Evaluation of Pediatric Hypertension

PRESENTED BY: THOMAS LOESEVITZ, D.O., PGY II
Disclosures

- None
Lecture objectives

- Understand importance of recognition of child and adolescent hypertension
- Define child and adolescent hypertension
- Distinguishing primary and secondary causes of hypertension
- Understand treatment and management of child and adolescent hypertension
Hypertension in children and adolescents

- Pediatric hypertension has not been previously shown to be related to disease outcomes.

- Adult hypertension contributes to the development of cardiovascular disease and renal disease.

  - 2445 subjects, observed at ages 7-18 years and again at 20-30 years.
  - During childhood, measurements of blood pressure, height, and weight were made in alternate years. Same measurements again were made during adulthood.
  - Study showed elevated adult blood pressure is correlated with elevated childhood blood pressure.
  - Similarly with childhood obesity.

Lauer et al, Pediatrics 1989;84:633
Adverse Events

- Hypertension is a known risk factor for myocardial infarction, stroke, and cardiovascular mortality in adults
- Children with severe elevation of BP also at increased risk of adverse outcomes
  - Hypertensive encephalopathy
  - Seizures
  - Stroke
  - Congestive heart failure
Early Atherosclerosis

- Study by Gerald et al set to understand the relation of multiple risk factors to the extent of asymptomatic atherosclerosis in young people

- 204 autopsies performed on people age 2-39 who died of various causes, principally trauma
  - Antemortem risk factors available for 93
  - Risk factors correlated with extent of atherosclerosis in the aorta and coronary arteries

- Extent of fatty streaks and fibrous plaques in aorta and coronary arteries increased with age
  - Correlation greater in coronary arteries ($P<0.001$) than the aorta ($P=0.03$)

Early Atherosclerosis

- Among cardiovascular risk factors
  - BMI, systolic and diastolic BP, total cholesterol, triglycerides, LDL, and HDL were strongly associated with the extent of lesions in the aorta and coronary arteries

- cigarette smoking
  - Intimal surface involved with fibrous plaques in the aorta (1.22% in smokers vs. 0.12% in nonsmokers), \( P=0.02 \)
  - Fatty streaks in the coronary vessels (8.27% vs. 2.89%), \( P=0.04 \)

- As the number of risk factors increased the percent of the intimal surface covered with fatty streaks also increased both in the aorta and coronary arteries

Development of Criteria for Childhood Hypertension

- Blood pressure in children varies among age and other factors
- The National High Blood Pressure Education Program Working Group (NHBPEP) developed guidelines for the definition of normal and elevated blood pressures in children
  - 1977, addressed by Task Force on Blood Pressure Control in Children
    - Revised version in 1987 (2nd Task Force) included normative blood pressure data derived from sampling more than 70,000 children
    - Updates in 1996
  - In 2004, after JNC 7 report, update by NHBPEP on hypertension in children and adolescent
    - 4th report on the diagnosis, evaluation and treatment
      - American Academy of Pediatrics

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
The Fourth Report

- Included new data from 1999-2000 National Health and Nutrition Examination Survey (NHANES)
- Revised blood pressure tables included blood pressure percentiles for the 50th, 90th, 95th, and 99th percentile
  - Categorized by gender, age, and height
- Hypertension defined based on the normative distribution of blood pressure and healthy children
- Contrast to Adult Hypertension, which is based on clinical outcome data such as cardiovascular disease and mortality
  - Unable to use similar outcomes in children

NHBPEP, Pediatrics Vol. 114 No. 2
August 2004
The Fourth Report

- Height added as important component in appropriately classifying hypertension
- In 1993, Rosner et al developed normative blood pressure levels for children, by sex, while accounting for age and height simultaneously
  - 8 US studies used in report from the second task force and one additional study of blood pressure in children were reanalyzed
  - **56,108 children**, aged 1-17 years seen in over 76,000 office visits
- When height taken into account, more short children (10th age-sex-specific height percentile) and fewer tall children (90th age-sex-specific height percentile) are likely to be classified as hypertensive compared to the then current age-sex-specific height percentiles
  Rosner B et al, J Pediatr 1993; 123:871
Method of blood pressure measurement

- Blood pressures based on auscultatory measurements with sphygmomanometer
  - Preferred method from 4th report

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Blood pressure measurement

- Use standard clinical sphygmomanometer
- Measure after child has been sitting quietly for 5 minutes
- Seated with his or her back supported. Feet on the floor and arm supported at heart level
- Right arm preferred to avoid possibility of false low readings in the left arm due to coarctation of the aorta
- Stethoscope placed over brachial artery pulse, proximal and medial to the cubital fossa

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Blood pressure measurement

- Stethoscope should be placed below the bottom edge of the cuff, around 2 cm above the cubital fossa
- Cuff should be appropriate size for the child’s upper arm
  - Cuff with an inflatable bladder with that is at least 40% of the arm circumference at the point midway between the olecranon and the acromion
  - Cuff bladder length should cover 80-100% of the circumference of the arm
- Blood pressure measurements are overestimated to greater degree with a cuff that is too small than they are underestimated by a cuff that is too large
- The fourth report recommended that measurements obtained by Oscillometric devices that exceed the 90th percentile should be repeated by auscultation

