



Addressing Cardiometabolic Risk in Children and Adolescents: CHALLENGES AND SOLUTIONS

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The Pressure is Rising: Hypertension in Children and Adolescents

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Objectives

1. Summarize the epidemiology and impacts of hypertension in the pediatric population
2. Review the screening and diagnosis of pediatric hypertension
3. Review the treatment of pediatric hypertension

Prevalence



- Hypertension is a global issue
- A recent meta-analysis in patients ≤ 19 y.o. estimated that 9.7% and 4.0% had pre-hypertension and hypertension respectively
- Using AAP clinical practice guideline definitions, from 2013-2016, 3.5% of US children/adolescents 8-17 years of age had hypertension.
- One report stated HTN has risen to 5% in adolescents in US; elevated blood pressure increased up to 12.6% in girls and 19.2% in boys
- Pediatric hypertension affects up to 24% of obese children

1. Jackson, et al. Hypertension among youths- United State, 2001-2006. MMWR Morb Mortal Wkly Rep 2018

2. Song, et al. Global prevalence of hypertension in children: a systematic review and meta-analysis. JAMA Ped 2019

3. Rosner et al. Childhood blood pressure trends and risk factors for high blood pressure: the NHANES experience 1988-2008. Hypertension 2013.

Epidemiology


- Recent studies have shown an incidence rate in children and adolescents from 0.8% to 4% and up to 24% in obese children.
- National average for obesity in Pediatric Population is 35%
- Rates of pediatric hypertension show an increasing linear relationship to adiposity
- Boys have a higher prevalence than girls
- Higher prevalence in Hispanic and non-Hispanic African Americans

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Hypertension Categories

- **White coat hypertension**
 - BP $\geq 95^{\text{th}}$ percentile in the office but $< 95^{\text{th}}$ percentile outside of the office
- **Masked Hypertension**
 - The presence of hypertension despite normal office BPs.
 - Obesity and chronic kidney disease patients are at risk for this.
- **Primary Hypertension**
 - AKA Essential hypertension
 - BP $\geq 95^{\text{th}}$ percentile without an identifiable cause
 - Usually have systolic HTN
- **Secondary Hypertension**
 - HTN with an identifiable cause (renal and urological disorders are common causes)
 - Usually have diastolic HTN



