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Hypertension Canada's 2016 CHEP Guidelines for Blood Pressure Measurement, Diagnosis and Assessment of Risk of Pediatric Hypertension

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ACCEPTED MANUSCRIPT

# Hypertension Canada's 2016 CHEP Guidelines for Blood Pressure Measurement, Diagnosis and Assessment of Risk of Pediatric Hypertension

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**Abstract**

We present the inaugural evidence-based Canadian recommendations for the measurement of blood pressure in children, and the diagnosis and evaluation of pediatric hypertension. Rates of pediatric hypertension are increasing concomitant with increased rates of childhood obesity. With this there is growing awareness of the need to measure blood pressure in children. Consequently, the present recommendations have been developed to address an important gap and improve the clinical care of children.

For 2016 a total of 15 recommendations are presented, these are categorized in a similar fashion to the existing adult recommendations. Specifically, we present recommendations on (1) accurate measurement of blood pressure in children; (2) criteria for diagnosis of hypertension in children; (3) assessment of overall cardiovascular risk in hypertensive children; (4) routine laboratory tests for the investigation of children with hypertension; (5) ambulatory blood pressure measurement in children; and, (6) role of echocardiography. We discuss the rationale for the recommendations and present additional supporting material for the clinician, including tables with standardized techniques for blood pressure measurement and determination of normative blood pressure values for children. Hypertension Canada's CHEP Guidelines Task Force will update the recommendations annually and develop future evidence-based recommendations to guide prevention and treatment of pediatric hypertension.



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**Key Words:** hypertension, children, high blood pressure, guidelines, recommendations, electronic oscillometric devices, ambulatory blood pressure monitoring, echocardiography



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**Brief Summary**

For 2016, new recommendations for pediatric hypertension have been developed. The recommendations presented include 3 recommendations for the accurate measurement of blood pressure in children, 3 recommendations on criteria for the diagnosis of hypertension in children, 1 recommendation on the evaluation of cardiovascular risk in hypertensive children, 3 recommendations for routine laboratory tests in hypertensive children, 3 recommendations on ambulatory blood pressure measurement in children and 2 recommendations on the role of echocardiography in hypertensive children.



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## Executive Summary

**Objective:**

To develop new evidence-based recommendations for the measurement of blood pressure, the diagnosis of hypertension in children and the evaluation of hypertensive children.

**Methods:**

A medical librarian independently conducted a MEDLINE search current to April 2015. Reference lists were reviewed to identify additional studies. Content and methodology experts reviewed and appraised included articles using standardized grading criteria. The recommendations were graded based on the strength of the supporting evidence and discussed at a consensus conference in Toronto, Canada on October 22, 2015. The new recommendations were voted on by the 75 members of Hypertension Canada's CHEP (Canadian Hypertension Education Program) Guidelines Task Force. Recommendations that received at least 70% task force approval were accepted as final.

**Recommendations:**

*Accurate Measurement of Blood Pressure in Children*

There are three recommendations for blood pressure measurement in children: (1) Blood pressure should be measured regularly in children 3 years of age and older by a health-care professional using standardized pediatric techniques, as presented in an accompanying table; (2) Blood pressure may be measured with a mercury sphygmomanometer, aneroid sphygmomanometer, or oscillometric device (abnormal oscillometric values should be confirmed by auscultation); (3) Blood pressure varies with age, sex and height in children and, therefore, BP values should be compared to norms for age, sex, and height.




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*Criteria for Diagnosis of Hypertension in Children*

There are three recommendations for the diagnosis of hypertension in children: (1) Using office BP measurements, children can be diagnosed as hypertensive if SBP or DBP is ≥ 95th percentile for age, sex, and height, measured on at least three separate occasions; (2) If the BP is ≥ 95th percentile, BP should be staged. Stage 1 is defined by BP between 95th percentile and 99th percentile plus 5 mmHg. Stage 2 is defined by BP > 99th percentile plus 5 mmHg. If BP is Stage 1, BP measurements should be repeated on two more occasions within one month; if hypertension is confirmed, evaluation and/or appropriate referral should be initiated within one month. If BP is Stage 2, prompt referral should be made for evaluation and therapy; (3) All children with suspected or confirmed hypertension should undergo a hypertension-focused history and physical evaluation.

*Assessment of Overall Cardiovascular Risk in Hypertensive Children*

We recommend that cardiovascular risk factors should be assessed in hypertensive children.

*Routine Laboratory Tests for the Investigation of Children with Hypertension*

Three recommendations are listed in this section: (1) Routine tests that should be performed for all children with hypertension include: a) Blood chemistry (sodium, potassium, chloride, total $CO_2$, and creatinine); b) Urinalysis; c) Renal ultrasound; (2) Routine laboratory tests that should be performed for the assessment of cardiovascular risk in all children with hypertension include: a) Fasting blood glucose; b) Serum total cholesterol and high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triglycerides; (3) Routine tests that should be performed for the assessment of target organ damage in all children with hypertension include: a) echocardiogram; b) retinal examination; c) albumin/creatinine ratio (first-morning).



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*Ambulatory BP Measurement (ABPM) in Children*

There are three recommendations pertaining to ABPM : (1) For children with elevated office BP readings, ABPM should be guided by a physician with expertise in pediatric hypertension; (2) Physicians should use only ABPM devices that have been validated independently in children using established protocols. A standard approach to obtaining ABPM readings should be used; (3) ABPM levels should be interpreted with appropriate pediatric normative data for children ≥5 years of age or height of ≥120 cm.

*Role of Echocardiography*

There are two recommendations for echocardiography: (1) Routine echocardiographic evaluation is recommended for children with confirmed hypertension; (2) The echocardiographic assessment should include measurements of left ventricular mass index, systolic and diastolic left ventricular function and evaluation of the aortic arch.

*Updates*

CHEP will update the recommendations annually.

**Introduction**

The prevalence of hypertension in children is rising,[1–3] in large part because of the childhood obesity epidemic. Elevated blood pressure (BP) in childhood tracks to adulthood,[4,5] in which hypertension is associated with adverse health outcomes including early cardiovascular events. Hypertensive children may display evidence of target organ damage at presentation and thus prompt identification and treatment of hypertensive children is important. While the prevalence of primary hypertension is rising in children, secondary causes of hypertension remain common and account for 35-55% of outpatient diagnoses.[6–8] In children less than 5 years old, primary hypertension is uncommon and secondary causes need to be aggressively sought to guide therapy and clinical follow-up.[6] The most common causes of secondary



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hypertension in children are renal, renovascular, endocrine and cardiac disorders. Conversely, in obese children and adolescents primary hypertension now predominates.[9,10]

There has been increasing awareness of the need to measure BP regularly in children, and primary care practitioners have expressed a need for guidance in BP measurement, evaluation and management in children. In response to clinician requests, CHEP developed a pediatric subcommittee in 2013 to develop pediatric-specific BP recommendations. The inaugural recommendations here address the measurement of BP, the criteria for diagnosis of hypertension and the evaluation of hypertensive children. These recommendations are intended to guide pediatric health care providers but should not replace clinical judgment. Clinicians should consider individual patient and family circumstances when applying the recommendations to individual children.

