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Ultrasound of the adrenal glands

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Topographical anatomy

The adrenal glands are located within the retroperitoneum. The right adrenal gland faces the right kidney superomedial and is located posterolaterally to the IVC between the lateral right liver lobe and the inferior (lumbar) crus of the right diaphragm. These are the principal landmarks on the right side. Typically the right adrenal gland is visualised behind the right lobe of the liver and anterior to the inferior diaphragmatic crus.

The left adrenal gland is inherently more difficult to scan than the right because it lacks the acoustic window of the liver and is obscured by air in the stomach. Approaching the left adrenal gland is possible using a transverse epigastric scan. Another option is to use an intercostal flank scan with the spleen as an acoustic window. The key anatomical landmarks are the abdominal aorta (medially), the left inferior crus of the diaphragm (dorsally), the lower pole of the spleen, the upper kidney pole (laterally) and the left renal vein and pancreatic tail. Not infrequently, the adrenal glands extend down to the level of the renal hilum (1). Enlarged adrenal glands (wings of glands, 2–5cm long and 6–10 mm thick) are detectable in a high percentage of cases. Normal-sized adrenal glands are visible with skilled or frequently practised examination techniques and by using high-resolution technology (from right to left). On each side the adrenal region appears as a triangular echogenic area bordered by the previously mentioned landmarks [Figure 1 and 2].

Figure 1 **Topographical relation of adrenal glands to the neighbouring retroperitoneal organs (Adr: adrenals; Ao: Aorta; E: oesophagus; ICV: inferior caval vein; K: kidneys; yellow: periadrenal fat).**

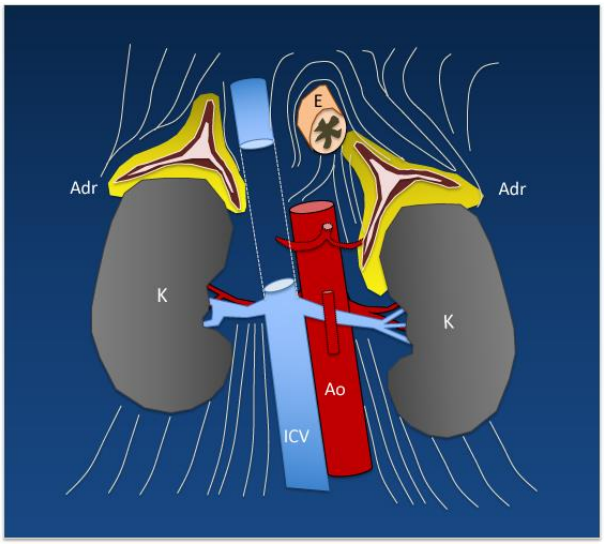
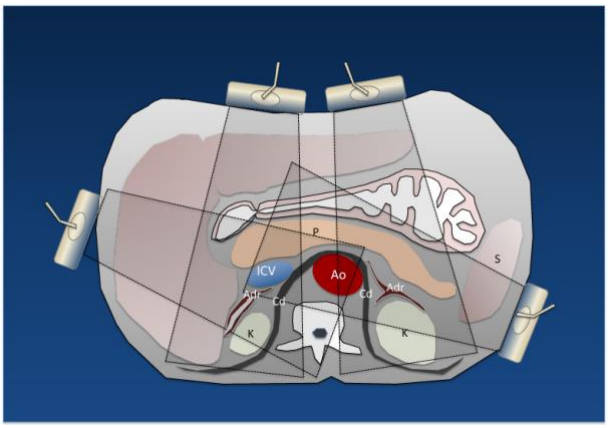


Figure 2 **Cross-section at the level of the adrenal glands. The adrenal glands are the Y-shaped structures anteromedially to the kidneys. Sonographic examination is possible with the patient in a supine position using liver and pancreatic head (right adrenal) or pancreatic tail (left adrenal) as an acoustic window. Moreover, lateral scanning is possible (right adrenal: from a right intercostal space in supine or left oblique patient position; left adrenal: using the spleen or upper kidney pole as an acoustic window in supine patient position) (Adr: adrenals; Ao: Aorta; Cd: diaphragmatic crus; ICV: inferior caval vein; K: kidneys; S: spleen).**



Anatomy

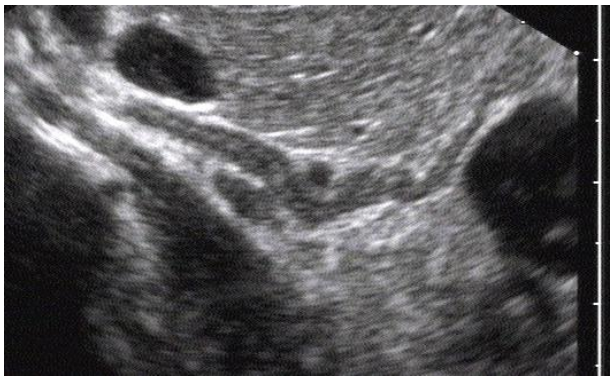
The adrenal glands are small, cap-like glandular organs situated in close proximity to the kidneys. Often these “suprarenal” glands are incorrectly sought above the kidneys, but as the term “adrenal” implies, each gland is predominantly medial to the upper pole of the associated kidney. The right adrenal gland has a linear or V-shape, while the left adrenal gland is more V- or Y-shaped. The wings of each gland are 30 – 60 mm long and 3 - 10 mm thick (2). Their physiological function is hormone production. The adrenal cortex secretes cortisol, aldosterone and sex hormones, while the adrenal medulla secretes epinephrine and norepinephrine.

To visualise the normal adrenal gland with transabdominal ultrasound requires good scanning conditions, a high-resolution transducer and meticulous examination by an

experienced sonographer. It is sometimes useful to speak of evaluating the “adrenal region” rather than the glands themselves. CT can consistently define normal-sized adrenal glands and therefore is the investigation of choice in the primary imaging of these structures.

Endoscopic ultrasound (EUS) of the upper gastrointestinal tract provides the best imaging quality for the adrenal gland [Figure 3]. However, this is consistently possible only at the left side. Endoscopic ultrasound evaluation of the right adrenal gland is only possible in 30 - 70 % of examinations (3, 4). The supplying vessels (left suprarenal arteries and veins) are visible only endosonographically. However, due to its semi-invasive character and the limitations to visualize the right adrenal, EUS is not the standard technique for primary diagnosis of adrenal gland abnormalities (1, 2).

Figure 3 **High-resolution endosonography of the left adrenal gland. The proximal and caudal limbs with its 5-layer structure are visible in high-resolution; the adrenal cortex is depicted as a slim hypoechoic rim-like structure surrounding the hyperechoic medulla. The whole gland is surrounded by an hyperechoic capsule.**

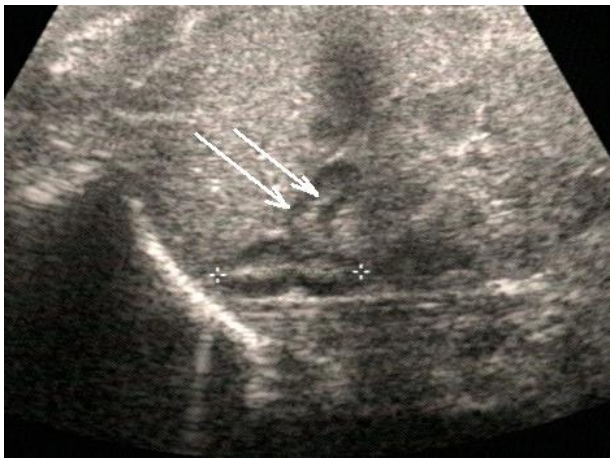


Echogenicity

On ultrasound, normal adrenal glands have a long and hyperechoic narrow shape and typically have a five layer-stratification (hyperechoic medulla surrounded by hypoechoic cortex and a hyperechoic capsule) [Figure 3]. The adrenal glands can almost always be visualised in newborns (5-7). The physiological hypertrophy at this stage of life results in

relatively large glands that can be easily identified; corticomedullary differentiation is easily depicted [Figure 4].

Figure 4 Normal adrenal gland of an infant consisting of a hyperechoic medulla and hypoechoic cortex (shown between markers).



