Hormonal abnormalities related to the adrenal gland include hypercortisolism (Cushing’s syndrome) and hyperaldosteronism (Conn’s syndrome). Hypercortisolism is adrenocorticotropic hormone (ACTH)–dependent in 80–85% of cases: of pituitary origin or in Cushing’s disease in 80–85%, due to an ectopic ACTH-secreting tumor in 10–15% [2, 4]; ACTH-independent Cushing’s syndrome is due to either adrenal adenoma or carcinoma in most cases [4]. The adrenal enlargement is most commonly diffuse (Figs. 1 and 2) but can be nodular or mixed. In patients with ACTH-dependent hyperplasia, Sohaib et al. [2] showed that ectopic tumor ACTH produced adrenal hyperplasia in a higher percentage of cases (90%) than pituitary ACTH hypersecretion. In those patients with hyperplasia due to ectopic ACTH production, the adrenal gland morphology was lobular in 40% and either smooth or nodular in 30% each. In the setting of pituitary-induced hyperplasia, 62% of adrenals were enlarged, most commonly smooth (55%), followed by lobular (28%) or nodular (17%) [2].

In the setting of hyperaldosteronism (Conn’s syndrome), the absence of an adenoma traditionally suggested adrenal hyperplasia as the cause. With improved CT resolution, gland measurements have proven useful. Lingam et al. [5] revealed that the medial and lateral limbs were significantly larger in hyperplasia. A cutoff of 5 mm was 47% sensitive and 100% specific; using a 3-mm cutoff, sensitivity was 100% and specificity, 54%. In comparison, the absence of

OBJECTIVE. The adrenal gland can enlarge or alter morphology in the presence of a range of nonneoplastic entities, including hyperplasia, hemorrhage, infection, or cystic mass. This article presents a description and representative CT images for each of these disorders.

CONCLUSION. Proper characterization is essential to ensure that life-threatening sequelae from Addisonian crisis are averted in infection and hemorrhage, or to identify “leave-alone” lesions such as pseudocyst and chronic calcification.

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Adrenal Imaging with MDCT:
Nonneoplastic Disease

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In addition to neoplastic disease, a range of disorders can alter the size or morphology of the adrenal gland. These include hyperplasia, hemorrhage, infection, and cystic lesions. Although these abnormalities may not represent potential malignancy, identification is important nonetheless. Associated clinical manifestations that can be corrected are not insignificant (i.e., Cushing’s syndrome, Conn’s syndrome, refractory hypertension), secondary adrenal insufficiency can be life-threatening (i.e., hemorrhage), and findings may represent systemic infection (i.e., granulomatous disease). In this article, the CT appearance of adrenal hyperplasia, hemorrhage, granulomatous infection, calcification, and pseudocyst are shown in conjunction with discussion of important correlative clinical findings.

Hyperplasia

Vincent et al. [1] reported, in a study performed with 10-mm sections, that normal adrenal limbs should be ≤ 5 mm. Performing CT with both 10- and 3- to 5-mm sections, Sohaib et al. [2] showed that slightly, but significantly larger measurements were obtained using the thinner sections (mean limb width, ~ 15% greater). Normal adrenal shape varies, even in the same patient at different levels, according to Wilms et al. [3]. The right side can be linear, an inverted V (with or without asymmetric limbs), horizontally linear, or K-shaped. The left adrenal gland has been described as an inverted V, an inverted Y, triangular, or linear [2, 3].

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Hemorrhage

Potential causes of unilateral or bilateral hemorrhage [6–9] are listed in Table 1. Tumors that are known to hemorrhage include myelolipoma, hemangioma, pheochromocytoma, adenoma, adrenal cortical carcinoma, and metastases. Patients with antiphospholipid antibody syndrome (APLS) who develop adrenal hemorrhage (Fig. 3) usually have concomitant predisposing factors such as infection, anticoagulation, or a postoperative state. Prozenzale et al. [10] reported on a series of four primary antiphospholipid antibody syndrome patients who had adrenal hemorrhage diagnosed with CT. In three of the four, the hemorrhage was bilateral, and two presented with “abrupt onset of adrenal insufficiency.”

