Evaluation and Management of Hypertension in Childhood
Written by

Joseph T. Flynn, M.D.
Director, Pediatric Hypertension Program

Division of Pediatric Nephrology
Montefiore Medical Center
111 East 210th Street
Bronx, NY 10467
Fax: 718.652.3136

<u>And modified by Ellin Lieberman, M.D.</u>

The most commonly used definitions of normal and abnormal blood pressure (BP_) in childhood were published in the Second Task Force Report (2). Data from 9 studies involving 70,000 children in the United States and United Kingdom were summarized, and age-specific BP percentile curves were generated. Normal BP was defined as systolic and diastolic BP readings below the 90th percentile for age, and hypertension was defined as systolic and diastolic BP readings > 95th percentile for age. To avoid over-diagnosis of hypertension, and because the incidence of hypertension in childhood is < 5% (4,5), at least 3 abnormal readings, obtained on separate occasions, should be obtained before considering a diagnosis of "hypertension" in an individual patient.

The Second Task Force data have been refined and height is thought to be the most important variable in determining whether a particular child has an elevated BP. . The actual definitions of normal BP and hypertension from the Second Task Force report were retained, but new tables of normal BP levels based on height percentiles were made(Tables 1 and 2).

Defining normal BP in infants, particularly newborns, is more difficult; it was reviewed in elsewhere

(7).

Importance of Identifying Hypertensive Children - Blood Pressure Tracking

What does it mean if a child has one or a few elevated BP readings? Do these children need specific follow-up?

Data are not definitive; however, many authors argue that such children may be destined for adult high BP.. This concept,is known as BP "tracking" has extensively studied. (8-11), One important study is the Muscatine study (8), [2445 children aged 7-18y in Muscatine, Iowa had family histories, BP, and other vital signs such as height and weight recorded between 1971-8. A group of them was then restudied as young adults (age 23-28y) for repeat assessment. Those who had systolic BP > the 90th percentile in childhood were 4 times more likely to develop adult hypertension than subjects without elevated systolic BP in childhood. Subjects with diastolic BP > t90th percentile in childhood were twice as likely to develop adult hypertension .Furthermore, the likelihood of developing adult hypertension increased with increasing numbers of childhood readings > 90th percentile, and the absence of abnormal readings in childhood was associated with a reduced risk of developing adult hypertension. Other important influences on adult BP were body mass and a positive family history of hypertension.

Etiology of Hypertension in Children

Overall, most childhood hypertension is secondary; that is, caused by another underlying disorder, which in most cases will be renal disease (14-18; Table 3). Essential or primary hypertension becomes more prevalent with increasing age. The distribution of causes of childhood hypertension

seen at a specific center or by a given practitioner varies according to the practice setting (primary vs. referral The diagnostic challenge in the non-referral setting therefore becomes making sure that children with secondary causes of hypertension are not diagnosed as having essential or primary hypertension.

As with the definition of hypertension, infants (< one year of age) are a unique population with respect to the causes of hypertension. Coarctation of the aorta and renovascular disease constitute the most frequent causes of hypertension (Table 3), with other diagnoses such as structural renal disease and bronchopulmonary dysplasia also being relatively frequent (7). Most infants with renovascular hypertension have a history of umbilical catheter placement (15),

Evaluation of the Child with Suspected Hypertension

One of the most important steps in the evaluation of children with suspected hypertension is to ensure that the BPs being measured correctly (2). A conventional mercury column or aneroid sphygmomanometer should be used in school-aged children and teenagers. Although less accurate, an automated, oscillometric device such as the Dynamap® (Critikon Inc., Tampa, FL), can be used in infants and toddlers who will not cooperate with manual BP determinastion.

The bladder of the cuff should encircle 80-100% of the circumference of the upper arm, and its width should be at 40% of the upper arm circumference (3). Since too narrow of a cuff will create false reading, children with longer upper arms than others of the same age require a wider cuff. Not to be overlooked is a large adult or thigh cuff for use in obese children. The child should be seated quietly for at least 5 minutes prior to BP determination. The arm should be supported at heart level. Infants' blood pressures should be obtained in the supine position. The disappearance of the 5th heart sound is now preferred for the diastolic reading (3).

If a child has been a persistently elevated BP, the first step is to obtain a thorough history, which

usually begins with asking whether any symptoms suggestive of hypertension exist such as headaches, dizziness, diplopia, vomiting, or nosebleed. The interview should then focus on whether symptoms of another underlying disorder are present, including symptoms of underlying renal disease (enuresis, gross hematuria, edema, fatigue), heart disease (chest pain, exertional dyspnea, palpitations), or diseases affecting other organ systems (endocrinologic, rheumatologic, etc.). The past history should include recent as well as chronic illnesses, prior hospitalizations or episodes of trauma, recurrent urinary tract infections or unexplained fevers and neonatal history of umbilical line placement (in infants). A family history of hypertension, diabetes, renal disease and other cardiovascular disease (hyperlipidemia, stroke) should be obtained.. Finally, it is important to ask about over-the-counter, prescription and illicit drug use, as many agents can either cause or exacerbate hypertension.

