Review Article

Current Concepts

Hypertension in Children

Alan R. Sinaiko, M.D.

THE measurement of blood pressure is now firmly established as an important component of the routine pediatric physical examination. Nevertheless, blood pressure in children has been given serious attention only since the mid-1960s. The first report of the Task Force on Blood Pressure Control in Children was published in 1977.[1] The long-term natural history of blood pressure in children is not well understood. Norms for blood pressure and definitions of hypertension were revised and strengthened by the second task force report, published in 1987,[2] and a recent revision contains modified recommendations and norms.[3]

FACTORS INFLUENCING BLOOD PRESSURE IN CHILDHOOD

Blood pressure is considerably lower in children than adults but almost always increases steadily throughout the first two decades of life. The average systolic blood pressure at one day of age in full-term infants is approximately 70 mm Hg, and it increases to approximately 85 mm Hg by one month of age.[4] Blood pressure in premature infants is considerably lower,[5] and it is related more closely to weight than to age.[6] Blood pressure increases at a greater rate in premature infants than full-term infants during the first year of life,[7] and there is a significant inverse relation between birth weight and the risk of hypertension in adulthood.[8]

During the preschool years blood pressure begins to follow a pattern: children at a given percentile of blood-pressure distribution tend to maintain that approximate value relative to their peer group as they grow older, with correlations ranging from 0.30 to 0.66 for systolic blood pressure and 0.12 to 0.57 for diastolic blood pressure in childhood and adolescence.[9] The pattern continues from adolescence into adult life,[10-12] which supports the hypothesis that essential hypertension begins in childhood. However, it is not currently possible to identify which children will have essential hypertension as adults.

A number of factors known to be associated with hypertension in adults have also been associated with higher levels of blood pressure in children and adolescents. A direct relation between weight and blood pressure has been documented as early as five years of age[13] and is more prominent in the second decade.[14] Height is independently related to blood pressure at all ages.[15] Sex and race do not have the same impact on blood pressure in children as in adults. No significant differences in blood pressure have been found in comparisons of whites, blacks, Hispanics, and Southeast Asians until adolescence. Even then, the differences are small and vary among epidemiologic studies. The reference standards for blood pressure in children do not distinguish between racial or ethnic groups, because the differences are not clinically relevant.[2,3] Blood pressure is slightly higher in boys than in girls during the first decade of life. This difference begins to widen around the onset of puberty, and blood pressure is significantly higher in young men by the end of the teenage years.[2] These differences do not appear to be related to developmental changes in concentrations of follicle-stimulating or luteinizing hormone.[16]

A familial influence on blood pressure can be identified early in life. Children from families with hypertension tend to have higher blood pressures than children from normotensive families.[17] There are significant correlations in blood pressure and cardiovascular risk factors between parents and their children,[18,19] and these have been observed as early as the newborn period.[4] The correlation in blood pressure between parents and adopted children is significantly lower than between parents and their biologic children.[17,20] Siblings of children with high blood pressure have significantly higher blood pressure than siblings of children with low blood pressure.[21] There is a greater correlation in blood pressures between mothers and their children than between fathers and their children,[17,21] suggesting a direct prenatal influence. In a relatively small study, the offspring of mothers who were hypertensive during their pregnancies and had sustained hypertension after giving birth had higher blood pressure during early and late adolescence than the offspring of mothers who were normotensive during pregnancy and afterward.[22]

From the University of Minnesota Medical School, Department of Pediatrics, 420 Delaware St., S.E., Box 491 UMHC, Minneapolis, MN 55455, where reprint requests should be addressed to Dr. Sinaiko.

CLINICAL EVALUATION OF BLOOD PRESSURE

Normal Blood Pressure

There are some special considerations in the measurement and evaluation of blood pressure in children. Measurement by the usual auscultation methods is not feasible in infants and very young children because of practical problems with cooperation and anxiety. Automated devices are of great help and are widely used in this age group, and they are reliable. The correlation between intraarterial and oscillometric measurements has been reported to be 0.97 for systolic and 0.90 for diastolic blood pressure,[23] although the accuracy decreases in smaller infants.[24]

