Problems in Family Practice

Elevated Blood Pressures in Infants and Children

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Blood pressure should be routinely measured in all infants and children. Measurements should be performed with an appropriate size cuff and observed pressures compared to normal values for age. Elevated blood pressure is seen in one to ten percent of children, depending on the age group surveyed and the definition of hypertension selected. Thirty to fifty percent of children with elevated blood pressures are asymptomatic. The remainder have symptoms which are nonspecific, including headaches, visual disturbances, seizures, congestive heart failure, and facial palsy. Hypertension in children, unlike hypertension in the adult, usually has a definite cause which often responds to adequate medical and/or surgical treatment. For this reason, children with well-confirmed hypertension should be thoroughly evaluated. The most common causes of hypertension found in children are renal disease (pyelonephritis, vascular disease, structural malformations) and coarctation of the aorta.

An approach to the child with transient or persistent hypertension is described. Diagnostic studies should be individualized and should follow clinical clues where possible. Medical management of the child with acute hypertension is discussed.

In the past hypertension has been considered an adult disease. However, with new techniques for measuring blood pressures in infants and children and with an increasing awareness of this condition by physicians, it now is clear that hypertension in childhood (1) is not uncommon,[1-4] (2) is often asymptomatic, (3) can lead to serious sequelae such as congestive heart failure, cerebral vascular accidents, and renal insufficiency, and (4) is frequently correctable, being caused by underlying conditions which often respond to adequate medical and/or surgical therapy.[2,3,5] For these reasons blood pressure measurements should be done routinely in infants and children. Persistent hypertension confirmed by repeated blood pressure measurements should be fully investigated. Unlike in the adult, in most pediatric cases a definite cause will be found.

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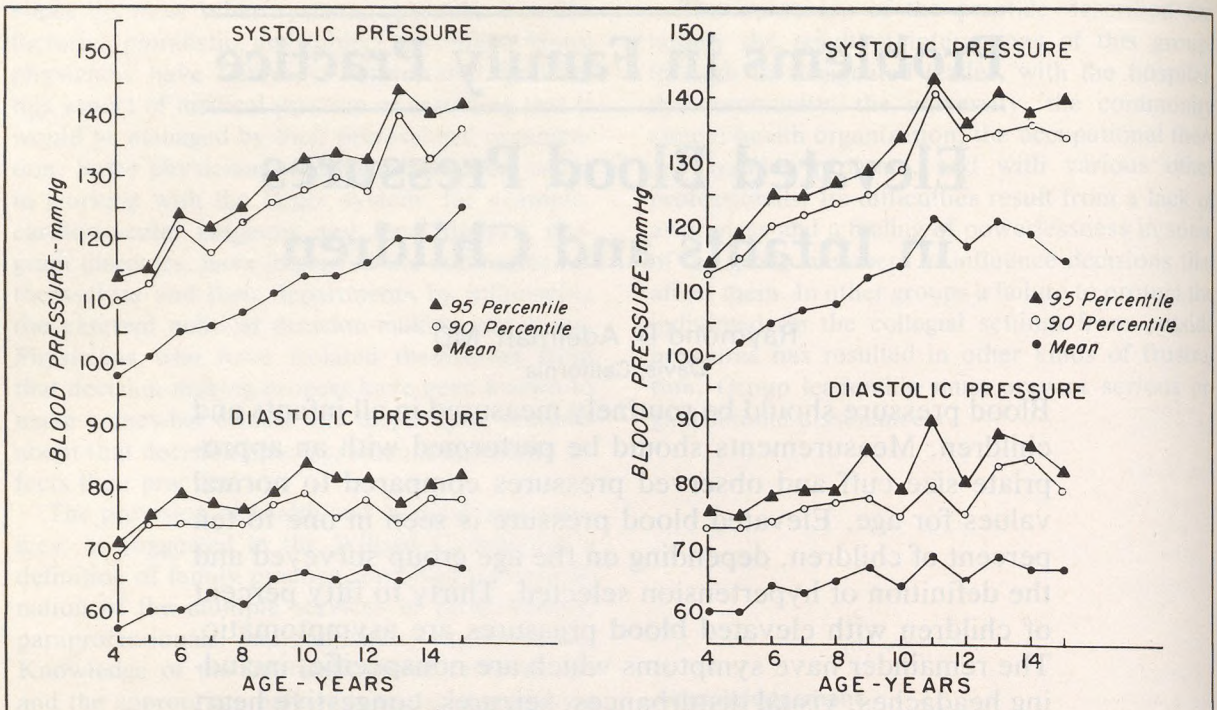

