Hypertension in Children and Adolescents

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The development of a national database on normative blood pressure levels throughout childhood has contributed to the recognition of elevated blood pressure in children and adolescents. The epidemic of childhood obesity, the risk of developing left ventricular hypertrophy, and evidence of the early development of atherosclerosis in children would make the detection of and intervention in childhood hypertension important to reduce long-term health risks; however, supporting data are lacking. Secondary hypertension is more common in preadolescent children, with most cases caused by renal disease. Primary or essential hypertension is more common in adolescents and has multiple risk factors, including obesity and a family history of hypertension. Evaluation involves a thorough history and physical examination, laboratory tests, and specialized studies. Management is multifaceted. Nonpharmacologic treatments include weight reduction, exercise, and dietary modifications. Recommendations for pharmacologic treatment are based on symptomatic hypertension, evidence of end-organ damage, stage 2 hypertension, stage 1 hypertension unresponsive to lifestyle modifications, and hypertension with diabetes mellitus. (Am Fam Physician 2006;73:1158-68. Copyright © 2006 American Academy of Family Physicians.)

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The prevalence and rate of diagnosis of hypertension in children and adolescents appear to be increasing.[1] This is due in part to the increasing prevalence of childhood obesity as well as growing awareness of this disease. There is evidence that childhood hypertension can lead to adult hypertension.[2] Hypertension is a known risk factor for coronary artery disease (CAD) in adults, and the presence of childhood hypertension may contribute to the early development of CAD. Reports show that early development of atherosclerosis does exist in children and young adults and may be associated with childhood hypertension.[3]

Left ventricular hypertrophy (LVH) is the most prominent clinical evidence of end-organ damage in childhood hypertension. Data show that LVH can be seen in as many as 41 percent of patients with childhood hypertension.[4-6] Patients with severe cases of childhood hypertension are also at increased risk of developing hypertensive encephalopathy, seizures, cerebrovascular accidents, and congestive heart failure. Based on these observations, early detection of and intervention in children with hypertension are potentially beneficial in preventing long-term complications of hypertension.

Data associating childhood hypertension with cardiovascular risk in adulthood are lacking. An update of recommendations for diagnosis, evaluation, and treatment of childhood hypertension is provided in the fourth report by the National High Blood Pressure Education Program (NHBPEP) Working Group on High Blood Pressure in Children and Adolescents.[7]

Epidemiology

Because body size is an essential determinant of blood pressure in children, it is necessary to include the child's height percentile to determine if blood pressure is normal. The revised childhood blood pressure tables include 50th, 90th, 95th, and 99th percentiles by sex, age, and height based on the 1999-2000 National Health and Nutrition Examination Survey data *(Appendices 1 and 2)*[7].

Table 1[7] shows the classifications of hypertension for children one year of age or older

SORT: KEY RECOMMENDATIONS FOR PRACTICE

Clinical recommendation	*Evidence rating*	*References*
Blood pressure should be checked routinely at every visit in children three years of age and older.	C	7
Three separate readings of an elevated blood pressure (greater than 90th percentile for age, height, and sex) on separate visits are needed to make the diagnosis of hypertension.	C	7
Patients diagnosed with primary hypertension should have a comprehensive assessment for cardiovascular risk factors (lipid profile, fasting glucose, body mass index).	C	7
Nonpharmacologic treatment (e.g., weight loss, dietary modifications, exercise) should be first-line therapy in patients with stage 1 hypertension.	C	7
Pharmacologic treatment should be initiated in patients with stage 2 hypertension, symptomatic hypertension, when end-organ damage is present (left ventricular hypertrophy, retinopathy, proteinuria); and in stage 1 hypertension when blood pressure is unresponsive to lifestyle changes.	C	7

A = consistent, good-quality patient-oriented evidence; B = inconsistent or limited-quality patient-oriented evidence; C = consensus, disease-oriented evidence, usual practice, expert opinion, or case series. For information about the SORT evidence rating system, see page 1495 or http://www.aafp.org/afpsort.xml.

and adolescents and the corresponding systolic and diastolic blood pressures. Blood pressure should be measured on three or more separate occasions before characterizing the type of hypertension.

Reports have shown an association between blood pressure and body mass index (BMI),[8,9] suggesting that obesity is a strong risk factor for developing childhood hypertension. There are insufficient data that define the role of race and ethnicity in childhood hypertension, although results of several studies[10-13] show black children having higher blood pressure than white children. Heritability of childhood hypertension is estimated at 50 percent.[14] One report[15] noted that 49 percent of patients with primary childhood hypertension had a relative with primary hypertension, and that 46 percent of patients with secondary childhood hypertension had a relative with secondary hypertension. Another report[16] showed that in adolescents with primary hypertension there is an overall 86 percent positive family history of hypertension. There is evidence that shows breastfeeding in infancy may be associated with a lower blood pressure in childhood.[17-19]

TABLE 1
Classifications of Hypertension in Children One Year of Age and Older and Adolescents

Normal blood pressure	SBP and DBP less than the 90th percentile
Prehypertension	SBP or DBP greater than or equal to 90th percentile but less than 95th percentile Blood pressure levels greater than or equal to 120/80 mm Hg for adolescents
Hypertension	SBP or DBP greater than or equal to 95th percentile
Stage 1 hypertension	SBP or DBP from 95th percentile to 99th percentile plus 5 mm Hg
Stage 2 hypertension	SBP or DBP greater than 99th percentile plus 5 mm Hg

NOTE: *Percentiles are for sex, age, and height for blood pressure measured on at least three separate occasions; if systolic and diastolic percentiles are different, categorize by the higher value.*

SBP = systolic blood pressure; DBP = diastolic blood pressure.