**Methods**

Hypertension Canada's CHEP Guidelines Task Force (GTF) is a multidisciplinary panel of content and methodological experts comprised of 1 Chair, a Central Review Committee (CRC), and 15 subgroups. Each subgroup addresses a distinct content area (see Supplementary Appendix A for the current CHEP membership list). Members of the Canadian Task Force on Preventive Health Care, Canadian Diabetes Association Guidelines Committee, Canadian Society of Nephrology, Canadian Stroke Network, Canadian Cardiovascular Society, and the Canadian Cardiovascular Harmonized National Guideline Endeavour Initiative regularly collaborate with CHEP members to facilitate harmonization of hypertension-related recommendations across organizations. In many cases, CHEP GTF members serve as volunteers for multiple organizations.



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Systematic literature searches current to April 2015 were performed by a Cochrane Collaboration librarian in MEDLINE/PubMed using text words and MeSH headings. Search terms included hypertension[MeSH], hypertens*[ti, ab], and BP; these were combined with topic-specific terms. Bibliographies of identified articles were also manually searched. Details of search strategies and retrieved articles are available upon request. Cross-sectional and cohort studies were reviewed for assessing BP measurement, diagnosis and evaluation of pediatric hypertension.

The pediatric subgroup examined the search results. Study characteristics and study quality were assessed using pre-specified, standardized algorithms developed by CHEP[11] for the critical appraisal of cohort studies. Recommendations were graded according to the strength of their underlying evidence (for details, see Table S1 in Supplementary Materials), ranging from Grade A (strongest evidence, based on high-quality studies) to Grade D (weakest evidence, based on low power, imprecise studies or expert opinion alone). Although CHEP does not utilize the Grading of Recommendations Assessment, Development and Evaluation (GRADE) recommendation scheme (www.gradeworkinggroup.org), it should be noted that all CHEP recommendations are considered to be 'strong' in nature (i.e., CHEP refrains from making 'weak' recommendations). Thus, the CHEP grading scheme refers only to the quality of evidence and not to the relative strength of the recommendation.

Pediatric subgroup members comprise hypertension specialists in pediatric cardiology, pediatric nephrology, and nursing. The pediatric subgroup was responsible for reviewing search results and drafting the recommendations. An independent Central Review Committee (CRC) consisting of methodological experts with no industry affiliations independently reviewed, graded and refined the proposed recommendations, which were then presented at a consensus conference of the GTF in Toronto, Canada on October 22, 2015. This meeting included the Chair, CRC, and members of all subgroups. Further revisions to proposed recommendations were based on these discussions.



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After the consensus meeting, the recommendations were finalized and submitted electronically to all 75 voting members of the CHEP GTF for approval. Members with potential conflicts of interest recused themselves from voting on specific recommendations (a list of conflicts is available as Supplementary Appendix B). Recommendations receiving over 70% approval passed. The CHEP recommendations process is in accordance with the AGREE2 guidelines[12] and has been externally reviewed. A summary of how the CHEP process aligns with AGREE2 can be found online http://www.hypertension.ca/overview-process. Materials to assist with patient and public education based on these recommendations are available at: http://www.hypertension.ca.

### I. Accurate measurement of BP in children

#### Recommendations

1. BP should be measured regularly in children 3 years of age and older by a health care professional using standardized pediatric techniques (Table 1) (Grade D).

2. BP may be measured with a mercury sphygomomanometer, aneroid sphygmomanometer, or oscillometric device (Grade D). Abnormal oscillometric values should be confirmed with auscultation (Grade C).

3. BP varies with age, sex and height in children and, therefore, BP values should be compared to norms for age, sex, and height (Table 2) (Grade D).

#### Background

Accurate measurement of BP is critical for the diagnosis of hypertension and its management. While there are practical challenges to accurately measuring BP in infants and very young children, it is



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important to measure BP regularly in children 3 years of age and older. The measurement of BP in children requires specific techniques. A standardized approach is presented in Table 1.

Different BP measurement methods exist for children including office BP measurement (OBPM), ambulatory BP measurement (ABPM) and home BP measurement (HBPM). Historically OBPM has been the predominant method to measure BP in children. This may be done using auscultation (with mercury or aneroid sphygmomanometers) or with an oscillometric device. Mercury has long been considered the gold standard, however, due to its potential toxicity it has largely been removed from health care settings. Aneroid sphygmomanometers and oscillometric devices represent alternatives for pediatric BP measurement. Aneroid sphygmomanometers have been evaluated in several small studies, and yield similar results to mercury sphygmomanometers.[13,14] The benefits of oscillometric measurement have been well documented in adults and include the lack of need for specialized training and low inter-observer variability. Limitations of the present oscillometric devices in children include that the algorithms are designed for adult BP ranges and these devices may not perform as well at the lower BP values common in young children. Additionally, in young children the high initial cuff inflation and the longer time needed to obtain a reading may preclude obtaining a reliable resting BP. The present literature comparing oscillometric devices to mercury or aneroid auscultatory methods has conflicting results.[15–19] The oscillometric device manufacturer, era, study setting and study populations are heterogenous, which may contribute to the spectrum of results observed. There is limited literature comparing auscultatory and oscillometric techniques in very young children. Therefore, it is reasonable to use either the auscultatory technique or an oscillometric device. Abnormal oscillometric values should be confirmed with auscultation.

Normative pediatric data now exist for both auscultatory and oscillometric methods.[20,21] Due to changes in BP with age, sex, and height, measured values should be compared to normative data in all children (Table 2).



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Home BP measurement (HBPM) is less frequently used in children than adults. Limited studies suggest that HBPM can be performed in children starting at 6 years old.[22–24] Patients or parents of younger children who measure their BP at home should have adequate training, including direct observation.

**II. Criteria for diagnosis of hypertension in children**

**Recommendations**

1. Using office BP measurements, children can be diagnosed as hypertensive if SBP or DBP is ≥ 95th percentile for age, sex, and height, measured on at least three separate occasions (Grade C).