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Blood pressure measurement

- Systolic blood pressure determined by onset of “tapping” Korotkoff sounds (K1)
- Diastolic blood pressure determined by the disappearance of Korotkoff sounds (K5)
  - In 1996, update for 1987 task force report
  - K5 became the new definition of diastolic blood pressure
- During blood pressure measurement, Korotkoff sounds may be heard to 0 mmHg
  - Should repeat with less pressure on head of stethoscope
  - If low K5 present, use K4 (muffling of the tapping) for the Diastolic
Advantages to Oscillometric devices

- Ease of use
  - Helpful for patient’s monitoring blood pressure at home
- Minimization of observer bias or digit preference
- Use referred in newborns and young infants in whom auscultation is difficult
- Preferred to use in ICU setting
Limitations of Oscillometric devices

- Oscillometric devices measure mean arterial blood pressure and then calculate systolic and diastolic values
- Companies have different proprietary algorithms
  - Variation from company to company and device to device
- Kuaufmann et al studying Oscillometric blood pressure measurements by different devices noted that results may vary widely and do not always match values obtained by auscultation
Definition of Hypertension

- In United States, blood pressure percentiles were developed by the NHBPEP Working Group based on normal data.
- Table with diastolic and systolic blood pressures based on gender, age, and height.
- These include blood pressure percentile in the 50th, 90th, 95th, and 99th percentile for both systolic and diastolic.
- Normal blood pressure - systolic and diastolic BP < 90th percentile.
- Prehypertension - systolic and/or diastolic BP ≥90th percentile but < 95th percentile, or if in adolescence the BP exceeds 120/80 mmHg even if <90th percentile.
- Hypertension defined as average systolic and/or diastolic blood pressure that is ≥95th percentile for gender, age, and height on ≥3 occasions.

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Hypertension

- Hypertension
  - Divided into stage I and stage II
  - Stage I allows time for evaluation before initiating treatment
  - Stage II May require evaluation and treatment
- Stage I hypertension - systolic and/or diastolic BP between 95th percentile and 5 mmHg above the 99th percentile
  - Or if in adolescence the BP exceeds 140/90 mmHg even if <95th percentile
- Stage II hypertension - systolic and/or diastolic BP ≥99th percentile plus 5 mmHg
Using Blood Pressure Table

- Determine child’s height percentile
- Measure and record systolic and diastolic blood pressure
- Use table corresponding to gender
- Find age on the left and match with height closest height percentile
- Match patient’s blood pressure to thresholds for 50th, 90th, 95th, and 99th percentile for systolic blood pressure and diastolic blood pressure
- Determining category of hypertension
- If there is discrepancy between systolic and diastolic use the more elevated to determine degree of hypertension

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
## Blood Pressure Levels for Boys by Age and Height Percentile

<table>
<thead>
<tr>
<th>Age (Year)</th>
<th>BP Percentile</th>
<th>Systolic BP (mmHg)</th>
<th>Diastolic BP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Percentile of Height</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5th</td>
<td>10th</td>
<td>25th</td>
</tr>
<tr>
<td>1</td>
<td>50th</td>
<td>80</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>90th</td>
<td>94</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>95th</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>99th</td>
<td>105</td>
<td>106</td>
</tr>
<tr>
<td>2</td>
<td>50th</td>
<td>84</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td>90th</td>
<td>97</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>95th</td>
<td>101</td>
<td>102</td>
</tr>
<tr>
<td></td>
<td>99th</td>
<td>109</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>50th</td>
<td>86</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>90th</td>
<td>100</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>95th</td>
<td>104</td>
<td>105</td>
</tr>
<tr>
<td></td>
<td>99th</td>
<td>111</td>
<td>112</td>
</tr>
<tr>
<td>4</td>
<td>50th</td>
<td>88</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>90th</td>
<td>102</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>95th</td>
<td>106</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>99th</td>
<td>113</td>
<td>114</td>
</tr>
</tbody>
</table>