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Blood Pressure Measurement

According to the NHBPEP recommendations, children three years of age or older should have their blood pressure measured when seen at a medical facility[7]; however, according to the U.S. Preventive Service Task Force (USPSTF), there is insufficient evidence to recommend for or against routine screening for childhood hypertension to reduce the risk of CAD.[20]

The preferred method for blood pressure measurement is auscultation. Aneroid manometers are used to measure blood pressure in children and are accurate when calibrated on a semiannual basis.[21]

Correct measurement of blood pressure in children requires use of a cuff that is appropriate to the size of the child's upper right arm. This is the preferred arm because of the possibility of decreased pressures in the left arm caused by

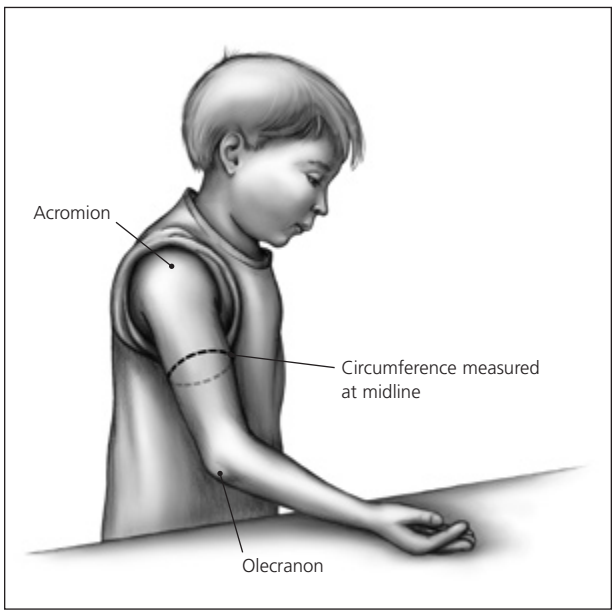

ILLUSTRATION BY RENEE CANNON

Figure 1. Arm circumference should be measured midway between the olecranon and acromial process.

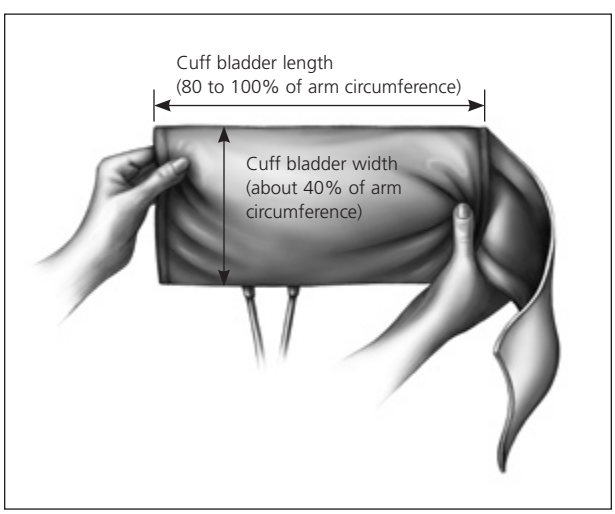

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Figure 2. Blood pressure cuff showing size estimation based on arm circumference.

coarctation of the aorta. By convention, an appropriate cuff size is one with an inflatable bladder width that is at least 40 percent of the arm circumference at a point midway between the olecranon and the acromion *(Figure 1)*. The cuff bladder length should cover 80 to 100 percent of the circumference of the arm[7] *(Figure 2)*. An oversized cuff can underestimate the blood pressure, whereas an undersized cuff can overestimate the measurement. Blood pressure should be measured in a controlled environment after five minutes of rest in the seated position with the right arm supported at heart level. If the blood pressure is greater than the 90th percentile, the blood pressure should be repeated twice at the same office visit to test the validity of the reading.

Ambulatory blood pressure monitoring (ABPM) requires a patient to wear a portable monitor that records blood pressure over a specified period. This allows measurements outside of the medical setting, where some patients may experience elevated blood pressure caused by anxiety ("white-coat hypertension"). Other uses for ABPM include episodic hypertension, autonomic dysfunction, and chronic kidney disease. ABPM also may have a role in differentiating primary from secondary hypertension and in identifying patients likely to have hypertension-induced end-organ damage.[22] The USPSTF maintains that ABPM is subject to many of the same errors seen in the physician's office.[20]

Etiologies

Most childhood hypertension, particularly in preadolescents, is secondary to an underlying disorder *(Table 2[7])*. Renal parenchymal disease is the most common (60 to 70 percent) cause of hypertension.[23] Adolescents usually have primary or essential hypertension, making up 85 to 95 percent of cases.[23] *Table 3*[23-25] shows causes of childhood hypertension according to age.