2. If the BP is ≥ 95th percentile, BP should be staged. Stage 1 is defined by BP between 95th percentile and 99th percentile plus 5 mmHg. Stage 2 is defined by BP > 99th percentile plus 5 mm Hg (Grade D).

    a. If BP is Stage 1, BP measurements should be repeated on two more occasions within one month; if hypertension is confirmed, evaluation (as described in section IV) and/or appropriate referral should be initiated within one month (Grade D).

    b. If BP is Stage 2, prompt referral should be made for evaluation and therapy (Grade C).

3. All children with suspected or confirmed hypertension should undergo a hypertension focused history and physical evaluation (Table 3) (Grade C).

**Background**

The diagnosis of hypertension in children is based on three separate measurements of SBP or DBP ≥ 95th percentile for age, sex, and height. This definition was initially based on being at the extreme end of a physiologic measurement, which is normally distributed in children. Because of the absence of hard



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outcomes for children with hypertension, there is a need to evaluate surrogate markers and consider the future implications of BP values documented during childhood. Children with BP≥95th percentile for age, sex, and height can have evidence of target organ damage.[25–31] Additionally, elevated BP in childhood predicts hypertension in adulthood, as demonstrated in a recent meta-regression analysis.[4]

Staging is important because children with Stage 2 hypertension should receive prompt specialist evaluation. In these children clinical symptoms are more common, there is an increased prevalence of target organ damage and hypertensive emergencies are more frequent.[32–34]

A focused history and physical exam is important in determining symptomatology and gaining insight to the possible etiology in cases of secondary hypertension (Table 3). Children with secondary hypertension are more likely to have a history of prematurity, and renovascular hypertension should be considered in children with a neonatal history of umbilical artery catheterization.[6,35] Children with primary hypertension are more likely to have a positive family history of hypertension.[6,7,36] Cardiovascular risk factors (low physical activity, high salt diet, low fruit intake, smoking) should be documented, as these predict target organ damage and future atherosclerosis in hypertensive children.[25,37–40] The physical exam is important to document body mass index, ensure that there is no BP difference between the upper and lower extremities (suggests possible coarctation of the aorta), and to evaluate for target organ damage including retinal changes, signs of heart failure or neurologic abnormalities.[8,29,34–36,39,41–44]

## III. Assessment of overall cardiovascular risk in hypertensive children

### <u>Recommendation</u>

1. Cardiovascular risk factors should be assessed in hypertensive children (Grade C).

### Background



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Pediatric hypertension clusters with other cardiovascular risk factors including obesity, insulin resistance and dyslipidemia.[45–51] These cardiovascular changes and risk factors track into, and may progress, during adulthood.[52,53] There is clear evidence from large cohort studies that early intervention during childhood can modify future cardiovascular risk.[54] The Cardiovascular Risk in Young Finns study demonstrated that adult vascular dysfunction (measured by carotid intima-media thickness) is predicted by childhood cardiovascular risk factors, including hypertension.[37] Increased physical activity and dietary improvement protect against future atherosclerosis. The Pathologic Determinants of Atherosclerosis in Youth study showed that changes in cardiovascular risk factors during adolescence are important predictors of atherosclerosis in adulthood.[55] Many of the cardiovascular risk factors identified are modifiable, indicating that intervention during childhood has important potential benefits in modifying the natural history of pediatric hypertension.[41]

**IV. Routine laboratory tests for the investigation of children with hypertension**

**Recommendations**

1. Routine tests that should be performed for the investigation of all children with hypertension include:
    a. Blood chemistry (sodium, potassium, chloride, total $CO_2$, and creatinine) (Grade D);
    b. Urinalysis (Grade D);
    c. Renal ultrasound (Grade D).
2. Routine laboratory tests that should be performed for the assessment of cardiovascular risk in all children with hypertension include the following:
    a. Fasting blood glucose (Grade C);



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b. Serum total cholesterol and high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, and triglycerides (Grade C);

3. Routine tests that should be performed for the assessment of target organ damage in all children with hypertension include:

   a. Echocardiogram (Grade C);

   b. Retinal examination (Grade C);

   c. Albumin/creatinine ratio (first morning) (Grade D).

**Background**

Routine investigations in hypertensive children are directed at determining the underlying etiology, evaluating target organ damage and assessing common comorbidities associated with primary hypertension. Children with secondary hypertension are more likely to have higher creatinine or lower calculated GFR and higher serum potassium.[7,8,36] Similarly, children with secondary hypertension are more likely to have renal abnormalities detected by ultrasound.[7,56] Urinalysis may detect proteinuria in hypertensive children.[57,58] Given the predominance of renal parenchymal and renovascular diseases in pediatric secondary hypertension (50-80%), these basic investigations should identify most causes of secondary hypertension.

Hypertensive children should be evaluated for comorbid cardiovascular risk factors. This includes a fasting glucose determination to assess insulin resistance and a lipid profile to diagnose dyslipidemia, given the known clustering of these risk factors with pediatric hypertension.[41,49,50,59] The modifiable nature of these risk factors mandates early identification and intervention to prevent long-term cardiovascular sequelae.



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Assessment of target organ damage is recommended for children with hypertension. Routine echocardiography should be used to assess for possible left ventricular hypertrophy (LVH) and quantify LV mass index (LVMI) (discussed further in section vi).[32,60,61] Up to 50% of children with hypertension have abnormalities on retinal exam and/or arteriolar narrowing.[28–30,44,62] Albuminuria is also common at presentation in hypertensive children.[28] Albuminuria is a predictor of LVMI and associates with regression of LVH with BP control.[63]

## V. Ambulatory BP measurement (ABPM) in children

### Recommendations

1. For children with elevated office BP readings, ABPM should be guided by a physician with expertise in pediatric hypertension; ABPM is useful to classify BP (Table 4) (Grade C).
2. Physicians should use only ABPM devices that have been validated independently in children using established protocols. A standard approach to obtaining ABPM readings should be used (Table 5) (Grade D).
3. ABPM levels should be interpreted with appropriate pediatric normative data for children ≥5 years of age or height of ≥120 cm (Grade D).

### Background

In children with elevated office BP readings, ABPM may be useful to classify BP. A schema for the classification of hypertension in children is presented in Table 4.



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In cross-sectional studies of children evaluated for hypertension an important proportion has masked hypertension and white-coat hypertension.[64–68] In children, masked hypertension is associated with evidence of end organ damage, including left ventricular hypertrophy.[64,65] A standard approach to obtaining ABPM readings in children is presented in Table 5.