Examination technique

The normal position for examination is dorsal decubitus. The right adrenal is best visualized using a subcostal flank scan, an intercostal scan or oblique subcostal scan. A second opportunity is a transverse section from the right hypochondrium. One option for the examination of the left adrenal is a transverse position of the transducer in the epigastrium with the pancreatic tail used as an acoustic window and aorta, splenic vein and left renal vein as anatomical landmarks. The second option is to use an intercostal flank scan through the spleen or the upper third of the left kidney. Additionally and sometimes with better success, adrenals are examined with the patient in left (for the right adrenal: the right liver lobe is used as an acoustic window) or right lateral position (the spleen or upper third of the left kidney are used as an acoustic window). In the case of intercostal scanning, slow deep breathing by the patient moves the organ from its original position under the ribs, which increases the visible region. Occasionally it is useful to examine the patient lying over a roll

(the so-called gabled position) (8) especially in the prone position. Normally a convex probe with high-resolution at depth and a tissue harmonic function is used.

The normal acoustic obstacle of examination of the left adrenal gland is air in the intestine (stomach, transverse colon, small intestine). Sometimes special preparations (fasting patient, water-filled stomach) and gentle and repeated compression and breathing maneuvers may be helpful. With endoscopic ultrasound, the distance in particular to the left adrenal is very close, and high-resolution imaging as well as sampling of adrenal tumors is possible (4, 9). The basic requirement for examination is a convex abdominal transducer (3–5MHz in B- mode). Vascularisation can be evaluated by power Doppler, and contrast - enhanced ultrasound (CEUS) can visualize the microvascularisation of adrenal gland tumors.

Normal adrenal gland

On the right side the normal adrenal gland is visible in more than 90% of cases [Figure 5]. The normal left adrenal gland is visible in only 40–50 % of cases [Figure 6] (2). The adrenal glands have a long axis of 40 - > 50 mm and a body thickness of approximately 10 mm, whereas the limbs are very slender with a diameter of up to 5 mm.

Figure 5 The normal right adrenal gland is visible dorsal to the right liver lobe as a slender layered organ with two limbs (arrows: right diaphragm).

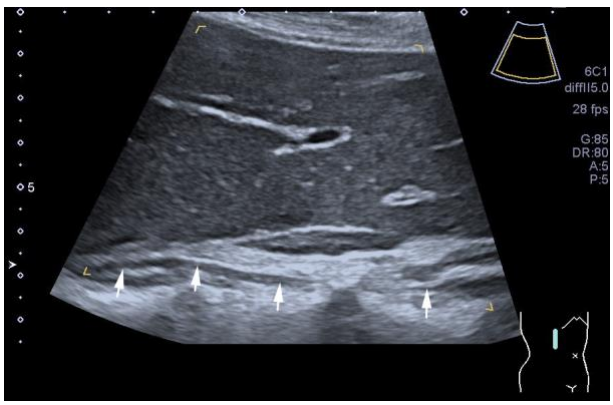
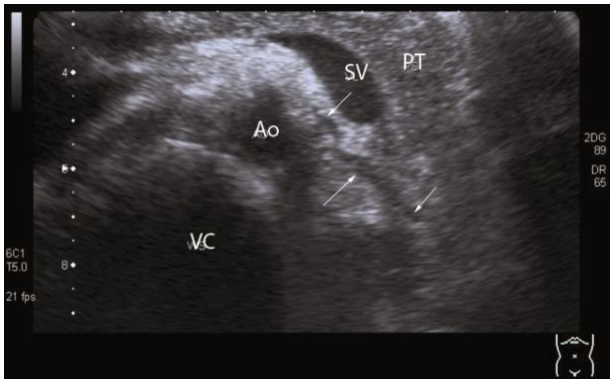


Figure 6 Visualization of the left adrenal gland (arrows) using the pancreatic tail (PT) as an acoustic window. Anatomical landmarks are the aorta (Ao), the vertebral column (10) and the splenic vein (SV).



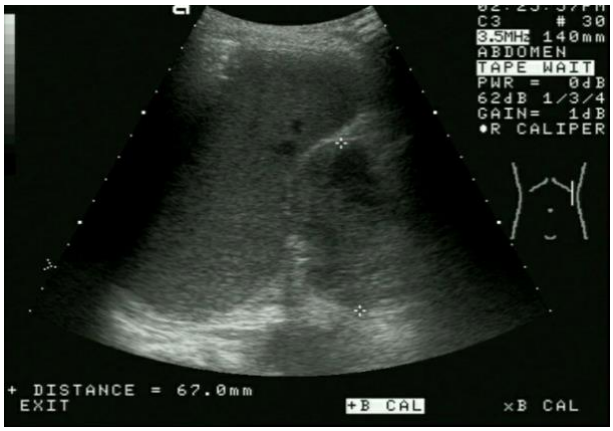
Enlarged adrenal gland and mass lesions

In adults the adrenal glands are better visible when they are enlarged. Some causes of enlargement have a pathological significance. Diseases of the adrenal glands may or may not be associated with endocrine symptoms [Table 1]. Examination of the adrenal region is indicated for the staging of oncological diseases (M-staging) and in case of endocrine disease. However, adrenal abnormalities are often detected incidentally. In the absence of current diagnosis or history of malignancy, an incidentally detected solid adrenal mass is called an incidentaloma**.**

Differential diagnosis (differentiation from other structures in the surrounding area)

Enlarged or tumorous adrenal glands require distinction from other possibly tumorous structures in the surrounding area of the adrenal gland. Tumors of the kidney, pancreas [Figure 7] and spleen (especially accessory spleen) or vascular abnormalities and lymphoma should be considered in the differential diagnosis. It must be taken into account that adrenal gland tumours always dislocate the surrounding structures. If the adrenal gland tumour is extremely large, it may be difficult to find the neighbouring organs.

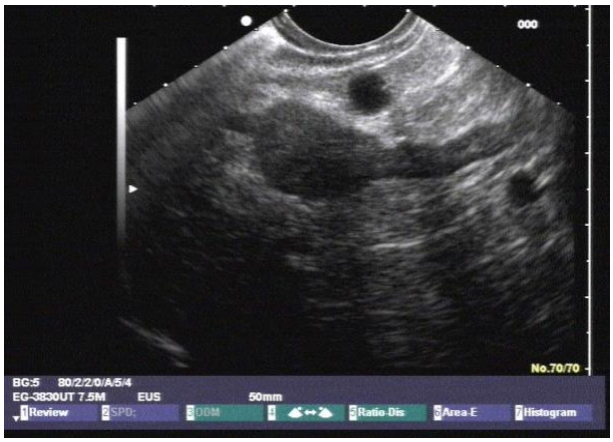
Figure 7 Transsplenic examination of a large, hypoechoic malignant tumor of the pancreatic tail; differentiation from left adrenal tumor is difficult.



Adrenal gland hyperplasia

Hyperplastic adrenal glands are usually hypoechoic, especially in the cortical zone. They appear plump and elongated, may show nodular structures and the borderline between cortex and medulla disappears. The adrenal gland in Figure 8 measures > 10 mm**.** Adrenal hyperplasia can occur, for example, as an adaptive response in adrenocorticotropic hormone (ACTH)-dependent Cushing's syndrome. It may have a paraneoplastic cause or occur in hyperaldosteronism. Hyperplasia is found bilaterally in most cases. Differentiation from adenoma is not possible by histology or cytology (FNAB).

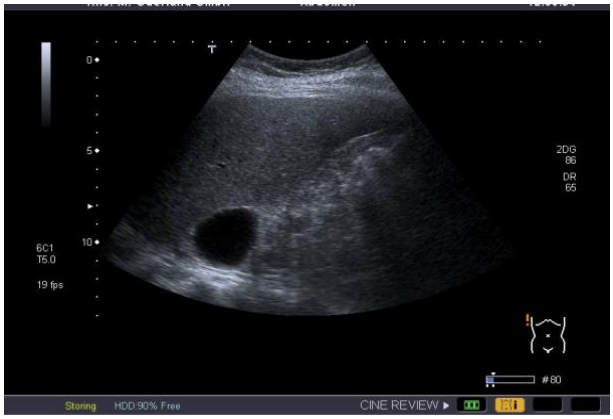
Figure 8 Endoscopic ultrasound shows a nodular enlargement within the proximal limb of the left adrenal gland (nodular hyperplasia)



Adrenal Cysts and cystic tumors

A cyst of the adrenal region is anechoic, has smooth margins and shows distal acoustic enhancement. Size is variable. True cysts have regular walls and are filled with serous fluid [Figure 9].