Essential hypertension rarely is found in children younger than 10 years and is a diagnosis of exclusion. Significant risk factors for essential hypertension include family history and increasing BMI. Some sleep disorders and black race can be potential risk factors for essential hypertension. Essential hypertension often is linked to other risk factors that make up metabolic syndrome and can lead to cardiovascular disease. These risk factors for metabolic syndrome include low plasma high-density lipoprotein, elevated plasma triglycerides, abdominal obesity, and insulin resistance/hyperinsulinemia. The prevalence of metabolic syndrome among adolescents is between 4.2 and 8.4 percent.[26]

Secondary hypertension is more common in children than in adults. It can present in adolescents, especially if they have physical findings not typically seen with essential hypertension. Renal disease is the most common cause of secondary hypertension in children.[23-25] Other causes include endocrine disease (e.g., pheochromocytoma, hyperthyroidism) and pharmaceuticals (e.g., oral contraceptives, sympathomimetics, some over-the-counter preparations, dietary supplements). Transient rise in blood pressure, which can be mistaken for hypertension, is seen with caffeine use and certain psychological disorders (e.g., anxiety, stress).

TABLE 2
Physical Findings Indicative of a Secondary Cause for Childhood Hypertension

Physical examination finding	*Possible etiologies*
Abdominal bruit	Renal artery stenosis
Abdominal mass	Polycystic kidney disease; hydronephrosis/obstructive renal lesions; neuroblastoma; Wilms' tumor
Acne	Cushing's syndrome
Adenotonsillar hypertrophy	Sleep disorder associated with hypertension
Decreased perfusion of lower extremities	Coarctation of the aorta
Diaphoresis	Pheochromocytoma
Flushing	Pheochromocytoma
Growth retardation	Chronic renal failure
Hirsutism	Cushing's syndrome
Joint swelling	Systemic lupus erythematosus
Malar rash	Systemic lupus erythematosus
Moon facies	Cushing's syndrome
Murmur	Coarctation of the aorta
Muscle weakness	Hyperaldosteronism
Obesity (general)	Association with primary hypertension
Obesity (of the face, neck, or trunk)	Cushing's syndrome
Tachycardia	Hyperthyroidism; pheochromocytoma; neuroblastoma
Thyromegaly	Hyperthyroidism

Adapted with permission from National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics 2004; 114(2 suppl 4th report):564.

TABLE 3
Causes of Childhood Hypertension According to Age Group

Age	*Causes*
One to six years	Renal parenchymal disease; renal vascular disease; endocrine causes; coarctation of the aorta; essential hypertension
Six to 12 years	Renal parenchymal disease; essential hypertension; renal vascular disease; endocrine causes; coarctation of the aorta; iatrogenic illness
12 to 18 years	Essential hypertension; iatrogenic illness; renal parenchymal disease; renal vascular disease; endocrine causes; coarctation of the aorta

NOTE: Causes listed in order of prevalence.

Information from references 23 through 25.

Evaluation

Once hypertension has been confirmed, an extensive history and careful physical examination should be conducted to identify underlying causes of the elevated blood pressure and to detect any end-organ damage. With the appropriate information, unnecessary and often expensive laboratory and imaging studies can be avoided. The NHBPEP has developed an algorithm to help the physician navigate the diagnostic and management choices in childhood hypertension *(Figure 3)*.[7]

HISTORY AND PHYSICAL EXAMINATION

As mentioned previously, the child with primary hypertension often has a positive family history of hypertension or cardiovascular disease. Other risk factors including metabolic syndrome and sleep-disordered breathing (from snoring to obstructive sleep apnea) also are associated with primary hypertension. A careful history will uncover these important elements. It is helpful to remember that secondary hypertension is more likely in a younger child with stage 2 hypertension, thus data about systemic conditions associated with elevated blood pressure should be elicited. Because most secondary hypertension is renovascular in origin, a focused review of that system may provide insight into the possible etiology. *Table 4*[7] is a summary of information in a patient's history that can help determine the causes of childhood hypertension. A medication history should include any use of over-the-counter, prescription, and illicit drugs because many medications and drugs can elevate blood pressure. The physician should also ask about the use of performance-enhancing substances, herbal supplements (e.g., ma huang), and tobacco use.

