KEY FEATURES

After reading this chapter you will understand:

- The pathogenesis of hypertension.
- How to determine which hypertensive patients are amenable to surgical correction.

One of six Americans is hypertensive, but approximately half of those affected are unaware they have the disease. Hypertension is significantly more common among African-Americans, in whom hypertension begins at an earlier age, tends to be more severe, and more often progresses to end-organ disease than in other groups. This high incidence in African-Americans is of particular interest, because hypertension is relatively uncommon among Africans living in Africa. Surgeons are interested in hypertension because it is a significant risk factor when considering surgical treatment of diseases unrelated to hypertension and because it can be caused by surgically treatable lesions. Identifying patients whose conditions fall into the latter group is obviously important; unfortunately, this continues to be difficult to accomplish.

HOW DO HYPERTENSIVE PATIENTS PRESENT?

Hypertension does not produce a characteristic complex of symptoms, and many hypertensive patients are totally asymptomatic. A dull occipital headache is commonly described and, because it is often relieved by control of the hypertension, cause and effect are assumed. When the hypertensive process results in functional and structural changes in other organ systems, a variety of symptom complexes develop. The most common target organs affected by hypertension are the cardiovascular system, kidneys, and brain. Hypertension is a leading cause of stroke and massive intracranial bleeding.

PATHOPHYSIOLOGY OF HYPERTENSION

Arterial blood pressure is determined by the interrelationship among blood volume, cardiac output, peripheral vascular resistance, and blood viscosity. Blood pressure is controlled by a highly complex system (which has neural, chemical, and hormonal components), the mechanism of which is not completely understood. The four principal control systems are:

1. The arterial baroreflex. Impulses from pressure sensors in the carotid sinus, aorta, and left ventricle are relayed through neural pathways to the brainstem. The efferent arc also involves the sympathetic adrenergic nerves and vagal cholinergic nerves.

2. Regulation of fluid volume. This is a slowly responding system that results in loss of fluid with elevated blood pressure and retention of fluid when blood pressure falls.

3. Renin and angiotensin. The initiating enzyme renin, released from the kidney, splits angiotensin I from plasma globulin, which is then converted to angiotensin II. Angiotensin II also stimulates aldosterone secretion (Fig. 24-1).
4. **Vascular autoregulation.** In several organ systems, changes in perfusion pressure result in local changes in vascular resistance that tend to keep perfusion constant.

A schematic of the various feedback loops is shown in Fig. 24-2.

**DIAGNOSIS**

The diagnosis of hypertension is established by measuring blood pressure. In many patients the initial blood pressure reading, particularly if it is performed in a medical setting, will be elevated.

It is important to repeat the measurement several times, even over a period of several days, to determine the patient's average resting pressure. The clinical significance of hypertension increases with increased levels of blood pressure, but even moderate elevations are associated with decreased life expectancy. For this reason, determining the cause of the hypertension is important in all patients whose diastolic pressure consistently exceeds 90 mm Hg. Causes of hypertension are listed and illustrated in the box below and Fig. 24-3, respectively. Table 24-1 outlines

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![Renin-angiotensin cascade](image)


![Major feedback loops regulating blood pressure](image)

**FIG. 24-2** Major feedback loops regulating blood pressure. (From Haber E, Slater BE. High blood pressure. In Rubenstein E, Federman DI, eds. Scientific American Medicine, Section I, Subsection VII. New York: Scientific American Medicine, 1988.)
### TABLE 24-1 Guide for Workup of a Patient With Hypertension

