Childhood Hypertension
New Concepts, Definitions, and Diagnostic Evaluations

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Although the incidence of hypertension is low in children, its prevalence appears to be increasing.[1] This can be related to the increasing prevalence of obesity in children and the growing awareness in detection of hypertension. Essential hypertension has its antecedents during childhood. It has become clear that hypertension begins in childhood and adolescence and can contribute to the early development of cardiovascular diseases. Left ventricular hypertrophy is the most detected evidence of cardiovascular diseases in childhood hypertension. In its severe cases, there is an increasing risk of developing hypertensive encephalopathy, cerebrovascular accidents, and congestive heart failure. Based upon these observations, identifying children at risk of hypertension could have an important impact on the long-term outcomes of cardiovascular diseases.

The definition of childhood hypertension is statistically based on the normative distribution of blood pressure (BP) in healthy children. The following definitions based on the National High Blood Pressure Education Program (NHBPEP) Working Group recommendations are used to classify BP measurements. In this approach, physiological effects of age and body size on BP during childhood are considered.[1] Since height is the closest covariate of BP among the different measures of body size, the 95th percentile of systolic BP and diastolic BP at a given height in each sex is used to define arterial hypertension in children.[2]

The NHBPEP classification of hypertension in children and adolescents is summarized in Table 1. There are 2 new additional terms in this classification that can help the physician to allocate the extent of urgency of laboratory investigations and establishment of medical therapy. Stage 1 hypertension allows time for evaluation before initiating treatment unless the patient is symptomatic, stage 2 hypertension needs more prompt evaluation and medical therapy, and symptomatic patients require immediate treatment and refer to pediatric nephrologists. There are detailed tables that define cutoff point pressure of the 95th percentile according to the NHBPEP report on the basis of age, height, and sex. Table 2 is adopted from these measures.[1]

For using this blood pressure table, 4 steps

Table 1. Classification of Hypertension in Children and Adolescents[1]

Stage	Definition
Normal	Systolic and diastolic BPs lower than the 90th percentile for age and sex
Prehypertension	Systolic and/or diastolic BP higher than the 90th percentile, but lower than the 95th percentile, or if BP exceeds 120/80 mm Hg, even if lower than the 90th percentile*
Stage 1 hypertension	Systolic and/or diastolic BP(s) between the 95th percentile and 5 mm Hg above the 99th percentile
Stage 2 hypertension	Systolic and/or diastolic BP(s) higher than the 99th percentile plus 5 mm Hg

*A systolic pressure of 120 mm Hg may typically occur at 12 years of age, while a diastolic pressure of 80 mm Hg typically occurs at 16 years of age.

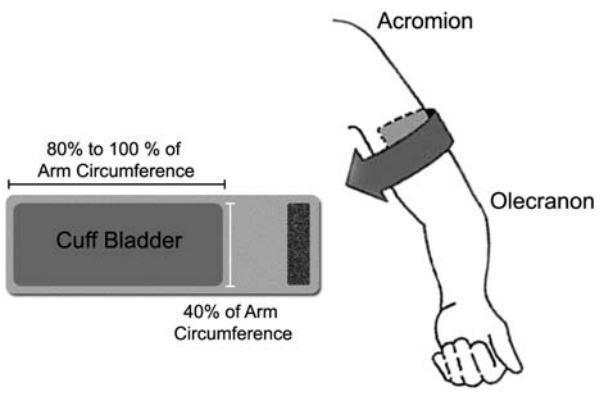
Table 2. Blood Pressure Levels for Boys and Girls by Age and Height Percentiles