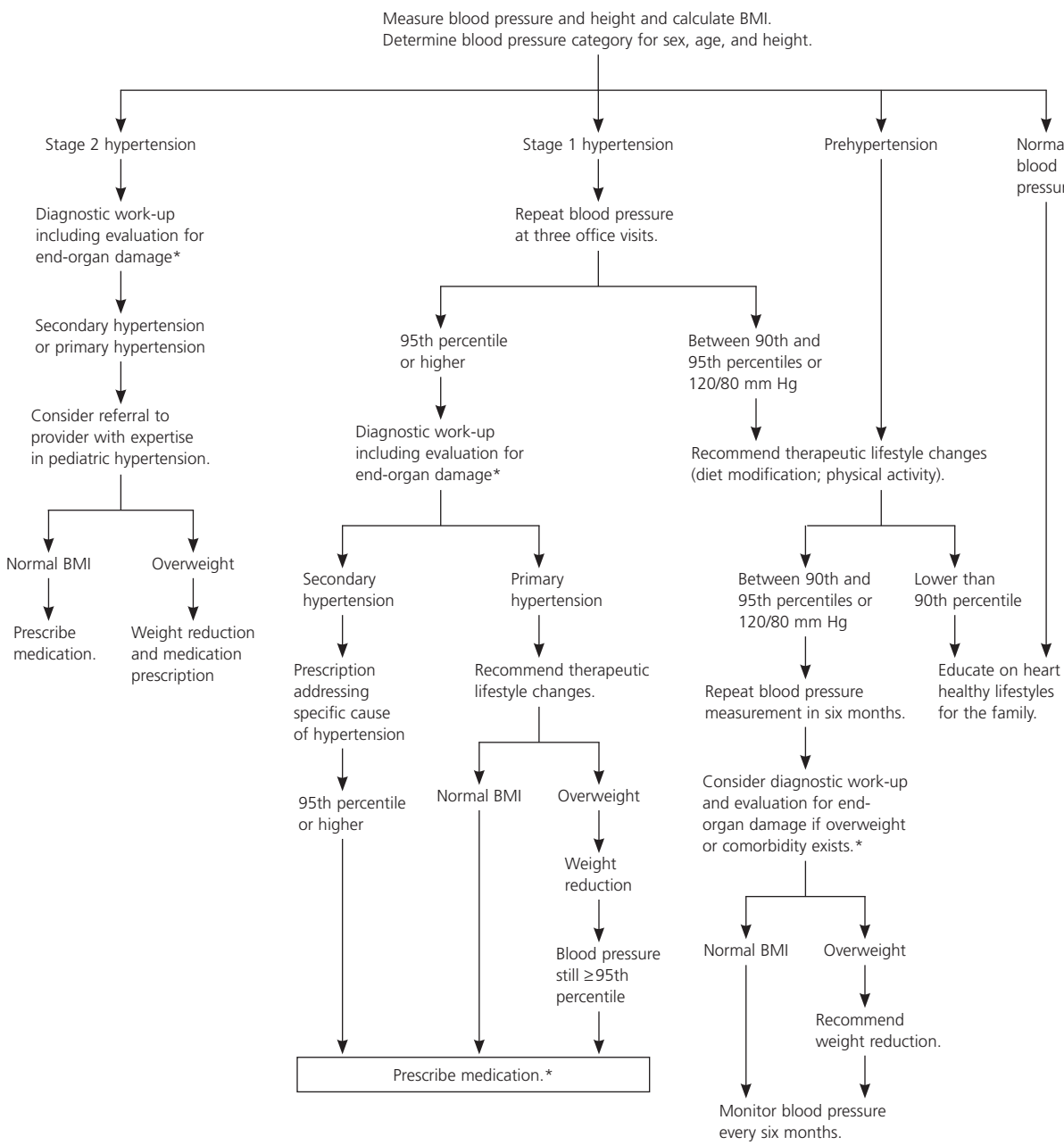
Renal disease is the most common cause of secondary hypertension in children.

Physical examination should include calculation of BMI because of the strong association between obesity and hypertension. Obtaining blood pressure readings in the upper and lower extremities to rule out coarctation of the aorta also is recommended. Examination of the retina should be included to assess the effect of hypertension on an easily accessed end organ. In the majority of children with hypertension, however, the physical examination will be normal.

LABORATORY AND IMAGING TESTS

Laboratory testing and imaging on a child with hypertension should screen for identifiable causes, detect comorbid conditions, and evaluate end-organ damage

Management of Childhood Hypertension



—Especially if patient is younger; has very high blood pressure; has little or no family history of high blood pressure; has diabetes or other risk factors.

Figure 3. Algorithm for the management of childhood hypertension. (BMI = body mass index.)

Adapted with permission from National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics 2004;114(2 suppl 4th report):571.

(Table 5[7]). Screening tests should be performed on all children with a confirmed diagnosis of hypertension. Decisions about additional testing are based on individual and family histories, the presence of risk factors, and the results of the screening tests. Young children, those with stage 2 hypertension, and those in whom a systemic condition is suspected require a more extensive evaluation because these children are more likely to have secondary hypertension. The child who is older or obese, with a family history of diabetes or other cardiovascular risk factors, will require further work-up for the metabolic abnormalities associated with primary hypertension.[7]

Hormone levels and 24-hour urine studies are readily available to most physicians, but more specialized tests such as renal angiography often require referral to a center with pediatric radiology, nephrology, and cardiology services. When renovascular disease is strongly suspected, conventional or intra-arterial digitally subtracted angiography are recommended. Scintography with or without angiotensin-converting enzyme (ACE) inhibition also can be used. These older imaging techniques are quite invasive. Data on newer studies such as magnetic resonance angiography and 3-dimensional or spiral computed tomography in children are limited, but documentation of their usefulness is increasing.[7]

In addition to the diagnostic tests already mentioned, an assessment of end-organ damage must be made. Retinopathy, microalbuminuria, and increased carotid artery thickness have all been reported in children with primary hypertension.[4,5] Documenting LVH is an important component of the evaluation of children with hypertension.[7] Because echocardiography is noninvasive, easily obtained, and more sensitive than electrocardiography,[23] it should be part of the initial evaluation of all children with hypertension and may be repeated periodically.