Figure 9 Adrenal cyst: sharply demarcated round echo-free mass located dorsally of the right liver and cranially of the right kidney.



Most cystic masses in the adrenal region are secondary cysts that develop following pancreatitis, haemorrhage or inflammation. Cystic tumors, such as pheochromocytoma (PCC) or lymphangioma, are seldom observed. In most cases, these tumors have cystic and solid components. Differentiation from cysts of the latero-dorsal liver may be challenging. Observation of cyst movement with breathing against the liver surface proves an adrenal origin. Lack of contact with the renal parenchyma distinguishes adrenal cysts from a cyst of the upper renal pole.

In the adrenal region the following types of cystic lesions have to be differentiated:

- Renal cysts: parietal cysts located in the upper pole of the kidney are particularly at risk of being mistaken for adrenal cysts. They are distinguished by defining the relation of the cyst to the renal parenchyma.
- Pancreatic pseudocysts and cystic pancreatic tumors: pancreatic pseudocysts often form in the retroperitoneum following acute pancreatitis. Mucinous cystadenoma and cystadenocarcinoma of the pancreas typically is located within the left parts of the pancreas and maybe confused with a cystic lesion of the left adrenal gland. In most cases, endoscopic ultrasound allows assignment of the cystic lesion either to the pancreatic tail or to the left adrenal.
- Splenic and collateral vessels: tortuous and ectatic splenic vessels (e.g. portosystemic shunts in portal hypertension) may mimic a cystic mass in the left adrenal region. Differentiation is easily achieved using colour Doppler.

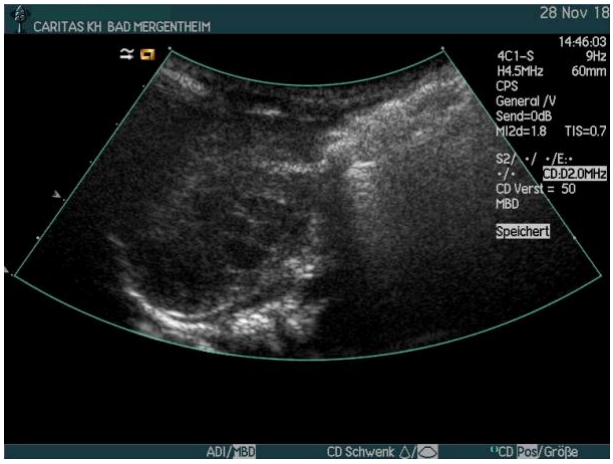
Intra-adrenal haemorrhage (haematoma)

Bleeding into the adrenal gland is anechoic in its early stage. It can occur in newborns due to obstetric trauma, hypoxia or coagulation disorders. Intra-adrenal haemorrhage may correlate clinically with adrenal insufficiency. A large central haemorrhage (adrenal apoplexy) consistently leads to a marked enlargement of the gland [Figure 10]. An older haemorrhage becomes increasingly echogenic over time and may eventually be completely absorbed. Differentiation is required from partially cystic neuroblastomas in small children.

Up to 25% of patients who sustain blunt abdominal trauma are discovered to have haematomas in the adrenal region. They also occur in patients on anticoagulant medication and can lead to hypocortisolism (Addison's disease) (11).

Figure 10 Intra-adrenal haemorrhage in a newborn using conventional B-mode and contrast enhanced ultrasound.

a



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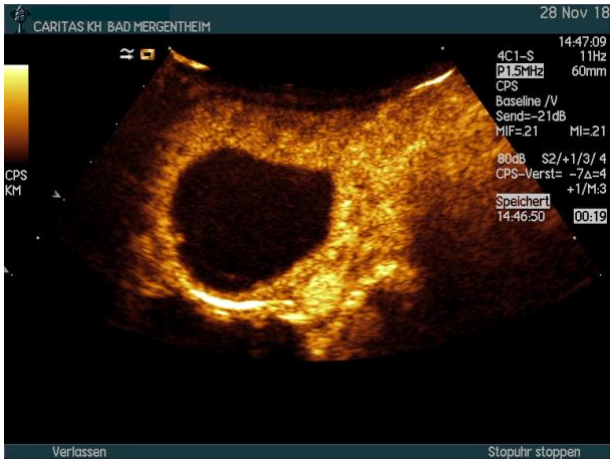


Adrenal abscess

An abscess of the adrenal glands is usually hypoechoic or has a complex echo-structure. When the contents are anechoic, the clinical and laboratory findings can differentiate the lesion from an ordinary cyst. The wall is irregular and distal acoustic enhancement may be present.

Differentiation of benign and malignant lesions

Benign adrenal gland tumors

Adenoma

Most adenomas are uniformly hypoechoic with smooth margins and a round to oval shape, although some lesions have scalloped borders (as so known as polycyclic borders) [Figures 11–14]. Larger adenomas occasionally have an inhomogeneous appearance [Figures 15, 16]. Autopsy statistics indicate that adrenal adenoma is relatively common (up to 8.7 %). Most adenomas (90 %) have no endocrine activity. The average size of adenomas in one study was 1.5 cm, although they may exceed 5cm in diameter. In a small percentage of patients adenomas are bilateral. Functioning and non- functioning adenomas are indistinguishable by their sonographic features (12-16).

Figure 11 Incidentally detected “mass lesion” of the right adrenal (diameter 10 mm; arrows: right diaphragm).

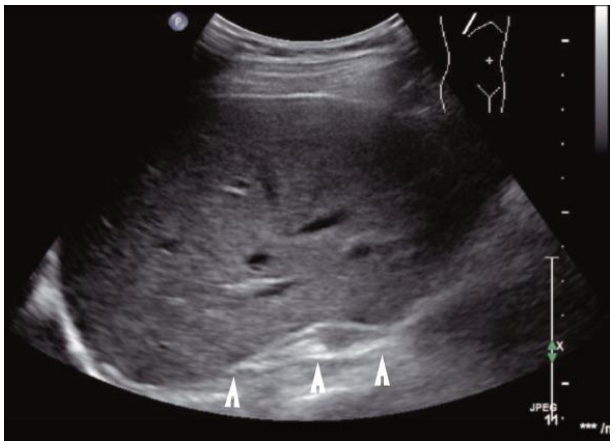


Figure 12 Two small adenomas of the right adrenal (diameters: 12mm and 15 mm, marked by arrows)

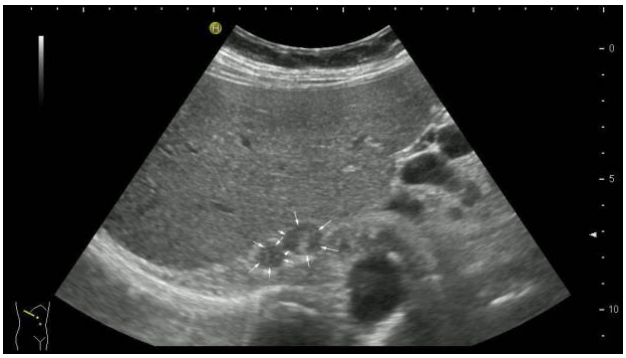


Figure 13 **Hypoechoic, sharply circumscribed adenoma of the right adrenal gland discovered at routine ultrasound and confirmed by ultrasound guided fine-needle aspiration.**

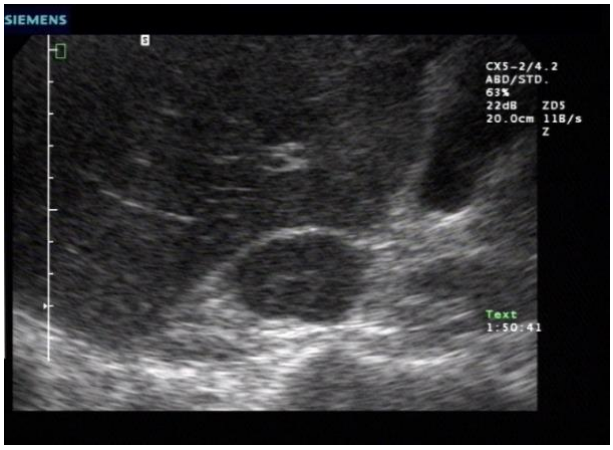


Figure 14 **Larger adenoma of the right adrenal with a slightly heterogeneous echo-pattern; the lesion was detected in a female patient with ovarian cancer, and malignancy was ruled out using transhepatic ultrasound-guided biopsy (arrow heads: right diaphragm; ICV: inferior cava vein)**

