Hypertension in children and adolescents

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Disclosure

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- My content will not include discussion/reference of any commercial products or services.
- I do not intend to discuss an unapproved/investigative use of commercial products/devices.

Case

- A 13 year-old boy visited his pediatrician's office for medical clearance to play on his school football team. His blood pressure was 136/80.

Questions?

- Does this boy have ‘hypertension’?
- What is the most likely diagnosis?
- How much work-up is required?
- Can he play on the football team?

Outline

- Are we screening blood pressure correctly in children and adolescents?
- What is the prevalence of hypertension in this population?
- How do we evaluate elevated BP?
- Does elevated BP persist into adulthood and have adverse consequences?
- How do we treat children and adolescents with elevated BP?

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Definition of Hypertension

- **Normal BP:** average SBP and DBP < 90 percentile for sex, age, and height
- **Prehypertension:** average SBP or DBP of 90-95 percentile
  - Adolescents with BP ≥ 120/80 mmHg are considered prehypertensive.
- **Hypertension:** average SBP and/or DBP ≥ 95 percentile on 3 or more occasions
  - **Stage 1:** 95 percentile to 99 percentile + 5 mmHg
  - **Stage 2:** > 99 percentile + 5 mmHg

Blood Pressure Tables: Example for 13 Year-Old Boys

<table>
<thead>
<tr>
<th>Age (Year)</th>
<th>50th</th>
<th>10th</th>
<th>25th</th>
<th>50th</th>
<th>75th</th>
<th>95th</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>104</td>
<td>101</td>
<td>103</td>
<td>105</td>
<td>107</td>
<td>111</td>
</tr>
<tr>
<td>90th</td>
<td>117</td>
<td>118</td>
<td>120</td>
<td>122</td>
<td>124</td>
<td>125</td>
</tr>
<tr>
<td>95th</td>
<td>121</td>
<td>122</td>
<td>124</td>
<td>126</td>
<td>128</td>
<td>130</td>
</tr>
<tr>
<td>99th</td>
<td>128</td>
<td>130</td>
<td>131</td>
<td>133</td>
<td>135</td>
<td>137</td>
</tr>
</tbody>
</table>

How frequently is blood pressure really measured? Shapiro et al. 2012

- Data from a nationally representative sample of ambulatory visits (National Ambulatory Medical Care Survey and National Hospital Ambulatory Medical Care Survey, 2000-2009).
- 93,534 patients, aged 3 to 18 years
- Hypertension screening occurred in **only 35% of visits.**

Underdiagnosis of Hypertension in Children and Adolescents Hansen et al. 2007

- 14187 participants aged 3 to 18 years
- Blood pressure was documented for **94% of visits.**
- 507 participants (3.6%) met criteria for hypertension, but **only 26% of them were actually diagnosed.**

Underdiagnosis of Hypertension in Children and Adolescents Brady et al. 2010

- Cross-sectional study of 2501 scheduled clinic visits for children 3 to 20 years of age at a pediatric primary care practice.
- BP was recorded in 80% of the cases.
- BP was elevated in 779 cases (39%), but **elevation was recognized in only 17% of those cases.**
Summary of screening of elevated blood pressure in children and adolescents

- BP is often not measured.
- When BP is measured, elevated readings are often unrecognized.
- The BP tables are cumbersome and difficult to use.
- The definition of hypertension may need refinement.
  - Height-specific BP thresholds (not age) (Chiolo et al. 2013)
  - Implement to electronic medical record

<table>
<thead>
<tr>
<th>Stage</th>
<th>BP Seg (mmHg)</th>
<th>Height (cm)</th>
<th>Sex</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>systolic</td>
<td>diastolic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>systolic</td>
<td>diastolic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>systolic</td>
<td>diastolic</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Whose BP should we measure?