Age, y	BP per-centile	Systolic/Diastolic Blood Pressure, mm Hg												
		Percentile of Height in Boys							Percentile of Height in Girls					
		5th	10th	25th	50th	75th	90th	95th	5th	10th	25th	50th	75th	90th	95th
1	90th	94/49	95/50	97/51	99/52	100/53	102/53	103/54	97/52	97/53	98/53	100/54	101/55	102/55	103/56
	95th	98/54	99/54	101/55	103/56	104/57	106/58	106/58	100/56	101/57	102/57	104/58	105/59	106/59	107/60
	99th	105/61	106/62	108/63	110/64	112/65	113/66	114/66	108/64	108/64	109/65	111/65	112/66	113/67	114/67
2	90th	97/54	99/55	100/56	102/57	104/58	105/58	106/59	98/57	99/58	100/58	101/59	103/60	104/61	105/61
	95th	101/59	102/59	104/60	106/61	108/62	109/63	110/63	102/61	103/62	104/62	105/63	107/64	108/65	109/65
	99th	109/66	110/67	111/68	113/69	115/70	117/71	117/71	109/69	110/69	111/70	112/70	114/71	115/72	116/72
3	90th	100/59	101/59	103/60	105/61	107/62	108/63	109/63	100/61	100/62	102/62	103/63	104/64	106/64	106/65
	95th	104/63	105/63	107/64	109/65	110/66	112/67	113/67	104/65	104/66	105/66	107/67	108/68	109/68	110/69
	99th	111/71	112/71	114/72	116/73	118/74	119/75	120/75	111/73	111/73	113/74	114/74	115/75	116/76	117/76
4	90th	102/62	103/63	105/64	107/65	109/66	110/66	111/67	101/64	102/64	103/65	104/66	106/67	107/67	108/68
	95th	106/66	107/67	109/68	111/69	112/70	114/71	115/71	105/68	106/68	107/69	108/70	110/71	111/71	112/72
	99th	113/74	114/75	116/76	118/77	120/78	121/78	122/79	112/76	113/76	114/76	115/77	117/78	118/79	119/79
5	90th	104/65	105/66	106/67	108/68	110/69	111/69	112/70	103/66	103/67	105/67	106/68	107/69	109/69	109/70
	95th	108/69	109/70	110/71	112/72	114/73	115/74	116/74	107/70	107/71	108/71	110/72	111/73	112/73	113/74
	99th	115/77	116/78	118/79	120/80	121/81	123/81	123/82	114/78	114/78	116/79	117/79	118/80	120/81	120/81
6	90th	105/68	106/68	108/69	110/70	111/71	113/72	113/72	104/68	105/68	106/69	108/70	109/70	110/71	111/72
	95th	109/72	110/72	112/73	114/74	115/75	117/76	117/76	108/72	109/72	110/73	111/74	113/74	114/75	115/76
	99th	116/80	117/80	119/81	121/82	123/83	124/84	125/84	115/80	116/80	117/80	119/81	120/82	121/83	122/83
7	90th	106/70	107/70	109/71	111/72	113/73	114/74	115/74	106/69	107/70	108/70	109/71	111/72	112/72	113/73
	95th	110/74	111/74	113/75	115/76	117/77	118/78	119/78	110/73	111/74	112/74	113/75	115/76	116/76	116/77
	99th	117/82	118/82	120/83	122/84	124/85	125/86	126/86	117/81	118/81	119/82	120/82	122/83	123/84	124/84
8	90th	107/71	109/72	110/72	112/73	114/74	115/75	116/76	108/71	109/71	110/71	111/72	113/73	114/74	114/74
	95th	111/75	112/76	114/77	116/78	118/79	119/79	120/80	112/75	112/75	114/75	115/76	116/77	118/78	118/78
	99th	119/83	120/84	122/85	123/86	125/87	127/87	127/88	119/82	120/82	121/83	122/83	123/84	125/85	125/86
9	90th	109/72	110/73	112/74	114/75	115/76	117/76	118/77	110/72	110/72	112/72	113/73	114/74	116/75	116/75
	95th	113/76	114/77	116/78	118/79	119/80	121/81	121/81	114/76	114/76	115/76	117/77	118/78	119/79	120/79
	99th	120/84	121/85	123/86	125/87	127/88	128/88	129/89	121/83	121/83	123/84	124/84	125/85	127/86	127/87
10	90th	111/73	112/73	114/74	115/75	117/76	119/77	119/78	112/73	112/73	114/73	115/74	116/75	118/76	118/76
	95th	115/77	116/78	117/79	119/80	121/81	122/81	123/82	116/77	116/77	117/77	119/78	120/79	121/80	122/80
	99th	122/85	123/86	125/86	127/88	128/88	130/89	130/90	123/84	123/84	125/85	126/86	127/86	129/87	129/88
11	90th	113/74	114/74	115/75	117/76	119/77	120/78	121/78	114/74	114/74	116/74	117/75	118/76	119/77	120/77
	95th	117/78	118/78	119/79	121/80	123/81	124/82	125/82	118/78	118/78	119/78	121/79	122/80	123/81	124/81
	99th	124/86	125/86	127/87	129/88	130/89	132/90	132/90	125/85	125/85	126/86	128/87	129/87	130/88	131/89
12	90th	115/74	116/75	118/75	120/76	121/77	123/78	123/79	116/75	116/75	117/75	119/76	120/77	121/78	122/78
	95th	119/78	120/79	122/80	123/81	125/82	127/82	127/83	119/79	120/79	121/79	123/80	124/81	125/82	126/82
	99th	126/86	127/87	129/88	131/89	133/90	134/90	135/91	127/86	127/86	128/87	130/88	131/88	132/89	133/90
13	90th	117/75	118/75	120/76	122/77	124/78	125/79	126/79	117/76	118/76	119/76	121/77	122/78	123/79	124/79
	95th	121/79	122/79	124/80	126/81	128/82	129/83	130/83	121/80	122/80	123/80	124/81	126/82	127/83	128/83
	99th	128/87	130/87	131/88	133/89	135/90	136/91	137/91	128/87	129/87	130/88	132/89	133/89	134/90	135/91
14	90th	120/75	121/76	123/77	125/78	126/79	128/79	128/80	119/77	120/77	121/77	122/78	124/79	125/80	125/80
	95th	124/80	125/80	127/81	128/82	130/83	132/84	132/84	123/81	123/81	125/81	126/82	127/83	129/84	129/84
	99th	131/87	132/88	134/89	136/90	138/91	139/92	140/92	130/88	131/88	132/89	133/90	135/90	136/91	136/92
15	90th	122/76	124/77	125/78	127/79	129/80	130/80	131/81	120/78	121/78	122/78	123/79	125/80	126/81	127/81
	95th	126/81	127/81	129/82	131/83	133/84	134/85	135/85	124/82	125/82	126/82	127/83	129/84	130/85	131/85
	99th	134/88	135/89	136/90	138/91	140/92	142/93	142/93	131/89	132/89	133/90	134/91	136/91	137/92	138/93
16	90th	125/78	126/78	128/79	130/80	131/81	133/82	134/82	121/78	122/78	123/79	124/80	126/81	127/81	128/82
	95th	129/82	130/83	132/83	134/84	135/85	137/86	137/87	125/82	126/82	127/83	128/84	130/85	131/85	132/86
	99th	136/90	137/90	139/91	141/92	143/93	144/94	145/94	132/90	133/90	134/90	135/91	137/92	138/93	139/93
17	90th	127/80	128/80	130/81	132/82	134/83	135/84	136/84	122/78	122/79	123/79	125/80	126/81	127/81	128/82
	95th	131/84	132/85	134/86	136/87	138/87	139/88	140/89	125/82	126/83	127/83	129/84	130/85	131/85	132/86
	99th	139/92	140/93	141/93	143/94	145/95	146/96	147/97	133/90	133/90	134/91	136/91	137/92	138/93	139/93

