Adrenal gland disease: multimodality imaging findings.

Poster No.: C-1553
Congress: ECR 2011
Type: Educational Exhibit
Authors: M. F. Cavallaro, P. Martingano, B. Cabibbo, E. marchese, F. Cacciato, F. Neri, S. Kus, M. Bertolotto, M. A. Cova; Trieste (TS)/IT
Keywords: Ultrasound, MR, CT, Kidney
DOI: 10.1594/ecr2011/C-1553

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Learning objectives

To illustrate the spectrum of adrenal gland disease.
Background

The adrenal gland is involved by a various range of disease including benign and malignant conditions. The detection of adrenal lesions has increased with the expanding use of cross-sectional imaging. Adrenal lesions could be incidental finding on radiological abdomen examination or could be part of specific disorders. In both cases radiological evaluation is required to correctly recognize and characterize the disease. A good knowledge of adrenal gland disease improves imaging interpretations. A spectrum of disease findings is described and illustrated.
Imaging findings OR Procedure details

The adrenal glands are located in the retroperitoneum, atop the kidneys, one on each side. They are surrounded by an adipose capsule and renal fascia. The glands normally have a "V" or "Y" shape configuration composed of two limbs, medial and lateral, which communicate through the apex or body. Each limb is approximately 3 to 6 mm thick, and the entire width of the gland should not be greater than 1 cm.

Each gland is supplied by superior, middle, and inferior adrenal arteries. The superior adrenal artery originates from the inferior phrenic artery, the middle from the aorta, and the inferior from a branch of the ipsilateral renal artery. Gland is drained by a single vein: the right adrenal vein, ended in inferior vena cava, and the left adrenal vein, ended in the left renal vein.

Microscopically each adrenal gland is separated into two distinct structures, the adrenal cortex and medulla, both of which produce hormones. The cortex is divided in three layers: zona glomerulosa, producing aldosterone, zona fasciculata, producing cortisol, and zona reticularis, producing androgens. The medulla produces catecholamines, epinephrine and norepinephrine.

On ultrasound (US) the adrenal gland is less echogenic than the surrounding perirenal fat (fig.1 on page ), and the medulla is evident as a highly echogenic central linear structure. US evaluation of adrenal gland is limited as a result of the effects of overlying bowel gas, especially in the assessment of the left side, and US has largely been replaced by computed tomography (CT), and magnetic resonance imaging (MRI). On CT (fig.2 on page ) and MRI (fig.3 on page ) evaluation, each gland is clearly depicted as a linear or inverted Y- or V-shaped organ located superior, medial, and anterior to each kidney. Neither CT nor MRI can be used to distinguish between the adrenal cortex and the medulla.

TYPICAL ADENOMA

Adrenal cortical adenoma is the most common lesion of the adrenal glands (90%). It is usually unilateral but can be bilateral (fig.4 on page ). It is a benign, functioning or non-functioning, tumor arising from the cortex of the adrenal gland. When functioning adenoma may cause Cushing syndrome, Conn syndrome, or hyperandrogenism.

Typical adenoma diagnosis is based on the identification of intracytoplasmatic fat.

On US examination adenoma appears as a well-defined, solid, round nodule, attached to the adrenal gland. In spite of presence the intracytoplasmic lipid adenomas are usually isoechoic to the adrenal gland, and are hypoechoic compared with perinephic fat (fig.5 on page ). In typical cases unenhanced CT shows a round nodule, generally less than
3 cm in diameter, with homogeneous attenuation values below of 10 Hounsfield Units (HU) (fig.6 on page ). After contrast medium administration an early enhancement with a rapid loss of contrast medium is demonstrated (fig.7 on page ). On MRI, the most specific findings for the adenoma diagnosis is the signal loss on chemical shift imaging due to intracytoplasmatic fat content. A decrease in the signal intensity on out-of-phase images relative to that on in-phase images is diagnostic (fig.8a on page /8b on page ). The signal intensity from the spleen can be used as a reference, and ensuring identical preimaging values with both sequences is important. The use of image subtraction, a postprocessing technique, improves diagnosis facilitating signal loss identification.

ATYPICAL ADENOMA

Atypical adenoma is a lipid poor adenoma, with unenhanced CT attenuation values above of 10 HU (fig. 9 on page ) and without a signal loss on chemical shift MRI (fig.10a on page /10b on page ).