Trauma typically produces unilateral hemorrhage. In a study by Rana et al. [8] that included 54 adrenal hematomas, most were right-sided (Fig. 4), and adrenal hemorrhage was associated with injuries of higher severity. Right-sided hemorrhage was associated with liver, spleen, bilateral renal injuries, and pneumothorax; when hemorrhage involved the left adrenal, splenic, left kidney, and pneumothoracic injuries were the most common accompanying injuries. In this series of 51 patients, the hematomas appeared as a mass (2/3 ovoid, 1/3 round) with mean maximum diameter of 2.8 cm and mean attenuation of 52 ± 12 (SD) HU. Periadrenal stranding was identified in most cases (89%) [8]; Sinelnikov et al. [9] reported their findings in 73 traumatic adrenal injuries, 77% of which were right-sided. CT often revealed a focal hematoma (30%) or mass (11%), but injury was also reflected by an indistinct (27%) or enlarged (18%) gland. Most patients in this series also had periadrenal stranding. Both investigations noted that active contrast extravasation was an infrequent finding (1–6%) [8, 9].

Infection

Among infectious disorders, both tuberculosis (TB) and histoplasmosis can involve the adrenal gland [11–15]. In addition to the morbidity associated with these systemic infections, if most (> 90%) of the gland is destroyed, patients develop Addison’s disease [11, 14].

The appearance of the gland at CT depends on the chronicity of the infection and whether it has been treated. Most patients have bilateral gland enlargement, masslike in 50–65% and adeniform in 35–50% [11, 12, 14]. Unenhanced CT shows attenuation to be more commonly homogeneous, but one third are heterogeneous [14]. After contrast infusion, the classic appearance of peripheral enhancement with central necrosis is seen in 40–50% of cases; alternatively, the glands may enhance heterogeneously [11, 14]. Yang et al. [11] showed that peripheral enhancement with central necrosis is significantly more common in tuberculosis than tumor. Untreated, TB causes adrenal calcification in 40–60% of patients [11, 14]. Atrophy and calcification both develop after treatment [12, 13].

Calcification

Adrenal calcification may reflect granulomatous infection (Fig. 5), may evolve after previous hemorrhage (Fig. 6), or can be present in an adrenal mass (myelolipoma, adrenocortical carcinoma [ACC], pheochromocytoma, cyst) [11–14].

Cyst

The most common adrenal cyst is reportedly a pseudocyst (Figs. 7 and 8), believed to be the sequel of previous hemorrhage (or possibly infection). These can also arise secondary to bleeding within a tumor, for example as occurs with melanoma [7]. Wang et al. [16] correlated CT appearance with pathology in seven pseudocysts. Only 43% (3/7) were predominantly cystic, with mixed or solid lesions reflecting organized hematoma; the predominantly cystic lesions contained liquefied hemorrhage (86%). Pseudocysts may be unilocular (Figs. 6–8) or multilocular (Fig. 9); calcification—mural, septal, or central—was identified in 43%. In six of the 32 pseudocysts analyzed by Erickson et al. [17], associated tumors were identified, including pheochromocytoma, adenoma, and ACC.

Other adrenal cysts include endothelial cysts, and less commonly, epithelial and parasitic cysts (i.e., echinococcus) [18]. In a case series and literature review, Rozenblit et al. [19] reported that pseudocysts were more likely to be unilocular (81%) with calcification (74%); multicollarity and calcification were identified in 44% of endometrial cysts. Those authors also noted that the wall was generally imperceptible in benign cystic masses but measured 4 mm in a cystic pheochromocytoma and > 6 mm in a cystic ACC. Accordingly, although it may not be possible to definitively determine whether the underlying mass is benign or malignant, the presence of nodular wall thickening (Fig. 10) should prompt consideration of tumor. In addition, the cyst fluid density was higher in tumors (22–25 HU) than in benign nonhemorrhagic cysts (5–17 HU); two hemorrhagic cysts measured 67 and 75 HU [19].

Conclusion

With respect to adrenal imaging, the key role of CT is to distinguish “leave-alone” lesions from those requiring further evaluation or representing specific disease processes. Correct characterization of benign entities that do not require intervention (i.e., longstanding calcification or pseudocyst) is important to properly guide patient management. Identification of hyperplasia warrants additional clinical evaluation. In addition to these, nonneoplastic pathologic processes that can involve the adrenal glands range from harbinger of serious systemic disease, as in tuberculosis, to complications of underlying medical conditions, such as hemorrhage in the setting of coagulopathy. Because adrenal insufficiency is a potentially life-threatening sequela of bilateral infection or hemorrhage, findings must be recognized as such and promptly communicated.
References

A

Fig. 1—79-year-old woman with adrenocorticotropic hormone (ACTH)–dependent Cushing’s disease. A and B, Axial arterial (A) and venous phase (B) images show that limbs of adrenal glands (arrows) are enlarged bilaterally, but shape is adreniform, compatible with hyperplasia. Precise source of Cushing’s disease could not be localized and symptoms were not controlled by medication, necessitating adrenalectomy. Pathology revealed nodular expansion of adrenal cortices bilaterally.