Pediatric Hypertension

Primary hypertension more likely than secondary

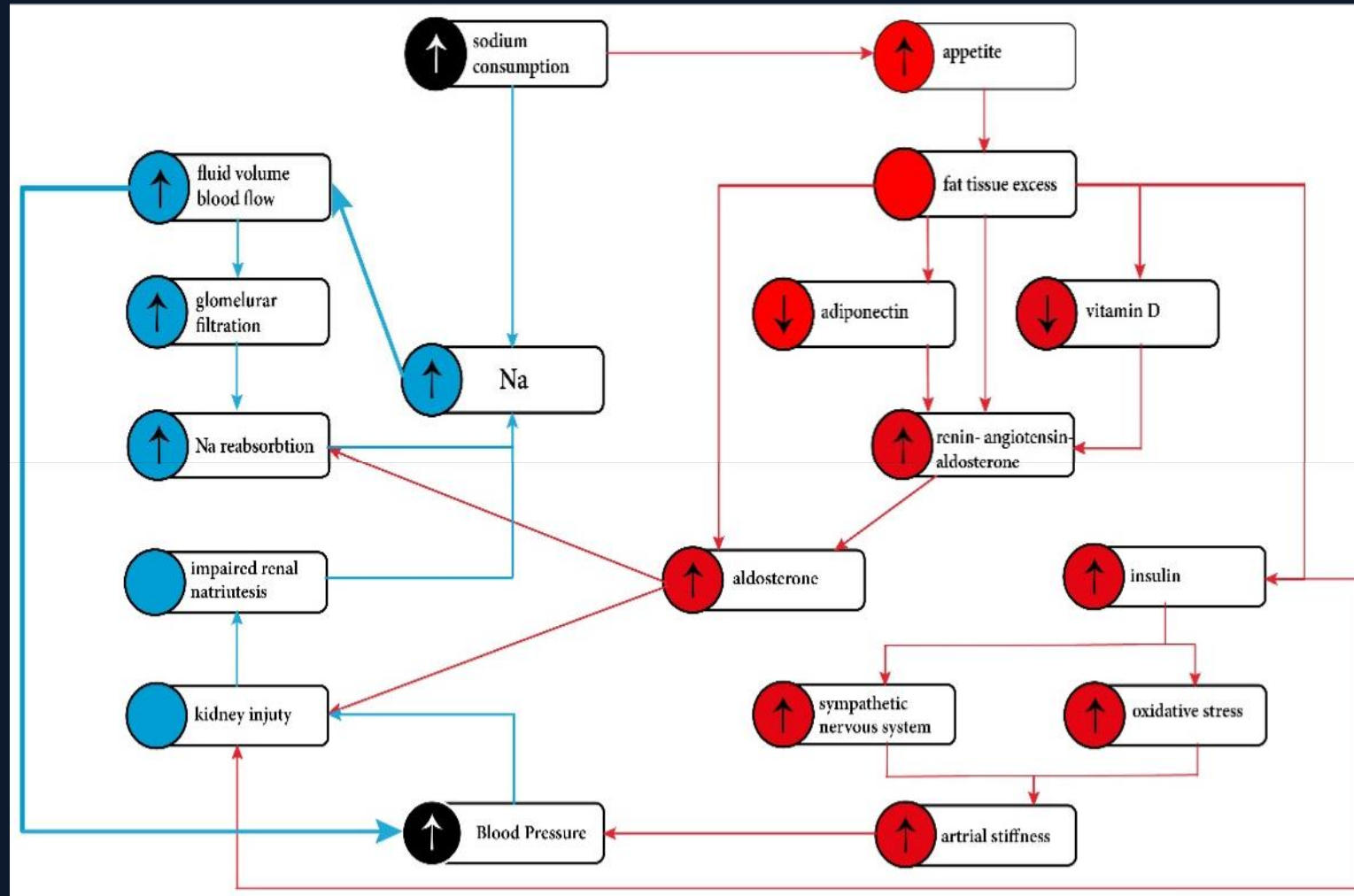
Pathogenesis

- Multi-factorial
- Correlation from dietary salt intake, blood pressure values, and morbidity and mortality from cardiovascular disease
- Regardless of weight, salt is considered a risk

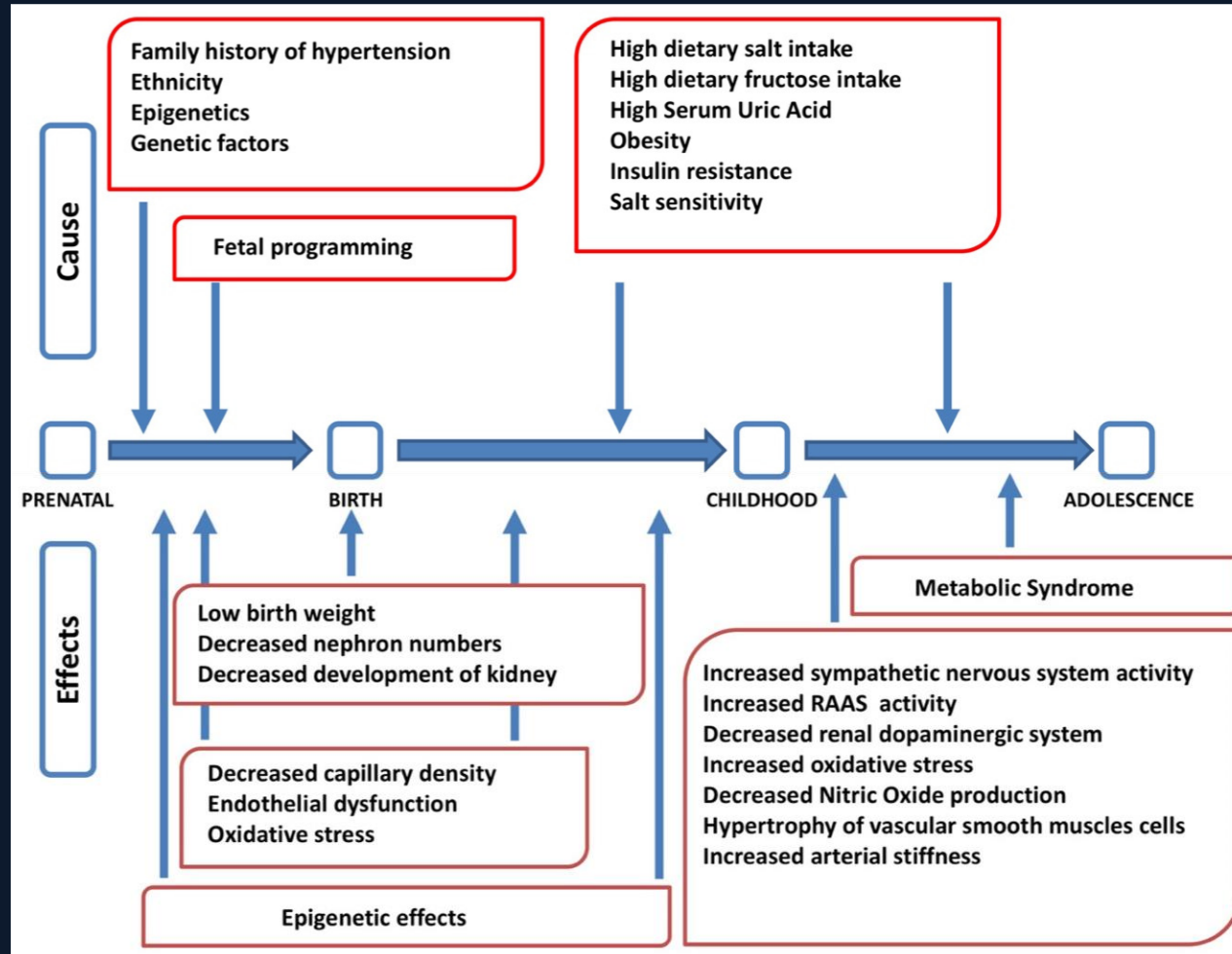
Metabolic syndrome in children and adolescents