*UpToDate*
<table>
<thead>
<tr>
<th>Age (Year)</th>
<th>BP Percentile ↓</th>
<th>Systolic BP (mmHg)</th>
<th></th>
<th>Diastolic BP (mmHg)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5th</td>
<td>10th</td>
<td>25th</td>
<td>50th</td>
</tr>
<tr>
<td>11</td>
<td>50th</td>
<td>99</td>
<td>100</td>
<td>102</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>90th</td>
<td>113</td>
<td>114</td>
<td>115</td>
<td>117</td>
</tr>
<tr>
<td></td>
<td>95th</td>
<td>117</td>
<td>118</td>
<td>119</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>99th</td>
<td>124</td>
<td>125</td>
<td>127</td>
<td>129</td>
</tr>
<tr>
<td>12</td>
<td>50th</td>
<td>101</td>
<td>102</td>
<td>104</td>
<td>106</td>
</tr>
<tr>
<td></td>
<td>90th</td>
<td>115</td>
<td>116</td>
<td>118</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td>95th</td>
<td>119</td>
<td>120</td>
<td>122</td>
<td>123</td>
</tr>
<tr>
<td></td>
<td>99th</td>
<td>126</td>
<td>127</td>
<td>129</td>
<td>131</td>
</tr>
<tr>
<td>13</td>
<td>50th</td>
<td>104</td>
<td>105</td>
<td>106</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>90th</td>
<td>117</td>
<td>118</td>
<td>120</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td>95th</td>
<td>121</td>
<td>122</td>
<td>124</td>
<td>126</td>
</tr>
<tr>
<td></td>
<td>99th</td>
<td>128</td>
<td>130</td>
<td>131</td>
<td>133</td>
</tr>
<tr>
<td>14</td>
<td>50th</td>
<td>106</td>
<td>107</td>
<td>109</td>
<td>111</td>
</tr>
<tr>
<td></td>
<td>90th</td>
<td>120</td>
<td>121</td>
<td>123</td>
<td>125</td>
</tr>
<tr>
<td></td>
<td>95th</td>
<td>124</td>
<td>125</td>
<td>127</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td>99th</td>
<td>131</td>
<td>132</td>
<td>134</td>
<td>136</td>
</tr>
</tbody>
</table>
Calculator: Blood pressure percentiles for girls (2 to 17 years)

**Input:**

- **Age:** 10 yr
- **Height:** 54 in
- **Systolic BP:** 112 mmHg
- **Diastolic BP:** 79 mmHg

**Results:**

- **Height Percentile:** 44
- **Systolic BP Percentile:** 84
- **Diastolic BP Percentile:** 96

Threshold for Stage II hypertension* (defined as 99th percentile plus 5 mmHg)

- **Systolic BP Threshold:** 131
- **Diastolic BP Threshold:** 91

[Reset form]
Establishing Diagnosis

- If blood pressure is >90th percentile, repeat measurement twice in the same visit and calculate average
- Must confirm on repeat visits
  - 3 or more
- Elevated blood pressure tends to fall on subsequent measurement
  - Accommodation affect
    - Reduction in anxiety from one visit to the next
Need for repeat measurements

- Illustrated by large cohort study by Lo et al. published in Pediatrics in 2013
  - Cohort included 199,513 children (24.3% aged 3-5 years, 34.5% aged 6-11 years, and 41.2% aged 12-17) with substantial racial/ethnic diversity
    - 35.9% white, 7.8% black, 17.6% Hispanic, 11.7% Asian/Pacific Islander, and 27.0% other/unknown
  - At first visit 81.9% were normotensive, 12.7% had prehypertension, and 5.4% had hypertension using BP classification based on fourth report
  - Of the 10,848 children with index hypertensive BP level, **3.8% with follow up had confirmed HTN (estimated 0.3% prevalence)**
  - **Increasing age and BMI** were significantly associated with prehypertension and confirmed hypertension
  - Among racial groups, Blacks and Asians had the highest prevalence of hypertension

Follow up based on Results

- <90<sup>th</sup> percentile - Recheck at next scheduled Physical Examination
- 90<sup>th</sup> to <95<sup>th</sup> or if BP exceeds 120/80 even if <90<sup>th</sup> - Recheck in 6 months
  - Weight-management counseling if overweight; introduce physical activity and diet management
  - No pharmacologic intervention unless patient with CKD, DM, HF or LVH present
- Stage 1 Hypertension - 95<sup>th</sup>-99<sup>th</sup> percentile plus 5 mm Hg - recheck in 1-2 weeks or sooner if patient is symptomatic
  - If elevated on 2 more occasions, evaluate or refer within 1 month
  - Lifestyle recommendations as previously mentioned
  - Initiate therapy if symptomatic, secondary HTN, target-organ damage (LVH), DM I or II, and persistent HTN despite non-pharmacologic measures

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Follow up based on Results

- Stage 2 Hypertension - >99th percentile plus 5 mm Hg
  - Evaluate or refer within 1 week or immediately if patient is symptomatic
  - Same lifestyle recommendations as previously described
  - Initiate pharmacologic therapy
Is blood pressure on the Rise in children?

- Study done by Din-Dzietham R et al. used national survey data obtained from multistage probability sampling of the US non-institutionalized population from 1963-2002
  - 8-17 year old non-Hispanic Blacks, whites, and Mexican Americans were included
- Study showed a rise in mean SBP by 1.3 mmHG and mean DBP by 8.4 mmHG between 1988-1994 and 1999-2002
  - This was in part due to increase in obesity in children

Din-Dzietham et al, Circulation 2007; 116:1488
Study done by Watkins D et al. examine secular trends in blood pressure over a 10 year period between two representative cohorts of adolescents from Northern Ireland

- 1015 adolescents studied between 1989 and 1990
- 2017 adolescents studied between 1999 and 2001
- Participants were aged 12 or 15
- Results showed decreases in both SBP (mean decrease 7.7 mmHg to 10.0 mm Hg) and DBP (8.8 mm Hg to 11.0 mmHg)
- These decreases were not accounted for by adjustment for potential confounders including age, height, body mass index, smoking, physical activity, aerobic fitness, and stratification of school by education board area and type