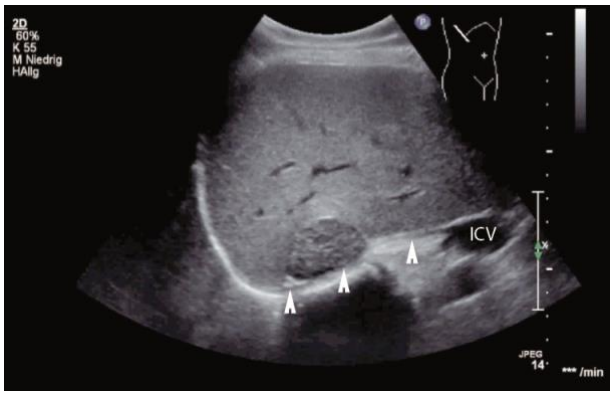


Figure 15 **Approximately 5cm hypoechoic inhomogeneous mass above the right kidney detected at routine upper abdominal ultrasound. The lesion turned out to be a non-functional and benign adrenal adenoma (incidentaloma), which was confirmed by histology.**

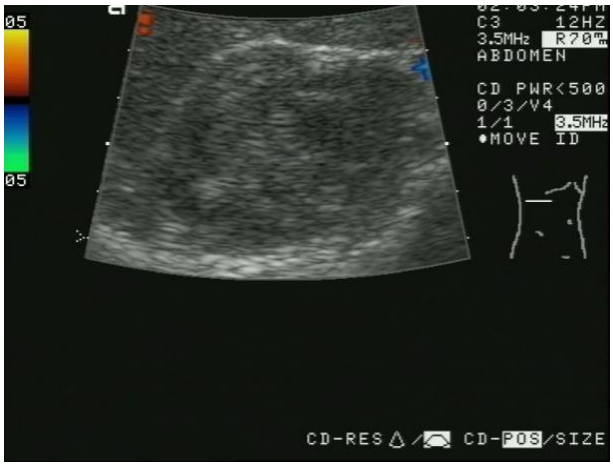
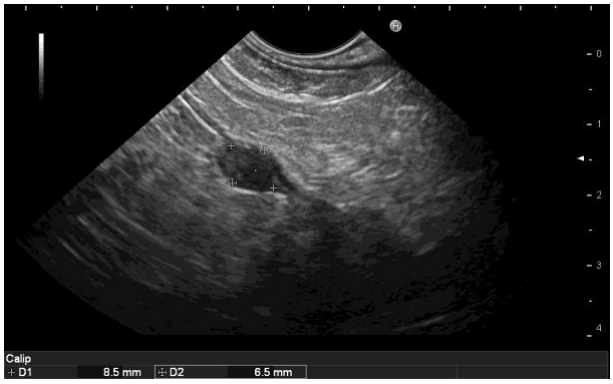


Figure 16 **Small adenoma of the left adrenal, detected incidentally using endoscopic ultrasound**



Lipoma and myelolipoma

Lipoma and myelolipoma are rare adrenal lesions with smooth margins and a homogeneous hyperechoic appearance [Figure 17]. Its sonographic features resemble a renal angiomyolipoma. Posterior acoustic shadowing may be present. Malignant transformation is not known to occur. Histologically, myelolipoma tumor consists of fat and bone marrow tissue (haematopoietic cells and reticular cells). Intratumoral haemorrhage and calcifications may be seen (17-20).

Figure 17 Typical adrenal myelolipomas: incidentally detected homogeneous, sharply circumscribed, hyperechoic tumour adjacent to the right kidney (a; transabdominal ultrasound) and two smaller hyperechoic and homogeneous tumors of the left adrenal gland of another patient, incidentally detected by endoscopic ultrasound (b: 8 x 6 mm, c: 4 x 3 mm).

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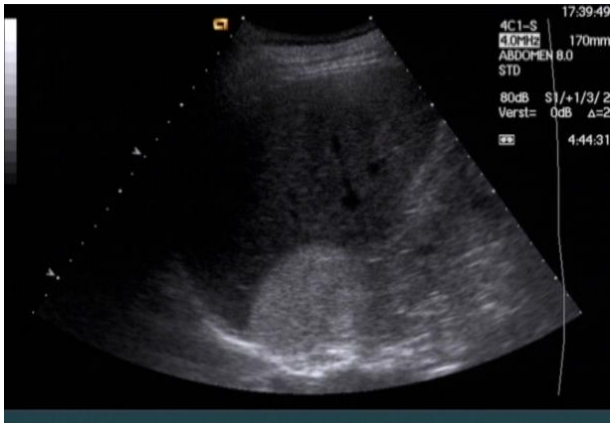

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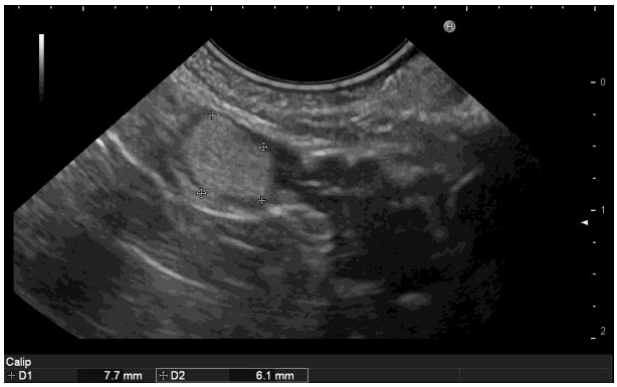

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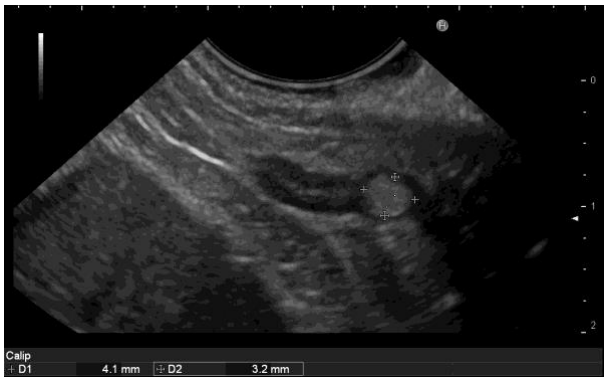


Calcification

Complete or partial calcification of the adrenal glands is characterised by hyperechoic structures with a posterior acoustic shadow. Calcifications can result from a retained intra-adrenal haemorrhage or a prior inflammatory process (*e.g.* tuberculosis) [Figure 18]. Patients occasionally show the clinical manifestations of Addison's disease; however, calcifications can also develop in tumors (carcinoma, metastases, PCC or adenoma) [Figure 19].

Figure 18 Multiple calcifications of the right adrenal (note the acoustic shadows; Courtesy of Kathleen Möller, Berlin, Germany).

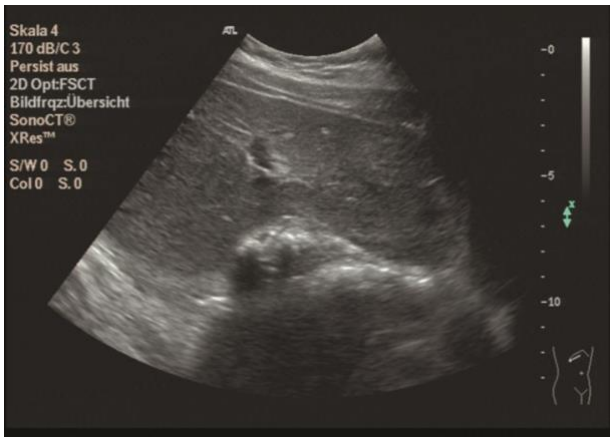
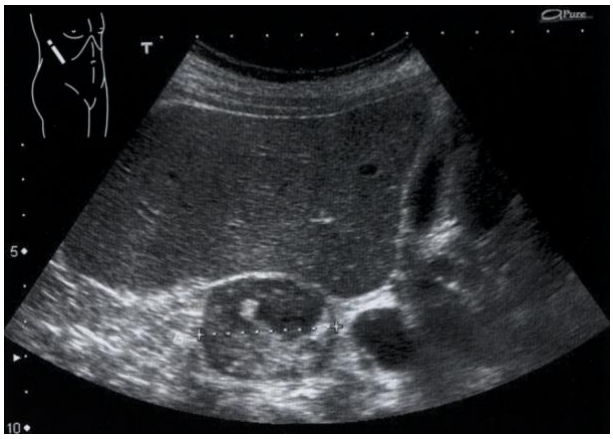


Figure 19 Small calcifications can occur in tumours of adrenal gland. They are usually observed in pheochromocytoma



Malignant adrenal gland tumours

Metastases

As a result of their rich blood supply, the adrenal glands are the fourth most frequent site for haematogenous metastasis with a prevalence of 27 % in malignant disease of variable locations of the primary (21, 22). Metastases to the adrenal glands account for the majority of solid adrenal tumors after adenomas.