Figure 1. Supine brachial artery cuff pressures in boys and girls, age 4 to 15 years, under office conditions.*

*Reprinted, by permission, from Londe S: Blood pressure in children as determined under office conditions. Clinical Pediatrics 5:71, 1966.

Measurement of Blood Pressure

Blood pressure can be measured by auscultation, palpation, flush, Doppler, oscillometer, and direct techniques. With auscultation, systolic blood pressure is indicated by the first appearance of sound, and diastolic blood pressure by the distinct change in quality or muffling of that sound. With palpation, the point at which a palpable pulse appears during cuff deflation approximates systolic blood pressure. Diastolic blood pressure is not measured. The flush technique approximates mean blood pressure and is the point at which a previously compressed and blanched extremity "flushes" during cuff deflation. The flush blood pressure is useful in infants in whom other techniques are difficult; however, a flush blood pressure of 70 mmHg, being a mean, may represent several blood pressures (eg, 90/50, 80/60, 85/55 mmHg). Both Doppler and oscillometer blood pressures are being used more in children, especially in the newborn infant, and are highly accurate, corresponding closely to direct intra-arterial readings. The palpation method, on the other hand, gives systolic values 5 to 10 mmHg lower than with direct readings.[3]

A few important points regarding the measurement of blood pressure deserve emphasis. It is extremely *important* that the proper size cuff be used, that is, a cuff whose bladder width is two thirds the length of the upper arm. Inappropriately small cuffs will give artifactually high blood pressures (the so-called small cuff syndrome); large cuffs will record spuriously low blood pressures. This caution regarding cuff size also applies to use of the Doppler technique. The cuff should fit snugly around the arm. Obese individuals may require larger cuffs to ensure that snug fit. Emotional tenseness, crying, and forced extension of the arm may raise both diastolic and systolic blood pressures. Hence the patient should be relaxed, quiet, and unagitated while blood pressure is taken. Several blood pressure readings may be required in the office or in the home by a visiting nurse or a family member before one is certain of the usual resting blood pressure. At times a limited stay in the hospital for multiple blood pressure ob-

Table 1. Maximal normal values (mean + two standard deviations) for systolic and diastolic blood pressures in infants and children.*

Age	Blood Pressure (mmHg)	
	Systolic	Diastolic
0-6 mos	110	65
3 years	120	70
8 years	125	80
11 years	135	80
15 years	140	85

*Adapted, by permission, from Lieberman E: Children with hypertension. American Family Physician 12:99, 1975

servations may be necessary. Standing blood pressures are often greater than supine blood pressures. Evening blood pressures, especially in the hypertensive, are often higher than morning blood pressures. The physician following the hypertensive patient should be aware that morning office measurements may not accurately reflect the patient's usual or maximal daily blood pressure.

Incidence

The incidence of hypertension in the pediatric age group has not been clearly established. One may simply statistically estimate that 2.5 percent of children will have hypertension since that number will have blood pressures two standard deviations above mean values for age. By defining hypertension, however, as a blood pressure above an arbitrary level, other investigators arrive at much higher estimates. Lauer[4] found 1.2 percent of children in the age range six to nine years and 12.2 percent of children in the age range 14 to 18 years to be hypertensive (diastolic pressure greater than 90 mmHg). Answers to this dilemma may come from additional screening programs and through wider acceptance by physicians of routine blood pressure measurements in children of all ages. This is not occurring now. In a recent survey of three large pediatric outpatient facilities, only five percent of examined children had had blood pressures measured.[6] Whether one selects higher or lower incidence figures, this is obviously a widely neglected problem of great magnitude and importance.