Blood pressure should be measured yearly after the age of three years, although data relating the frequency of measurement during childhood to improvement in health status are not available at this time. Conventional sphygmomanometers and auscultation should be used rather than automated devices, because the current blood-pressure standards are based on these measurements, and no standards for automated devices are available. The use of an appropriate-sized blood-pressure cuff is necessary to ensure accurate measurement. The current commercially marketed series of pediatric cuffs, along with the regular and oversized arm and thigh cuffs for adults, provide a sufficiently broad range of sizes. The method routinely used in population-based epidemiologic studies is to measure the circumference of the upper arm at the midpoint between the acromion and olecranon of the right arm and select a cuff whose width is 40 percent of the circumference. It may be impractical to obtain these measurements in a busy clinical setting. In that setting, it is reasonable to use the manufacturer's suggested markings on the cuff or to select a cuff size whose width is approximately two thirds of the distance between the shoulder and elbow. Use of an inappropriately small cuff may falsely elevate the blood-pressure reading, whereas the use of too large a cuff will give a falsely low reading.[25] However, if two cuffs are close in size to the measured width of the arm, the larger cuff should be selected; it is uncommon for a slightly large cuff to mask true hypertension, whereas use of a small cuff will often lead to elevated readings.

Until recently, the phase 4 Korotkoff sound was used to designate diastolic blood pressure in children less than 13 years of age and the phase 5 Korotkoff sound (disappearance of the Korotkoff sounds) was used for diastolic blood pressure in children 13 years of age or older.[2] With the availability of more epidemiologic blood-pressure data on children and a reanalysis of the data used to establish previous standards, it has been determined that the phase 5 Korotkoff sound is a reliable measure of diastolic blood pressure for children of all ages.[3] The experience with ambulatory blood-pressure monitors in children is limited,[26] and reliable population standards are not available.

Blood pressure in children is classified according to the percentile distribution of the various levels within the population. Tables derived from epidemiologic studies of 70,000 children and adolescents have been the accepted blood-pressure reference standards,[2] but they classify blood pressure only according to age. These tables were recently revised[3] and now take into account the effects of body size and rates of growth[15] by relating blood pressure to both age and height. The new tables are based on a reanalysis of previous data,[15] with the incorporation of data from a more recent large epidemiologic study[27] and from the 1988–1991 National Health and Nutrition Examination Survey.[3] The average 95th percentiles of systolic and diastolic blood pressures for boys and girls are provided according to height in Table 1. As might be expected, blood-pressure norms for any given age decrease with decreasing height and increase with increasing height. Referring to these published norms[3] should prevent one from mislabeling tall children who are not overweight as hypertensive or from missing a diagnosis of high-normal blood pressure or hypertension in short, heavy children, as was the case when only a single value for blood pressure was used for each age.

Hypertension

There are no long-term outcome data relating blood pressure in childhood or adolescence to cardiovascular risk in adulthood. The current defini-

TABLE 1. 95TH PERCENTILE OF BLOOD PRESSURE IN BOYS AND GIRLS 3 TO 16 YEARS OF AGE, ACCORDING TO HEIGHT.*

BLOOD PRESSURE	AGE	HEIGHT PERCENTILE FOR BOYS				HEIGHT PERCENTILE FOR GIRLS			
		5TH	25TH	75TH	95TH	5TH	25TH	75TH	95TH
	yr	mm Hg				mm Hg			
Systolic	3	104	107	111	113	104	105	108	110
	6	109	112	115	117	108	110	112	114
	10	114	117	121	123	116	117	120	122
	13	121	124	128	130	121	123	126	128
	16	129	132	136	138	125	127	130	132
Diastolic	3	63	64	66	67	65	65	67	68
	6	72	73	75	76	71	72	73	75
	10	77	79	80	82	77	77	79	80
	13	79	81	83	84	80	81	82	84
	16	83	84	86	87	83	83	85	86

*The height percentiles were determined with standard growth curves. Data are adapted from those of the Task Force on High Blood Pressure in Children and Adolescents.[3]

TABLE 2. SYMPTOMS AND CAUSES OF HYPERTENSION IN NEONATES AND YOUNG INFANTS.

Symptom
Failure to thrive
Irritability
Feeding problems, including vomiting
Cyanosis
Respiratory distress
Cardiac failure
Seizures
Cause
Most common
Renal-artery thrombosis after umbilical-artery catheterization
Coarctation of the aorta
Congenital renal disease
Renal-artery stenosis
Less common
Bronchopulmonary dysplasia
Patent ductus arteriosus
Intraventricular hemorrhage

TABLE 3. CAUSES OF HYPERTENSION IN CHILDREN AND ADOLESCENTS.