In contrast to adenomas adrenal metastases are less homogeneous and often have irregular margins [Figure 20–22]. The most common primaries (in Europe) are lung cancer (accounting for 25–30 %), breast cancer and malignant melanoma. Other possible sources are gastrointestinal (especially in Asia), urological and gynaecological tumors (renal carcinoma, gastric carcinoma, pancreatic carcinoma and others). Adrenal metastases are bilateral in up to 30 % of cases and this can lead to a clinical manifestation of Addison's disease. Lung cancer is virtually the only tumor that is associated with isolated adrenal metastases (approximately 15–20 %) (23-25).

Figure 20 **Large right adrenal metastasis from lung cancer with a very inhomogeneous echo pattern. Solid components are seen along with central liquid areas (necrosis).**

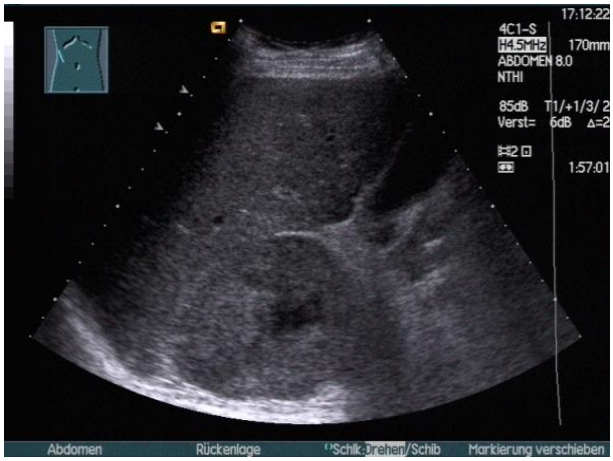


Figure 21 **Transverse scan shows a right adrenal metastasis with a complex echo-structure “wedged” between right lobe of the liver, inferior vena cava, the kidney and spinal column.**

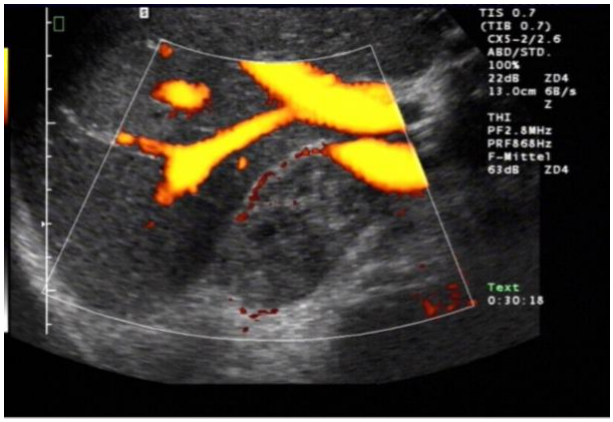
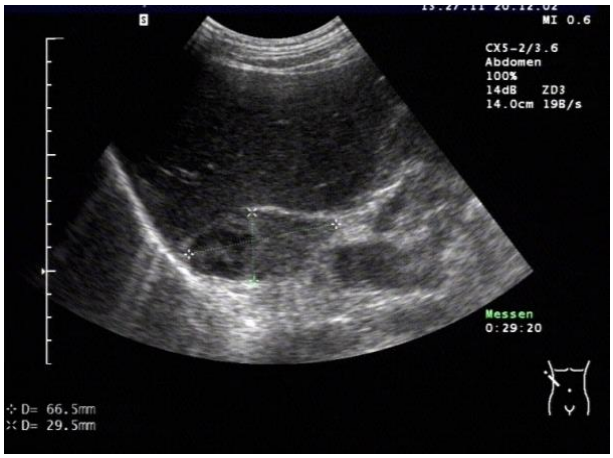


Figure 22 Transverse scan of a metastasis of the right adrenal gland with complex echopattern (primary tumor was lung cancer).



Pheochromocytoma (PCC)

PCC is a tumour of the adrenal medulla that is generally detected sonographically (80–90 % of cases) following the appearance of clinical symptoms (hypertension and tachycardia caused by increased catecholamine secretion). Most PCCs are already several centimetres in diameter when diagnosed. They have smooth margins, a round shape, and a non-homogeneous or complex echo pattern. Hypoechoic semi-liquid components are also observed. A wide spectrum of appearances may be seen [Figure 23 and 24]. PCCs are bilateral in approximately 10 % of cases and extra-adrenal in 10–20 %. The “Zuckerkandl organ” should be looked for at the level of the origin of the inferior mesenteric artery and anterior to the aorta. Rarely, PCC is diagnosed in the setting of multiple endocrine neoplasia (MEN). 2–5 % of PCCs are malignant. Owing to the risk of inducing a hypertensive crisis, FNAB is debated controversially and often regarded as a contra-indication (10, 26-40).

Figure 23 Inhomogeneous large tumor of the right adrenal gland with a hyperechoic centre. Increased catecholamine secretion indicated pheochromocytoma (Courtesy of Albrecht Holle, Rostock, Germany).

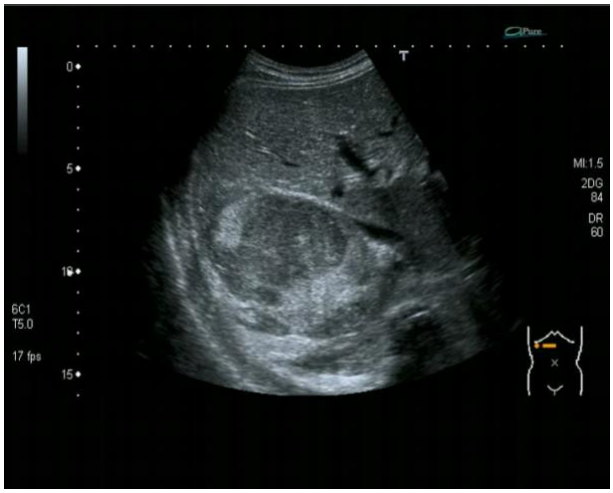
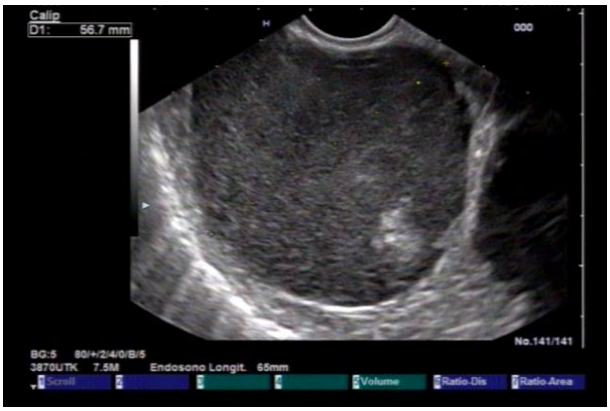


Figure 24 Large, functionally active pheochromocytoma (7cm in diameter) of the left adrenal gland (EUS). The tumor is hypoechoic with localized hyperechoic areas.