Physical examination includes the child's height and weight percentiles. Following this, 4 extremity BP are taken; The remainder of the physical examination should focus on discovering specific findings that may provide clues to the etiology and/or degree of hypertension. Common examples of such findings are listed in Table 4.

Many hypertensive children have normal physical examinations, even in the presence of significant underlying renal or other organ system disease. Therefore, laboratory testing is usually necessary in

order to complete the child's evaluation. Before starting
on laboratory testing, however, the child's age, history, physical exam findings, and degree of blood pressure elevation should be used to decide what are the best studies for the particular child. Dividing the laboratory evaluation into screening, specific and specialized phases as outlined in Table 5 is helpful .

All hypertensive children should undergo the screening laboratory tests listed. These can easily be obtained in most primary care office settings or in community hospitals, and will usually detect whether significant renal disease or another chronic illness is present. Of the more specific tests, only those indicated by the history, physical examination and screening tests should be obtained. For example, chest radiographs need only be obtained in hypertensive children with heart murmurs, or those with a gradient of more than 30 mmHg between the upper and lower extremity BP
An exception would be the echocardiogram, which should be obtained in any hypertensive child because left ventricular hypertrophy can be present even in children with mild hypertension (21,22). On the other hand, renal ultrasounds probably only need to be obtained in preadolescent children with hypertension, and in hypertensive adolescents with abnormal urinalyses or unusually severe hypertension. It may be helpful to consult a specialist with experience in pediatric hypertension at this stage of the evaluation, especially if one or more of the screening studies was abnormal.

The specialized studies listed in Table 5 are typically done at referral centers, or by pediatric sub-specialists with extensive experience managing hypertensive children. Several of these are used to investigate the possibility of renal artery stenosis, which as discussed earlier is a relatively common cause of hypertension in children with secondary hypertension (Table 3). While a detailed discussion of the relative merits of these procedures is beyond the scope of this review, it is important to note

that since renal artery stenosis in children is typically caused by fibromuscular dysplasia (23), angiography is still the gold standard for diagnosis because of its superior ability to detect branch vessel disease, especially in infants and young children (24). Magnetic resonance angiography, which is finding increased use for evaluation of hypertension in adults (25) may have a role in the adolescent or older child who can cooperate with the procedure. However, if the magnetic resonance angiogram reveals the presence of renal artery stenosis, the child may still need to undergo an angiogram prior to revascularization surgery.

One other diagnostic study that deserves specific mention is ambulatory blood pressure monitoring (ABPM). In this procedure, the subject wears a blood pressure cuff that takes BP at regular intervals for an entire day. Lightweight devices and a variety of cuff sizes are widely available, making it possible to obtain ABPM studies in young children as well as teenagers (25).

Finally, no diagnostic evaluation of a hypertensive child would be complete without including one or more studies to assess for the presence of end-organ damage (29). Although hypertension itself is virtually unknown as a cause of chronic renal failure in childhood, both left ventricular hypertrophy and retinal changes are relatively common, even in children with essential hypertension (21,22,30). As will be discussed later, if such abnormalities are present, the child will likely require antihypertensive drug treatment.

Treatment of childhood hypertension

effective treatment of hypertensive children requires a comprehensive approach incorporating patient/family education, non-pharmacologic measures, and antihypertensive medications, as well as monitoring for medication side effects and treatment response. This

can be a time-consuming endeavor but it is essential to include all components, as hypertension can be a lifelong problem for many children and adolescents, particularly those with secondary forms of hypertension.

Generally, treatment should begin with non-pharmacologic measures such as weight loss, aerobic exercise and dietary modifications such as sodium restriction (2,3,29). Obese children clearly respond well to weight loss; both systolic and diastolic blood pressure reduction has been demonstrated in controlled settings (31,32). Unfortunately, successful weight loss is difficult to achieve, especially in the primary care setting. It may be appropriate to refer such children to comprehensive weight loss programs that include not only nutritional intervention, but also exercise and family counseling (33,34). Exercise is frequently recommended as a treatment for hypertension, and clearly does have a role in the management of hypertensive children (29,35). Reviews of the effects of exercise on blood pressure have demonstrated a blood pressure-lowering effect in both normotensive and hypertensive individuals (36). It is important to emphasize that aerobic exercise activities such as running, walking, or cycling are the preferred forms of exercise in the management of hypertension, as static exercise activities can lead to dangerous acute blood pressure elevation (35). It is usually possible to find some form of aerobic exercise that the child enjoys and incorporate it into the child's treatment plan. Frequently the child is already participating in an appropriate activity on occasion and will only need to increase the amount of time they spend in that activity to achieve an antihypertensive effect.