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Initial</th>
<th>Additional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic renal disease</td>
<td>Urinalysis, BUN or creatinine,</td>
<td>Renin assay, renal biopsy, IVP</td>
</tr>
<tr>
<td></td>
<td>sonography</td>
<td></td>
</tr>
<tr>
<td>Renovascular disease</td>
<td>Bruit, isotopic renography and plasma</td>
<td>Aortogram, renal vein renins</td>
</tr>
<tr>
<td></td>
<td>renin before and 1 hr after 50 mg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>captopril</td>
<td></td>
</tr>
<tr>
<td>Coarctation</td>
<td>Blood pressure in legs</td>
<td>Aortogram</td>
</tr>
<tr>
<td>Primary aldosteronism</td>
<td>Plasma potassium; plasma renin/</td>
<td>Urinary potassium; plasma aldosterone</td>
</tr>
<tr>
<td></td>
<td>aldosterone ratio</td>
<td>after saline</td>
</tr>
<tr>
<td>Cushing’s syndrome</td>
<td>AM plasma cortisol after 1 mg</td>
<td>Urinary cortisol after variable doses of</td>
</tr>
<tr>
<td></td>
<td>dexamethasone at bedtime</td>
<td>dexamethasone</td>
</tr>
<tr>
<td>Pheochromocytoma</td>
<td>Urine test for metanephrine</td>
<td>Urinary VMA and catechols; plasma catechols,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>basal, and after 0.3 mg clonidine is administered</td>
</tr>
</tbody>
</table>


BUN = Blood urea nitrogen; VMA = vanillylmandelic acid.

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**FIG. 24-3** Causes of some forms of hypertension. Note that many of the causes can be treated by operation.

*Effectively treated by operative procedure.*
the initial and subsequent diagnostic procedures used to more accurately determine the cause of hypertension.

WHAT IS PRIMARY (ESSENTIAL) HYPERTENSION?
In approximately 95% of hypertensive patients, no specific cause for hypertension can be determined; these patients are considered to have primary hypertension. Patients with mild, untreated hypertension are probably not at increased risk at operation, but patients with diastolic pressures exceeding 100 mm Hg should be treated before undergoing elective operations. Because the management of primary hypertension involves long-term follow-up, patients should be referred to a primary care physician.

The treatment for essential hypertension is a combination of dietary salt restriction and administration of a variety of drugs. These are listed by type of action and drug name in the Surgical Pharmacopeia, pp. 458-459. The side effects of common drugs are also listed. Adequate control of hypertension by a single drug is frequently difficult; therefore combinations of agents are commonly employed. There is good evidence that control of hypertension significantly lowers the incidence of target organ damage. Many drugs used in the treatment of hypertension significantly alter the patient’s response to some anesthetic agents. Early consultation with an anesthesiologist is advisable before operating on patients who are hypertensive.

SURGICALLY CORRECTABLE FORMS OF HYPERTENSION
From 1% to 10% of hypertensive patients have a surgically correctable cause of the elevated blood pressure; this is a highly significant group of patients, and making a correct diagnosis is important, because most patients in this group will respond well to the proper treatment.

Coarctation of the Aorta
Congenital aortic coarctation is one of the most common causes of hypertension in children but may be encountered at any age. Patients with significant coarctation have diminished or absent femoral pulses. A combination of hypertension and diminished femoral pulses should instantly suggest the diagnosis. Additional findings that suggest increased collateral flow, such as rib notching seen on a chest radiograph or interscapular pulsations, corroborate the diagnosis. The mechanism by which coarctation of the aorta produces hypertension has been debated for years. Evidence suggests that both a mechanical factor (increased vascular resistance) and the renin-angiotensin mechanism are involved.

Patients suspected of having coarctation of the aorta should have the diagnosis confirmed by angiography and, when significant coarctation is present, it should be corrected surgically. It is clear that the earlier coarctation is surgically treated, the better the chance for blood pressure reduction. The likelihood of significant control of hypertension becomes so small over time that coarctation probably should not be routinely repaired in patients who are older than 50 years of age.

Renal Artery Stenosis
Several disease processes may produce extrarenal narrowing of the renal arteries of a sufficient degree to activate the renin-angiotensin pressor system. These lesions include arteriosclerosis, fibromuscular dysplasia, dissecting aneurysm of the aorta, and trauma. The clinical picture produced by all of these entities is hypertension, with or without its cardiac, pulmonary, cerebral, or renal manifestations. The stimulus for increased renin production in renal artery stenosis is probably damping of the pulse pressure in the renal artery distal to the stenotic lesion. Details of the renin-angiotensin I and angiotensin II systems will not be reviewed here; however, the renin-angiotensin cascade is demonstrated in Fig. 24-1.