Definition

Figure 1 and Table 1 give normal systolic and diastolic blood pressure values for children, as reported by two investigators.[1,7] Blood pressure values vary with age. A diastolic pressure of 80 mm Hg is clearly abnormal in a two-year-old child but not in a 13-year-old adolescent. It is important to refer to published normal values before making or excluding the diagnosis of hypertension. As a rough guide, hypertension should be suspected with diastolic blood pressures above 65 mmHg in the full-term newborn, above 70 mmHg in the toddler, above 80 mmHg in the child under eight, and above 85 mm Hg in the child over eight. The exact significance of elevations in systolic blood pressure is not clear. Actuarial studies in adults show a decreased longevity associated with systolic hypertension, regardless of the level of diastolic pressure.[2] In the pediatric population, further information including long-term follow-up is needed to assess the risk of systolic hypertension. This review will focus primarily on persistent elevation of diastolic blood pressure.

Symptoms and Signs

Thirty to 50 percent of children with hypertension have no symptoms.[3] In the symptomatic child, the symptoms of hypertension are nonspecific and include headaches, visual disturbances, irritability, abdominal pain, anorexia, hemiplegia, and Bell palsy. Hypertension should be suspected in any child with unexplained convulsions or congestive heart failure.

It is important to examine carefully the fundi (hemorrhages, exudates, AV nicking, papilledema), heart (heave, abnormal PMI, gallop, murmur, muffled sounds) and abdomen (mass, bruit). Blood pressure should always be measured in the legs to rule out coarctation. Coarctation may also be associated with cardiac, flank, and back murmurs. The physical examination may provide additional clues regarding the etiology of the hypertension. For example, one may see cafe au lait spots (neurofibromatosis), a macular rash (sys-

Table 2. Causes of Persistent Hypertension in Infants and Children

	Common	Less Common	Uncommon
Renal Parenchymal	Pyelonephritis Glomerulonephritis Post renal transplant	Cystic disease Dysplasia Hypoplasia Hydronephrosis	Neoplasm Trauma Radiation Collagen disease
Renal Vascular	Stenosis	Thrombosis Embolism	Fibromuscular hyperplasia Arteritis Aneurysm
Cardiovascular	Coarctation— thoracic aorta		Coarctation— abdominal aorta
Endocrine			Pheochromocytoma Neuroblastoma Cushing disease Hyperaldosteronism Adrenogenital syndrome
Miscellaneous	Artifact Drugs steroids oral contraceptives amphetamines Essential	Increased intracranial pressure: (bleeding, tumor, abscess, etc)	Toxins: lead mercury Metabolic hypercalcemia hypernatremia Familial dysautonomia Turner Syndrome Congenital rubella

temic lupus erythematosus, oral contraceptives), purpura (Henoch-Schönlein disease, hemolytic-uremic syndrome), hirsutism (adrenogenital syndrome, Cushing disease), and signs of excessive circulating catecholamines such as sweating, tachycardia, fever (pheochromocytoma). There may be no associated findings on physical examination.

Causes

The causes of persistent hypertension with some indication of the relative frequency of occurrence are listed in Table 2. Renal disease, especially pyelonephritis, vascular disease, and structural malformations are by far the most common underlying conditions, present in 50 to 70 percent of pediatric hypertensive patients. Coarctation of the aorta is also common. Endocrine disease is an uncommon cause of hypertension in children. In the newborn, renal vascular hypertension appears to be a problem of increasing importance, probably as a consequence of renal artery thrombosis originating from indwelling umbilical artery catheters.[5] Infants undergoing an umbilical artery catheterization are at high risk and should have their blood pressure measured both during and following catheterization. Essential hypertension is rare in the prepubertal child. However, perhaps 25 percent of adolescent hypertension may be labeled essential. Londe[8] has suggested that the percentage may be even higher in children with mild elevations in blood pressure, with obesity, and/or with family histories of hypertension. He suggests such children do not require extensive evaluations but should be carefully followed. It is important to note that Londe defined hypertension as blood pressure exceeding 90th percentile values for age rather than exceeding 95th percentile values, which might be more appropriate. He furthermore included children with