The role of dietary modification in the treatment of hypertension has received a great deal of attention, most of which has focused on the role of sodium. Whether or not excessive sodium intake

actually causes hypertension is a still unresolved debate (37). However, many individuals with hypertension, children included, are “salt-sensitive,” and will probably benefit from a reduction in their sodium intake (38,39). Other dietary constituents that have been examined with respect to hypertension include potassium and calcium, both of which have been demonstrated to have antihypertensive effects (39-43). Therefore a diet that is low in sodium content but enriched in potassium and calcium may be even more effective than a diet that restricts sodium only. An example of such a diet is the so-called “DASH” diet, which has been shown to have a clear blood pressure-lowering effect in adults with hypertension, even in those receiving antihypertensive medication (44). Although this diet has not been specifically studied in children, if used under the supervision of a registered pediatric dietitian, the basic elements of the DASH diet should be easily adaptable to the treatment of hypertensive children. The DASH diet also incorporates measures designed to reduce dietary fat intake, an important strategy given the frequent presence of both hypertension and elevated lipids in children and adolescents (13).

Deciding which children require antihypertensive drug treatment is the most crucial step in the management of children with hypertension. Generally, any child with symptomatic hypertension, end organ damage, or who fails non-pharmacologic measures deserves drug therapy (29,45). Other factors such as the presence of obesity and/or a family history of hypertension may also influence the decision to treat. The following quote from the Second Task Force Report (2) is appropriate to keep in mind whenever contemplating starting a child on antihypertensive medications: "Major questions still remain unresolved with regard to the long-term effects of drug treatment on children and adolescents…a definite need must be established before [antihypertensive] therapy...is introduced during the 1st or 2nd decade of life." Given this, consultation with a specialist experienced in managing childhood

hypertension is recommended at the initiation of drug therapy.

Some general principles should be followed in the treatment of hypertensive children when drug therapy is deemed necessary. First and foremost of these is that non-pharmacologic measures should be incorporated into every hypertensive child's treatment plan. As noted above, weight loss, aerobic exercise and dietary modifications can play an important role in the management of hypertension. The second important principle is that drug therapy should be designed to maximize compliance and minimize adverse effects. This means that drugs with longer duration of action should be chosen over those with shorter duration, and that agents with predictable adverse effects should be avoided (for example, avoidance of diuretics in teen athletes).

As in adults, the "stepped care" approach has been recommended for children treated with antihypertensive medications (2,29,45,46). Utilizing this approach, the dose of the initial agent chosen is increased until either the blood pressure is controlled, the maximal dose is reached or side effects appear, then a second agent of a different pharmacologic class added and its dose increased as with the first agent, and so on. If possible, the initial agent chosen should be directed at the underlying pathophysiology of the child's hypertension (45); for example, a vasodilator or diuretic would be appropriate in the case of hypertension related to acute glomerulonephritis. The goal of treatment should be reduction of blood pressure to below the 90th percentile for age and gender (2). As noted above, effective therapy should also be designed to maximize compliance and minimize side effects.

A challenge perhaps more significant than deciding which child to treat with antihypertensive medications is the decision of which agent to choose as the initial agent, particularly in

children with essential hypertension. Whereas there are many studies comparing different antihypertensive regimens in adults, no such comparative studies have ever been conducted in children. Although a few studies of the efficacy and safety of antihypertensive medications in children have been published, until recently most of these data have been retrospective in nature (47,48). Furthermore, pediatric dosing recommendations have been published for only a handful of agents, mostly older agents that have fallen out of favor in the modern management of hypertension (48,49). Given this, it is difficult to make specific recommendations at this juncture, other than to note that recent publications have focused on calcium channel antagonists and angiotensin converting enzyme inhibitors as suitable initial choices (3,45,46). Recommended pediatric doses for selected antihypertensive agents are listed in Table 6. As noted in the table, there are very few commercially available suspension formulations of antihypertensive medications, which has lead to frequent compounding of so-called "extemporaneous" suspensions for use in infants and younger children; fortunately, stability data for some of these suspensions have recently been published (50,51).

Important adjunctive aspects to the drug therapy of childhood hypertension include ongoing monitoring of blood pressure (especially home blood pressure monitoring), surveillance for medication side effects, periodic monitoring of electrolytes in children treated with angiotensin converting enzyme inhibitors or diuretics, counseling regarding other cardiovascular risk factors, and continual emphasis on non-pharmacologic measures. It may also be appropriate to consider "step-down" therapy in selected patients. This involves an attempt at gradual reduction in medication after an extended course of good blood pressure control, with the eventual goal of completely discontinuing drug therapy. Children with essential hypertension, especially obese children who

successfully lose weight, are the best candidates for the step-down approach. Such patients usually require continued blood pressure monitoring after the cessation of drug therapy, as well as continued non-pharmacologic treatment.