Hypertension produced by renal artery stenosis has no clinically distinguishing features but, because it is highly amenable to surgical treatment, the diagnosis is very important. It is estimated that up to 8% of the hypertensive population have renal artery stenosis. Any patient with moderate to severe diastolic hypertension who would be considered for surgical correction if a renovascular lesion were present should have an intravenous pyelogram (IVP). The rapid-sequence excretory urogram is a relatively simple variation of the IVP that gives additional information. If renovascular hypertension is suggested by the preliminary screening, renal vein renin levels should be measured. In unilateral renal artery obstruction, the involved kidney produces excessive amounts of renin, which is detected in the renal vein assay. When the level of renin is 1.5 times or greater than that of the uninvolved side, a significant lesion is almost certainly present. Renal systemic renin indices (RSRI) may be elevated as follows:

\[
\text{Ind RSRI} = \boxed{\text{Re}}
\]

Arteriography demonstrating Surgical rev significant arte reduction of bl Aortorenal byp instances. Find patch angioplasty splenic artery r tions. Translusions is of great choice in many plasia. Unfortu mon when this sclerotic lesions

Unilateral Renal
Occasionally a tension, a contr findings indica tions. Historica ney has not resu sure in most pa served that the physiologically mined by split says, nephrectomy reduction.

Cushing’s Sync
The principal f are the “moon” striae, and hypo induced by excess cessive glucocorticogenic admin lesions, or nonac tation, principally.

The diagnosis begins with clini negative physical ch screening test is creation of 17-hyd cortisol level car urinary 17-hydrox elevated in Cusl of ACTH levels some suppression ing pituitary dis
(RSRI) may be of additional help. This is calculated as follows:

\[
\text{RSRI} = \frac{\text{Individual renal renin activity} - \text{Systemic renin activity}}{\text{Systemic renin activity}}
\]

Arteriography is the most accurate method of demonstrating renal artery stenosis.

Surgical revascularization of a kidney with significant arterial lesions results in significant reduction of blood pressure in 90% of patients. Aortorenal bypass grafting is employed in most instances. Endarterectomy, with or without patch angioplasty, or reconstruction using the splenic artery may be preferable in some situations. Transluminal dilation of renal artery lesions is of great interest and is the treatment of choice in many patients with fibromuscular dysplasia. Unfortunately, rapid restenosis is common when this technique is used for arteriosclerotic lesions of the renal arteries.

**Unilateral Renal Parenchymal Disease**

Occasionally a patient is found to have hypertension, a contracted kidney, and arteriographic findings indicating no extrarenal stenotic lesions. Historically, removal of the involved kidney has not resulted in reduction of blood pressure in most patients. Recently it has been observed that when the atrophic kidney behaves physiologically like an ischemic kidney, as determined by split renal function or renin vein assays, nephrectomy will result in blood pressure reduction.

**Cushing's Syndrome**

The principal features of Cushing's syndrome are the "moon" face, central obesity, cutaneous striae, and hypertension. The syndrome is produced by excess circulating glucocorticoids. Excessive glucocorticoid levels may result from iatrogenic administration, pituitary or adrenal lesions, or nonadrenal sources of ACTH production, principally malignant neoplasms.

The diagnosis of Cushing's syndrome usually begins with clinical observation of the distinctive physical changes. The most widely used screening test is measurement of the urinary excretion of 17-hydroxy steroids. The plasma cortisol level can be determined, and, like the urinary 17-hydroxy steroids, it is usually elevated in Cushing's syndrome. Measurement of ACTH levels and its response to dexamethasone suppression may be helpful in differentiating pituitary disease from adrenal disease. Cranial and abdominal CT scans and/or magnetic resonance imaging are currently the most accurate methods of demonstrating the lesions anatomically.

The most satisfactory treatment of Cushing's syndrome is surgical removal of the lesion responsible for the syndrome. This is more completely discussed in Chapter 12.