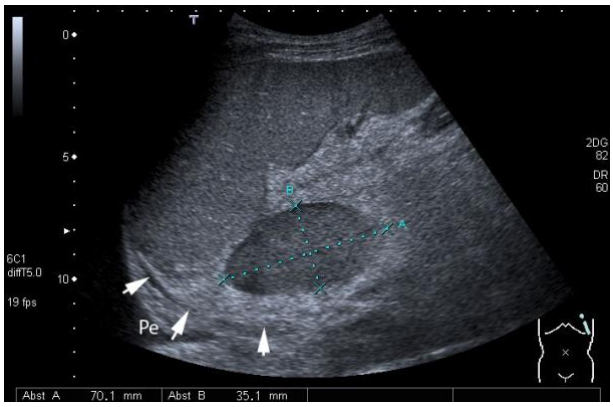


Lymphoma

The adrenal region is a rare extranodal site of occurrence for lymphoma. There are no typical features allowing differentiation of malignant adrenal lymphoma from other adrenal tumors [Figure 25].

Differentiation is required from lymphomas in the renal or splenic hilum. If invasion by lymphoma is suspected, other nodal stations should be scanned and commonly infiltrated organs (e.g. spleen and liver) should be closely scrutinised (41-46).

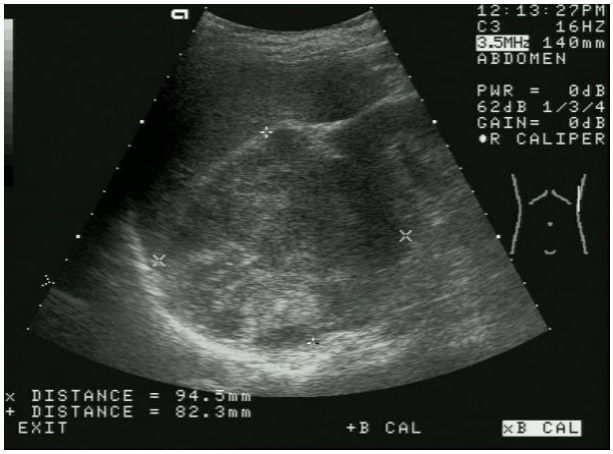
Figure 25 Transsplenic view of a well-circumscribed hypoechoic mass lesion of the left adrenal which turned out to be malignant lymphoma (between markers; arrowheads: left diaphragm; Pe: small pleural effusion)



Adrenal carcinoma

Adrenal carcinoma is usually inhomogeneous hypoechoic or echo-complex with irregular margins. It frequently infiltrates its surroundings (including tumor thrombus in the inferior caval vein), and metastases can be demonstrated in the adrenal region and in other organs (e.g. the liver) [Figure 26]. Adrenal carcinoma is a very rare (prevalence: 1 in 1.7 million), highly malignant tumor with a poor prognosis. Adrenal carcinoma is indistinguishable sonographically from a metastasis. However, a solitary large inhomogeneous mass lesion of one adrenal in patients without a history or current diagnosis of an extra-adrenal malignancy is highly suspicious of an adrenal carcinoma. Most adrenal carcinomas are hormone producing. The tumour is usually only detected after it has reached a considerable size (often over 8cm). An adrenal carcinoma with a diameter of ≤ 4 cm is very rare (47). Intratumoral haemorrhage, necrotic foci and calcifications may occur which add to the variegated appearance (48).

Figure 26 Adrenal carcinoma may be hypoechoic or may have a complex echo-structure. Usually they are relatively large when diagnosed (in this case 8×9cm) with irregular margins.



Rare entities

Neuroblastoma

Neuroblastoma develops from cells of the adrenal medulla. Besides the Wilm's tumor, it is the most common malignant abdominal tumour in children. Approximately 70 % of neuroblastomas are located in the adrenal glands, the rest occur at other sites in the sympathetic chain. Most neuroblastomas are very large and predominantly hyperechoic. Some have cystic elements (due to haemorrhage) and calcifications. Laboratory tests usually show an increase in catecholamine secretion.

Considerably less common are benign neural tumors, such as ganglioneuromas. They have only been described sporadically in the adrenal glands and occur more commonly in the posterior mediastinum and at paravertebral sites.

A particular clinical situation: Adrenal incidentaloma

An incidentaloma is an adrenal tumor that is detected incidentally in an asymptomatic patient. Incidentalomas are found in up to 5 % of CT examinations. The prevalence increaes with age (49-51). No data are available for incidental detection of adrenal lesions using state-of-the-art abdominal ultrasound [Figures 11-13, 15-17, 23 and 24]. Approximately 90 % of adrenal incidentalomas do not exhibit any endocrine activity. Overt endocrinopathy is rare. Sub-clinical endocrine activity may contribute to clinically relevant morbidity (arterial hypertension, obesity, osteoporosis, diabetes mellitus) and should therefore be ruled out. The recommended endocrine work-up is detailed in the Guidelines of the European Society for Endocrinology (52) and is summarized in Table 1 (53). According to recent data, the cumulative risk of an adrenal incidentaloma to be malignant is as low as 3 % (54). The role of image-guided FNA is limited. Whereas the European Guidelines recommend against performing FNA of incidental adrenal tumors (52), several authors suggest US- or EUS-guided FNA in particular to establish a diagnosis in non-functional adrenal incidentalomas with a diameter of 4-6 cm and lacking imaging features of malignancy [Figure 29] (55-65).

Figure 27 Most hypoechoic lesions < 2 cm are found incidentally with abdominal ultrasound

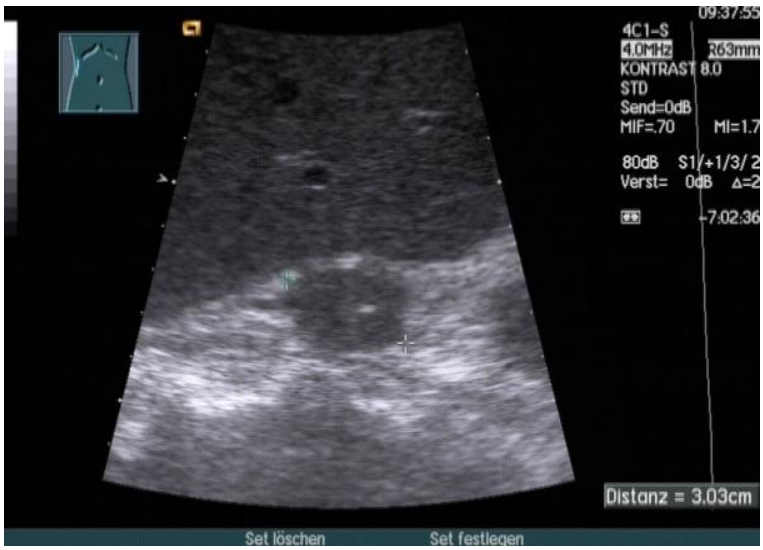


Figure 28 **The majority of adrenal incidentalomas turn out to be non-functional adenomas. They exhibit smooth borders and most commonly a homogeneous echo-pattern.**

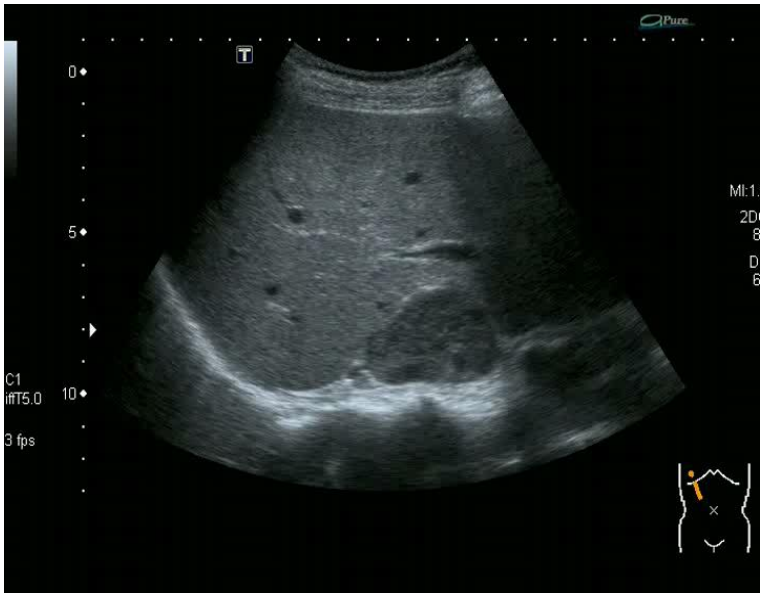


Table 1 **Endocrine laboratory work-up of adrenal incidentaloma (based on Reinke et al. (63) and Fassnacht et al. (52))**