Finally, there are some children who will require surgical intervention for their hypertension. Such patients are typically those with renovascular hypertension, aortic coarctation, or other secondary forms of hypertension. They should be referred to a children's hospital or other tertiary center where appropriate pediatric surgical and medical specialists are available.

Conclusions

Blood pressure elevation in childhood may be the first clue to underlying renal or other organ system pathology, or simply a warning sign of future cardiovascular risk. Careful measurement of blood pressure and thorough evaluation of children with sustained blood pressure elevation should allow identification of those who require treatment. While few data exist regarding the optimal agents for treatment of hypertensive children, usually a combination of pharmacologic and non-pharmacologic measures will result in satisfactory control of hypertension while allowing a normal quality of life.

References

1. The Task Force on Blood Pressure Control in Childhood: Report of the Task Force. Pediatrics 1977; 59:797-820.
2. Task force on Blood Pressure Control in Children. Report of the second task force on blood pressure control in children - 1987. Pediatrics 1987; 79:1-25.
3. National High Blood Pressure Education Program Working Group. Update on the 1987 Task Force Report on High Blood Pressure in Children and Adolescents: A working group report from the National High Blood Pressure Education Program. Pediatrics 1996; 98:649-58.
4. Munger R, Prineas R, Gomez-Marin O. Persistent elevation of blood pressure among children with a family history of hypertension: The Minneapolis Children's Blood Pressure Study. J Hypertens 1988; 6:647-53.
5. Sinaiko AR, Gomez-Marin O, Prineas RJ. Prevalence of "significant" hypertension in junior high school-aged children: the Children and Adolescent Blood Pressure Program. J Pediatr 1989; 114:664-9.
6. Hansen HS, Hyldebrandt N, Nielsen JR, Froberg K. Blood pressure distribution in a school-age population aged 8-10 years: the Odense schoolchild study. J Hypertens 1990; 8:641-6.
7. Flynn JT. Neonatal hypertension: diagnosis and management. Pediatr Nephrol 2000;14:332-41.
8. Lauer RM, Clarke WR. Childhood risk factors for adult blood pressure: the Muscatine Study. Pediatrics 1989; 84:633-41.
9. Shear CL, Burke GL, Freedman DS, Berenson GS. Value of childhood blood pressure measurements and family history in predicting future blood pressure status: results from

8 years of follow-up in the Bogalusa Heart Study. Pediatrics 1986; 77:862-9.

10. Bao W, Threefoot SA, Srinivasan SR, Berenson GS. Essential hypertension predicted by tracking of elevated blood pressure from childhood to adulthood: The Bogalusa Heart Study. Am J Hypertens 1995; 8:657-65
11. Paffenbarger RS, Thorne MC, Wing AL. Chronic disease in former college students. VIII. Characteristics in youth predisposing to hypertension in later years. Am J Epidemiol 1968; 88:25-32.
12. Sagie A, Larson MG, Levy D. The natural history of borderline isolated systolic hypertension. N Engl J Med 1993; 329:1912-7.
13. Gidding SS. Relationships between blood pressure and lipids in childhood. Pediatr Clin N Am 1993; 40:41-9.
14. Hanna JD, Chan JCM, Gill JR. Hypertension and the kidney. J Pediatr 1991; 118:327-39.
15. Arar MY, Hogg RJ, Arant Jr BS, Seikaly MG. Etiology of sustained hypertension in children in the southwestern United States. Pediatr Nephrol 1994; 8:186-9.
16. Feld LG, Springate JE. Hypertension in children. Curr Probl Pediatr 1988; 18:317-373.
17. McCrory WW. Definition, prevalence and distribution of causes of hypertension. In: Loggie JMH, ed. Pediatric and Adolescent Hypertension. Boston; Blackwell Scientific Publications, 1992:104-11.
18. Wyszynska T, Cichocka E, Wieteska-Klimczak A, Jobs K, Januszewicz P. A single center experience with 1025 children with hypertension. Acta Pædiatrica, 1992; 81:244-6.
19. Plumer LB, Kaplan GW, Mendoza SA. Hypertension in infants – a complication of umbilical arterial catheterization. J Pediatr 1976; 89:802–5.
20. Merten DF, Vogel JM, Adelman RD, Goetzman, BW, Bogren HG. Renovascular hypertension as a complication of umbilical arterial catheterization. Radiology 1978;

126:751–7.