TABLE 4
History Suggesting Possible Etiologies or Associations with Hypertension

	Possible etiology and/or associations
Family history	
Cardiovascular disease (e.g., myocardial infarction, stroke)	Primary hypertension
Deafness	Congenital or familial renal disease
Dyslipidemia	Primary hypertension
Endocrine problems (e.g., diabetes, thyroid, adrenal)	Familial endocrinopathies
Hypertension	Primary hypertension
Kidney disease	Congenital or familial renal disease
Sleep apnea	Primary hypertension
Child's history	
Chest pain	Cardiovascular disease
Diaphoresis (abnormal)	Endocrinopathies
Dyspnea on exertion	Cardiovascular disease
Edema	Cardiovascular disease
Enuresis	Renovascular disease, renal scarring
Growth failure	Endocrinopathies
Heat or cold intolerance	Endocrinopathies
Heart palpitations	Cardiovascular disease
Headaches	Primary hypertension
Hematuria	Renovascular disease, renal scarring
Joint pain or swelling	Rheumatologic disorders
Myalgias	Rheumatologic disorders
Neonatal hypovolemia/shock	Renovascular disease, renal scarring
Recurrent rashes	Rheumatologic disorders
Snoring or other sleep problems	Primary hypertension
Umbilical artery catheterization	Renovascular disease, renal scarring
Urinary tract infections (recurrent)	Renovascular disease, renal scarring
Weight or appetite changes	Endocrinopathies

Information from reference 7.

Management

Managing childhood hypertension is directed at the cause of the elevated blood pressure and the alleviation of any symptoms. End-organ damage, comorbid conditions, and associated risk factors also influence decisions about therapy.

Nonpharmacologic and pharmacologic treatments are recommended based on the age of the child, the stage of hypertension, and response to treatment.

NONPHARMACOLOGIC TREATMENTS

For children and adolescents with prehypertension or stage 1 hypertension, therapeutic lifestyle changes are recommended. These include weight control, regular exercise, a low-fat and low-sodium diet, smoking cessation, and abstinence from alcohol use.

Obesity increases the occurrence of hypertension threefold while favoring the development of insulin resistance, hyperlipidemia, and salt sensitivity.[24,27] Significant obesity also increases the likelihood of LVH independent of blood pressure level.[27] Exercise has been shown to lower blood pressure in children but does not

TABLE 5
Laboratory Tests for the Child with Hypertension

Reason to test	*Tests*	*Purpose of result*
To identify cause	Complete blood count with differential, platelets	Rule out anemia, consistent with chronic renal disease
	Electrolytes, blood urea nitrogen, creatinine, calcium, phosphorus, uric acid	Rule out renal disease, calculi; chronic pyelonephritis
	Renal ultrasound	Rule out renal scarring; congenital renal anomalies; unequal renal size
	Urinalysis, urine culture	Rule out infection; hematuria; proteinuria
To identify comorbidities	Drug screen	Identify drug-induced hypertension
	Fasting lipid panel, fasting glucose, insulin	Identify hyperlipidemias, metabolic syndrome, or diabetes
	Polysomnography	Identify sleep disorders associated with hypertension
To identify end-organ damage	Echocardiography	Identify left ventricular hypertrophy
	Retinal examination	Identify retinal vascular changes
Additional testing (as clinically indicated)	24-hour urine for protein and creatinine, creatinine clearance	Rule out chronic renal disease
	Advanced imaging: renal scan; magnetic resonance angiogram; duplex Doppler flow studies; 3-dimensional computed tomography; arteriography (classic or digital subtraction)	Rule out renovascular disease
	Ambulatory blood pressure monitoring	Rule out physician anxiety-induced ("white-coat") hypertension
	Hormone levels (thyroid, adrenal)	Rule out hyperthyroidism, adrenal dysfunction
	Plasma renin levels	Rule out mineralocorticoid-related disease
	Urine and plasma catecholamines	Rule out catecholamine-mediated hypertension

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affect left ventricular function.[28,29] Competitive sports are permitted for children with prehypertension, stage 1 hypertension, or controlled stage 2 hypertension in the absence of symptoms and end-organ damage.

Data regarding dietary changes in children with hypertension are limited. Nevertheless, the NHBPEP has taken an aggressive stance on sodium restriction, recommending a sodium intake of 1,200 mg per day. A no-salt-added diet with more fresh fruits and vegetables combined with low-fat dairy and protein akin to the DASH (Dietary Approaches to Stop Hypertension) food plan[30] may be successful in lowering blood pressure in children. Increased intake of potassium and calcium also have been suggested as nutritional strategies to lower blood pressure.[31,32] Whatever lifestyle changes are recommended, a family-centered rather than patient-oriented approach usually is more effective.[7]

PHARMACOTHERAPY

Reasons to initiate antihypertensive medication in children and adolescents include symptomatic hypertension, end-organ damage (e.g., LVH, retinopathy, proteinuria), secondary hypertension, stage 1 hypertension that does not respond to lifestyle changes, and stage 2 hypertension.[7] In the absence of end-organ damage or comorbid conditions, the goal is to reduce blood pressure to less than the 95th percentile for age, height, and sex. When end-organ damage or coexisting illness is present, a blood pressure goal of less than the 90th percentile is recommended. Drug therapy is always an adjunct to nonpharmacologic measures.