*Adopted with permission from the National High Blood Pressure Education Program Working Group.[1]

should be followed: (1) using the standard height charts to determine the child height percentile, (2) measurement of the child's systolic BP and diastolic BP, (3) using the correct table for BP of boys and girls, and (4) finding the child's age on the left side of the table. For example, a systolic BP of 114 mm Hg and a diastolic BP of 73 are the upper normal limit (95th percentile) of BP for a 5-year-old boy whose height conform to the 75th percentile of height for his age.

The first and most important step in diagnosis of hypertension is an accurate technique for BP measurement. The importance of technique in BP measurement was illustrated in a comparison of normal BP readings reported by 10 different investigators in which the highest and lowest percentile values (5th and 95th) for boys differed by as much as 20 mm Hg.[3] Confounding factors included cuff size, the number of measurements, type of instruments, and patient position (supine or sitting). According to the NHBPEP, all children older than 3 years old who are seen in a medical setting should have their BP measured. An appropriate cuff size to the size of the child's upper arm is required for accurate measurement; cuff bladder length should be 80% to 100% of the arm midway circumference, and its width, about at least 40% of the arm midway circumference (Figure). The preferred method of BP measurement is auscultation using a standard clinical sphygmomanometer. The aneroid manometers are accurate, but they need to be calibrated on a semi-annual basis and should be used if a mercury manometer is not available (in some countries such as UK, usage of mercury manometer are prohibited). Confirmation of elevated BP on 3 repeated and separate visits (at least a week apart) are needed prior to the diagnosis of hypertension.[1] The BP should be measured after 5 minutes of rest in the seated position with the child's back and feet supported in a quiet environment. The BP should be taken with the patient's right arm supported at the level of the heart. The right arm is preferred in repeated measures of BP for consistency and comparison with standard tables.[4]



Blood pressure cuff showing size estimation based on arm circumference.