21. Zahka KG, Neill CA, Kidd L, Cutilletta MA, Cutilletta AF. Cardiac involvement in adolescent hypertension: Echocardiographic determination of myocardial hypertrophy. Hypertension 1981; 3:664-8.
22. Laird WP, Fixler DE. Left ventricular hypertrophy in adolescents with elevated blood pressure: Assessment by chest roentgenography, electrocardiography and echocardiography. Pediatrics 1981; 67:255-9.
23. Deal JE, Snell MF, Barratt TM, Dillon MJ. Renovascular disease in childhood. J Pediatr 1992; 121:378–84.
24. Prince MR. Renal MR angiography: a comprehensive approach. J Magn Reson Imaging 1998; 8:511-6.
25. Sorof JM, Portman RJ. Ambulatory blood pressure monitoring in the pediatric patient. J Pediatr 2000; 136:578-86.
26. Belsha CW. Ambulatory blood pressure monitoring and hypertensive target-organ damage in children. Blood Press Monit 1999; 4:161-4.
27. Flynn JT. Impact of ambulatory blood pressure monitoring on the management of hypertension in children. Blood Press Monit 2000; in press.
28. Flynn JT. Use of ambulatory blood pressure monitoring (ABPM) to differentiate between primary and secondary hypertension (HTN) in children (abstract). Pediatr Res 2000; 47(4, pt. 2):446A.
29. Falkner B, Tannenbaum J. Decision-making in childhood hypertension. In: Bühler FR, Laragh JH, eds. Handbook of Hypertension, Vol. 13: The management of hypertension. Elsevier Science Publishers, 1990:495-508.
30. Daniels SR, Lipman MJ, Burke MJ, Loggie JMH. The prevalence of retinal vascular

abnormalities in children and adolescents with essential hypertension. Am J Opthalmol 1991; 111:205-8.

31. Brownell KD, Kelman JH, Stunkard AJ. Treatment of obese children with and without their mothers: changes in weight and blood pressure. Pediatrics 1983; 71:515-23.
32. Rocchini AP, Katch V, Anderson J, et al. Blood pressure in obese adolescents: effect of weight loss. Pediatrics 1988; 82:16-23.
33. Williams CL, Campanaro LA, Squillace M, Bollella M. Management of childhood obesity in pediatric practice. Ann N Y Acad Sci 1997; 817:225-40.
34. Pinelli L, Elerdini N, Faith MS, et al. Childhood obesity: results of a multicenter study of obesity treatment in Italy. J Pediatr Endocrinol Metab 1999; 12(Suppl 3):795-9.
35. Alpert BS, Fox ME. Hypertension. In: Goldberg B, ed. Sports and Exercise for Children with Chronic Health Conditions. Champaign, IL; Human Kinetics, 1995:197-205.
36. Arrol B, Beaglehole R. Does physical activity lower blood pressure: a critical review of the clinical trials. J Clin Epidemiol 1992; 45:439-47.
37. Dustan HP, Kirk KA. Corcoran lecture: the case for or against salt in hypertension. Hypertension 1989; 13(6 Pt 2):696-705.
38. Weinberger MH. Salt sensitivity of blood pressure in humans. Hypertension 1996; 27(3 Pt 2):481-90.
39. Cutler JA. The effects of reducing sodium and increasing potassium intake for control of hypertension and improving health. Clin & Exp Hypertens 1999; 21:769-83.
40. Gillman MW, Oliveria SA, Moore LL, Ellison RC. Inverse association of dietary calcium with systolic blood pressure in young children. J Am Med Assoc 1992; 267:2340-3.
41. Gillman MW, Hood MY, Moore LL, et al. Effect of calcium supplementation on blood pressure in children. J Pediatr 1995; 127:186-92.

42. Suter PM. Potassium and hypertension. Nutr Rev 1998; 56(5 Pt 1):151-3.

43. Kawano Y, Minami J, Takishita S, Omae T. Effects of potassium supplementation on office, home, and 24-h blood pressure in patients with essential hypertension. Am J Hypertens 1998; 11:1141-6.

44. Appel LJ, Moore TJ, Obarzanek E, et al. A clinical trial of the effects of dietary patterns on blood pressure. N Engl J Med 1997; 336:1117-24.

45. Balfe JW, Levin L, Raddle IC. Hypertension and its treatment. In: Raddle IC, MacLleod SM, eds. Pediatric Pharmacology and Therapeutics, 2nd ed. St. Louis; Mosby, 1993:573-97.

46. Sinaiko AR. Treatment of hypertension in children. Pediatr Nephrol 1994; 8:603-9.

47. Schreiner MS. Safety and effectiveness data: will children gain access? Am Ht J 1998; 136:4-5.

48. Flynn JT. Pediatric use of antihypertensive medications: much more to learn. In press, Curr Ther Res.

49. Physicians' Desk Reference®, 54th edition, Medical Economics Company, Montvale, NJ, 2000.

50. MacDonald JL, Johnson CE, Jacobson P. Stability of isradipine in an extemporaneously compounded oral liquid. Am J Hosp Pharm 1994; 51:2409-11.