ABPM may also be considered in the evaluation of secondary hypertension, to evaluate the risk of target organ damage, and to assess BP control during antihypertensive drug treatment.[69–74] Screening ABPM may be considered in targeted high-risk children, including those with diabetes mellitus, chronic kidney disease, solid-organ transplant recipients and obesity.[75–90]

## VI. Role of echocardiography

**Recommendations**

1. Routine echocardiographic evaluation in children with confirmed hypertension is recommended (Grade D).
2. The echocardiographic assessment should include measurements of left ventricular mass index, systolic and diastolic left ventricular function and evaluation of the aortic arch (Grade D).

**Background**

Left ventricular hypertrophy is common at the time of presentation in hypertensive children who undergo echocardiography (prevalence of 15-40%).[32,61,91,92] LVH is more likely in secondary hypertension. Target-organ damage may influence the medical treatment of hypertension, thus diagnosing LVH is important in managing hypertensive children. Given the potential for aortic arch obstruction as a cause of secondary hypertension, echocardiographic evaluation should include evaluation for coarctation of the aorta as well as chamber dimensions and indices of systolic and diastolic ventricular function, which may



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be altered in hypertensive children.[93,94] Follow-up echocardiography in children with uncontrolled hypertension or those with LVH at baseline should be considered.

**Summary/Future Directions**

The present manuscript is the culmination of 2 years of work by the Pediatric Subcommittee with the support of the GTF. The GTF will continue to conduct systematic reviews of the literature and update the present recommendations as new evidence becomes available. Additionally, the Pediatric Subcommittee will develop evidence-based recommendations addressing the prevention and treatment of pediatric hypertension with a future update.

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**Disclosures**

Please see Supplemental Appendix A2 for a complete list of author disclosures.



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**References**

1. Muntner P, He J, Cutler JA, Wildman RP, Whelton PK. Trends in blood pressure among children and adolescents. *JAMA*. 2004;291(17):2107-2113. doi:10.1001/jama.291.17.2107.

2. Din-Dzietham R, Liu Y, Bielo M-V, Shamsa F. High blood pressure trends in children and adolescents in national surveys, 1963 to 2002. *Circulation*. 2007;116(13):1488-1496. doi:10.1161/CIRCULATIONAHA.106.683243.

3. Flynn J. The changing face of pediatric hypertension in the era of the childhood obesity epidemic. *Pediatr Nephrol*. 2013;28(7):1059-1066. doi:10.1007/s00467-012-2344-0.

4. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. *Circulation*. 2008;117(25):3171-3180. doi:10.1161/CIRCULATIONAHA.107.730366.

5. 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(7):657-665. doi:10.1016/0895-7061(95)00116-7.

6. Gupta-Malhotra M, Banker A, Shete S, et al. Essential hypertension vs. secondary hypertension among children. *Am J Hypertens*. 2015;28(1):73-80. doi:10.1093/ajh/hpu083.

7. Baracco R, Kapur G, Mattoo T, et al. Prediction of primary vs secondary hypertension in children. *J Clin Hypertens (Greenwich)*. 2012;14(5):316-321. doi:10.1111/j.1751-7176.2012.00603.x.

8. Flynn J, Zhang Y, Solar-Yohay S, Shi V. Clinical and demographic characteristics of children with hypertension. *Hypertension*. 2012;60(4):1047-1054. doi:10.1161/HYPERTENSIONAHA.112.197525.

9. Yoon EY, Cohn L, Freed G, et al. Use of antihypertensive medications and diagnostic tests among privately insured adolescents and young adults with primary versus secondary hypertension. *J Adolesc Health*. 2014;55(1):73-78. doi:10.1016/j.jadohealth.2013.12.006.

10. Kapur G, Ahmed M, Pan C, Mitsnefes M, Chiang M, Mattoo TK. Secondary hypertension in overweight and stage 1 hypertensive children: a Midwest Pediatric Nephrology Consortium report. *J Clin Hypertens (Greenwich)*. 2010;12(1):34-39. doi:10.1111/j.1751-7176.2009.00195.x.

11. McAlister FA. The Canadian Hypertension Education Program--a unique Canadian initiative. *Can J Cardiol*. 2006;22(7):559-564. http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2560862&tool=pmcentrez&rendertype=abstract. Accessed December 8, 2015.

12. Brouwers MC, Kho ME, Browman GP, et al. AGREE II: advancing guideline development, reporting and evaluation in health care. *CMAJ*. 2010;182(18):E839-E842. doi:10.1503/cmaj.090449.

13. Ostchega Y, Prineas RJ, Nwankwo T, Zipf G. Assessing blood pressure accuracy of an aneroid sphygmomanometer in a national survey environment. *Am J Hypertens*. 2011;24(3):322-327. doi:10.1038/ajh.2010.232.

14. Shah AS, Dolan LM, D'Agostino RB, et al. Comparison of mercury and aneroid blood pressure measurements in youth. *Pediatrics*. 2012;129(5):e1205-e1210. doi:10.1542/peds.2011-3087.



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15. Menard SW, Park MK, Yuan CH. The San Antonio Biethnic Children's Blood Pressure Study: auscultatory findings. *J Pediatr Health Care*. 13(5):237-244. doi:10.1016/S0891-5245(99)90005-6.

16. Midgley PC, Wardhaugh B, Macfarlane C, Magowan R, Kelnar CJH. Blood pressure in children aged 4-8 years: comparison of Omron HEM 711 and sphygmomanometer blood pressure measurements. *Arch Dis Child*. 2009;94(12):955-958. doi:10.1136/adc.2008.137059.

17. Ostchega Y, Nwankwo T, Sorlie PD, Wolz M, Zipf G. Assessing the validity of the Omron HEM-907XL oscillometric blood pressure measurement device in a National Survey environment. *J Clin Hypertens (Greenwich)*. 2010;12(1):22-28. doi:10.1111/j.1751-7176.2009.00199.x.

18. Ostchega Y, Zhang G, Sorlie P, et al. Blood pressure randomized methodology study comparing automatic oscillometric and mercury sphygmomanometer devices: National Health and Nutrition Examination Survey, 2009-2010. *Natl Health Stat Report*. 2012;(59):1-15. http://www.ncbi.nlm.nih.gov/pubmed/24984529. Accessed December 7, 2015.

19. Foster TA, Berenson GS. Measurement error and reliability in four pediatric cross-sectional surveys of cardiovascular disease risk factor variables—The Bogalusa Heart Study. *J Chronic Dis*. 1987;40(1):13-21. doi:10.1016/0021-9681(87)90092-0.

20. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents. *Pediatrics*. 2004;114(Supplement_2):555-576. http://pediatrics.aappublications.org/content/114/Supplement_2/555. Accessed December 7, 2015.

21. Krmar RT, Holtbäck U, Bergh A, Svensson E, Wühl E. Oscillometric casual blood pressure normative standards for Swedish children using ABPM to exclude casual hypertension. *Am J Hypertens*. 2015;28(4):459-468. doi:10.1093/ajh/hpu182.

22. Stergiou GS, Yiannes NG, Rarra VC, Panagiotakos DB. Home blood pressure normalcy in children and adolescents: the Arsakeion School study. *J Hypertens*. 2007;25(7):1375-1379. doi:10.1097/HJH.0b013e328122d3fc.

23. Stergiou GS, Christodoulakis G, Giovas P, Lourida P, Alamara C, Roussias LG. Home blood pressure monitoring in children: how many measurements are needed? *Am J Hypertens*. 2008;21(6):633-638. doi:10.1038/ajh.2008.38.

24. Stergiou GS, Karpettas N, Kapoyiannis A, Stefanidis CJ, Vazeou A. Home blood pressure monitoring in children and adolescents: a systematic review. *J Hypertens*. 2009;27(10):1941-1947. doi:10.1097/HJH.0b013e32832ea93e.

25. Daniels SD, Meyer RA, Loggie JM. Determinants of cardiac involvement in children and adolescents with essential hypertension. *Circulation*. 1990;82(4):1243-1248. doi:10.1161/01.CIR.82.4.1243.

26. Brady TM, Fivush B, Parekh RS, Flynn JT. Racial differences among children with primary hypertension. *Pediatrics*. 2010;126(5):931-937. doi:10.1542/peds.2009-2972.

27. Kollias A, Dafni M, Poulidakis E, Ntineri A, Stergiou GS. Out-of-office blood pressure and target organ damage in children and adolescents: a systematic review and meta-analysis. *J Hypertens*. 2014;32(12):2315-2331; discussion 2331. doi:10.1097/HJH.0000000000000384.



医脉通 medlive.cn

guide.medlive.cn

28. Conkar S, Yılmaz E, Hacıkara Ş, Bozabalı S, Mir S. Is Daytime Systolic Load an Important Risk Factor for Target Organ Damage in Pediatric Hypertension? *J Clin Hypertens (Greenwich)*. 2015;17(10):760-766. doi:10.1111/jch.12608.

29. Daniels SR, Lipman MJ, Burke MJ, Loggie JMH. The Prevalence of Retinal Vascular Abnormalities in Children and Adolescents With Essential Hypertension. *Am J Ophthalmol*. 1991;111(2):205-208. doi:10.1016/S0002-9394(14)72260-3.

30. Mitchell P, Cheung N, de Haseth K, et al. Blood pressure and retinal arteriolar narrowing in children. *Hypertension*. 2007;49(5):1156-1162. doi:10.1161/HYPERTENSIONAHA.106.085910.

31. Juonala M, Järvisalo MJ, Mäki-Torkko N, Kähönen M, Viikari JSA, Raitakari OT. Risk factors identified in childhood and decreased carotid artery elasticity in adulthood: the Cardiovascular Risk in Young Finns Study. *Circulation*. 2005;112(10):1486-1493. doi:10.1161/CIRCULATIONAHA.104.502161.

32. McNiece KL, Gupta-Malhotra M, Samuels J, et al. Left ventricular hypertrophy in hypertensive adolescents: analysis of risk by 2004 National High Blood Pressure Education Program Working Group staging criteria. *Hypertension*. 2007;50(2):392-395. doi:10.1161/HYPERTENSIONAHA.107.092197.

33. Yang W-C, Wu H-P. Clinical analysis of hypertension in children admitted to the emergency department. *Pediatr Neonatol*. 2010;51(1):44-51. doi:10.1016/S1875-9572(10)60009-5.

34. Wu H-P, Yang W-C, Wu Y-K, Zhao L-L, Chen C-Y, Fu Y-C. Clinical significance of blood pressure ratios in hypertensive crisis in children. *Arch Dis Child*. 2012;97(3):200-205. doi:10.1136/archdischild-2011-300373.

35. Roebuck DJ, McLaren CA. Noninvasive imaging in children with hypertension. *Pediatr Radiol*. 2013;43(4):502-505. doi:10.1007/s00247-013-2659-4.

36. Gomes RS, Quirino IG, Pereira RM, et al. Primary versus secondary hypertension in children followed up at an outpatient tertiary unit. *Pediatr Nephrol*. 2011;26(3):441-447. doi:10.1007/s00467-010-1712-x.

37. Juonala M, Viikari JSA, Kähönen M, et al. Life-time risk factors and progression of carotid atherosclerosis in young adults: the Cardiovascular Risk in Young Finns study. *Eur Heart J*. 2010;31(14):1745-1751. doi:10.1093/eurheartj/ehq141.

38. Lobelo F, Pate RR, Dowda M, Liese AD, Daniels SR. Cardiorespiratory fitness and clustered cardiovascular disease risk in U.S. adolescents. *J Adolesc Health*. 2010;47(4):352-359. doi:10.1016/j.jadohealth.2010.04.012.

39. Shi Y, de Groh M, Morrison H. Increasing blood pressure and its associated factors in Canadian children and adolescents from the Canadian Health Measures Survey. *BMC Public Health*. 2012;12(1):388. doi:10.1186/1471-2458-12-388.

40. Rosner B, Cook NR, Daniels S, Falkner B. Childhood blood pressure trends and risk factors for high blood pressure: the NHANES experience 1988-2008. *Hypertension*. 2013;62(2):247-254. doi:10.1161/HYPERTENSIONAHA.111.00831.

41. McMahan CA, Gidding SS, Fayad ZA, et al. Risk scores predict atherosclerotic lesions in young



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people. *Arch Intern Med*. 2005;165(8):883-890. doi:10.1001/archinte.165.8.883.

42. Peres A, Martins JDF, Paramés F, et al. Isolated aortic coarctation: experience in 100 consecutive patients. *Rev Port Cardiol*. 2010;29(1):23-35. http://www.ncbi.nlm.nih.gov/pubmed/20391897. Accessed December 8, 2015.

43. Rahiala E, Tikanoja T. Suspicion of aortic coarctation in an outpatient clinic: How should blood pressure measurements be performed? *Clin Physiol*. 2001;21(1):100-104. doi:10.1046/j.1365-2281.2001.00295.x.