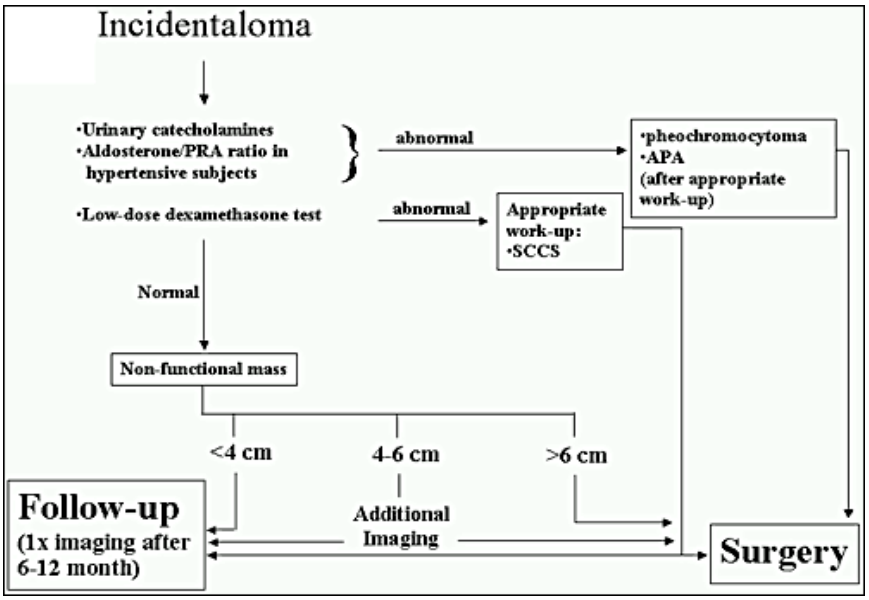
Initial work-up	
Mandatory	► Clinical and laboratory examination: clinical criteria for Diabetes mellitus, arterial hypertension, hypokaliemia, Cushing's syndrome? ► Serum cortisol in overnight 1mg-dexamethasone suppression test (autonomous cortisol secretion/ subclinical Cushing's syndrome) ► Free metanephrines (Plasma) or in 24h urine (pheochromocytoma)

Optional	► Plasma aldosterone and renin activity after 30 min rest period, aldosteron/renin ratio in patients with arterial hypertension or unexplained hypokaliemia (Conn's syndrome) ► Potassium excretion in 24h urine (Conn's syndrome) ► Sex hormones and steroid precursors in patients with clinical and/or imaging features suggestive of adrenocortical carcinoma
Extended work-up if initial findings are abnormal	
Autonomous cortisol secretion (so-called "Sub-clinical Cushing's syndrome")	► In patients with (possible) autonomous cortisol secretion: evaluation of clinically relevant co-morbidities (arterial hypertension, diabetes melllitus, obesity, osteoporosis/ vertebral fractures) and efficiency of medical treatment ► High-dose overnight dexamethasone suppression test (8 mg) ► 24 hour free urinary cortisol ► Serum ACTH and CRH stimulation test
Conn's syndrome	► Aldosterone-18-glucuronide in 24h urine ► Plasma renin activity and aldosterone at rest and orthostasis

	► Selective renal vein catheterisation with bilateral blood sampling for aldosterone and cortisol in adrenal venous blood

CRH, Corticotropin-releasing hormone

Figure 29 Algorithm for investigating an adrenal incidentaloma. Recommendations of the National Institutes of Health (NIH) State-of-the-Science Conference (66).



SCCS, Subclinical Cushing's syndrome; PRA, plasma renin aldosteron; APA, aldosterone producing adenoma.

(Endoscopic) Ultrasound-guided fine-needle aspiration of an adrenal lesion

In patients with adrenal incidentaloma the clinical value of adrenal biopsy is limited. It may be considered on an individual basis in patients with medium-sized adrenal incidentaloma (40-60 mm) or with no definite imaging criteria of a benign lesion, if surgery is not the first option. However, in patients with a history or current clinical diagnosis of malignancy (oncological setting), imaging-guided FNA has a major role if cytologic or histologic proof of adrenal metastasis may change management of the patient. Importantly, due to the high

prevalence of adrenal adenoma, in patients with a diagnosis of a history of (lung) cancer, only approximately 50% of adrenal mass lesions finally turn out to be metastasis (1). Ultrasound-guided FNA can provide material for cytological or histological analysis with a relatively low-risk of complications (2.5 %) [Figure 30]. The sensitivity of adrenal ultrasound-guided FNA is between 90 % and 95 % [Table 2]. A recent meta-analysis reported a pooled sensitivity and specificity of 87 % and 100 % of percutaneous image-guided biopsy for the diagnosis of malignancy (67). The procedure is performed with the patient in a lateral position. Access is easier in a right-sided lesion compared with a left-sided one; the complication rate is a little bit higher on the left side (22, 68-89). For sampling of left adrenal tumors, EUS-guided FNA is preferred [Figure 31]. A diagnostic yield between 76 % and 100 % was reported in cohort studies with a relatively small number of cases (90).

Table 2 Ultrasound-guided fine-needle aspiration biopsy in adrenal glands tumors

Author	Year (test)	Number	Sensitivity (%)	Specificity (%)	Accuracy (%)
Tikkakoski et al (91)	1991 (c)	56	91.3	97.0	85.7
Dock et al (70)	1992 (c+h)	47			85.1
Görg et al (73)	1992 (h)	37	95.2	100	97.0
Kojima et al (92)	1994 (h)	12	91.0		100
Fröhlich et al (72)	1995 (c+h)	33	88.2	92.9	90.3
Nürnberg et al (93)	1995 (c+h)	22	95.4	100	95.4
Lumachi et al (94)	2001 (h)	70	93.3	100	98.6
Liao et al (95)	2001 (c+h)	116	93.6		
Saeger et al (96)	2003 (h)	220	94.6	95.3	90.0
Kocijanicic et al (97)	2004 (c)	64	90.0	100	91.0

Explanations. c, cytology; h, histology: Sensitivity = RP×100/RP+FN%: Specificity = RN×100/RN+FP%: Accuracy = (RP+RN)×100/(RP+FP+RN+FN)%: Where, RP, right positive; FN, false negative; RN, right negative; and FP, false positive.

Figure 30 Algorithm for sonographic adrenal tumors and the use of ultrasound-guided fine-needle aspiration (UFNA) (taken from Froehlich et al. with permission) (72, 98)