Information about long-term, untreated childhood hypertension and the impact of antihypertensive medications on growth and development is insubstantial. According to the NHBPEP, pharmacotherapy should

TABLE 6
Antihypertensive Medications with FDA Approval for Use in Children

Class	*Drug*	*Initial dosage*	*Maximum dosage*
Angiotensin-converting enzyme inhibitor*†‡	Benazepril (Lotensin)§	0.2 mg per kg per day up to 10 mg per day	0.6 mg per kg per day up to 40 mg per day
	Enalapril (Vasotec)§	0.08 mg per kg per day up to 5 mg per day	0.6 mg per kg per day up to 40 mg per day
	Fosinopril (Monopril)	Children heavier than 50 kg: 5 to 10 mg per day	Children heavier than 50 kg: 40 mg per day
	Lisinopril (Zestril)§	0.07 mg per kg per day up to 5 mg per day	0.6 mg per kg per day up to 40 mg per day
Angiotensin-receptor blocker*†‡	Irbesartan (Avapro)	Six to 12 years of age: 75 to 150 mg per day	Same as initial
		13 years of age: 150 to 300 mg per day	Same as initial
	Losartan (Cozaar)§	0.7 mg per kg per day up to 50 mg per day	1.4 mg per kg per day up to 100 mg per day
Beta blocker	Propranolol (Inderal)‖	1 to 2 mg per kg per day	4 mg per kg per day up to 640 mg per day
Calcium channel blocker¶	Amlodipine (Norvasc)§	6 to 17 years of age: 2.5 to 5.0 mg per day	10 mg per day
Diuretic**	Hydrochlorothiazide (Hydrodiuril)	1 mg per kg per day up to 50 mg per day	3 mg per kg per day up to 50 mg per day

FDA = U.S. Food and Drug Administration.

**—Contraindicated during pregnancy; females of childbearing age should be counseled to use contraception.*

†—Check serum potassium and creatinine periodically to monitor for hyperkalemia or azotemia.

‡—FDA approval is limited to children six years of age or older with creatinine clearance of at least 30 ml per min per 1.73 m^2.

§—Can be prepared as a suspension.

‖—Contraindicated in asthma and heart failure. Heart rate is dose-limiting. May impair athletic performance. Should not be used in insulin-dependent patients with diabetes. A sustained-release, once-daily formulation is available.

¶— May cause tachycardia.

***—All patients treated with diuretic medications should have electrolytes monitored shortly after initiation of therapy and periodically thereafter. Useful as add-on therapy in patients being treated with drugs from other drug classes.*

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follow a step-up plan, introducing one medication at a time at the lowest dose, then increasing the dose until therapeutic effects are seen, side effects are seen, or the maximal dose is reached. Only then should a second agent, preferably one with a complementary mechanism of action, be initiated. Long-acting medication is useful in improving compliance, and predictable problems such as the effect of diuretic medications in young athletes should be avoided.[7]

The choice of initial drug therapy is largely at the discretion of the physician. Diuretics and beta blockers have documented safety and effectiveness in children. Preferential use of specific classes of medications for certain underlying or coexisting pathology has led to the prescribing of ACE inhibitors in children with diabetes or proteinuria and beta-adrenergic or calcium channel blockers for children with migraines.[33] Becoming familiar with medications in each major class and with effective combinations of medications will facilitate treatment. Many medications have growing research to support their use. Those with approval from the U.S. Food and Drug Administration for use in children are listed in *Table 6*.[7] As with any chronic health issue, medical follow-up and appropriate monitoring are key to long-term success.

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Appendix 1. Blood Pressure Levels for Boys by Age and Height Percentile