44. Gopinath B, Baur LA, Wang JJ, et al. Blood pressure is associated with retinal vessel signs in preadolescent children. *J Hypertens*. 2010;28(7):1406-1412. doi:10.1097/HJH.0b013e3283395223.

45. Litwin M, Sladowska J, Antoniewicz J, et al. Metabolic abnormalities, insulin resistance, and metabolic syndrome in children with primary hypertension. *Am J Hypertens*. 2007;20(8):875-882. doi:10.1016/j.amjhyper.2007.03.005.

46. Krebs A, Schmidt-Trucksäss A, Alt J, et al. Synergistic effects of elevated systolic blood pressure and hypercholesterolemia on carotid intima-media thickness in children and adolescents. *Pediatr Cardiol*. 2009;30(8):1131-1136. doi:10.1007/s00246-009-9510-6.

47. van Vliet M, Van der Heyden JC, Diamant M, et al. Overweight is highly prevalent in children with type 1 diabetes and associates with cardiometabolic risk. *J Pediatr*. 2010;156(6):923-929. doi:10.1016/j.jpeds.2009.12.017.

48. Falaschetti E, Hingorani AD, Jones A, et al. Adiposity and cardiovascular risk factors in a large contemporary population of pre-pubertal children. *Eur Heart J*. 2010;31(24):3063-3072. doi:10.1093/eurheartj/ehq355.

49. McCrindle BW, Manlhiot C, Millar K, et al. Population trends toward increasing cardiovascular risk factors in Canadian adolescents. *J Pediatr*. 2010;157(5):837-843. doi:10.1016/j.jpeds.2010.05.014.

50. May AL, Kuklina E V, Yoon PW. Prevalence of cardiovascular disease risk factors among US adolescents, 1999-2008. *Pediatrics*. 2012;129(6):1035-1041. doi:10.1542/peds.2011-1082.

51. Shashaj B, Bedogni G, Graziani MP, et al. Origin of cardiovascular risk in overweight preschool children: a cohort study of cardiometabolic risk factors at the onset of obesity. *JAMA Pediatr*. 2014;168(10):917-924. doi:10.1001/jamapediatrics.2014.900.

52. Rademacher ER, Jacobs DR, Moran A, Steinberger J, Prineas RJ, Sinaiko A. Relation of blood pressure and body mass index during childhood to cardiovascular risk factor levels in young adults. *J Hypertens*. 2009;27(9):1766-1774. doi:10.1097/HJH.0b013e32832e8cfa.

53. Tirosh A, Afek A, Rudich A, et al. Progression of normotensive adolescents to hypertensive adults: a study of 26,980 teenagers. *Hypertension*. 2010;56(2):203-209. doi:10.1161/HYPERTENSIONAHA.109.146415.

54. Juhola J, Magnussen CG, Berenson GS, et al. Combined effects of child and adult elevated blood pressure on subclinical atherosclerosis: the International Childhood Cardiovascular Cohort Consortium. *Circulation*. 2013;128(3):217-224. doi:10.1161/CIRCULATIONAHA.113.001614.



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55. McMahan CA, Gidding SS, Viikari JSA, et al. Association of Pathobiologic Determinants of Atherosclerosis in Youth risk score and 15-year change in risk score with carotid artery intima-media thickness in young adults (from the Cardiovascular Risk in Young Finns Study). *Am J Cardiol*. 2007;100(7):1124-1129. doi:10.1016/j.amjcard.2007.05.035.

56. Wiesen J, Adkins M, Fortune S, et al. Evaluation of pediatric patients with mild-to-moderate hypertension: yield of diagnostic testing. *Pediatrics*. 2008;122(5):e988-e993. doi:10.1542/peds.2008-0365.

57. Guthrie RM, Lott JA. Screening for proteinuria in patients with hypertension or diabetes mellitus. *J Fam Pract*. 1993;37(3):253-256. http://www.ncbi.nlm.nih.gov/pubmed/8409876. Accessed December 8, 2015.

58. Liao C-C, Su T-C, Chien K-L, et al. Elevated blood pressure, obesity, and hyperlipidemia. *J Pediatr*. 2009;155(1):79-83, 83.e1. doi:10.1016/j.jpeds.2009.01.036.

59. Li H-Y, Wei J-N, Ma W-Y, et al. Hypertension and hypercholesterolemia aggregate in nondiabetic children and adolescents with higher fasting plasma glucose levels. *Pediatr Diabetes*. 2011;12(1):41-49. doi:10.1111/j.1399-5448.2010.00648.x.

60. Stabouli S, Kotsis V, Rizos Z, et al. Left ventricular mass in normotensive, prehypertensive and hypertensive children and adolescents. *Pediatr Nephrol*. 2009;24(8):1545-1551. doi:10.1007/s00467-009-1165-2.

61. Richey PA, Disessa TG, Somes GW, Alpert BS, Jones DP. Left ventricular geometry in children and adolescents with primary hypertension. *Am J Hypertens*. 2010;23(1):24-29. doi:10.1038/ajh.2009.164.

62. Kurniawan ED, Cheung N, Cheung CY, Tay WT, Saw SM, Wong TY. Elevated blood pressure is associated with rarefaction of the retinal vasculature in children. *Invest Ophthalmol Vis Sci*. 2012;53(1):470-474. doi:10.1167/iovs.11-8835.

63. Assadi F. Effect of microalbuminuria lowering on regression of left ventricular hypertrophy in children and adolescents with essential hypertension. *Pediatr Cardiol*. 28(1):27-33. doi:10.1007/s00246-006-1390-4.

64. Stabouli S, Kotsis V, Toumanidis S, Papamichael C, Constantopoulos A, Zakopoulos N. White-coat and masked hypertension in children: association with target-organ damage. *Pediatr Nephrol*. 2005;20(8):1151-1155. doi:10.1007/s00467-005-1979-5.

65. Lurbe E, Torro I, Alvarez V, et al. Prevalence, persistence, and clinical significance of masked hypertension in youth. *Hypertension*. 2005;45(4):493-498. doi:10.1161/01.HYP.0000160320.39303.ab.

66. Matsuoka S, Awazu M. Masked hypertension in children and young adults. *Pediatr Nephrol*. 2004;19(6):651-654. doi:10.1007/s00467-004-1459-3.

67. Verberk WJ, Kessels AGH, de Leeuw PW. Prevalence, causes, and consequences of masked hypertension: a meta-analysis. *Am J Hypertens*. 2008;21(9):969-975. doi:10.1038/ajh.2008.221.

68. Furusawa ÉA, Filho UD, Junior DM, Koch VH. Home and ambulatory blood pressure to identify white coat and masked hypertension in the pediatric patient. *Am J Hypertens*. 2011;24(8):893-897.