**Hyperaldosteronism**

Hyperaldosteronism is a condition that occurs much less commonly than was once thought. It is caused by hypersecretion of aldosterone, a mineralocorticoid, by an adrenal adenoma or adrenal hyperplasia. Hypertension is present but is usually not severe in adults. The diagnosis is suspected when persistent hypernatremia, hypokalemia, and metabolic alkalosis are detected in hypertensive patients who are not receiving diuretic therapy. Plasma renin activity is usually low and urinary aldosterone levels are elevated. Treatment is discussed in Chapter 12.

**Pheochromocytoma**

Pheochromocytoma is a rare neoplasm arising in the adrenal medulla and producing norepinephrine and/or epinephrine. The tumor may be unilateral or bilateral, benign or malignant. Patients with pheochromocytomas have episodic or sustained hypertension. Determinations of urinary catecholamines and vanillylmandelic acid (VMA) levels are probably the best screening tests for pheochromocytoma. Confirming tests include measurement of plasma epinephrine and norepinephrine levels. When biochemical evidence for pheochromocytoma exists, it becomes important to localize the responsible neoplasm. CT scan of the abdomen appears to be the most valuable diagnostic tool for locating adrenal lesions as well as other retroperitoneal mass lesions; it has superseded conventional tomography, arteriography, and retroperitoneal gas insufflation.

Operations on patients with unsuspected pheochromocytoma can be disastrous because anesthesia and operative manipulation of the tumor may result in uncontrollable hypertension or hypotension. The use of alpha-adrenergic and beta-adrenergic blocking agents for preoperative preparation of patients with pheochromocytoma has decreased the surgical risk for such patients. The conduct of anesthesia is also extremely important. The surgical treatment of pheochromocytoma is discussed in Chapter 12.
PITFALLS AND PEARLS

Pitfalls
- Significant fluctuation in blood pressure during induction of anesthesia may be caused by an unanticipated alpha blocker and constricting splanchnic vascular beds.

- The procedure is extremely hazardous to the hypertensive patient.

- Do not allow a hypertensive on the basis of a single blood pressure determination.

PEARLS
- Accurately identify and record all hyperensive medications and dosages in every patient who may be given anesthetic agents.

- Palpate femoral pulse in every patient found to be hypertensive.

SURGICAL PHARMACOPEIA

<table>
<thead>
<tr>
<th>Drug (Trade Name)</th>
<th>Indication/Complications</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Treatment of Chronic Hypertension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diuretics 1. Hydrochlorothiazide (HCTZ) (Hydrodiuril, Esidrix, Oretic)</td>
<td>May require potassium supplementation</td>
<td>12.5-50 mg/day</td>
</tr>
<tr>
<td>2. Potassium-sparing diuretics Spironolactone (Aldactone) Triamterene plus HCTZ (Dyazide)</td>
<td>Used alone in hyperaldosteronism</td>
<td>50-100 mg/day</td>
</tr>
<tr>
<td>3. Electrolyte supplements</td>
<td>Relatively contraindicated in the setting of renal insufficiency</td>
<td>50/25 mg/day</td>
</tr>
<tr>
<td>Sympatholytic Agents 1. Centrally acting alpha-adrenergic agents Methyl dopa (Aldomet) Clonidine (Catapres)</td>
<td>Rarely: anemia, liver dysfunction, and mental depression Sedation, dry mouth, drug interactions; rebound hypertension on discontinuation</td>
<td>250-2000 mg/day 0.2-0.8 mg/day</td>
</tr>
<tr>
<td>2. Beta-adrenergic-blocking agents Propranolol (Inderal) Metoprolol (Lopressor) Atenolol (Tenormin)</td>
<td>Contraindicated in setting of AV conduction delay; may accelerate cardiac failure or cause bronchospasm Same; less risk of bronchospasm Same; less risk of bronchospasm Oral and intravenous forms available; may cause nausea and diarrhea; also has alpha block activity</td>
<td>40-640 mg/day 50-100 mg bid 50-100 mg/day 200-1200 mg/day PO 40-80 mg q5-10min IV prn</td>
</tr>
<tr>
<td>3. Alpha-adrenergic-blocking agents Prazosin (Minipress) Terazosin (Hytrin)</td>
<td>Syncope, particularly with the initial dose; alcohol intolerance Also used for symptoms of BPH</td>
<td>2-20 mg/day (divided dose) 1-20 mg/day</td>
</tr>
<tr>
<td>Direct Vasodilators Hydralazine (Apresoline)</td>
<td>May precipitate angina or lead to retention of fluid; occasionally implicated in concomitant rheumatoid syndrome</td>
<td>20-300 mg/day</td>
</tr>
</tbody>
</table>