Age, years	Blood pressure percentile	Systolic blood pressure (mm Hg) Percentile of height							Diastolic blood pressure (mm Hg) Percentile of height						
		5th	10th	25th	50th	75th	90th	95th	5th	10th	25th	50th	75th	90th	95th
1	50th	80	81	83	85	87	88	89	34	35	36	37	38	39	39
	90th	94	95	97	99	100	102	103	49	50	51	52	53	53	54
	95th	98	99	101	103	104	106	106	54	54	55	56	57	58	58
	99th	105	106	108	110	112	113	114	61	62	63	64	65	66	66
2	50th	84	85	87	88	90	92	92	39	40	41	42	43	44	44
	90th	97	99	100	102	104	105	106	54	55	56	57	58	58	59
	95th	101	102	104	106	108	109	110	59	59	60	61	62	63	63
	99th	109	110	111	113	115	117	117	66	67	68	69	70	71	71
3	50th	86	87	89	91	93	94	95	44	44	45	46	47	48	48
	90th	100	101	103	105	107	108	109	59	59	60	61	62	63	63
	95th	104	105	107	109	110	112	113	63	63	64	65	66	67	67
	99th	111	112	114	116	118	119	120	71	71	72	73	74	75	75
4	50th	88	89	91	93	95	96	97	47	48	49	50	51	51	52
	90th	102	103	105	107	109	110	111	62	63	64	65	66	66	67
	95th	106	107	109	111	112	114	115	66	67	68	69	70	71	71
	99th	113	114	116	118	120	121	122	74	75	76	77	78	78	79
5	50th	90	91	93	95	96	98	98	50	51	52	53	54	55	55
	90th	104	105	106	108	110	111	112	65	66	67	68	69	69	70
	95th	108	109	110	112	114	115	116	69	70	71	72	73	74	74
	99th	115	116	118	120	121	123	123	77	78	79	80	81	81	82
6	50th	91	92	94	96	98	99	100	53	53	54	55	56	57	57
	90th	105	106	108	110	111	113	113	68	68	69	70	71	72	72
	95th	109	110	112	114	115	117	117	72	72	73	74	75	76	76
	99th	116	117	119	121	123	124	125	80	80	81	82	83	84	84
7	50th	92	94	95	97	99	100	101	55	55	56	57	58	59	59
	90th	106	107	109	111	113	114	115	70	70	71	72	73	74	74
	95th	110	111	113	115	117	118	119	74	74	75	76	77	78	78
	99th	117	118	120	122	124	125	126	82	82	83	84	85	86	86
8	50th	94	95	97	99	100	102	102	56	57	58	59	60	60	61
	90th	107	109	110	112	114	115	116	71	72	72	73	74	75	76
	95th	111	112	114	116	118	119	120	75	76	77	78	79	79	80
	99th	119	120	122	123	125	127	127	83	84	85	86	87	87	88
9	50th	95	96	98	100	102	103	104	57	58	59	60	61	61	62
	90th	109	110	112	114	115	117	118	72	73	74	75	76	76	77
	95th	113	114	116	118	119	121	121	76	77	78	79	80	81	81
	99th	120	121	123	125	127	128	129	84	85	86	87	88	88	89
10	50th	97	98	100	102	103	105	106	58	59	60	61	61	62	63
	90th	111	112	114	115	117	119	119	73	73	74	75	76	77	78
	95th	115	116	117	119	121	122	123	77	78	79	80	81	81	82
	99th	122	123	125	127	128	130	130	85	86	86	88	88	89	90
11	50th	99	100	102	104	105	107	107	59	59	60	61	62	63	63
	90th	113	114	115	117	119	120	121	74	74	75	76	77	78	78
	95th	117	118	119	121	123	124	125	78	78	79	80	81	82	82
	99th	124	125	127	129	130	132	132	86	86	87	88	89	90	90
12	50th	101	102	104	106	108	109	110	59	60	61	62	63	63	64
	90th	115	116	118	120	121	123	123	74	75	75	76	77	78	79
	95th	119	120	122	123	125	127	127	78	79	80	81	82	82	83
	99th	126	127	129	131	133	134	135	86	87	88	89	90	90	91
13	50th	104	105	106	108	110	111	112	60	60	61	62	63	64	64
	90th	117	118	120	122	124	125	126	75	75	76	77	78	79	79
	95th	121	122	124	126	128	129	130	79	79	80	81	82	83	83
	99th	128	130	131	133	135	136	137	87	87	88	89	90	91	91
14	50th	106	107	109	111	113	114	115	60	61	62	63	64	65	65
	90th	120	121	123	125	126	128	128	75	76	77	78	79	79	80
	95th	124	125	127	128	130	132	132	80	80	81	82	83	84	84
	99th	131	132	134	136	138	139	140	87	88	89	90	91	92	92
15	50th	109	110	112	113	115	117	117	61	62	63	64	65	66	66
	90th	122	124	125	127	129	130	131	76	77	78	79	80	80	81
	95th	126	127	129	131	133	134	135	81	81	82	83	84	85	85
	99th	134	135	136	138	140	142	142	88	89	90	91	92	93	93
16	50th	111	112	114	116	118	119	120	63	63	64	65	66	67	67
	90th	125	126	128	130	131	133	134	78	78	79	80	81	82	82
	95th	129	130	132	134	135	137	137	82	83	83	84	85	86	87
	99th	136	137	139	141	143	144	145	90	90	91	92	93	94	94
17	50th	114	115	116	118	120	121	122	65	66	66	67	68	69	70
	90th	127	128	130	132	134	135	136	80	80	81	82	83	84	84
	95th	131	132	134	136	138	139	140	84	85	86	87	87	88	89
	99th	139	140	141	143	145	146	147	92	93	93	94	95	96	97

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Appendix 2. Blood Pressure Levels for Girls by Age and Height Percentile