Watkins D, BMJ 2004; 329:139
Accounting for BMI

- Normative BP percentiles are based upon data that includes all children regardless of their BMI.
- Obesity prevalence results in an overall increase in childhood blood pressure.
- Proposed to create normal BP values using on children with normal weight (BMI <85th percentile).
- Study by Rosner et al. used data from 49,967 children included in database of the NHBPEP Working Group to develop norms for childhood blood pressure among normal-weight children (BMI <85th percentile). 11

Accounting for BMI

- Concluded that prehypertension and hypertension threshold values are slightly lower than what was determined in the fourth report.
- Whether using BP percentile based upon normal weight children is a better method and identifying pre-hypertension and hypertension remains an open question.
- Authors concluded that blood pressure varies considerably.
- Not uncommon to find children who are prehypertensive or hypertensive at one visit and normotensive at a second visit.

Global variation in Blood Pressure Norms

- Study by Menghetti et al in Italy set to develop a national standard level of blood pressure for Italian children
- Used data from 21 Italian studies conducted according to the recommendations of the American Task Force between 1988 and 1994
- 11,519 healthy individuals (6258 boys and 5261 girls) aged 5-17 years in various locations throughout Italy
- Measurements performed at school
- With respect to the American standards, the levels in Italy for the 90th and 95th percentiles were 3-8 mm Hg higher for the systolic and diastolic BP in both sexes between 5-12 years, and 2-3 mmHg higher in older males
- Also concluded that with respect to Northern Europe, in the lower ages, levels in Italy were quite similar, although slightly higher
- Late adolescence- Northern European levels higher especially in males, with difference of 4-5 mmHG for the mean values and 8-12 mm Hg for the 95th percentile

Menghetti, J Hypertens. 1999;17(10):1363
2016 European Society of Hypertension guidelines for Children and Adolescents

- ESH continues to use normative data from 2004 U.S. NHBPEP for children up to 16 years of age
- Individuals 16 years or older, the ESH guidelines recommend using adult thresholds

Lurbe J Hypertens. 2016 Oct;34(10):1887-920
Study by Hansen et al in 2007 set to determine frequency of undiagnosed hypertension and prehypertension

Cohort of 14,187 children and adolescents aged 3-18 years seen at least 3 times for well-child care between June 1999 and September 2006 in Northeast Ohio

Results concluded that of 507 children and adolescents (3.6%) who had HTN, **only 131 (26%)** had a diagnosis of HTN or elevated blood pressure documented in the EMR

Of 485 children and adolescents (3.4%) who had prehypertension, **only 55 (11%)** had an appropriate diagnosis document in the EMR

Underdiagnosed

- Factors that increased the adjusted odds of a correct diagnosis of Hypertension
  - 1-year increase in age over age 3
  - Number of elevated blood pressure readings beyond 3
  - Increase of 1% in height-for-age percentile
  - Having an obesity-related diagnosis
  - Number of blood pressure readings in the stage 2 hypertension range

Primary Vs. Secondary Hypertension

- Prepubertal more likely to have secondary HTN while adolescents usually have primary HTN
- Polish study done from January 1982-December 1989
  - 1025 patients 1 month-18 years with increased BP referred for evaluation
  - 636 had significant HTN
- In 351 patients, HTN was secondary to known cause
  - Renal parenchymal diseases- 68%
  - Renovascular- 10%
  - Endocrine- 11%
- 258 children less than 15 years
  - All but 6 had secondary HTN
- 75% of adolescents had essential HTN

Factors associated with Primary Hypertension

- Adolescence
- Stage I hypertension
- Overweight or obese
- Children with family history of primary hypertension
- Asymptomatic
Factors associated with Secondary Hypertension

- Prepubertal
- Severe hypertension (stage 2)
- Diastolic hypertension
- Nocturnal hypertension
- Family history with monogenic cause
  - E.g., autosomal dominant polycystic kidney disease
- Symptomatic
  - Headache
  - Sweating
  - Tachycardia
Primary Hypertension

- Often associated with other risk factors
- History, physical, and laboratory evaluation of hypertensive children and adolescents should include assessment for additional cardiovascular risk
- Include:
  - Low HDL
  - Elevated LDL
  - Elevated triglycerides
  - Abnormal glucose tolerance
Primary Hypertension

- BP between 90-94th percentile (Prehypertension) and all children with BP >95th percentile should have
  - Fasting lipid panel
  - Fasting glucose tolerance test or hemoglobin A1c
- Should repeat tests over time to monitor for changes

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Risk Factors for Cardiovascular Disease

- Hypertension
- Overweight/obesity
- Dyslipidemia
- Family history of premature CVD
- Type 1 and type 2 diabetes mellitus
- Chronic kidney disease associated with CVD
Sleep Disorders

- Associated with hypertension, coronary artery disease, heart failure, and stroke in adults
- Study by Marcus et al. set to evaluate hypertension in children with obstructive sleep apnea
  - Measured blood pressure during polysomnography in 41 children with OSA compared to children with primary snoring
  - BP measured every 15 minutes with automated system
  - Children with OSA had significantly higher diastolic BP during sleep
  - No significant difference in systolic BP between both groups
  - Concluded that childhood OSA is associated with systemic diastolic hypertension