51. Nahata MC, Morosco RS, Hipple TF. Stability of amlodipine besylate in two liquid dosage forms. J Am Pharm Assoc 1999; 39:375-77.

Table 1. 90th and 95th percentile blood pressures for boys aged 1-17 years by height percentile[1]

		Systolic BP (mmHg)							**Diastolic BP (mmHg)**						
Height[2] Age	BP	5%	10%	25%	50%	75%	90%	95%	5%	10%	25%	50%	75%	90%	95%
1	**90th**	94	95	97	98	100	102	102	50	51	52	53	54	54	55
	95th	98	99	101	102	104	106	106	55	55	56	57	58	59	59
2	**90th**	98	99	100	102	104	105	106	55	55	56	57	58	59	59
	95th	101	102	104	106	108	109	110	59	59	60	61	62	63	63
3	**90th**	100	101	103	105	107	108	109	59	59	60	61	62	63	63
	95th	104	105	107	109	111	112	113	63	63	64	65	66	67	67
4	**90th**	102	103	105	107	109	110	111	62	62	63	64	65	66	66
	95th	106	107	109	111	113	114	115	66	67	67	68	69	70	71
5	**90th**	104	105	106	108	110	112	112	65	65	66	67	68	69	69
	95th	108	109	110	112	114	115	116	69	70	70	71	72	73	74
6	**90th**	105	106	108	110	111	113	114	67	68	69	70	70	71	72
	95th	109	110	112	114	115	117	117	72	72	73	74	75	76	76
7	**90th**	106	107	109	111	113	114	115	69	70	71	72	72	73	74
	95th	110	111	113	115	116	118	119	74	74	75	76	77	78	78
8	**90th**	107	108	110	112	114	115	116	71	71	72	73	74	75	75
	95th	111	112	114	116	118	119	120	75	76	76	77	78	79	80
9	**90th**	109	110	112	113	115	117	117	72	73	73	74	75	76	77
	95th	113	114	116	117	119	121	121	76	77	78	79	80	80	81
10	**90th**	110	112	113	115	117	118	119	73	74	74	75	76	77	78
	95th	114	115	117	119	121	122	123	77	78	79	80	80	81	82
11	**90th**	112	113	115	117	119	120	121	74	74	75	76	77	78	78
	95th	116	117	119	121	123	124	125	78	79	79	80	81	82	83
12	**90th**	115	116	117	119	121	123	123	75	75	76	77	78	78	79
	95th	119	120	121	123	125	126	127	79	79	80	81	82	83	83
13	**90th**	117	118	120	122	124	125	126	75	76	76	77	78	79	80
	95th	121	122	124	126	128	129	130	79	80	81	82	83	83	84
14	**90th**	120	121	123	125	126	128	128	76	76	77	78	79	80	80
	95th	124	125	127	128	130	132	132	80	81	81	82	83	84	85
15	**90th**	123	124	125	127	129	131	131	77	77	78	79	80	81	81
	95th	127	128	129	131	133	134	135	81	82	83	83	84	85	86
16	**90th**	125	126	128	130	132	133	134	79	79	80	81	82	82	83
	95th	129	130	132	134	136	137	138	83	83	84	85	86	87	87
17	**90th**	128	129	131	133	134	136	136	81	81	82	83	84	85	85
	95th	132	133	135	136	138	140	140	85	85	86	87	88	89	89

Legend to Table 1:

[1]Reproduced by permission of Pediatrics (Ref. 2).

[2]Height percentile as determined by standard growth curves

Table 2. 90th and 95th percentile blood pressures for girls aged 1-17 years by height percentile[1]