- Main features defining metabolic syndrome include: (1) disturbed glucose metabolism, (2) arterial hypertension, (3) dyslipidemia, and (4) abdominal obesity.
- A systolic or diastolic blood pressure $> 95^{\text{th}}$ percentile suggests hypertension
- Despite rising pediatric overweight and obesity in China, hypertension prevalence is stable.
 - This suggests obesity multifactorial effect on childhood BP.

“New” Pathophysiology of Hypertension



Pathogenesis





In order to diagnose hypertension we must first identify hypertension

Making the Diagnosis

- Blood pressure should be measured at every well child exam starting at 3 years
- Multiple measurements should be made during an office visit and average used for blood pressure classification



Review of Clinical Practice Guideline

What's the same, what's different, what do I need to know?

Children are not little adults.....

- Hypertension in childhood is defined by using normative data from children that are healthy
- Hypertension in the adult population is defined by clinical outcomes

AAP CPG

- The 2017 AAP Clinical Practice Guidelines made changes from 2004 report (which used percentiles to define BP category for adolescents).
- Simplified BP categorization in adolescents, which caused a large shift in the diagnosis of HTN in children.
- Revised normative pediatric BP values

Table 1 Definition of hypertension (HTN) based on the 2017 AAP CPG, 2016 ESH Guidelines, and the 2004 Fourth Report

	2017 AAP CPG		2016 ESH Guidelines		2004 Fourth Report
	< 13 years	≥ 13 years	< 16 years	≥ 16 years	
Normal BP	< 90th percentile	< 120/< 80	< 90th percentile	< 130/85	< 90th percentile
Elevated BP*	≥ 90th to < 95th percentile or 120–129/< 80	120–129/< 80	≥ 90th to < 95th percentile	130–139/85–89	≥ 90th to < 95th percentile or > 120/80
Stage 1 HTN	≥ 95th to < 95th percentile + 12 mmHg or 130/80 to 139/89	130–139/80–89	≥ 95th to < 99th percentile + 5 mmHg	140–159/90–99	≥ 95th to < 99th percentile + 5 mmHg
Stage 2 HTN	≥ 95th percentile + 12 mmHg or ≥ 140/90	≥ 140/90	≥ 99th percentile + 5 mmHg	160–179/100–109	≥ 99th percentile + 5 mmHg

AAP Hypertension Guidelines Highlights

- New reference tables for blood pressure
- “Elevated blood pressure” instead of “prehypertension”
- New thresholds for elevated blood pressure, stage 1 hypertension, stage 2 hypertension in children up to 13y
- 13 y and older static threshold defining BP categories used in adults was adopted