Identifying Sleep Disorders

- Obtain history of sleeping patterns
  - Bedtime problems
  - Excessive daytime sleepiness
  - Awakening during the night
  - Regularity and duration of sleep
  - Sleep-disordered breathing (snoring)
- Consider evaluation with polysomnography
History

- Family history of hypertension
- Caffeine intake including sodas/energy drinks
  - Preparations aimed at enhancing athletic performance
- History of Smoking
- Alcohol intake
- Physical activity
- Past history of urinary tract infection such as pyelonephritis, or underlying congenital kidney or urologic anomalies
History

- Symptoms suggesting catecholamine excess such as headache, sweating, and tachycardia
  - Pheochromocytoma
  - Neuroblastoma
  - Use of sympathomimetic drugs such as decongestants
  - Cocaine
  - Amphetamines
  - Epinephrine
  - Monoamine oxidase inhibitors with ingestion of tyramine-containing foods
History

- Ambiguous genitalia
  - Congenital adrenal hyperplasia
- Edema and hematuria
  - Associated with renal parenchymal disease
- Arthritis, rash, and abdominal pain
  - Henoch-Schönlein purpura
  - Systemic lupus erythematosus
- Family history of congenital renal disease
  - Polycystic kidney disease
- Other conditions associated with HTN
  - Neurofibromatosis
  - Tuberous sclerosis
History

- Medications
  - Glucocorticoids
  - Anabolic steroids
  - Oral contraceptives
  - Oral decongestants

- Perinatal history
  - Umbilical arterial catheterization as neonate
    - Predisposes to renovascular disease
  - Oligohydramnios
  - Perinatal anoxia
History

- Type 1 or type 2 Diabetes Mellitus
- Chronic kidney disease
- Organ transplantation
- Cardiac disease
  - Chest pain, exertional dyspnea, palpitations
- Kawasaki disease
Physical Examination

- Determine child’s height, weight, and percentiles for age
- Determine BMI of patient given strong correlation with obesity and HTN
  - Also, poor growth may indicate chronic illness
- When HTN is confirmed
  - Measure BP in both arms and in a leg
  - If leg BP lower than arm BP or femoral pulses weak or absent
    - Consider Coarctation of the aorta
  - Obesity by itself is insufficient explanation for diminished femoral pulses

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
<table>
<thead>
<tr>
<th>Finding*</th>
<th>Possible Etiology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital signs</td>
<td><strong>Tachycardia</strong>&lt;br&gt;&lt;br&gt;<strong>Decreased lower extremity pulses; drop in BP from upper to lower extremities</strong>&lt;br&gt;&lt;br&gt;<strong>Coarctation of the aorta</strong></td>
</tr>
<tr>
<td>Eyes &lt;br&gt;&lt;br&gt;<strong>Retinal changes</strong> &lt;br&gt;&lt;br&gt;<strong>Severe hypertension, more likely to be associated with secondary hypertension</strong></td>
<td></td>
</tr>
<tr>
<td>Ear, nose, and throat &lt;br&gt;&lt;br&gt;<strong>Adenotonsillar hypertrophy</strong> &lt;br&gt;&lt;br&gt;<strong>Suggests association with sleep-disordered breathing (sleep apnea), snoring</strong></td>
<td></td>
</tr>
<tr>
<td>Height/weight &lt;br&gt;&lt;br&gt;<strong>Growth retardation</strong>&lt;br&gt;&lt;br&gt;<strong>Chronic renal failure</strong>&lt;br&gt;&lt;br&gt;<strong>Obesity (high BMI)</strong>&lt;br&gt;&lt;br&gt;<strong>Primary hypertension</strong>&lt;br&gt;&lt;br&gt;<strong>Truncal obesity</strong>&lt;br&gt;&lt;br&gt;<strong>Cushing syndrome, insulin resistance syndrome</strong></td>
<td></td>
</tr>
<tr>
<td>Head and neck &lt;br&gt;&lt;br&gt;<strong>Moon facies</strong>&lt;br&gt;&lt;br&gt;<strong>Cushing syndrome</strong>&lt;br&gt;&lt;br&gt;<strong>Elfin facies</strong>&lt;br&gt;&lt;br&gt;<strong>Williams syndrome</strong>&lt;br&gt;&lt;br&gt;<strong>Webbed neck</strong>&lt;br&gt;&lt;br&gt;<strong>Turner syndrome</strong>&lt;br&gt;&lt;br&gt;<strong>Thyromegaly</strong>&lt;br&gt;&lt;br&gt;<strong>Hyperthyroidism</strong></td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Pallor, flushing, diaphoresis</td>
<td>Pheochromocytoma</td>
</tr>
<tr>
<td>Acne, hirsutism, striae</td>
<td>Cushing syndrome, anabolic steroid abuse</td>
</tr>
<tr>
<td>Café-au-lait spots</td>
<td>Neurofibromatosis</td>
</tr>
<tr>
<td>Adenoma sebaceum</td>
<td>Tuberous sclerosis</td>
</tr>
<tr>
<td>Malar rash</td>
<td>Systemic lupus erythematosis</td>
</tr>
<tr>
<td>Acanthosis nigricans</td>
<td>Type 2 diabetes</td>
</tr>
<tr>
<td>Chest</td>
<td></td>
</tr>
<tr>
<td>Widely spaced nipples</td>
<td>Turner syndrome</td>
</tr>
<tr>
<td>Heart murmur</td>
<td>Coarctation of the aorta</td>
</tr>
<tr>
<td>Friction rub</td>
<td>Systemic lupus erythematosis (pericarditis), collagen-vascular disease, end stage renal disease with uremia</td>
</tr>
<tr>
<td>Apical heave</td>
<td>LVH/chronic hypertension</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Mass</td>
</tr>
<tr>
<td>------------------</td>
<td>-------------------------------</td>
</tr>
<tr>
<td>Epigastric/flank</td>
<td>Bruit</td>
</tr>
<tr>
<td>Palpable kidneys</td>
<td></td>
</tr>
<tr>
<td>Genitalia</td>
<td>Ambiguous/virilization</td>
</tr>
<tr>
<td>Extremities</td>
<td>Joint swelling</td>
</tr>
<tr>
<td></td>
<td>Muscle weakness</td>
</tr>
</tbody>
</table>
Coarctation of the aorta
Retinal Changes