both systolic and diastolic elevations. In fact only 15 percent of children had diastolic blood pressures exceeding the 95th percentile values for age. Finally, only slightly more than half of his patients even had intravenous pyelograms and few underwent arteriography, leaving one to question the diagnosis of "essential" hypertension. In this author's opinion, essential hypertension is a diagnosis given only after other causes of hypertension have been excluded by appropriate studies.

Table 3. Conditions Which Are Associated with Acute Transient Hypertension or Intermittent Hypertension*

Renal
Acute post-streptococcal glomerulonephritis
Hemolytic uremic syndrome
Anaphylactoid purpura with nephritis
After genitourinary tract surgery
After blood transfusion to patient with azotemia and preexisting hypertension
Use of sympathomimetic drugs in patients with azotemia and preexisting hypertension
After renal transplant (immediate and during episodes of rejection)
Miscellaneous
Raised intracranial pressure from any cause
Administration of corticosteroids
Hypernatremia
Hypercalcemia
Burns
Stevens-Johnson syndrome
Guillain-Barré syndrome
Leukemia
Bacterial endocarditis
Poliomyelitis
Familial dysautonomia
Mercury poisoning
Amphetamine overdose

*Adapted, by permission, from Loggie JMH: Systemic hypertension in children and adolescents. Pediatric Clinics of North America 18:1273, 1971.

There appear to be familial tendencies toward hypertension. Children of hypertensive parents are at a much higher risk for developing hypertension than children of nonhypertensive parents. These tendencies may surface during the childhood years. The factor or factors responsible for this phenomenon—genetic, environmental, dietary, etc—have not been clarified, nor is it clear what fraction of these patients ultimately fall into the category of essential hypertension.

Table 3 lists several conditions in which transient hypertension may be seen. The physician should monitor blood pressures serially in such patients.

Diagnostic Approach

Blood pressures should be routinely measured in children from infancy through adolescence. Femoral pulses should be palpated in all newborns.

A reasonable approach to the patient with elevated blood pressure is listed in Table 4. It should be clear to the physician that not all the tests listed will be required for each individual. Diagnostic studies should follow clues given by history and physical findings. In the absence of such leads, clinical judgment is required. Unfortunately, there are no good data available to predict the value of various sequences of diagnostic evaluations. Patients with *transient* hypertension, in whom the physician is assured that no chronic underlying condition exists, require a less extensive workup, including urinalysis (hematuria, proteinuria, red blood cell casts), urine culture (urinary tract infection), complete blood count (hemolytic uremic syndrome, leukemia), electrolytes, creatinine, blood urea nitrogen, calcium (hypernatremia, azotemia, hypercalcemia), chest x-ray (cardiomegaly), and electrocardiogram (left ventricular hypertrophy). In the patient with *persistent* hypertension in which renal pathology is strongly suspected, the physician should add a fast-sequence intravenous pyelogram (renal vascular disease, pyelonephritis, obstruction, cystic disease, trauma). The hypertensive intravenous pyelogram, however, may be normal in 30 to 50 percent of patients with significant renal vascular lesions.[2,3]

Table 4. Basic Laboratory Studies for the Evaluation of Persistent Hypertension

Urinalysis and urine culture
Hemoglobin, hematocrit, white blood cell count, and differential count
Carbon dioxide, chloride, sodium, potassium, blood urea nitrogen, creatinine, calcium, phosphorus, peripheral plasma renin
Chest x-ray and electrocardiogram
24-hour urine collection for norepinephrine, epinephrine, metanephrines, vanillylmandelic acid (VMA), dopamine, homovanillic acid (HVA)
24-hour urine collection for 17-hydroxysteroids and 17-ketosteroids
Fast-sequence intravenous pyelogram
Thoracic or abdominal aortogram
Renal scan
Renal vein renins