		Systolic BP (mmHg)							Diastolic BP (mmHg)						
Age	Height[2] BP	5%	10%	25%	50%	75%	90%	95%	5%	10%	25%	50%	75%	90%	95%
1	**90th**	97	98	99	100	102	103	104	53	53	53	54	55	56	56
	95th	101	102	103	104	105	107	107	57	57	57	58	59	60	60
2	**90th**	99	99	100	102	103	104	105	57	57	58	58	59	60	61
	95th	102	103	104	105	107	108	109	61	61	62	62	63	64	65
3	**90th**	100	100	102	103	104	105	106	61	61	61	62	63	63	64
	95th	104	104	105	107	108	109	110	65	65	65	66	67	67	68
4	**90th**	101	102	103	104	106	107	108	63	63	64	65	65	66	67
	95th	105	106	107	108	109	111	111	67	67	68	69	69	70	71
5	**90th**	103	103	104	106	107	108	109	65	66	66	67	68	68	69
	95th	107	107	108	110	111	112	113	69	70	70	71	72	72	73
6	**90th**	104	105	106	107	109	110	111	67	67	68	69	69	70	71
	95th	108	109	110	111	112	114	114	71	71	72	73	73	74	75
7	**90th**	106	107	108	109	110	112	112	69	69	69	70	71	72	72
	95th	110	110	112	113	114	115	116	73	73	73	74	75	76	76
8	**90th**	108	109	110	111	112	113	114	70	70	71	71	72	73	74
	95th	112	112	113	115	116	117	118	74	74	75	75	76	77	78
9	**90th**	110	110	112	113	114	115	116	71	72	72	73	74	74	75
	95th	114	114	115	117	118	119	120	75	76	76	77	78	78	79
10	**90th**	112	112	114	115	116	117	118	73	73	73	74	75	76	76
	95th	116	116	117	119	120	121	122	77	77	77	78	79	80	80
11	**90th**	114	114	116	117	118	119	120	74	74	75	75	76	77	77
	95th	118	118	119	121	122	123	124	78	78	79	79	80	81	81
12	**90th**	116	116	118	119	120	121	122	75	75	76	76	77	78	78
	95th	120	120	121	123	124	125	126	79	79	80	80	81	82	82
13	**90th**	118	118	119	121	122	123	124	76	76	77	78	78	79	80
	95th	121	122	123	125	126	127	128	80	80	81	82	82	83	84
14	**90th**	119	120	121	122	124	125	126	77	77	78	79	79	80	81
	95th	123	124	125	126	128	129	130	81	81	82	83	83	84	85
15	**90th**	121	121	122	124	125	126	127	78	78	79	79	80	81	82
	95th	124	125	126	128	129	130	131	82	82	83	83	84	85	86
16	**90th**	122	122	123	125	126	127	128	79	79	79	80	81	82	82
	95th	125	126	127	128	130	131	132	83	83	83	84	85	86	86
17	**90th**	122	123	124	125	126	128	128	79	79	79	80	81	82	82
	95th	126	126	127	129	130	131	132	83	83	83	84	85	86	86

Legend to Table 2:

[1]Reproduced by permission of Pediatrics (Ref. 2).

[2]Height percentile as determined by standard growth curves

Table 3. Causes of Childhood Hypertension by Age Group[1]

	Infants[2]	School-age	Adolescents
Primary/Essential	**<1%**	**15-30%**	**85-95%**
Secondary	**99%**	**70-85%**	**5-15%**[3]
Renal Parenchymal Disease	**20%**	**60-70%**	
Renovascular	**25%**	**5-10%**	
Endocrine	**1%**	**3-5%**	
Aortic Coarctation	**35%**	**10-20%**	
Reflux Nephropathy	**0%**	**5-10%**	
Neoplastic	**4%**	**1-5%**	
Miscellaneous	**20%**	**1-5%**	

Legend to Table 3:

[1]Adapted from references 7,14-18.

[2]Less than one year of age.

[3]Breakdown of causes is generally similar to that for school-age children.

Table 4. Physical Exam findings in Childhood Hypertension

	Finding	Possible Etiology
Vital Signs	**Tachycardia** **Decreased LE pulses; drop in BP from UE's to LE's**	**Hyperthyroidism, Pheochromocytoma, Neuroblastoma, Essential Hypertension** **Aortic Coarctation**
Height/weight	**Growth retardation** **Obesity** **Truncal obesity**	**Chronic renal failure** **Primary hypertension** **Cushing's syndrome**
Head & Neck	**Moon facies** **Elfin facies** **Webbed neck** **Thyromegaly**	**Cushing's syndrome** **Williams syndrome** **Turner's syndrome** **Hyperthyroidism**
Skin	**Pallor, flushing, diaphoresis** **Acne, hirsutism, striae** **Cafe-au-lait spots** **Adenoma sebaceum** **Malar rash**	**Pheochromocytoma** **Cushing's syndrome, anabolic steroid abuse** **Neurofibromatosis** **Tuberous sclerosis** **Systemic Lupus Erythematosus**
Chest	**Widely spaced nipples** **Heart murmur** **Friction rub** **Apical heave**	**Turner's syndrome** **Coarctation** **Systemic Lupus Erythematosus (pericarditis)** **Left ventricular hypertrophy/chronic hypertension**
Abdomen	**Mass** **Epigastric/flank bruit** **Palpable kidneys**	**Wilms' tumor, Neuroblastoma, Pheochromocytoma** **Renal artery stenosis** **Polycystic kidney disease, hydronephrosis, Multicystic-dysplastic kidney**

Genitalia	Ambiguous/virilization	Adrenal hyperplasia
Extremities	Joint swelling Muscle weakness	Systemic Lupus Erythematosus Hyperaldosteronism, Liddle's syndrome

Legend to Table 4:

Abbreviations used in table: BP, blood pressure; LE, lower extremity; UE, upper extremity.