- Retinal hemorrhages
- Cotton wool patches
Moon facies

- Cushing's syndrome
- Anabolic steroid abuse
Adenoma sabaceum

- Tuberous Sclerosis
- Angiofibromas
- Red papules on nasolabial folds, cheek and chin
Acanthosis Nigricans

- Type II Diabetes
Elfin Faces

- William’s syndrome
- Elfin facies
  - Short, upturned nose
  - Flat nasal bridge
  - Long philtrum
  - Flat malar area
  - Wide mouth
  - Micrognathia
  - Periorbital fullness
Physical Examination

- Frequently normal except for BP elevation
- Laboratory evaluation is based on child’s age, history, physical examination findings, and level of BP elevation
  - Majority of children with secondary hypertension will have renal or renovascular causes for BP elevation
- Evaluation directed to determine cause, identify other CVD risk factors, and detect end-organ damage
Initial laboratory evaluation

- CMP, CBC, and UA
- Evaluation of Serum BUN, Cr, electrolytes
  - Assessment of renal function
  - Evaluate glucose for diabetes mellitus
  - Potassium- CKD or congenital adrenal hyperplasia
  - Abnormal UA and/or elevation in serum creatinine suggest underlying renal disease
- Measure fasting glucose and lipids
  - Should also be performed in children who are obese, have family history of CVD, or CKD
Renal Imaging

- Useful to evaluate presence of both kidneys, presence of any congenital anomaly or size in kidneys
- NHBPEP recommends renal US for all children and adolescents diagnosed with HTN
Left Ventricular Hypertrophy

- LVH is most prominent clinical evidence of target-organ damage caused by HTN in children and adolescents
  - reported 34-38% of children and adolescents with mild, untreated BP elevation
- Evaluation by Echocardiography
- Presence of LVH may be indication for initiating or intensifying pharmacologic therapy
- In patients with LVH
  - Left ventricular mass index should be measured periodically

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
ECG predictors of LVH

- Ramaswamy et al. set to determine the efficacy of ECG in detecting LVH in pediatric hypertension.
- Study included concomitant ECHOs and ECGs in 108 children with pediatric hypertension.
  - Left ventricular mass, assessed by ECHO was used as a basis for diagnosis of LVH.
  - 14 ECG variables were compared between subjects with and without ECHO LVH.
- Of the 108 subjects, 35 (32%) met pediatric criteria for LVH on ECG.
  - Standard ECG criteria predicted LVH with high specificity (>90%), but low sensitivity (<35%).
- Not an adequate predictor of LVH.

Renin Profiling

- Plasma renin level or plasma renin activity useful for detecting mineralocorticoid related diseases
- May be low and associated with hypokalemia
- Plasma renin activity levels higher in patient who have renal artery stenosis
  - ~15% of children with arteriographically evident renal artery stenosis will have normal PRA values
Liddle’s Syndrome

- Liddle’s syndrome- Rare genetic disorder
  - abnormality in function of collecting tubule sodium channel
  - Increased function in Liddle’s syndrome
- Child may present at young age with hypertension, hypokalemia, and metabolic alkalosis
  - Presents similar to primary aldosteronism
  - However, both plasma aldosterone concentration and urinary excretion of aldosterone are reduced
  - Low plasma renin activity

Liddle’s Syndrome

- Search for family history of hypertension at young age associated with hypokalemia
  - Genetic testing - Most reliable method
- Exon 13 of SCNN1B and SCNN1G is sequenced
- Recommended treatment is amiloride or triamterene - Potassium sparing diuretics block the collecting tubule sodium channels
  - Spironolactone is ineffective since increase in sodium channel activity is not mediated by aldosterone