Its correct characterization requires delayed phase CT. It has been shown that adenomas enhance rapidly and show a rapid loss of contrast medium. A 10 minute delay scan with an absolute percentage washout more than 50% has a high sensitivity and specificity for the detection of adenoma. Washout is calculated as follows:

1. Intravenous contrast agent is administered, and a scan is obtained after an 80-seconds delay.
2. A subsequent scan is obtained after a 10-minute delay.
3. A region of interest is drawn over the adrenal mass, and the attenuation is measured in HU at 80 seconds and at 10 minutes.
4. The percentage of contrast agent washout is equal to \( 1 - \frac{\text{attenuation at 10 minutes}}{\text{attenuation at 80 seconds}} \) X 100 (fig.11 on page ).

MYELOLIPOMA

Myelolipoma is a rare, benign, nonfunctioning tumor composed of varying proportions of mature fat tissue and proliferating hematopoietic cells. It is thought to arise in the zona fasciculata of the adrenal cortex.

On US, myelolipoma is typically seen as an echogenic mass in the adrenal gland (fig.12 on page ). If tumor is large and a significant amount of fat is present, propagation speed artifacts may occur as a result of decreased sound velocity through the fatty masses. Unenhanced CT is the modality of choice for its characterization, demonstrating a round and well defined lesion with attenuation values of fat, ranging from -30 to -115 HU (fig.13 on page ). Calcifications may be present. On MRI lesion appears hyperintense on T1 images and hypointense on fat saturated T1 images because of the presence of macroscopic fat.
Adrenal cysts are rare and more than 90% are solitary and unilateral. Adrenal cysts have been divided into four groups: endothelial lined cysts, pseudocysts, cysts secondary to infectious agents, and epithelial-lined or true adrenal cysts. Endothelialized cysts are the most common subtype, accounting for 40% of cases.

US may show a round, anechoic lesion. CT and MRI are more indicated. CT shows a round, regular lesion with water attenuation density and no enhancement (fig.14a on page 14b on page ). On MRI cysts typically appear hypointense on T1 weighted images and hyperintense on T2 weighted images, with no contrast enhancement.

PHEOCHROMOCYTOMA

Pheochromocytoma is a tumor arising from the neuroectodermal tissue of the adrenal medulla. In 90% of cases pheochromocytomas are functioning tumors with increased catecholamine production.

Most tumors are large, often >3 cm, and well defined on US. They are either homogenenously solid or heterogeneous, depending on the hemmorrhage or necrosis (fig.15 on page ). On CT pheochromocytomas appear as round or oval masses with soft tissue attenuation values. Larger lesions frequently demonstrate necrosis, hemorrhage, and fluid-fluid levels. Calcifications are rare. After contrast medium administration vary degrees of enhancement are demonstrated (fig.16 on page ). On MRI scans, pheochromocytomas are usually hypointense or isointense on T1 weighted images, and are highly intense on T2 ones. If intratumoral bleeding is present, MRI appearance depends of the age of hemorrhage. After contrast material administration enhancement is seen.

HEMORRHAGE AND POST TRAUMATIC CHANGES

Adrenal hemorrhage is an uncommon event observed in patients of all ages. It is due to blunt abdominal trauma, causing usually an unilateral involvement, or it may be secondary to stress, or a coagulopathic state, usually with bilateral involvement.

On US performed in the early state, adrenal gland is large, hyperechoic, and masslike (fig.17 on page ). As the hemorrhage resolves, the gland reduces, and the hematoma becomes more centrally hypoechoic and eventually completely anechoic.

Unenhanced CT scan demonstrates a hyperdense, 50-90 HU, masslike distortion of the normal adrenal gland shape (fig.18 on page ). Inflammatory stranding to the periadrenal fat is noted (fig.19 on page ). Periadrenal hemorrhage with extension of perinephric space may be seen. Over time hematoma decreases in size and attenuation, and may resolve completely. An organized chronic hematoma, the so called adrenal
pseudocyst, appears as hypoattenuating mass with or without calcifications (fig.20 on page ).

On MRI signal intensity is variable and reflects the presence of hemorrhagic products. In the acute stage, less than 7 days, hematoma appears isointense or slightly hypointense on T1 sequences and markedly hypointense on T2 sequences. In the subacute stage, from 7 days to 7 weeks, the hematoma appears hyperintense on both sequences. In the chronic stage a hypointense rim is present on T1 and T2 weighted images.

