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ADRENAL GLAND DISORDERS: PATHOPHYSIOLOGY, DIAGNOSIS, AND TREATMENT APPROACHES

Yakubbekova Mavluda Kozimjonovna,

Department of Hospital Therapy and Endocrinology

Abstract: Adrenal gland disorders encompass a wide range of clinical conditions, including adrenal insufficiency, Cushing's syndrome, congenital adrenal hyperplasia, and adrenal tumors. These conditions often present with diverse clinical manifestations, ranging from fatigue and hypotension to obesity, hypertension, and electrolyte imbalance. This article reviews the pathophysiology, clinical features, diagnostic methods, and treatment strategies of major adrenal disorders. Emphasis is placed on the importance of early recognition, timely treatment, and advances in imaging and molecular diagnostics that have improved patient care.

Keywords: adrenal gland, adrenal insufficiency, Cushing's syndrome, adrenal tumors, cortisol, endocrine disorders

Introduction

The adrenal glands are small but vital endocrine organs located on the superior poles of the kidneys. They are composed of two distinct regions: the adrenal cortex, which produces corticosteroids, mineralocorticoids, and androgens, and the adrenal medulla, which secretes catecholamines such as epinephrine and norepinephrine. Disorders of the adrenal glands can result in either hormone excess or deficiency, each of which produces significant systemic consequences.

Adrenal insufficiency (Addison's disease) is a potentially life-threatening condition characterized by cortisol and, in some cases, aldosterone deficiency. Conversely, hypercortisolism (Cushing's syndrome) leads to profound metabolic disturbances, obesity, and cardiovascular disease. Congenital adrenal hyperplasia represents a group of genetic disorders of cortisol synthesis, while adrenal tumors may be benign or malignant and can lead to hormone hypersecretion or mass effects. Advances in endocrinology, molecular biology, and imaging have significantly enhanced the detection and management of adrenal gland disorders.

Methods

This review is based on a literature analysis of studies published from 2014 to 2025 using PubMed, Scopus, and Web of Science. Keywords included "adrenal gland disorders," "Addison's disease," "Cushing's syndrome," and "adrenal tumors." Clinical practice guidelines from the Endocrine Society were reviewed to provide evidence-based management recommendations.

Results

Adrenal Insufficiency

Primary adrenal insufficiency (Addison's disease) is most often caused by autoimmune adrenalitis but may also result from infections such as tuberculosis. Clinical manifestations include chronic fatigue, weight loss, hyperpigmentation, hypotension, and electrolyte disturbances (hyponatremia, hyperkalemia). Diagnosis is confirmed with low serum cortisol and

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elevated adrenocorticotropic hormone (ACTH) levels, along with an inadequate response to the ACTH stimulation test. Treatment requires lifelong glucocorticoid and, in some cases, mineralocorticoid replacement.

Cushing's Syndrome

Cushing's syndrome results from prolonged exposure to high cortisol levels. Endogenous causes include ACTH-secreting pituitary adenomas (Cushing's disease), ectopic ACTH production, and adrenal tumors. Patients present with central obesity, moon face, striae, hypertension, and glucose intolerance. Diagnosis involves cortisol measurement via 24-hour urinary cortisol, late-night salivary cortisol, and dexamethasone suppression testing. Management strategies include surgical removal of pituitary or adrenal tumors, medical therapy (ketoconazole, metyrapone), and, in severe cases, bilateral adrenalectomy.

Adrenal Tumors

Adrenal tumors include benign adenomas, adrenocortical carcinoma, and pheochromocytomas. Functioning tumors may produce cortisol, aldosterone, or catecholamines. Pheochromocytomas present with paroxysmal hypertension, palpitations, and sweating. Diagnosis involves plasma metanephrine measurements and imaging modalities such as CT or MRI. Treatment typically involves surgical resection, preceded by medical management with alpha-adrenergic blockers in pheochromocytoma.

Congenital Adrenal Hyperplasia (CAH)

CAH is caused by enzymatic defects in cortisol biosynthesis, most commonly 21-hydroxylase deficiency. Clinical presentation varies from neonatal salt-wasting crises to ambiguous genitalia in females. Early diagnosis through newborn screening programs is crucial. Management involves lifelong glucocorticoid replacement and, when necessary, mineralocorticoid therapy.

Discussion

Adrenal gland disorders represent a diverse group of endocrine conditions with potentially severe health consequences. Advances in diagnostic endocrinology, including high-resolution imaging and molecular testing, have greatly improved diagnostic accuracy. Early diagnosis and effective treatment are critical for preventing long-term complications, particularly in conditions like adrenal insufficiency and Cushing's syndrome. Despite progress, challenges remain in timely recognition, especially in resource-limited regions where diagnostic facilities may be scarce.

Conclusion

Adrenal gland disorders significantly impact human health due to their systemic effects on metabolism, blood pressure, and stress response. Early detection, improved diagnostic methods, and individualized treatment strategies have enhanced patient outcomes. Ongoing research in molecular endocrinology and targeted therapies promises further improvements in the management of these complex disorders.

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