Often arteriography and even selective renal arteriograms are necessary. Radionuclide evaluations, especially those using computerized compartmental analysis of data, appear to be a sensitive and noninvasive means of assessing the presence or absence of significant renal vascular lesions.[5] However, more experience is needed before it can be confidently used in place of arteriography. Not all renal artery stenoses cause hypertension and not all hypertension is relieved by correction of renal artery stenoses.[9] Surgical outcome is more likely to be successful if renal vein renin production from the involved kidney is 1.5 or more times greater than that from the contralateral kidney (whose renin production is often suppressed).[10] Arteriography and renal vein renin studies should be performed in a facility with specialists experienced in pediatric procedures and in the management of pediatric hypertension.

Coarctation of the aorta may be demonstrated by barium swallow. In patients in whom renal disease and coarctation are not strongly suspected, 24-hour urine collections for norepinephrine, epinephrine, metanephrine, vanillymandelic acid, homovanillic acid, 17-hydroxysteroids, and 17-ketosteroids should be obtained. It is the author's practice to collect such urines in hypertension of unclear etiology even though endocrine causes of hypertension are usually clinically evident by history and physical examination.

Treatment

1. Who to Treat

Hypertension from unilateral renal parenchymal disease and from many forms of vascular disease may respond to surgical correction, al-

Table 5. Oral and Parenteral Drug Dosages for Management of Acute Hypertension in Children

	Oral	Parenteral
Hydrochlorothiazide	2-4 mg/kg/d Divided q 12 h	—
Ethacrynic Acid	2-3 mg/kg/d Given q.d.	1-3 mg/kg IV
Furosemide	2-3 mg/kg/d Given q.d.	1-3 mg/kg IV
Methyldopa	10-40 mg/kg/d Divided q 12 h	5-10 mg/kg IV repeat q 6 h
Reserpine	—	0.05 mg/kg IM repeat q 8-24 h
Hydralazine	0.75-5.0 mg/kg/d Divided q 6 h	0.2-1.0 mg/kg IV or IM repeat q 6 h
Diazoxide	—	3-5 mg/kg IV

though some authors still prefer medical management. In the author's experience, neonatal hypertension from renal artery thrombosis usually responds to conservative medical management. Hypertension from bilateral parenchymal disease and from certain types of vascular disease may not be amenable to surgical treatment but often responds well to antihypertensive medical therapy.

Patients who are symptomatic from hypertension should be treated. The management of the asymptomatic patient is unclear. It seems reasonable that moderate to severe diastolic hypertension merits treatment even in the absence of symptoms because of the risk of significant morbidity and mortality reported in children and adults.[11,12] Until data are available regarding management of the asymptomatic patient with diastolic pressures less than 5 to 10 mmHg above normal, no recommendation for or against pharmacologic intervention can be made. However, clearly these patients must be closely followed and counseled, whenever appropriate, regarding weight loss in the presence of obesity, reduction of sodium intake, and avoidance of drugs with pressor effects such as common cold medications containing ephedrine, epinephrine, etc.

2. Some General Principles

Table 5 lists some commonly used antihypertensive drugs and their dosages for children. A few notes about treatment: (1) It is best to view hypertension as the cumulative effect of multiple factors such as cardiac output, peripheral vascular resistance, blood volume, stress, etc, and to aim at correcting what appears to be the most predominant factor or factors in the pathogenesis of the hypertension. Hence, a patient with marked renal insufficiency, edema, and weight gain may have volume overload hypertension which would appropriately be treated initially with sodium restriction and diuretics. (2) Be familiar with drug pharmacology, site of action, range of dosages, onset of action, time of maximal effect, and side effects. (3) Start with one drug at a low dosage and gradually increase the dosage to reach effect. Change to another drug if no effect is seen or add another drug if maximum antihypertensive effect is not reached at the time toxicity develops. Again begin the second drug at a low dosage and gradually increase until blood pressure is brought under control or until toxicity occurs. (4) Diuretics are often useful in the treatment of mild hypertension or in