医脉通 medlive.cn guide.medlive.cn

doi:10.1038/ajh.2011.72.

69. Flynn JT. Differentiation between primary and secondary hypertension in children using ambulatory blood pressure monitoring. *Pediatrics*. 2002;110(1 Pt 1):89-93. http://www.ncbi.nlm.nih.gov/pubmed/12093951. Accessed December 8, 2015.

70. Patzer L, Seeman T, Luck C, Wühl E, Janda J, Misselwitz J. Day- and night-time blood pressure elevation in children with higher grades of renal scarring. *J Pediatr*. 2003;142(2):117-122. doi:10.1067/mpd.2003.13.

71. Seeman T, Palyzová D, Dusek J, Janda J. Reduced nocturnal blood pressure dip and sustained nighttime hypertension are specific markers of secondary hypertension. *J Pediatr*. 2005;147(3):366-371. doi:10.1016/j.jpeds.2005.04.042.

72. Sorof JM, Cardwell G, Franco K, Portman RJ. Ambulatory blood pressure and left ventricular mass index in hypertensive children. *Hypertension*. 2002;39(4):903-908. http://www.ncbi.nlm.nih.gov/pubmed/11967247. Accessed December 8, 2015.

73. Richey PA, Disessa TG, Hastings MC, Somes GW, Alpert BS, Jones DP. Ambulatory blood pressure and increased left ventricular mass in children at risk for hypertension. *J Pediatr*. 2008;152(3):343-348. doi:10.1016/j.jpeds.2007.07.014.

74. Páll D, Juhász M, Lengyel S, et al. Assessment of target-organ damage in adolescent white-coat and sustained hypertensives. *J Hypertens*. 2010;28(10):2139-2144. doi:10.1097/HJH.0b013e32833cd2da.

75. Suláková T, Janda J, Cerná J, et al. Arterial HTN in children with T1DM--frequent and not easy to diagnose. *Pediatr Diabetes*. 2009;10(7):441-448. doi:10.1111/j.1399-5448.2009.00514.x.

76. Chatterjee M, Speiser PW, Pellizzarri M, et al. Poor glycemic control is associated with abnormal changes in 24-hour ambulatory blood pressure in children and adolescents with type 1 diabetes mellitus. *J Pediatr Endocrinol Metab*. 2009;22(11):1061-1067. http://www.ncbi.nlm.nih.gov/pubmed/20101892. Accessed December 8, 2015.

77. Dost A, Klinkert C, Kapellen T, et al. Arterial hypertension determined by ambulatory blood pressure profiles: contribution to microalbuminuria risk in a multicenter investigation in 2,105 children and adolescents with type 1 diabetes. *Diabetes Care*. 2008;31(4):720-725. doi:10.2337/dc07-0824.

78. Lurbe E, Redon J, Kesani A, et al. Increase in nocturnal blood pressure and progression to microalbuminuria in type 1 diabetes. *N Engl J Med*. 2002;347(11):797-805. doi:10.1056/NEJMoa013410.

79. Karavanaki K, Kazianis G, Konstantopoulos I, Tsouvalas E, Karayianni C. Early signs of left ventricular dysfunction in adolescents with type 1 diabetes mellitus: the importance of impaired circadian modulation of blood pressure and heart rate. *J Endocrinol Invest*. 2008;31(4):289-296. doi:10.1007/BF03346360.

80. Lee SH, Kim JH, Kang MJ, Lee YA, Won Yang S, Shin CH. Implications of nocturnal hypertension in children and adolescents with type 1 diabetes. *Diabetes Care*. 2011;34(10):2180-2185. doi:10.2337/dc11-0830.



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guide.medlive.cn

81. Samuels J, Ng D, Flynn JT, et al. Ambulatory blood pressure patterns in children with chronic kidney disease. *Hypertension*. 2012;60(1):43-50. doi:10.1161/HYPERTENSIONAHA.111.189266.

82. McGlothan KR, Wyatt RJ, Ault BH, et al. Predominance of nocturnal hypertension in pediatric renal allograft recipients. *Pediatr Transplant*. 2006;10(5):558-564. doi:10.1111/j.1399-3046.2006.00521.x.

83. Babinska K, Kovacs L, Janko V, Dallos T, Feber J. Association between obesity and the severity of ambulatory hypertension in children and adolescents. *J Am Soc Hypertens*. 6(5):356-363. doi:10.1016/j.jash.2012.08.002.

84. Ben-Dov IZ, Bursztyn M. Ambulatory blood pressure monitoring in childhood and adult obesity. *Curr Hypertens Rep*. 2009;11(2):133-142. http://www.ncbi.nlm.nih.gov/pubmed/19278603. Accessed December 8, 2015.

85. Lurbe E, Alvarez V, Liao Y, et al. The impact of obesity and body fat distribution on ambulatory blood pressure in children and adolescents. *Am J Hypertens*. 1998;11(4 Pt 1):418-424. http://www.ncbi.nlm.nih.gov/pubmed/9607379. Accessed December 8, 2015.

86. Shatat IF, Flynn JT. Relationships between renin, aldosterone, and 24-hour ambulatory blood pressure in obese adolescents. *Pediatr Res*. 2011;69(4):336-340. doi:10.1203/PDR.0b013e31820bd148.

87. Aguilar A, Ostrow V, De Luca F, Suarez E. Elevated Ambulatory Blood Pressure in a Multi-Ethnic Population of Obese Children and Adolescents. *J Pediatr*. 2010;156(6):930-935. doi:10.1016/j.jpeds.2009.12.028.

88. Stabouli S, Kotsis V, Karagianni C, Zakopoulos N, Konstantopoulos A. Blood pressure and carotid artery intima-media thickness in children and adolescents: the role of obesity. *Hellenic J Cardiol*. 53(1):41-47. http://www.ncbi.nlm.nih.gov/pubmed/22275742. Accessed December 8, 2015.

89. Leung LCK, Ng DK, Lau MW, et al. Twenty-four-hour ambulatory BP in snoring children with obstructive sleep apnea syndrome. *Chest*. 2006;130(4):1009-1017. doi:10.1378/chest.130.4.1009.

90. Amin RS, Carroll JL, Jeffries JL, et al. Twenty-four-hour ambulatory blood pressure in children with sleep-disordered breathing. *Am J Respir Crit Care Med*. 2004;169(8):950-956. doi:10.1164/rccm.200309-1305OC.