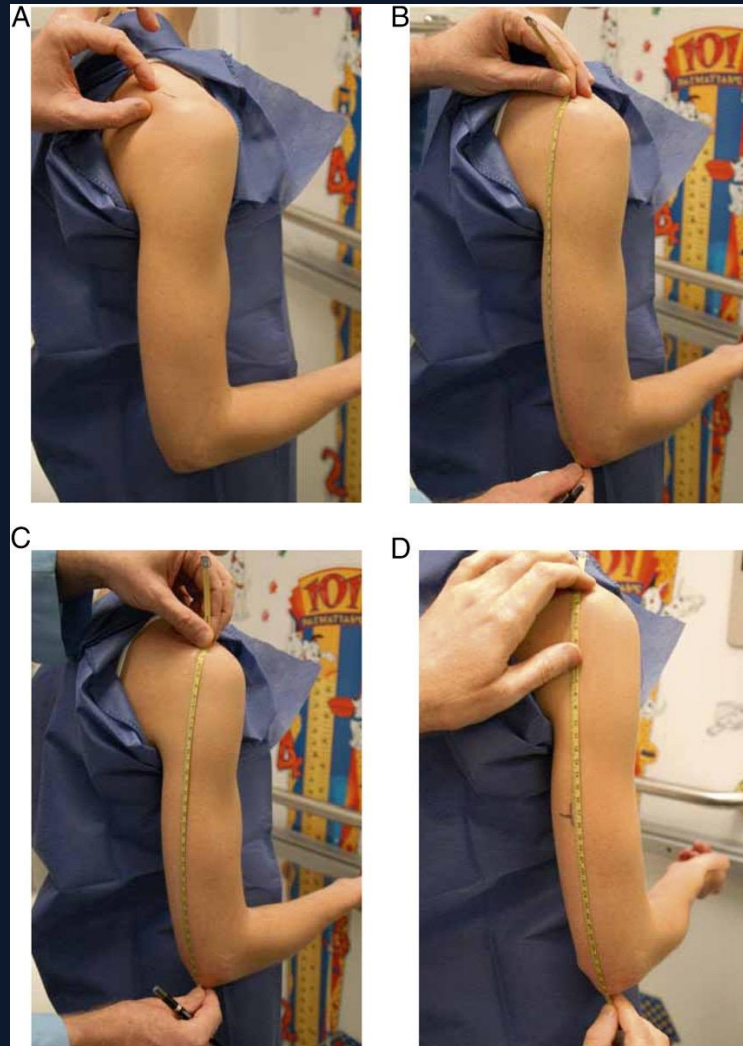
The “New” Normal

	<13 years old	≥ 13 years old
Normal Blood Pressure	<90 th percentile	<120/<80
Elevated Blood Pressure	≥90 th percentile or 120-129/80	120-129/<80
Stage 1 Hypertension	≥95 th to < 95 th percentile + 12mmHg or 130/80 to 139/89	130-139/80-89
Stage 2 Hypertension	≥95 th percentile + 12mmHg or > 140/90	≥140/90



Screening

Determination of Proper BP Cuff Size



Methods of BP measurement

- Automatic Oscillometric Devices

- Increasingly being used
- Automatic
- Measures oscillations transmitted from disrupted arterial flow to determine mean arterial pressure
- Very helpful in pre-schoolers and non-cooperative children
- AAP guideline allows for screening



- Mercury Sphygmomanometers

- “Gold standard” for BP estimation
- Age appropriate proper sized cuff should be used for precise BP measurements in children
- Concern for mercury contamination has lead to many health facilities replacing mercury manometers



Comparison between BP measurement

- A recent meta-analysis found that compared to the mercury sphygmomanometer automatic blood pressure monitors have strong measurement validity.
- Concluded oscillometric or automatic devices can be a suitable alternative to auscultation for initial screening and these can be safely used in BP measurements of children and adolescents

Pediatric Hypertension Across the Globe

Definitions of Childhood Hypertension by Consensus Organizations and National Societies 2022