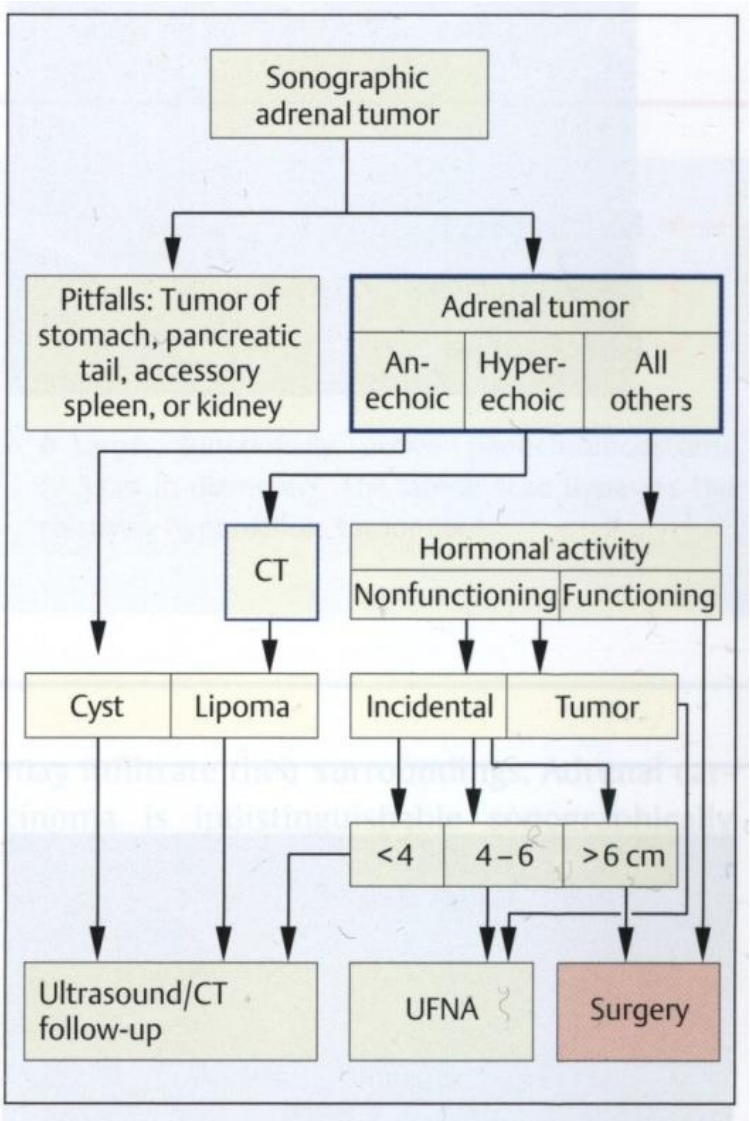
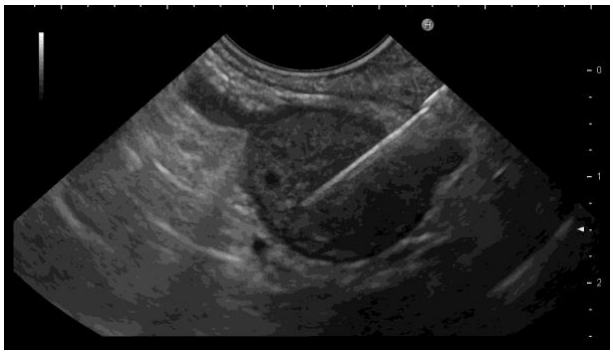


Figure 31: EUS-guided FNA of a 15 mm mass lesion of the left adrenal gland in a patient with suspected lung cancer

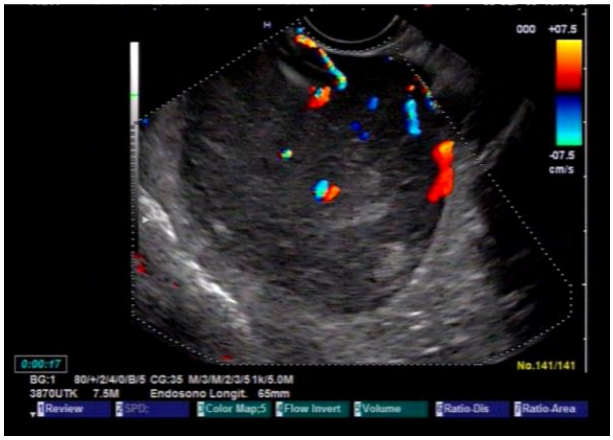


Special ultrasound techniques in differentiation of adrenal gland tumors

Colour Doppler imaging

Cysts do not show colour Doppler signals; only border areas are highlighted, this also applies to haematoma or abscesses. Metastasis, lymphoma and endocrine tumors (e.g. PCC) are often hypervascularised [Figure 32].

Figure 32 EUS image of a pheochromocytoma showing a lot of intratumoral vessels with colour Doppler imaging.



Contrast -enhanced ultrasound

With help of CEUS cysts, abscesses and haematoma are identified as avascular lesions. Lipoma and myelolipoma usually do not show a wash-out effect [Figure 33]. Variable contrast -enhancement patterns are observed in malignant adrenal tumors, both wash-out and persistent contrast enhancement may be observed in the late phase [Figure 34]. A late phase wash-out is also observed in benign adenoma. Even after numerous studies it is not possible to distinguish exactly between benign (adenoma) and malignant tumors (metastasis) without histology or cytology.

Laparascopic ultrasound

Laparoscopic ultrasound is used for better orientation in the surgical area during laparoscopic surgery; most adrenal gland surgery is performed by laparoscopic access (99-107).

Figure 33 On contrast -enhanced ultrasound a myelolipoma shows a nearly constant contrast enhancement without wash-out.

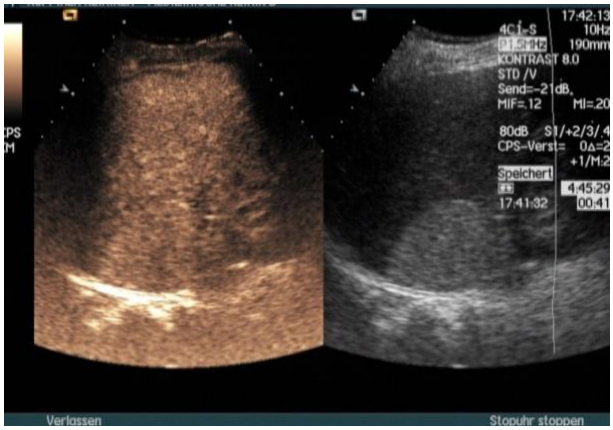
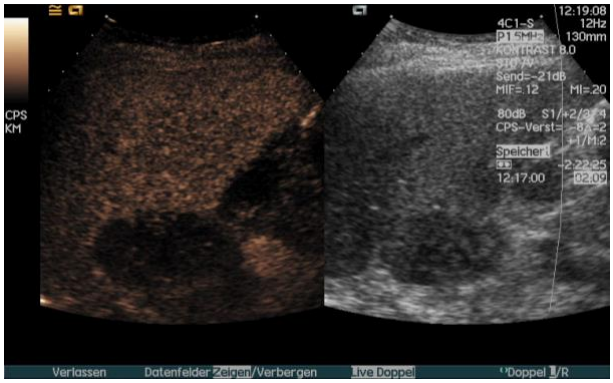


Figure 34 Late phase wash-out of an adrenal metastasis in a lung cancer patient.



The clinical importance of adrenal gland ultrasound in daily clinical practice

Sonography of the adrenal glands:

- is able to show the normal adrenal glands (right adrenal more often than left adrenal);
- is very sensitive for the detection of enlarged adrenal glands and, especially, adrenal gland tumors;
- therefore often detects adrenal mass lesions incidentally;
- is sufficient in differentiation between cystic adrenal gland lesions and solid tumors;
- despite colour Doppler and contrast-enhanced techniques is limited in differentiation of solid tumors;
- should be used in patients with malignant disease (staging, sampling) and with endocrine disease;
- is very useful in guidance for FNAB (ultrasound and endoscopic ultrasound-guidance);
- is very helpful in the follow-up of enlarged adrenal gland.

EUS is the best imaging method for the examination and sampling of the left adrenal gland.

Indication for examination:

Ultrasonography of the adrenal region should be a standard part of abdominal ultrasonography because a large number of pathological changes do not show any

symptoms and early detection (especially of adrenal tumors) allows a better chance of treatment.

The number of patients with a so-called incidentaloma of the adrenal gland rises with increasing number of sonographic examinations. Most of these lesions are benign and watchful waiting (using ultrasound examinations) in collaboration with endocrinologists is usually sufficient.

Table 3 Sonographic features of adrenal diseases with or without endocrine symptoms (taken from Allolio with permission) (55).

Diseases with endocrine symptoms	Sonographic appearance
Addison's disease	Adrenal atrophy is detectable with ultrasound; possible calcifications are evidence of prior tuberculosis.
Conn's disease	Unilateral adenomas usually ≤ 2 cm and not detectable on ultrasound.
Cushing's syndrome	In 80 % of cases, bilateral hyperplasia owing to pituitary (75 %) or paraneoplastic (5 %) ACTH overproduction; hyperplasia is usually not detectable with ultrasound.
Pheochromocytoma	Can be localised with ultrasound in 80–90 % of cases; extra-adrenal location is difficult and usually prevents identification.
Diseases without endocrine symptoms	
Adrenal adenoma	Most common solid mass.
Adrenal carcinoma	Often quite large (several centimetres) despite absence of symptoms; sometimes detected incidentally on ultrasound.
Adrenal metastases	Common with bronchial carcinoma, malignant lymphoma, breast cancer, renal cancer, pancreatic

	cancer and melanoma.
Adrenal tumours and cysts	Detectable at 1–1.5 cm on the right side and at 1.5–2 cm on the left side

ACTH, adrenocorticotropic hormone

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