- children > 3 years old
- children < 3 years old with the following conditions:
  - History of prematurity, very low birth weight, or other neonatal complication requiring intensive care.
  - Congenital heart disease (repaired or non-repaired)
  - Known renal disease or urologic malformations
  - Family history of congenital renal disease
  - Solid-organ transplant
  - Malignancy or bone marrow transplant
  - Treatment with drugs known to raise BP
  - Other systemic illness associated with hypertension (neurofibromatosis, tuberous sclerosis, etc.)
  - Elevated intracranial pressure

Use an appropriate cuff correctly

- Rest 3-5 minutes
- Use Right arm
- Rest cubital fossa at heart level
- Cuff bladder length should be 80-100% of the circumference of the arm measured midway between the olecranon and acromion

Which BP Measurement Devices?

- Auscultation is the preferred method.
- Take at least three BP measurements in each visit, and calculate the average.
- To confirm hypertension, at least three abnormal BP readings must be obtained at different times.
- If oscillometric devices show BP > 90 percentile, repeat by auscultation.
- Also measure BP outside of the clinic at school or home.
Ambulatory Blood Pressure Monitoring (ABPM)

- Patient wears lightweight monitor that takes BP at regular intervals for 24 hr.
- Readings are recorded and later downloaded for analysis.
- Equipment is available for use in children.
- Validity has been confirmed in children.

### BP categories

<table>
<thead>
<tr>
<th>Office BP</th>
<th>Ambulatory BP</th>
<th>CV risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal BP</td>
<td>Normal</td>
<td>-</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>Elevated</td>
<td>+/-</td>
</tr>
<tr>
<td>Sustained HTN</td>
<td>Elevated</td>
<td>+++</td>
</tr>
<tr>
<td>White Coat HTN</td>
<td>Elevated</td>
<td>+/-</td>
</tr>
<tr>
<td>Masked HTN</td>
<td>Normal</td>
<td>+++</td>
</tr>
</tbody>
</table>

### Indications for ABPM

- Identify sustained hypertension vs. white coat hypertension
- Identify masked hypertension
- Assess BP control with anti-hypertensive medications.
- Evaluate BP in patients with chronic diseases:
  - CKD
  - diabetes
  - autonomic dysfunction
  - obesity
  - sleep apnea
  - genetic syndromes (NF type 1, Turner syndrome, Williams syndrome, etc.)

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Initial Screening After 3 measurement sessions

N = 6790, mean age 12.7 years (11-17)

The Obesity Epidemic: National Health and Nutrition Examination Survey 2009-2010

- Cross-sectional analysis of US children and adolescents (N = 4111).
- 33% were overweight or obese (BMI ≥ 85 percentile).

Primary vs. Secondary Hypertension

Causes of Secondary Hypertension in Children and Adolescents

<table>
<thead>
<tr>
<th></th>
<th>Infants</th>
<th>School-age</th>
<th>Teens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>1%</td>
<td>15-30%</td>
<td>85-95%</td>
</tr>
<tr>
<td>Secondary</td>
<td>99%</td>
<td>70-85%</td>
<td>5-15%</td>
</tr>
<tr>
<td>Renal Parenchymal</td>
<td>20%</td>
<td>70-90%</td>
<td></td>
</tr>
<tr>
<td>Renovascular</td>
<td>25%</td>
<td>5-10%</td>
<td></td>
</tr>
<tr>
<td>Coarctation</td>
<td>35%</td>
<td>10-20%</td>
<td></td>
</tr>
<tr>
<td>Endocrine</td>
<td>1%</td>
<td>3-5%</td>
<td></td>
</tr>
<tr>
<td>Neoplastic</td>
<td>4%</td>
<td>1-5%</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>20%</td>
<td>1-5%</td>
<td></td>
</tr>
<tr>
<td>Pulmonary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CNS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medications</td>
<td></td>
<td></td>
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Evaluation of hypertension

- Comprehensive medical history, medications, family history, and risk factors (diet, sleep patterns, and activity level)
- Comprehensive physical examination
- Differentiate primary from secondary hypertension
- Identify comorbid cardiovascular disease risk factors
- Identify stage 2 hypertension or hypertension with evidence of end-organ damage for initiation of pharmacological therapy.