In contrast to adults, most cases of hypertension in childhood, especially in pre-adolescents, are secondary to an underlying disorder; however, adolescents have primary or essential hypertension up to 85% to 95% of cases.[5] Table 3 shows causes of childhood hypertension in age groups.[5] When hypertension is confirmed, a careful history and physical examination should be conducted to identify the underlying cause of the elevated BP and any damage of end organs. Table 4 shows the initial laboratory evaluations that must be done in all children with persistent hypertension. Then the physician should individualize additional specific investigations.[1] Managing childhood hypertension is directed at the cause of the elevated BP and alleviation of any symptoms. Decision about therapy is based on end-organ damage, comorbid conditions, and associated risk factors. The NHBPEP has developed an algorithm to help the physician navigate the diagnostic and management choices in childhood BP.[1] We summarized its recommendations in Table 5.

In summary, physicians must consider that the value of BP in children and adolescents is tightly related to their age and body size, and they should be aware that a BP value which seems to be in the normal range for adults may indicate serious stage of hypertension in a child. The abovementioned definitions and recommendations by the NHBPEP

Table 3. Causes of Hypertension in Children and Adolescents

Age, y	Causes
1 to 12	Renal parenchymal disease Renal vascular disease Endocrine causes Coarctation of the aorta Essential hypertension Iatrogenic illness
12 to 18	Essential hypertension Iatrogenic illness Renal parenchymal disease Renal vascular disease Endocrine causes Coarctation of the aorta

Table 4. Initial and Additional Tests for Childhood Hypertension[1]*

Test	Description
Initial evaluation	
Blood urea nitrogen, serum creatinine and electrolytes, urinalysis, and urine culture	Quick assessment of kidney function
Complete blood count	Detection of anemia reflecting chronic diseases such as vasculitis and chronic kidney disease
Renal ultrasonography	Detection any scar, congenital anomaly, difference in kidney size, or adrenal mass
Fasting plasma glucose and lipids	Assessment of prehypertensive children with obesity or a family history of hypertension, cardiovascular disease, or chronic kidney disease
Echocardiography	Evaluation of left ventricular mass
Additional evaluation	
Serum C3, C4, ANA, and anti-dsDNA antibody	Evaluation of hypertensive children with proteinuria, hematuria, or kidney dysfunction
Diuretic-enhanced DTPA renal scan and VCUG	Evaluation of children with hydronephrosis
Serum aldosterone and plasma renin activity	Evaluation of hypertensive children with metabolic alkalosis and hypokalemia
Blood and urinary catecholamine levels and adrenal MRI and/or MIBG scan	Evaluation of children with severe hypertension but normal plasma renin activity
Intra-arterial digital subtraction angiogram, spiral CT scan, or Gadolinium-enhanced MR angiography.	Additional testing for renovascular disease only in patients with severe hypertension and elevated plasma renin activity and aldosterone level

*C3 indicates complement 3; C4, complement 4; ANA, antinuclear antibody; dsDNA, double-stranded DNA; DTPA, diethylenetriaminepentaacetic acid; VCUG, voiding cystourethrography; MRI, magnetic resonance imaging; MIBG, metaiodobenzylguanidine; CT, computed tomography; and MR, magnetic resonance.

Table 5. Recommendations for Managing Childhood Hypertension[1]*

Stage	Recommendation
Prehypertension	Recommend lifestyle change (diet modification, physical exercise). If BP is within the 90th and 95th percentiles, consider diagnostic workup, and if overweight exists, recommend weight reduction. Monitor BP every 6 months.
Stage 1 hypertension	
BP within 90th and 95th percentiles	Management is like that for prehypertension.
BP > 95th percentile	Consider diagnostic workup. Primary hypertension: recommend lifestyle change and if overweight exists, recommend weight reduction. If persisted, prescribe medication. Secondary hypertension: prescription addressing specific cause of hypertension.
Stage 2 hypertension	Diagnostic workup including evaluation for end-organ damage should be performed. Either secondary or primary hypertension, consider referral to provider with expertise in pediatric hypertension. Prescribe medication and if overweight exists, recommend weight reduction.

*BP indicates blood pressure.

can be used to determine who should be considered as hypertensive, which kind of assessment must be made, and finally, when the patients need lifestyle change or medical therapy.

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