Issuing body	Year	Criteria for hypertension	Comments	Reference
American Academy of Pediatrics	2017	≥95 th percentile for age and sex; or ≥130/80, whichever is lower	Adopts static cut points from ACC/AHA guideline starting at 13 y of age; percentiles based on revised, lower normative BP data	Flynn et al
Chinese Hypertension League	2018	≥95 th percentile for age and sex	Percentiles based on Chinese-specific normative BP data	Joint Committee for Guideline Revision
European Society of Hypertension	2016	≥95 th percentile for age and sex up to age 16 y; ≥140/90 starting at 16 y	Static cut point based on adult thresholds in use at the time; percentiles based on normative BP data from 2004 Fourth Report	Lurbe et al
Hypertension Canada	2020	≥95 th percentile for age and sex; or >120/80 for ages 6-11 y, or >130/85 for ages 12-17 y	Static cut points derived from one analysis of the Bogalusa Heart Study	Rabi et al
Japanese Society of Hypertension	2019	≥age-based static cut point ranging from 120/70 in preschool students to 140/85 in high-school students	Screening BP values 10-15 mm Hg higher than those in percentile-based reference charts	Umemura et al

ACC = American College of Cardiology; AHA = American Heart Association; BP = blood pressure.

*All require the child's BP to be at or above this level on multiple visits (usually 3) before making a diagnosis of hypertension.

Stage 1-

- $\geq 95^{\text{th}}$ to $< 95^{\text{th}}$ percentile + 12mmHg or 130/80 to 139/89
- Asymptomatic
 - Lifestyle Management
 - Follow up in 1-2 weeks
 - Re-check via auscultation
 - Ambulatory blood pressure monitoring and pharmacologic treatment if the blood pressure is elevated after 3 visit

Stage 2

- $\geq 95^{\text{th}}$ percentile + 12mmHg or $> 140/90$
- Asymptomatic
 - Repeat blood pressures in upper and lower extremities at that visit
 - Refer for nutrition and weight
 - Follow up in 1 week
 - If elevated start ABPM
 - Order imaging
 - Pharmacologic Management

Blood Pressure Tables

- Simplified Blood Pressure Table
 - Based on 90th percentile BP for age and sex
 - Screening tool ONLY
 - Nursing
 - For diagnosis use traditional tables

TABLE 6 Screening BP Values Requiring Further Evaluation

Age, y	BP, mm Hg			
	Boys		Girls	
	Systolic	DBP	Systolic	DBP
1	98	52	98	54
2	100	55	101	58
3	101	58	102	60
4	102	60	103	62
5	103	63	104	64
6	105	66	105	67
7	106	68	106	68
8	107	69	107	69
9	107	70	108	71
10	108	72	109	72
11	110	74	111	74
12	113	75	114	75
≥13	120	80	120	80

There's An App for That

AAP Pediatric Hypertension Guidelines


Diagnoses hypertension in pediatric patients; official guideline of the American Academy of Pediatrics.

IMPORTANT


This tool has been developed in partnership with the American Academy of Pediatrics. The authors, editors, and contributors are expert authorities in the field of pediatrics. No commercial involvement of any kind has been solicited or accepted in the development of the content of this tool. Advertising does not influence editorial decisions or content. The appearance of advertising on MDCalc sites is neither a guarantee nor an endorsement by the AAP of the product, service, or company, or the claims made for the product in such advertising.


INSTRUCTIONS

Use in children aged 1-17 years. Not for use in patients with low blood pressure. Recommendations are based on AAP's [2017 Clinical Practice Guideline](#) (Table 3). Note that cutoffs reported in the calculator may vary slightly from the published tables, as the calculator accommodates for ages between whole numbers (e.g. 5.5 years), and the tables use simplified values to account for ages between whole numbers. For children ≥ 13 years of age, this calculator has been adjusted to meet definitions presented in the [2017 AHA/ACC hypertension guidelines](#) for adults.

When to Use 

Pearls/Pitfalls 

Why Use 

Age	10	years
Decimal values recommended (e.g. for a child who is 5 years and 6 months, enter 5.5)		
Sex	<div>Male</div> <div>Female</div>	
Height	60	in 
Systolic BP	105	mm Hg
Normal values are age-dependent; do not use this calculator in patients with hypotension		
Diastolic BP	76	mm Hg
Normal values are age-dependent; do not use this calculator in patients with hypotension		

Stage 1 HTN

Stage 1 HTN in this 10-year-old girl is SBP 120-132 and/or DBP 76-88 (see Evidence for details)

Stage 1 hypertension

- If asymptomatic, lifestyle interventions should be initiated.
- BP should be rechecked by auscultatory measurement in 1-2 weeks.
 - If it remains classified as Stage 1 HTN at 1-2 weeks, upper and lower extremity BP should be checked, and BP should be checked in 3 months by auscultation with consideration for nutrition/weight management referral.
 - If BP continues to be classified as Stage 1 HTN after 3 visits, ABPM should be ordered along with diagnostic evaluation, and treatment should be initiated with consideration for subspecialty referral.