Angiotensin-Converting Enzyme (ACE) Inhibitors Captopril (Capoten) Enalapril, Enalaprilat, Lisinopril, Quinapril, Ramipril | Rash; may cause decreased renal function and hyperkalemia in renal-insufficient patients | 50-150 mg/day (divided dose) |

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- Drug Facts for Compariso Ernst CB, Boc ratios and tension. Ar Fletcher AE, sure be low.
- Francis CK. H norities. Ar Haber E, Slate stein E, Fe Medicine, 1988.
Surgical Pharmacopeia—cont'd

<table>
<thead>
<tr>
<th>Drug (Trade Name)</th>
<th>Indication/Complications</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calcium Channel-Blocking Agents</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nifedipine (Procardia, Adalat)</td>
<td>Sublingual dosage quickly lowers blood pressure; contraindicated in patients with aortic stenosis and heart failure or AV conduction delay</td>
<td>30-120 mg/day</td>
</tr>
<tr>
<td>Verapamil (Calan, Isoptin)</td>
<td>Same; no sublingual form; may cause constipation</td>
<td>240-480 mg/day</td>
</tr>
<tr>
<td>Diltiazem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nicardipine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**For Control of Acute Hypertension**

<table>
<thead>
<tr>
<th>Drug</th>
<th>Indication/Complications</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitroprusside (Nipride, Nitropress)</td>
<td>Most rapidly acting and consistently effective agent for treating hypertensive emergencies; may cause rebound tachycardia, nausea, emesis, or headache</td>
<td>0.5 to 10 μg/kg/min drip or continuous infusion</td>
</tr>
<tr>
<td>Nitroglycerine (Nitro-bid, Nitrostat, Tridil)</td>
<td>Useful in controlling hypertension in the patient with known coronary artery disease</td>
<td>5 to 200 μg/min drip</td>
</tr>
<tr>
<td>Labetalol (Normodyne, Trandate)</td>
<td>Oral and intravenous forms available, thus useful for converting a patient from a controlled hypertensive crisis to oral therapy; may cause nausea and diarrhea</td>
<td>20 mg IV slowly; may repeat up to 80 mg IV q10min or 2 mg/min continuous or drip infusion</td>
</tr>
<tr>
<td>Hydralazine (Apresoline)</td>
<td>May precipitate angina or fluid retention</td>
<td>20-300 mg/day PO</td>
</tr>
</tbody>
</table>

BIBLIOGRAPHY


CHAPTER REVIEW

Questions

1. Physical findings are suggestive of which types of surgically treatable hypertension?
2. Persistent hypokalemia in a patient with hypertension suggests what condition?
3. What pathologic lesions are responsible for most instances of renovascular hypertension?
4. How are patients with pheochromocytoma pharmacologically prepared for operation?
5. List the lesions responsible for development of Cushing's syndrome.
6. What levels of hypertension should be controlled by medication before operation?
7. Why is surgical correction of coarctation of the aorta not routinely advised after the age of 50?
8. When is the measurement of plasma renin levels of clinical significance?
9. What organ systems are commonly affected by severe hypertension?
Answers
1. Coarctation, Cushing's disease
2. Hyperaldosteronism
3. Atherosclerosis, fibromuscular hyperplasia
5. Excessive intake of exogenous corticosteroids, pituitary adenoma, adrenal adenoma, adrenal hyperplasia
6. A sustained diastolic pressure of 100 or above
7. The likelihood of relief of hypertension is much diminished in patients older than 50 years of age.
8. Principally in the determination of significant renal artery stenosis
9. Cardiovascular, kidney, and central nervous system