Congenital Adrenal Hyperplasia

- Frequent cause of excess mineralocorticoid secretion in children
- May present as neonate with ambiguous genitalia
- Defect in enzymatic steps of cortisol biosynthesis
  - Impaired cortisol synthesis
  - Impaired aldosterone synthesis
  - Excessive synthesis of precursor steroids
    - Due to increase in ACTH secretion
    - Leads to oversecretion of steroids whose production does not require the deficient enzyme
      - 21-hydroxylase, 11-beta-hydroxylase, and 17-alpha-hydroxylase
    - Leads to androgen excess and thus virilization
  - Excessive synthesis of mineralocorticoids such as deoxycorticosterone may cause hypertension

- Excessive synthesis of mineralocorticoids such as deoxycorticosterone may cause hypertension
Aldosterone-secreting tumors

- Primary hypersecretion of aldosterone
  - Rare genetic disorder of glucocorticoid-remediable hyperaldosteronism
- Hypokalemia is absent in more than half of these patients
- Suspect diagnosis
  - family history of early HTN- before age 21
  - Marked hypokalemia after thiazide diuretic administration
Renin-secreting tumor

- Rare in children and adults
- Presents with severe hypertension, hypokalemia, metabolic alkalosis and markedly elevated renin levels
Evaluation for Renovascular Hypertension

- Caused by arterial lesion or lesions impeding flow to 1 or both kidneys
- Affected children usually, but not always, have elevated BP
- Consider in children with:
  - History of prior umbilical artery catheter placements
  - Neurofibromatosis
  - Abdominal bruit
  - Kidney size discrepancy on renal US
Testing for Renovascular Hypertension

- Gold standard for diagnosing renal artery stenosis is renal arteriography
- Less invasive testing
  - Duplex Doppler US
  - CT angiography
  - MRA
- Consider
  - Radiation exposure
  - Need for conscious sedation or general anesthesia
  - Consideration for corrective procedure
Pheochromocytomas

- Pheochromocytomas are infrequent in children
  - About 1% of cases of hypertension
- Presenting symptoms of hypertension, palpitations, headaches
  - “classic triad” of headache, sweating, and tachycardia is unusual especially in children
- Diagnosis with measurement of 24-hour fractionated urinary metanephrines and catecholamines
  - Follow with radiographic localization of tumor
    - Consider paragangliomas, which do not originate from adrenal medulla
    - Sensitivity 98%, Specificity 98%

Neuroblastoma

- Refers to spectrum of neuroblastic tumors including neuroblastomas, ganglioneuroblastomas, and ganglioneuromas
  - From primitive sympathetic ganglion cells
  - produce catecholamines
- May present with
  - Hypertension
  - Abdominal mass/pain or constipation
  - Proptosis
  - Periorbital ecchymosis
  - Horner syndrome (miosis, ptosis, anhidrosis)
  - Anemia
- Histological diagnosis from tumor tissue or increased urine (or serum) catecholamines or metabolites
- Or, evidence of metastasis to bone marrow on aspirate or biopsy with elevation of urinary (or serum) catecholamines
Treatment of Child and Adolescent Hypertension

- Therapeutic lifestyle changes vs. pharmacologic therapy
- From the 4th report
  - Lifestyle changes including healthy diet, sleep, and physical activity recommended for all categories of blood pressure
  - Pharmacologic therapy recommended for both stage I and II hypertension
    - Consider treatment in patients with prehypertension if there is underlying CKD, DM, CHF, or LVH
Nonpharmacologic measures

- Weight reduction for obesity
- Exercise and avoidance of sedentary activity
- Dietary modification
  - Salt restriction
  - Increased intake in fresh vegetables, fruits, and low-fat dairy
- Preventing or treating dyslipidemia
- Avoid smoking, alcohol, caffeine, and energy drinks
Lower Weight improves Blood Pressure

- Well documented that weight loss lowers BP in adults
- Data not as clear in children by suggestive
- Holm et al set to investigate BP in relation to changes in BMI in obese children through weight loss and weight regain
- Longitudinal study of obese boys and girls investigated through a 12-week weight loss intervention with follow-up investigations spanning 28 months.
- Study included 115 obese children, 53 boys and 62 girls (age 8-15)
  - 99 completed weight loss program and 68 entered the follow up
  - Height, weight, SBP, and DBP were recorded and analysed
- 51% of obese children were pre or hypertensive at baseline
- Both DBP and SBP declined significantly with weight loss
- Study also showed a rebound in HTN with weight regain
  - DBP increased during weight regain
  - SBP remained lower than baseline during 28 months of continuous weight gain

Holm JC, J Hypertens. 2012;30(2);368
Role of Exercise

- Known to lower blood pressure in children
- Study of 1170 children and adolescents (age 8-17 years)
- Showed inverse relationship between quantity and vigor of physical activity and the SBP and DBP
- Results showed that participants were less likely to have HTN if they participated in moderate or vigorous physical activity
- Results also showed improvement in odds ratio for hypertension in children exercising 60 minutes vs. 30 minutes

Dietary Modification

- Sodium reduction in children and adolescents has been associated with small reductions in BP in the range of 1-3 mmHg.

- Despite limited evidence, NHBPEP currently suggests to limits daily sodium intake to 1.2g/day for 4-8 year olds and 1.5 g/day for older children.