Age, years	Blood pressure percentile	Systolic blood pressure (mm Hg) Percentile of height							Diastolic blood pressure (mm Hg) Percentile of height						
		5th	10th	25th	50th	75th	90th	95th	5th	10th	25th	50th	75th	90th	95th
1	50th	83	84	85	86	88	89	90	38	39	39	40	41	41	42
	90th	97	97	98	100	101	102	103	52	53	53	54	55	55	56
	95th	100	101	102	104	105	106	107	56	57	57	58	59	59	60
	99th	108	108	109	111	112	113	114	64	64	65	65	66	67	67
2	50th	85	85	87	88	89	91	91	43	44	44	45	46	46	47
	90th	98	99	100	101	103	104	105	57	58	58	59	60	61	61
	95th	102	103	104	105	107	108	109	61	62	62	63	64	65	65
	99th	109	110	111	112	114	115	116	69	69	70	70	71	72	72
3	50th	86	87	88	89	91	92	93	47	48	48	49	50	50	51
	90th	100	100	102	103	104	106	106	61	62	62	63	64	64	65
	95th	104	104	105	107	108	109	110	65	66	66	67	68	68	69
	99th	111	111	113	114	115	116	117	73	73	74	74	75	76	76
4	50th	88	88	90	91	92	94	94	50	50	51	52	52	53	54
	90th	101	102	103	104	106	107	108	64	64	65	66	67	67	68
	95th	105	106	107	108	110	111	112	68	68	69	70	71	71	72
	99th	112	113	114	115	117	118	119	76	76	76	77	78	79	79
5	50th	89	90	91	93	94	95	96	52	53	53	54	55	55	56
	90th	103	103	105	106	107	109	109	66	67	67	68	69	69	70
	95th	107	107	108	110	111	112	113	70	71	71	72	73	73	74
	99th	114	114	116	117	118	120	120	78	78	79	79	80	81	81
6	50th	91	92	93	94	96	97	98	54	54	55	56	56	57	58
	90th	104	105	106	108	109	110	111	68	68	69	70	70	71	72
	95th	108	109	110	111	113	114	115	72	72	73	74	74	75	76
	99th	115	116	117	119	120	121	122	80	80	80	81	82	83	83
7	50th	93	93	95	96	97	99	99	55	56	56	57	58	58	59
	90th	106	107	108	109	111	112	113	69	70	70	71	72	72	73
	95th	110	111	112	113	115	116	116	73	74	74	75	76	76	77
	99th	117	118	119	120	122	123	124	81	81	82	82	83	84	84
8	50th	95	95	96	98	99	100	101	57	57	57	58	59	60	60
	90th	108	109	110	111	113	114	114	71	71	71	72	73	74	74
	95th	112	112	114	115	116	118	118	75	75	75	76	77	78	78
	99th	119	120	121	122	123	125	125	82	82	83	83	84	85	86
9	50th	96	97	98	100	101	102	103	58	58	58	59	60	61	61
	90th	110	110	112	113	114	116	116	72	72	72	73	74	75	75
	95th	114	114	115	117	118	119	120	76	76	76	77	78	79	79
	99th	121	121	123	124	125	127	127	83	83	84	84	85	86	87
10	50th	98	99	100	102	103	104	105	59	59	59	60	61	62	62
	90th	112	112	114	115	116	118	118	73	73	73	74	75	76	76
	95th	116	116	117	119	120	121	122	77	77	77	78	79	80	80
	99th	123	123	125	126	127	129	129	84	84	85	86	86	87	88
11	50th	100	101	102	103	105	106	107	60	60	60	61	62	63	63
	90th	114	114	116	117	118	119	120	74	74	74	75	76	77	77
	95th	118	118	119	121	122	123	124	78	78	78	79	80	81	81
	99th	125	125	126	128	129	130	131	85	85	86	87	87	88	89
12	50th	102	103	104	105	107	108	109	61	61	61	62	63	64	64
	90th	116	116	117	119	120	121	122	75	75	75	76	77	78	78
	95th	119	120	121	123	124	125	126	79	79	79	80	81	82	82
	99th	127	127	128	130	131	132	133	86	86	87	88	88	89	90
13	50th	104	105	106	107	109	110	110	62	62	62	63	64	65	65
	90th	117	118	119	121	122	123	124	76	76	76	77	78	79	79
	95th	121	122	123	124	126	127	128	80	80	80	81	82	83	83
	99th	128	129	130	132	133	134	135	87	87	88	89	89	90	91
14	50th	106	106	107	109	110	111	112	63	63	63	64	65	66	66
	90th	119	120	121	122	124	125	125	77	77	77	78	79	80	80
	95th	123	123	125	126	127	129	129	81	81	81	82	83	84	84
	99th	130	131	132	133	135	136	136	88	88	89	90	90	91	92
15	50th	107	108	109	110	111	113	113	64	64	64	65	66	67	67
	90th	120	121	122	123	125	126	127	78	78	78	79	80	81	81
	95th	124	125	126	127	129	130	131	82	82	82	83	84	85	85
	99th	131	132	133	134	136	137	138	89	89	90	91	91	92	93
16	50th	108	108	110	111	112	114	114	64	64	65	66	66	67	68
	90th	121	122	123	124	126	127	128	78	78	79	80	81	81	82
	95th	125	126	127	128	130	131	132	82	82	83	84	85	85	86
	99th	132	133	134	135	137	138	139	90	90	90	91	92	93	93
17	50th	108	109	110	111	113	114	115	64	65	65	66	67	67	68
	90th	122	122	123	125	126	127	128	78	79	79	80	81	81	82
	95th	125	126	127	129	130	131	132	82	83	83	84	85	85	86
	99th	133	133	134	136	137	138	139	90	90	91	91	92	93	93

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