ADRENAL GLAND INFECTIONS

Adrenal gland infections are a relatively uncommon clinical entity in the Western countries but represent the major cause of Addison's disease in the developing world.

The adrenal gland can be directly infected by various microbial pathogens, including a diverse array of viruses, fungi, and bacteria. Granulomatous infections are frequent with Mycobacterium tuberculosis being the most common causative agent.

US findings are not specific. CT appearance of early infection include bilateral adrenal enlargement with a central necrotic area of hypoattenuation and a peripheral enhancing rim. In the late phase adrenal glands become calcified and atrophic (fig.21 on page ). MRI is not routinely used.

ADRENOCORTICAL CARCINOMA

Adrenocortical carcinoma is a rare tumor of the adrenal cortex, which can manifest as a hyperfunctioning mass causing Cushing syndrome. When identified, tumors frequently are large, measuring 4-10 cm in diameter, and may be bilateral.

US appearance is variable depending on the size of the mass. Smaller lesions are homogeneous and may be difficult to differentiate from adenomas; larger ones demonstrate a heterogeneous echo pattern with cystic areas when the tumors grow as a result of hemorrhage and necrosis (fig.22 on page ). On CT scans, adrenal cortical carcinoma appears as a large mass, often with central necrosis. Calcifications are observed in about 30% of patients. After contrast medium administration the tumor enhances heterogeneously (fig.23a on page /23b on page ). Invasion into adjacent structures and venous extension into the renal vein or inferior vena cava may be present.

On MRI the lesion appears hypointense on T1 sequences and hyperintense on T2 sequences. Often, the tumor may demonstrate heterogeneously hyperintensity both on T1 and T2 weighted images, due to the central necrosis and hemorrhage. Because the mass usually does not contain any significant intracellular lipid, no signal loss is seen on out-of-phase imaging.
MALIGNANT MEDULLARY TUMORS

Malignant medullary tumors are rare lesions including pheochromocytoma, and neuroblastoma.

Pheochromocytoma is a neoplasm of the adrenal medulla. Although it is typically benign, in 10% of patients it may be malignant with recurrence and metastatic disease possibility. Radiologic appearance is not specific.

Neuroblastoma is an embryonal malignancy of the sympathetic nervous system arising from neuroblasts. In the developing embryo, these cells invaginate, migrate along the neuraxis, and populate the sympathetic ganglia, adrenal medulla, and other sites. Neuroblastoma is one of the most common solid tumours of early childhood usually found in babies or young children. Radiologic appearance is not specific.

METASTASIS

Adrenal glands are the fourth most common site of metastatic disease after lung, liver, and bone. The primary tumors which most often involved adrenal glands are lung, breast, thyroid, colon ones, and melanoma.

On US adrenal metastases appear as solid lesions, usually hypoechoic compared with perinephic fat (fig.24 on page ). Anechoic foci are due to necrosis (fig.25 on page ). CT is the modality of choice for adrenal metastasis identification. Metastasis appear as focal masses or distortion of the contour of the gland. After contrast medium administration lesions are heterogeneous (fig.26a on page /26b on page ) and no washout on delayed phase scan is seen. Larger lesions may have central necrosis (fig.27a on page /27b on page ) or hemorrhage. On MRI adrenal metastasis typically appear hypointense on T1 weighted images and hyperintense on T2 weighted ones, without signal loss on out phase sequences.

HEMANGIOMA

Hemangioma of the adrenal gland is an extremely uncommon lesion usually involving the adrenal cortex. The tumor is well delimited and encapsulated. At microscopic analysis hemangiomas are most commonly cavernous and rarely capillary.

The US appearance is not specific and the tumor may be hypoechoic, hyperechoic, and of mixed echogenicity. Unenhanced CT demonstrates a hypoattenuating mass. Necrotic area or calcifications may be present. After contrast medium administration peripheral enhancement reveals contrast material-filled lakes. Centripetal enhancement is less frequent than in liver hemangiomas. On MRI lesion appears hypointense on T1 weighted images and hyperintense on T2 sequences. The enhancement pattern is the same than seen at CT.
Conclusion

Adrenal gland lesions are frequent findings and imaging evaluation is essential for diagnosis. So it is important to become confident with possible imaging findings.
Personal Information

Marco Francesco Cavallaro, MD.
Department of Radiology, Cattinara Hospital, Trieste, Italy
mrc.cavallaro@virgilio.it