Secondary hypertension

- More common in children than in adults.
- Occurs in prepubertal children.
- May be seen in a thin child with a negative family history of hypertension.
- May show an acute rise in blood pressure.
- Severe or stage 2 hypertension.
- Clinical signs may suggest systemic conditions.
- Specific ambulatory BP patterns (e.g. sustained diastolic HTN, nocturnal HTN, and/or blunted nocturnal HTN).

Labs and imaging studies

- Look for identifiable causes
  - UA with micro
  - Urine cx if indicated
  - BUN, creatinine, electrolytes
  - Renal US with bladder
- Look for comorbidities
  - Fasting lipid and glucose
  - Thyroid function
  - BEARS
  - Polysomnography
  - Drug screen
- Look for target-organ damage
  - Echo
  - Retinal exam
- Additional evaluation as indicated
  - Plasma renin
  - Renovascular imaging
  - Plasma and urine steroid level
  - Plasma and urine chatecholamines

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Elevated BP in children and adolescents tends to persist and progress

- Chen & Wang (Circulation 2008) found that childhood elevated BP is associated with adult hypertension.
- The Muscatine Study (Lauer et al., Pediatrics 1989) showed that elevated BP tracks from childhood into adulthood.
- Redwine et al., J Clin Hypertens 2012) found that pre-hypertension may progress to hypertension in adolescents. The highest risk for progression (6.6% per year) was seen in adolescents with elevated BP at all three visits. These findings could potentially translate into nearly half a million hypertensive adolescents after 5 years.
Adverse effects: target organ damage

- Left ventricular hypertrophy (LVH)
- Carotid intima-media thickening
- Arterial stiffness
- Retinal vascular abnormalities
- Kidney injury
- Neurocognitive deficits

LVH in Children and Adolescents with Hypertension

- Daniels et al. (1998) studied young patients (n = 130) aged 6 to 23 years with persistent BP > 90th percentile. 46% had LVH (> 95th percentile).
- Hanevold et al. (2004) reviewed the prevalence of LVH in children and adolescents. Among 129 patients (mean age = 13.6 ± 3.6 years), the prevalence of LVH was 15.5% using adult criteria and 41.1% using pediatric criteria.
- Brady et al. (2008) found that among 184 children aged 3 to 20 years who were referred for initial evaluation of elevated BP, 41% had LVH.

Left Ventricular Hypertrophy

- Left ventricular mass scales with height\(^2.7\).
  \[
  \text{LV Mass Index (g/m}^2) = (0.80 \times (IVS + LVED + LVPW))^{0.66} - (LVED + 0.6) / \text{height}^{2.7}
  \]
- A conservative cutpoint that defines LVH is
  - Adults: 51 g/m\(^2\)
  - Children: 95th percentile for age and gender

Evidence of CVD in Children

- The Bogalusa Heart Study (Berenson et al. 1992)
  - Persons aged 6 to 30 years were studied at necropsy.
  - Atherosclerosis of the aorta and coronary arteries.
  - Fatty streaks in the coronary arteries correlated with high systolic BP.
- Pathobiological Determinants of Atherosclerosis in Youth (PDAY) (McGill et al. 1995)
  - Hypertension was associated with accelerated atherosclerosis in youth.

Cognitive Effects of Hypertension

Lande et al. 2003, 2009

- National Health and Nutrition Examination Survey III: cross-sectional data for 5077 children aged 6 to 16 years.
- 3.4% had SBP ≥ 90 percentile; 1.6% had DBP ≥ 90 percentile.
- Elevated BP was associated with lower scores in block design and math and a lower digit span.

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Therapeutic lifestyle changes

- Weight reduction
- Physical activity
- Dietary modification
  - Dietary approaches to stop hypertension (DASH)
- Family-based intervention

Pharmacologic agents

- Angiotensin converting enzyme (ACE) inhibitors
- Angiotensin receptor blockers (ARBs)
- Calcium channel blockers (CCBs)
- Diuretics
- Beta-blockers

Indications for pharmacologic therapy

- Symptomatic hypertension
- Secondary hypertension
- Hypertensive target-organ damage
- Diabetes (types 1 and 2)
- Persistent hypertension despite non-pharmacologic measures

Pharmacologic therapy

- Initiate pharmacologic therapy with a single drug.
- Goal BP < 95 percentile.
- If concurrent conditions are present, goal BP < 90 percentile.
- Severe, symptomatic hypertension should be treated with intravenous antihypertensive drugs.