B

Fig. 2—27-year-old woman with history of Cushing’s disease. A and B, Axial unenhanced CT image (A) and coronal contrast-enhanced multiplanar reformation (B) show bilateral adrenal enlargement (arrows) and mild asymmetry of lateral limbs (arrowheads, B).

Fig. 3—51-year-old man with antiphospholipid antibody syndrome and clinical concern for pulmonary embolism underwent contrast-enhanced CT (not shown), which revealed high-density right adrenal mass with mild periadrenal stranding. A and B, Repeated MDCT scan 12 hours later (A) for delayed phase characterization confirmed persistent high density (arrow, A). In conjunction with previous study from 7 days prior (B) showing no adrenal mass, findings are compatible with adrenal hemorrhage. Subsequent studies over 4 months confirmed progressive decrease in size.
Fig. 4—69-year-old man with history of lymphoma and motor vehicle accident 2 months earlier, who presented with right-sided flank pain.

A, Axial unenhanced CT scan shows 6.4-cm mildly heterogeneous mass (arrows) in right adrenal gland with some regions of high attenuation (47 HU), compatible with resolving hematoma. MRI confirmed presence of hemorrhage, and PET/CT from several weeks earlier (not shown) revealed no hypermetabolic activity below diaphragm.

B, Follow-up CT image 10 months later shows decrease in size and liquefaction (18 HU) of mass (arrows), consistent with interval resolution of hemorrhage.

Fig. 5—54-year-old man with pancreatic mass (not shown).

A and B, Axial (A) and coronal (B) volume-rendered images from contrast-enhanced CT show dense calcification of both adrenal glands (arrows), compatible with prior granulomatous disease.
Fig. 6—58-year-old woman with incidentally discovered adrenal mass. A–D, Unenhanced axial image (A), unenhanced coronal multiplanar reformation (B), delayed contrast-enhanced coronal volume-rendered image (C), and coronal volume-rendered image with parameters modified to show calcification (D) show nonenhancing, low-density right adrenal mass (arrows, A–C) with dense peripheral calcification, compatible with pseudocyst or old hematoma. Attenuation in center of lesion ranged from 23 HU on unenhanced, to 21 HU at 1 minute and 18 HU on delayed acquisition, reflecting lack of enhancement.
Fig. 7—55-year-old woman with abdominal pain. A and B, Coronal arterial (A) and delayed phase (B) volume-rendered images from IV contrast-enhanced MDCT show 4 × 3 cm cystic mass (arrows) with dense calcifications superiorly and inferiorly (arrowheads), most compatible with pseudocyst caused by old adrenal hematoma.

Fig. 8—55-year-old man with stable cystic mass in right adrenal gland. A–D, Axial unenhanced (A), axial contrast-enhanced (B), and contrast-enhanced coronal volume-rendered (C and D) images show cyst (arrows) with peripheral calcification. Fluid measured 13 HU. Findings are most compatible with pseudocyst caused by old hematoma.
Fig. 9—48-year-old woman with history of pancreatitis secondary to pancreas divisum and hypertriglyceridemia. A and B, Coronal (A) and sagittal (B) multiplanar reformations from contrast-enhanced CT show bilobed cyst (arrows) and mural calcification in region of adrenal gland. C, Varices in the gastric fundus (arrowheads) reflect splenic vein occlusion. Biopsy of suprarenal mass confirmed pseudocyst.

Fig. 10—47-year-old woman with abdominal pain and history of neurofibromas. A and B, Bilateral pheochromocytomas are present in adrenal glands, depicted on contrast-enhanced axial section (A) and coronal multiplanar reformation (B). Left-sided mass is predominantly cystic and right is solid with cystic components. Note thickened, irregular wall (arrowheads), a finding associated with neoplasms as opposed to pseudocyst.

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