Table 5. Laboratory evaluation of the child with hypertension

Phase	Studies
Screening tests	**Urinalysis and culture** **Electrolytes, BUN, creatinine, glucose, calcium, phosphorus, uric acid** **Lipid panel (cholesterol, triglycerides, etc.)** **CBC with differential, platelet count**
Specific tests	**24 hour urine collection for protein excretion & creatinine clearance** **Urine and serum catecholamines** **Hormone levels (thyroid, adrenal, etc.)** **Echocardiogram** **Renal ultrasound**
Specialized studies	**Renin profiling (plasma renin & 24 hour urinary sodium excretion)** **Renal ultrasound with Doppler study of renal arteries** **Captopril challenge test** **Renal angiography with renal vein renins** **Magnetic resonance angiography** **Captopril renal scan** **Ambulatory blood pressure monitoring** **Renal biopsy**

Table 6. Antihypertensive agents useful for chronic treatment of childhood hypertension[1]

Class	Drug	Starting Dose	Usual Interval[2]	Maximum Dose	Other Comments
ACEI's	Captopril[3]	**0.5-1.0 mg/kg/dose**	**TID**	**6 mg/kg/day**	**Cough and hyperkalemia may occur**
	Enalapril	**0.2 mg/kg/dose**	**QD-BID**	**1 mg/kg/day up to 40 mg/day**	**As above**
	Lisinopril	**0.2 mg/kg/day**	**QD-BID**	**1 mg/kg/day**	**As above**
AT receptor antagonist	**Losartan**	**25 mg/day**	**QD-BID**	**100 mg/day**	**No pediatric data available**
α/β **antagonist**	**Labetalol[3]**	**2-3 mg/kg/day**	**BID**	**10-12 mg/kg/day up to 2.4 g/day**	**Relatively weak alpha effect in oral formulation**
β-**antagonists**	**Atenolol**	**0.5-1 mg/kg/day**	**QD-BID**	**2 mg/kg/day**	**Cardioselective; monitor for bradycardia**
	Metoprolol	**1-2 mg/kg/day**	**BID**	**6 mg/kg/day up to 450 mg/day**	**As above**
	Propranolol[4]	**1 mg/kg/day**	**BID-TID**	**16 mg/kg/day**	**Non-cardioselective; adverse CNS effects possible**
CCA's	**Amlodipine[3]**	**0.1-0.3 mg/kg/dose**	**QD-BID**	**0.6 mg/kg/day up to 20 mg/day**	**Long-acting; adjust dose every 5-7 days**
	Isradipine[3]	**0.05-0.15 mg/kg/dose**	**TID-QID**	**0.8 mg/kg/day up to 20 mg/day**	**Rapidly-acting; useful for both acute & chronic hypertension**
	Extended-release Nifedipine	**0.25-0.5 mg/kg/day**	**QD-BID**	**3 mg/kg/day up to 180 mg/day**	**Large tablet size limits use to older children**
Central α**-agonists**	**Transdermal Clonidine**	**0.1 mg**	**Q 5-7 days**	**0.3 mg**	**May cause transient sedation initially**
	Methyldopa[4]	**10 mg/kg/day**	**BID-TID**	**65 mg/kg/day up to 3 g/day**	**As above**
Diuretics	**Chlorothiazide[4]**	**10 mg/kg/day**	**BID-QID**	**40 mg/kg/d**	**Monitor electrolytes**
	Furosemide[4]	**0.5-2.0 mg/kg/dose**	**BID- QID**	**10-15 mg/kg/d**	**Usually reserved for acute hypertension from volume overload**
	Hydrochloro-thiazide[4]	**1 mg/kg/day**	**BID**	**4 mg/kg/day**	**Monitor electrolytes**
Peripheral α**-antagonists**	**Doxazosin**	**1 mg/day**	**QD**	**4 mg/day**	**Orthostatic hypotension common with first dose**
	Prazosin	**0.05-0.1 mg/kg/day**	**BID-TID**	**0.4 mg/kg/d up to 15 mg/day**	**As above**
	Terazosin	**1 mg/day**	**QD**	**16 mg/day**	**As above**
Vasodilators	**Hydralazine[3]**	**0.25 mg/kg/dose**	**TID-QID**	**7.5 mg/kg/day up to 200 mg/day**	**Tachycardia, fluid retention may occur**

	Minoxidil[3]	**0.1-0.2 mg/kg/dose**	**BID-TID**	**1 mg/kg/day up to 50 mg/day**	**Hypertrichosis, fluid retention common**

Legend to Table 6

Abbreviations used in table: ACEI's, angiotensin converting enzyme inhibitors; AT, angiotensin; BID, twice daily; CCA's, calcium channel antagonists; QD, once daily; QID, four times daily; TID, three times daily.

[1]Compiled from references 2,3,45,46,49

[2]Manufacturers' recommendation for adults followed by interval frequently used in children.

[3]Extemporaneous suspension may be compounded for use in infants and young children.

[4]Suspension formulation commercially available.