Back to the Case

13 y/o boy
Repeated BP readings were 137/85, 135/82, 140/80
He denies any symptoms, such as headache, epistaxis, or blurred vision. He sleeps well and has good energy level.
He has no h/o UTI. No enuresis. He is not on any medications or supplements. He denies illicit drug use.

The Case: Follow-up

PMH: He was born on term. He was never been hospitalized. He has normal growth and development. He broke his left pinky finger at age 10.
SH: 7th grade. He lives with his parents and one older sister. Denies illicit drug use.
FH: Father has hypertension. His paternal grandmother has DM and hypertension.
PE: Height 166 cm (90 percentile), Weight 85 kg (> 99 percentile)
BMI 30 kg/m2 (>99 percentile), RR 15, HR 77, BP 136/82, 130/90, 140/80 BP 95 percentile: 129/83
The rest of his PE was essentially normal.
The Case: Follow-up

Labs: UA and fasting labs including lipid panels, glucose were normal. Assessment: prehypertension and obesity.
Plan: Get a nutritional consult. Obtain a home BP monitor. Provide information about a family-based weight loss program. Ok to play football.
Follow up in 6 months.

Pediatric hypertension clinic

- Initial evaluation
- Consultation
- Nutritional evaluation and counseling
- Ambulatory blood pressure monitoring (ABPM)
- Medication management
- Diagnostic testing
- 24-hour consultation

Our multidisciplinary team

Nephrology
- Providers
  - Mazen Araj, MD
  - Daniel Ranch, MD
  - Kep Yamauchi, MD, PhD
  - Ivette Jones, MSN, RN, CPNP
- Nurses
  - Crystal Gonzalez
  - Rose Gonzalez
  - Sarah Hinjosa
- Dietitian
  - Lori Grant
- Pharmacist
  - Barrett Growther
- Social Worker
  - Maggie Farias

Other subspecialties

- Cardiology
  - Josie Molina
  - David Bush, MD, PhD
  - Christopher Curzon, MD
  - Elaine Maldonado, MD

- Endocrinology
  - Jane Lynch, MD

- Sleep Medicine
  - Karen Hentschel-Franks, DO

- Interventional Radiology
  - Rajiv Sun, MD
  - Jorge Lopez, MD

- Surgery
  - Boulos Tournier, MD
  - Gregory Abrahamian, MD

- Urology
  - Dennis Peppas, MD

PEDIATRIC HYPERTENSION PROGRAM
AMBULATORY BLOOD PRESSURE STUDY REPORT

TECHNICAL ANALYSIS:
Hours of Study: 24
Number of Successful Readings: 68
Percent of Successful Reading: 10%

STATISTICAL ANALYSIS:

<table>
<thead>
<tr>
<th>Threshold Ambulatory BP’s</th>
<th>Awake: 142/83</th>
<th>Sleep: 124/66</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean 24-hr BP</td>
<td>139/76</td>
<td>Mean Sleep BP: 112/52</td>
</tr>
<tr>
<td>Awake BP load</td>
<td>Systolic: 135 % Diastolic: 13 %</td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>Diastolic: 10 %</td>
<td></td>
</tr>
<tr>
<td>Sleep BP load</td>
<td>Systolic: 130 % Diastolic: 4 %</td>
<td></td>
</tr>
<tr>
<td>Dipping status</td>
<td>Systolic: 16 % Diastolic: 30 %</td>
<td></td>
</tr>
</tbody>
</table>

INTERPRETATION: The study was of adequate technical quality. There was evidence of pre-hypertension with an elevated sleep SBP load. Nocturnal dipping was normal.
Conclusion: Abnormal study consistent with pre-hypertension