conjunction with other drugs when they seem to exert a potentiating effect. (5) The Veteran's Administration Cooperative Study Group showed a significant reduction in mortality and morbidity when hypertensive patients were treated.[11] Although data are limited in children, there is no reason to assume that children should respond any differently. It is well known that without treatment, children with diastolic pressures greater than 110 mm Hg have a 90 percent mortality rate within a year.[12]

3. Management of Acute Hypertension

In the management of mild to moderate acute hypertension, diuretics such as hydrochlorothiazide are often useful. Hydralazine, either orally or parenterally (if more rapid effect is desired) may be added if the response to diuretics is inadequate.

Severe acute hypertension may be treated initially by hydralazine, a potent vasodilator which acts within 10 to 20 minutes when given parenterally. Since the response to hydralazine is variable, it is prudent to start with a low dosage of 0.2 mg/kg intravenously or intramuscularly, and repeat every 20 to 30 minutes (to a maximum cumulative dose of 1 mg/kg) until a response occurs or toxicity ensues (flushing, tachycardia, headache, vomiting, diarrhea).

If response to hydralazine is inadequate, one should use either rapid intravenous administration of diazoxide 3 to 5 mg/kg or reserpine .05 mg/kg intramuscularly. Diazoxide is an extremely potent vasodilator, acting within seconds, with a duration of 4 to 12 hours. Significant side effects include hypotension and hyperglycemia. Reserpine acts through depletion of tissue catecholamines and is a potent antihypertensive agent. Onset of action is usually within two hours. The drug may be repeated as needed in 6 to 12 hours. It should not be used in the newborn where nasal stuffiness may cause airway obstruction. Instead of diazoxide or reserpine, methyldopa 5 to 10 mg/kg/dose, may be slowly administered intravenously over 20 minutes in the event of failure of response to hydralazine. Some authors, however, feel methyldopa acts too slowly for the effective treatment of acute severe hypertension. Once the blood pressure is under control, lower drug dosages often prove effective.

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References

1. Londe S: Blood pressure in children as determined under office conditions. Clin Pediatr 5:71, 1966
2. Loggie JMH: Systemic hypertension in children and adolescents. Pediatr Clin North Am 18:1273, 1971
3. Rance CP, Arbus GS, Balfe JW, et al: Persistent systemic hypertension in infants and children. Pediatr Clin North Am 21:801, 1974
4. Lauer RM, Connor WE, Leaverton PS, et al: Coronary heart disease risk factors in school children: The Muscatine study. J Pediatr 86:697, 1975
5. Adelman RD, Goetzman B, Vogel J, et al: Neonatal renovascular hypertension: A non-surgical approach. Pediatr Res 10:434, 1976
6. Pazdral PT, Lieberman HM, Pazdral WE, et al: Awareness of pediatric hypertension: Measuring blood pressure. JAMA 235:2320, 1976
7. Lieberman E: Children with hypertension. Am Fam Physician 12:99, 1975
8. Londe S, Bourgoignie J, Robson A, et al: Hypertension in apparently normal children. J Pediatr 78:569, 1971
9. Eyler WR, Clark MD, Garmon JE, et al: Angiography of the renal areas including a comparative study of renal arterial stenosis in patients with and without hypertension. Radiology 78:879, 1962
10. Juncos LI, Strong CG, Hunt JC: Prediction of results of surgery for renal and renovascular hypertension. Arch Intern Med 134:655, 1974
11. Veteran's Administration Cooperative Study Group on Antihypertensive Agents: Effects of treatment on morbidity in hypertension. JAMA 202:1028, 1967
12. Still JL, Cotton D: Severe hypertension in childhood. Arch Dis Child 42:34, 1967