Let's Recap

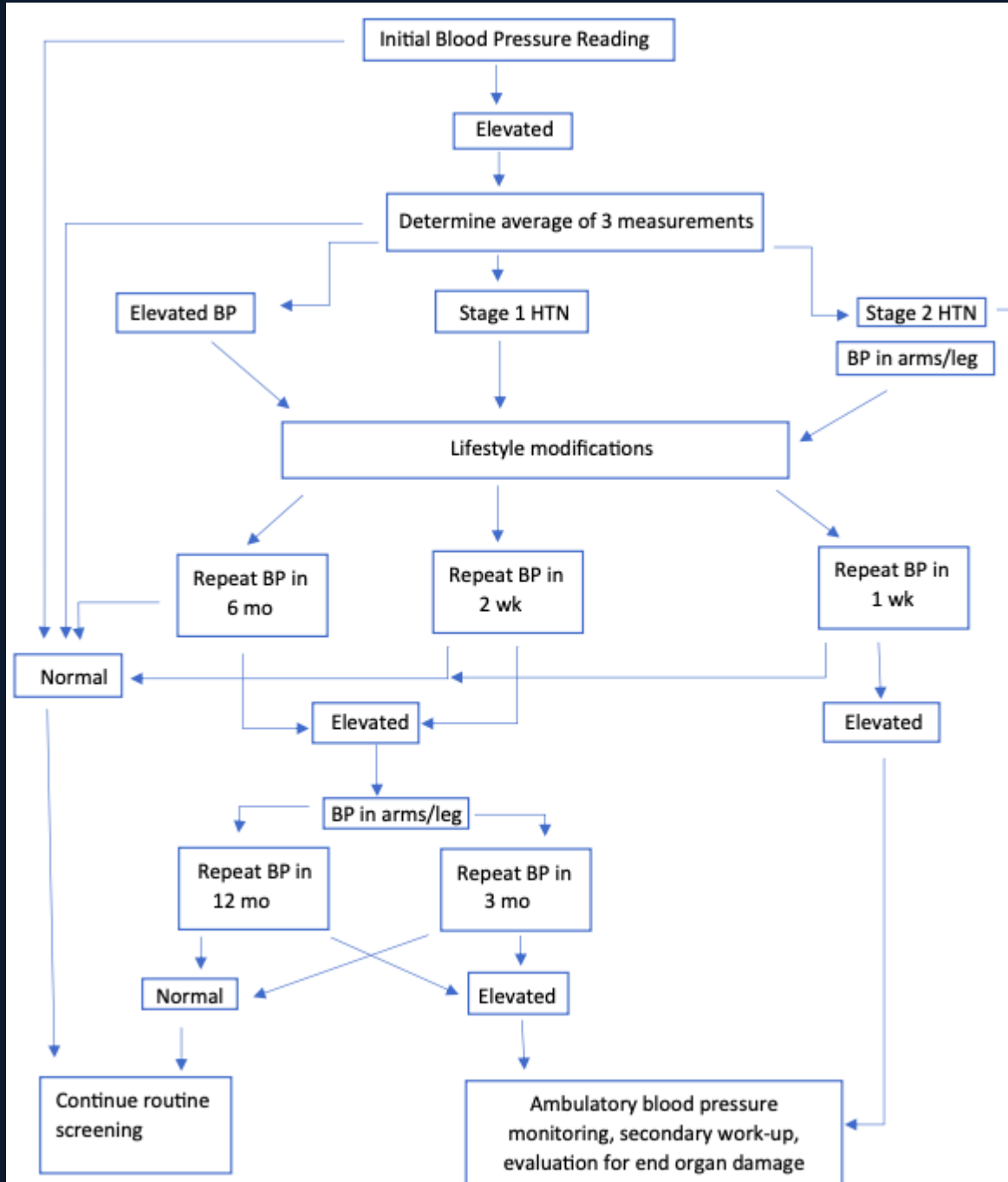


Fig. 1. Pediatric hypertension evaluation.