AGE GROUP	CAUSE	
	MOST COMMON	LESS COMMON
1 to 10 yr	Renal disease Coarctation of the aorta	Renal-artery stenosis Hypercalcemia Neurofibromatosis Neurogenic tumors Pheochromocytoma Mineralocorticoid excess Primary hyperaldosteronism 11β-hydroxylase deficiency 17α-hydroxylase deficiency Apparent mineralocorticoid excess Liddle's syndrome Glucocorticoid-remediable aldosteronism Hyperthyroidism Transient hypertension after urologic surgery Hypertension induced by immobilization (traction) Sleep-apnea–associated hypertension Essential hypertension (rare)
11 yr to adolescence	Renal disease Essential hypertension	All diagnoses listed above

tions of normal and high blood pressure have been derived from clinical experience as applied to largely descriptive population surveys of blood pressure and are therefore less precise than the definitions of hypertension in adults.

Normal blood pressure during the first two decades of life is defined as systolic and diastolic blood pressure below the 90th percentile of the distribution for age and sex. High-normal blood pressure is defined as systolic or diastolic blood pressure between the 90th and 95th percentiles, and hypertension is defined as systolic or diastolic blood pressure greater than the 95th percentile. The last definition implies that 5 percent of children and adolescents have hypertension. However, a diagnosis of hypertension should be made only after elevated blood pressure is confirmed in three separate, consecutive examinations. Blood-pressure readings tend to decrease with repeated measurements because of an accommodation by the child to the measurement procedure or relaxation and because of the statistical phenomenon of regression toward the mean. Thus, the true prevalence of hypertension after repeated measurements is considerably lower than 5 percent. In a cohort of junior-high-school students the prevalence of hypertension fell from 4.2 percent at an initial examination to 1.1 percent after only one repeated examination,[28] and similar results have been reported by others.[29] As might be expected, the prevalence of more severe hypertension is even lower.[30,31]

Hypertension in children is often due to an identifiable disease process. Hypertension in infants is usually related to renal or vascular disease (Table 2), and this finding warrants an aggressive evaluation of the patient. Young infants may present in acute distress with signs and symptoms of congestive heart failure (Table 2). In contrast, after infancy hypertension is frequently silent and detected only during a routine physical examination. Symptoms or signs are rarely evident unless the level of blood pressure is particularly high or hypertension has been present for years. An underlying cause can be found in most children with hypertension who are 1 to 10 years old. In the majority of cases the cause will be related to renal disease, although there are a number of other, less common, causes (Table 3).

There are no data on the prevalence of essential hypertension in children. Reviews of the causes of hypertension before adulthood have tended to rely on data from medical center referrals of patients with severe elevations of blood pressure, and these patients usually have secondary causes of their hypertension. Nevertheless, it has become clear since the incorporation of blood-pressure measurement into the routine physical examination that in most cases mild-to-moderate hypertension in students in junior and senior high school is not associated with secondary disease and that essential hypertension should be an important consideration. Renal disease continues to be the most common cause of hypertension when a diagnosis is made in this age group, but secondary causes are found much less frequently than in younger patients (Table 3).

In the evaluation of the hypertensive child one

must recognize that the likelihood of identifying a secondary cause of hypertension is directly related to the level of blood pressure and inversely related to the age of the child. Severe elevations of blood pressure, regardless of age, warrant aggressive evaluation, as outlined in Table 4. However, since mild elevations of blood pressure (i.e., those slightly above the 95th percentile) are usually not associated with secondary disease, the initial evaluation is uncomplicated and aims mainly to identify renal disease. If renal disease is not identified, the additional diagnostic tests listed in Table 4 are usually reserved for patients with higher levels of blood pressure. The echocardiogram rarely reveals any abnormalities in children without severe hypertension; however, it can be helpful in the diagnosis of coarctation of the aorta and in identifying patients with cardiac hypertrophy who need aggressive evaluation and treatment.

TABLE 4. DIAGNOSTIC EVALUATION OF THE HYPERTENSIVE CHILD.

Initial evaluation
Complete blood count
Measurement of serum electrolytes, creatinine, urea nitrogen, calcium, uric acid, cholesterol
Measurement of plasma renin activity
Urinalysis
Urine culture
Renal ultrasonography
Additional tests, if necessary
Echocardiography
Isotopic renography with administration of captopril
Urine collection for catecholamines
Measurement of plasma and urinary steroids
Renal arteriography

Treatment of Hypertension

A recent review of the treatment of hypertension in children included dosing recommendations (Table 5).[32] The goal of treatment is the reduction of blood pressure to a level below the 95th percentile. Children with chronic secondary forms of hypertension will require drug therapy, and in the past these children commonly required multidrug regimens for blood-pressure control. Therapy now tends to be initiated with converting-enzyme inhibitors and calcium-channel blockers because they are generally effective and have few side effects. However, there is no single recommended regimen for children, and the spectrum of drugs commonly prescribed for adults has also been used successfully in children.[3,31] Diuretic therapy should be considered and can be a particularly valuable adjunct in patients with renal disease.

