and eosinophilic cells
in which the immunohistochemical study (vimentin+, CD10+, inibin-) suggesting a renal origin.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

**Fig. 17**: Right adrenal metastasis of a pulmonary carcinoma. Axial precontrast phase (a), axial arterial phase (b), axial (c) and coronal (d) portal venous phase contrast-enhanced CT scans shows a right adrenal mass with predominant central necrosis and a small peripheral hypervascular component. This patient had also hepatic metastasis (*) and retroperitoneal lymphadenopathy (+). The diagnosis of metastasis of an adenocarcinoma was done, in which the (e) immunohistochemical study (CK7+, TTF1+), along with the past personal history of lung cancer, favored a pulmonary origin.

References: Radiology, Instituto Portugues de Oncologia de Lisboa Francisco Gentil E.P.E. - Queluz/PT

On MR imaging, adrenal metastases usually exhibit low signal intensity on T1-weighted images and high signal intensity on T2-weighted images, with progressive enhancement after administration of contrast material.

The most important diagnostic feature is the lack of signal loss on out-of-phase images, in opposite to adenomas.
Conclusion

A cross-sectional imaging systematic approach is fundamental in the evaluation and characterization of adrenal masses.

The analysis of their imaging features, either on CT or on MR imaging, in association with the acknowledge of the patient clinical context (particularly history of malignancy), are crucial to determine the benign or malignant nature of these lesions, thus allowing a correct diagnosis and an appropriate management.
References


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