Impacts of Pediatric Hypertension

Impacts of Pediatric Hypertension During Childhood

- Left Ventricular Hypertrophy
 - Surrogate marker for morbidity and mortality related to hypertension
- Increased markers of vascular stiffness
- Damage to microvasculature, ie retina kidneys, heart ,brain
 - Stage 2
- Faster progression of chronic kidney disease
 - Microalbumenia
- Impaired cognition
 - Improved with treatment

Impacts of Pediatric Hypertension During Adulthood

- Elevated blood pressure in childhood increased the risk for adult hypertension

Neurocognitive Impact of Pediatric Hypertension

- Pediatric hypertension associated with:
 - Cognitive declines
 - Lower performance on executive functioning
 - Lower performance on verbal memory
 - Lower performance on processing speed tasks
- Mental health disorders have the potential for developing or worsening hypertension



Diagnosis

Diagnosis

- Average clinic measured systolic blood pressure and/or diastolic blood pressure \geq 95th percentile

Pediatric Hypertension

- Primary hypertension more likely than secondary

Diagnostic work-up in hypertensive children

Urinalysis

Chem 7

Lipid Profile

Renal U/S if <6yo
or abnormal
UA/Chem 7

- If Obese, then add:
 - HgbA1C
 - Fasting lipids
 - ALT/AST

Diagnostic work-up in hypertensive children

TABLE 10 Screening Tests and Relevant Populations

Patient Population	Screening Tests
All patients	Urinalysis Chemistry panel, including electrolytes, blood urea nitrogen, and creatinine Lipid profile (fasting or nonfasting to include high-density lipoproteina and total cholesterol) Renal ultrasonography in those <6 y of age or those with abnormal urinalysis or renal function
In the obese (BMI >95th percentile) child or adolescent, in addition to the above	Hemoglobin A1c (accepted screen for diabetes) Aspartate transaminase and alanine transaminase (screen for fatty liver) Fasting lipid panel (screen for dyslipidemia)
Optional tests to be obtained on the basis of history, physical examination, and initial studies	Fasting serum glucose for those at high risk for diabetes mellitus Thyroid-stimulating hormone Drug screen Sleep study (if loud snoring, daytime sleepiness, or reported history of apnea) Complete blood count, especially in those with growth delay or abnormal renal function

Adapted from 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). Available at: www.pediatrics.org/cgi/content/full/122/5/e988.

Diagnostic work-up continued....

In the obese (BMI >95th percentile) child or adolescent, in addition to the above

Optional tests to be obtained on the basis of history, physical examination, and initial studies

Hemoglobin A1c (accepted screen for diabetes)

Aspartate transaminase and alanine transaminase (screen for fatty liver)

Fasting lipid panel (screen for dyslipidemia)

Fasting serum glucose for those at high risk for diabetes mellitus

Thyroid-stimulating hormone

Drug screen

Sleep study (if loud snoring, daytime sleepiness, or reported history of apnea)

Complete blood count, especially in those with growth delay or abnormal renal function



Treatment

Treatment of Pediatric Hypertension

- Goal with non pharmacologic and pharmacologic therapy should be a reduction in SBP and DBP to $< 90^{\text{th}}$ percentile or $< 130/80$ which ever is lower
- Lifestyle modifications first-line management

Treatment

- Diet has been stressed by the AAP guidelines to lower BP
- Angiotensin-converting enzyme inhibitors and angiotensin receptor blockers may be the best anti-hypertensive medications for the pediatric population
 - Both of these agents were found to significantly outperform placebo in lowering SBP and DBP.
- Of interest, pediatric African American patients were most successfully treated with Lisinopril.

Treatment

Siddiqui, et al. Hypertension in Children and Adolescents: A review of recent guidelines. Ped Annals (2020).