91. Brady TM, Fivush B, Flynn JT, Parekh R. Ability of blood pressure to predict left ventricular hypertrophy in children with primary hypertension. *J Pediatr*. 2008;152(1):73-78, 78.e1. doi:10.1016/j.jpeds.2007.05.053.

92. Falkner B, DeLoach S, Keith SW, Gidding SS. High risk blood pressure and obesity increase the risk for left ventricular hypertrophy in African-American adolescents. *J Pediatr*. 2013;162(1):94-100. doi:10.1016/j.jpeds.2012.06.009.

93. Border WL, Kimball TR, Witt SA, Glascock BJ, Khoury P, Daniels SR. Diastolic filling abnormalities in children with essential hypertension. *J Pediatr*. 2007;150(5):503-509. doi:10.1016/j.jpeds.2007.01.038.



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guide.medlive.cn

94. Zhu H, Yan W, Ge D, et al. Cardiovascular characteristics in American youth with prehypertension. *Am J Hypertens*. 2007;20(10):1051-1057. doi:10.1016/j.amjhyper.2007.05.009.

95. Flynn JT, Daniels SR, Hayman LL, et al. Update: ambulatory blood pressure monitoring in children and adolescents: a scientific statement from the American Heart Association. *Hypertension*. 2014;63(5):1116-1135. doi:10.1161/HYP.0000000000000007.



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Table 1. Standard approach for BP measurement in children (Grade D).

| |
|---|
| 1. Children who will undergo BP measurement should avoid stimulant medications prior to evaluation. At the time of evaluation, the child should be seated in a quiet room for 5 minutes with back supported prior to the measurement of blood pressure. |
| 2. The right arm is the preferred location for BP measurement for comparison to normative data due to the possibility of coarctation of the aorta, which may result in an erroneously low BP measurement being obtained in the left arm. |
| 3. A cuff size with a bladder width that is at least 40% of the arm circumference and the cuff bladder length should cover 80-100% of the circumference of the arm. The arm should be bare and supported with the BP cuff at heart level. In order to obtain accurate measurements in children a range of pediatric and adult cuff sizes should be available. |
| 4. The pressure should be increased rapidly to 30 mmHg above the level at which the radial pulse is extinguished. |
| 5. The stethoscope should be placed below the bottom edge of the cuff and above the antecubital fossa. The bell or diaphragm of the stethoscope should be held gently and steadily over the brachial artery. |
| 6. The control valve should be opened so that the rate of deflation of the cuff is approximately 2 mmHg per heartbeat. |
| 7. The systolic level - the first appearance of a clear tapping sound (phase I Korotkoff) - and the diastolic level (*the point at which the sounds disappear (phase V Korotkoff)) should be recorded. In some children, Korotkoff sounds can be heard to 0 mmHg. If Korotkoff sounds persist as the level approaches 0 mmHg, then the point of muffling of the sound is used (phase IV Korotkoff) to indicate the diastolic pressure. |
| 8. The BP should be recorded to the closest 2 mmHg on the manometer (or 1 mmHg on electronic devices). |



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**Table 2.** Determining normative data for BP values in children (Grade D).

| |
|---|
| 1. The BP Tables utilize growth parameters as defined by the Centers for Disease Control and Prevention (CDC) growth charts. |
| 2. The normative BP data obtained with auscultatory method includes the US National Health and Nutrition Examination Survey from 1999-2000. Normative BP data for oscillometric measurements are now available. |
| 3. To determine BP percentile, use the standard CDC height charts to determine the height percentile. |
| 4. Measure the child's blood pressure. Use the appropriate gender table. Locate the child's age on the left side of the table and follow the age row horizontally across the table to the intersection of the line for the height percentile as shown in the vertical column. |
| 5. The 50th, 90th, 95th, and 99th percentiles are defined for systolic and diastolic blood pressure based on gender, age and height. |



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**Table 3.** History and Physical Examination (Grade C).

| |
|---|
| 1. Medical History:<br><br>Symptoms<br>▫ Of hypertension<br>▫ Of an underlying disorder*<br><br>Past Medical History<br>▫ For underlying cause of hypertension*, including neonatal history<br><br>Identify other cardiovascular risk factors including inactivity, smoking, and dietary factors<br><br>Family History |
| 2. Patient physical examination:<br><br>Height, weight, and body mass index<br>Vital signs including upper and lower limb blood pressures<br>Evaluation for signs of end-organ damage<br>Fundi, cardiovascular and neurologic systems<br>Evaluation for underlying cause of hypertension* |

*Systems to review include renal, cardiovascular, endocrine, and neurologic, as well as medications/drugs and sleep disorders



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**Table 4.** Suggested schema to classify BP in children.[95]

| Classification | Office BP† | Mean ambulatory SBP or DBP‡ during wake or sleep period, or both | SBP or DBP load (%) |
|---|---|---|---|
| White coat hypertension | ≥ 95th percentile | < 95th percentile | < 25 |
| Masked hypertension | < 95th percentile | ≥ 95th percentile | ≥ 25 |
| Ambulatory hypertension | ≥ 95th percentile | ≥ 95th percentile | 25-50 |
| Severe ambulatory hypertension | ≥ 95th percentile | ≥ 95th percentile | > 50 |



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**Table 5.** Standard approach to obtaining ABPM readings in children (Grade D).

| |
|---|
| 1. ABPM should be performed by a health care professional with specific training in application of the device and interpretation of ABPM data in children. |
| 2. Monitor should be applied to the nondominant arm unless contraindicated or on the arm with the higher BP (if a significant discrepency between the extremities exist). |
| 3. BP should be recorded every 15-20 minutes during waking hours and every 20-30 minutes during sleep. |
| 4. BP measured with the device should be compared with resting, clinic BP by the same technique used by ABPM (ausculatory or oscillometric). These resting BP measurements made immediately after the application of the ABPM device should be edited out. |
| 5. Patients should record activity, sleep/wake times and antihypertensive medication administration in a diary. |
| 6. A minimum of 1 reading per hour (including during sleep) and at least 40-50 readings for a full 24-hour report are needed to consider the study optimal for interpretation. |
| 7. ABPM software should be programmed to discard values that fall outside of the following range:<br>- SBP 60-220 mmHg<br>- DBP 35-120 mmHg<br>- Heart rate 40-180 mmHg<br>- Pulse pressure 40-120 mmHg |
| 8. Standard calculations should be reported during the 24-hour, awake and sleep periods:<br>- Mean ambulatory SBP and DBP<br>- BP load (percentage of readings above the ambulatory 95th percentile)<br>- Dipping ([mean awake BP – mean sleep BP] / mean awake BP x 100) for both SBP and DBP |



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