TABLE 5. ANTIHYPERTENSIVE DRUGS FREQUENTLY USED IN CHILDREN.

DRUG	DOSE*	
	INITIAL	MAXIMUM
Hypertensive emergencies		
Nifedipine	0.25 mg/kg of body weight	0.5 mg/kg
Sodium nitroprusside	0.5 μg/kg/min intravenously	8 μg/kg/min intravenously
Labetalol	1 mg/kg/hr intravenously; can be given as a bolus or a steady infusion	3 mg/kg/hr intravenously
Long-term therapy		
Captopril		
Neonates	0.03 mg/kg/day	2 mg/kg/day
Children	1.5 mg/kg/day	6 mg/kg/day
Enalapril	0.15 mg/kg/day	?
Extended-release nifedipine	0.25 mg/kg/day	3 mg/kg/day
Propranolol	1 mg/kg/day	8 mg/kg/day
Atenolol	1 mg/kg/day	8 mg/kg/day
Prazosin	0.05–0.1 mg/kg/day	0.5 mg/kg/day
Minoxidil	0.1–0.2 mg/kg/day	1 mg/kg/day
Hydrochlorothiazide	1 mg/kg/day	2–3 mg/kg/day
Furosemide	1 mg/kg/day	12 mg/kg/day
Bumetanide	0.02–0.05 mg/kg/day	0.3 mg/kg/day

*Unless otherwise indicated the drugs are given orally.

Conservative management is recommended as initial therapy in children with essential hypertension. Attention should be given to weight, exercise, and diet, with the recognition that success increases with frequent reinforcement and encouragement. Effective sodium restriction is not feasible in this age group. Obese adolescents have significant reductions in blood pressure with weight loss, and the effect on blood pressure is enhanced when exercise is incorporated into the weight-loss program.[14] The degree of physical fitness has been shown to be inversely related to blood pressure in grade-school children.[13,33,34] Questions may arise about the ability of a hypertensive adolescent to participate in organized sports. There is no evidence to suggest that children with mild or moderate hypertension are at increased risk of cardiovascular events while participating in these sports,[35] and the occurrence of sudden cardiac death does not appear to be related to the presence of hypertension in young athletes.[36] Because fitness contributes to blood-pressure control, exercise should be encouraged, except for those with untreated severe hypertension or identified cardiac abnormalities.

As in adults, emergency therapy is indicated for children with severe elevations of blood pressure or symptoms such as cardiac failure, malignant renal changes, severe headache, eyeground changes, or seizure. Oral nifedipine is widely used in asymptomatic

children, but for rapid absorption the drug must first be removed from the capsule or the patient must bite through the capsule. If this drug is not effective or symptoms are present, intravenous treatment should be started with sodium nitroprusside or labetalol.[32]

RELATION OF BLOOD PRESSURE IN CHILDHOOD TO HYPERTENSION IN ADULTHOOD

It is clear from familial and longitudinal studies of blood pressure that there is a link between genetic and environmental influences on blood pressure during childhood and the development of essential hypertension. Recent observations from England trace this influence back to gestation.[8] Systolic blood pressure correlates inversely with birth weight, beginning in the first decade of life, and the relation becomes stronger with increasing age in adulthood.[37] Moreover, the inverse relation to birth weight has been associated with insulin resistance and hyperlipidemia.[38]

There is a relation between blood pressure and cardiac size, even though the absolute levels of blood pressure considered high in children are significantly lower than the levels considered to indicate hypertension in adults. Left ventricular size is directly related to blood pressure in normotensive children,[39,40] and it increases with increasing percentiles of blood pressure, suggesting a continuous rather than a threshold effect.[40] There is a significant correlation between blood pressure and insulin levels measured during fasting in grade-school children and adolescents.[41-43] Higher insulin levels have been noted in obese grade-school children[44] and adolescents,[45] and this is associated with sensitivity to sodium[46] and increased vascular reactivity,[47] both of which are reversible with weight loss.

CONCLUSIONS

Approximately 25 percent of the adult population in the United States has hypertension.[48] Although the prevalence is far lower in children and adolescents,[28] increasing evidence indicates that essential hypertension begins to develop during the first two decades of life. Since even small decrements in blood pressure can have substantial effects on hypertension-related morbidity and mortality,[49,50] greater attention to blood pressure early in life may ultimately lead to considerable improvements in cardiovascular health.

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