Pharmacological Treatment of Hypertension				
Class	Mechanism of action	Agent	Dose	Side effects
Angiotensin-converting enzyme inhibitor ^a	Degradation of bradykinin through the blockade of kinin-kallikrein system Efferent artery dilation	Captopril Enalapril Lisinopril (in patients >6 years)	Initial: 0.3 to 0.5 mg/kg/dose (tid-qid) Maximum: 6 mg/kg/day Initial: 0.08 mg/kg/day (qd-bid) Maximum: 0.6 mg/kg/day to 40 mg/day Initial: 0.07 mg/kg/day (qd) Maximum: 0.6 mg/kg/day to 40 mg/day	Cough Hyperkalemia Acute renal failure Angioedema Neutropenia Thrombocytopenia
Angiotensin receptor blockers ^a	Block the binding of angiotensin II to type I angiotensin II receptors	Losartan	Initial: 0.7 mg/kg/day Maximum: 1.4 mg/kg/day to 100 mg/day	Hyperkalemia Acute renal failure
Calcium channel blockers	Block the influx of calcium into smooth muscle, resulting in arteriole dilatation	Amlodipine Isradipine Nifedipine XL Nifedipine (short-acting)	Initial: 0.1 mg/kg/day Maximum: 0.6 mg/kg/day to 10 mg/day Initial: 0.05 mg/kg to 0.1 mg/kg/day Maximum: 0.6 mg/kg/day to 10 mg/day Initial: 0.2 mg/kg/day to 0.5 mg/kg/day Maximum: 3 mg/kg/day (up to 120 mg/day) Initial: 0.04 mg/kg/day to 0.25 mg/kg/dose Maximum: 1 mg/kg/day to 2 mg/kg/day	Tachycardia Peripheral Edema Headaches Flushing Gingival hyperplasia
Beta-blockers	Competitively inhibiting catecholamines from binding to B1, B2, and B3 receptors	Atenolol Metoprolol Propranolol Labetalol	Initial: 0.5 to 1 mg/kg/dose (qd- bid) Maximum: 2 mg/kg/day to 100 mg/day Initial: 1 mg/kg/day to 2 mg/kg/day (bid) Maximum: 6 mg/kg/day to 200 mg/day Initial: 1 mg/kg/day to 2 mg/kg/day (bid-tid) Maximum: 4 mg/kg/day to 640 mg/day Initial: 1 mg/kg/day to 3 mg/kg/day (bid) Maximum: 10-12 mg/kg/day to 1200 mg/day	Decrease cardiac contractility Bronchospasm Fatigue Insomnia
Diuretic	Thiazides inhibit the Na ⁺ Cl-transporter in the early distal convoluted tubule Loop diuretics: inhibit Na-K-2Cl carrier in the thick ascending limb of the loop of Henle	Hydrochlorothiazide Furosemide Amiloride Spironolactone	Initial: 1 mg/kg/day (qd) Maximum: 3 mg/kg/day up to 50 mg Initial: 0.5 mg/kg/day to 2.0 mg/kg/day (qd-bid) Maximum: 6 mg/kg/day Initial: 0.4 mg/kg/day to 0.6 mg/kg/day (qd) Maximum: 20 mg/day Initial: 1 mg/kg/day (qd-bid) Maximum 3.3 mg/kg/day to 100 mg/day	Electrolyte abnormalities Hyponatremia Hypokalemia Hypochloremia Hypercalciuria/stones ^b Hypocalciuria ^c Ototoxicity Dehydration Renal failure

Treatment of Pediatric Hypertension

Single Medication at low end of dosing range



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graph TD; A[Single Medication at low end of dosing range] --> B[Increase every 2-4 weeks until blood pressure is controlled, max dose is reached, or adverse event occurs]; B --> C[If blood pressure remains uncontrolled second agent can be added and dose can be titrated up];
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Increase every 2-4 weeks until blood pressure is controlled, max dose is reached, or adverse event occurs

If blood pressure remains uncontrolled second agent can be added and dose can be titrated up

Hypertensive Crisis

- Acute severe elevation in BP
- AAP states concern for end organ damage should arise when BP increases 30mmHg or more above the 95th percentile for age and height
- Hypertensive emergency → life threatening condition associated with severe BP elevation and end-organ damage

Sports Clearance

- Children with severe hypertension or Stage 2 should NOT be initially cleared
- Must undergo further work up and see a subspecialist
- Avoidance of powerlifting and bodybuilding
- Stage 1 can be *cleared with provision* they follow up for hypertension
 - Provisional clearance can be removed

Summary

- Pediatric hypertension affects up to 24% of obese children
- Screening should take place at every visit starting at age 3
- Ensure proper screening techniques
- Utilize blood pressure tables
- Goal of treatment is reduction in SBP and DBP to < 90th percentile or < 130/80 whichever is lower