- NHBPEP also suggest increased dietary intake of fresh vegetables, fruits, fiber, and nonfat dairy.

- Lower BP had been associated with increased intake of potassium, magnesium, folic acid, unsaturated fat, and fiber.
  - Associations are small in children and data limited.

- Generally accepted to apply this to children as well.

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Pharmacologic therapy

- Indications to start therapy
  - secondary hypertension
  - insufficient response to lifestyle modifications
  - Symptomatic HTN (headache, seizure, changes in mental status, focal neurologic complaints, cardiovascular complaints)
  - Stage II HTN
  - Stage I with no evidence of end-organ damage
  - Hypertensive end-organ damage
    - LVH
  - Stage I HTN in patients with DM or other cardiovascular risk factors, such as dyslipidemia
  - Prehypertension with comorbid conditions, such as CKD and DM
Choice of Antihypertensive

- Lack of reliable pediatric data for older, commonly used drugs with expired patent protection.
  - No incentives exist for industry-sponsored trials of such drugs to continue their study
- Pediatric clinical trials of antihypertensive have focused only on ability to lower BP and have not compared the effects of these drugs on clinical endpoints.
- All classes have been shown to lower BP in children
  - Therefore, choice resides with physician
- Some diuretics and beta blockers were recommended as initial therapy in 1st and 2nd task force reports given long history of safety and efficacy
- Studies have also shown ACE/ARBs and CCB to be safe and well-tolerated with noted reductions in blood pressures

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Choice of Antihypertensive

- Important to consider underlying or concurrent medical conditions
  - Using ACE/ARBs in children with DM and microalbuminuria or proteinuric renal disease
  - BB/CCB in hypertensive children with migraine headaches
  - ACE/ARBs contraindicated in pregnancy and females of child bearing age should use contraception
  - BB may impair athletic performance
- Recommended to start at low dose and titrate up as needed
  - In uncomplicated primary hypertension and no target-organ damage goal should be <95\textsuperscript{th} percentile for gender, age, and height
  - In children with CKD, DM, or target-organ damage, goal BP should be <90\textsuperscript{th} percentile
Choice for therapy

- Dependent upon prescribing physician
  - Lisinopril
    - Initial: 0.07 mg/kg/day up to 5 mg/day
    - Maximum: 0.6 mg/kg/day up to 40 mg/day
  - Losartan
    - Initial: 0.7 mg/kg/day up to 50 mg/day
    - Maximum: 1.4 mg/kg/day up to 100 mg/day
  - Labetalol
    - Initial: 1-3 mg/kg/day
    - Maximum: 10-12 mg/kg/day up to 1200mg/day

NHBPEP, Pediatrics Vol. 114 No. 2 August 2004
Choice for therapy

- **Chlorthalidone**
  - Initial: 0.3 mg/kg/day
  - Maximum: 2 mg/kg/day up to 50 mg/day

- **Spironolactone**
  - Initial: 1 mg/kg/day
  - Maximum: 3.3 mg/dg/day up to 100 mg/day

- **Metoprolol**
  - Initial: 1-2 mg/kg/day
  - Maximum: 6 mg/kg/day up to 200 mg/day

- **Amlodipine**
  - Children 6-17 years: 2.5-5 mg once daily
Follow up and guidance

- Need for ongoing monitoring of target-organ damage
- Monitoring of BP
- Surveillance for drug side effects
- Periodic monitoring of electrolytes in patients taking ACE or diuretic
- Counseling for other cardiovascular risk factors
- Continued emphasis on nonpharmacological measures
- Consider “step down” therapy when indicated
- Need to have follow up after cessation of drug therapy to monitor for recurrence of HTN
<table>
<thead>
<tr>
<th>SBP or DBP Percentile*</th>
<th>Frequency of BP Measurement</th>
<th>Therapeutic Lifestyle Changes</th>
<th>Pharmacologic Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt;90th</td>
<td>Recheck at next scheduled physical examination</td>
<td>Encourage healthy diet, sleep, and physical activity</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>90th to &lt;95th or if BP exceeds 120/80 even if &lt;90th percentile up to &lt;95th percentile†</td>
<td>Recheck in 6 mo</td>
<td>Weight-management counseling if overweight; introduce physical activity and diet management‡</td>
</tr>
<tr>
<td>Stage 1 hypertension</td>
<td>95th-99th percentile plus 5 mm Hg</td>
<td>Recheck in 1-2 wk or sooner if the patient is symptomatic; if persistently elevated on 2 additional occasions, evaluate or refer to source of care within 1 mo</td>
<td>Weight-management counseling if overweight; introduce physical activity and diet management‡</td>
</tr>
<tr>
<td>Stage 2 hypertension</td>
<td>&gt;99th percentile plus 5 mm Hg</td>
<td>Evaluate or refer to source of care within 1 wk or immediately if the patient is symptomatic</td>
<td>Weight-management counseling if overweight; introduce physical activity and diet management‡</td>
</tr>
</tbody>
</table>
Thank You!
References


References


19. https://www.uptodate.com/contents/image?imageKey=NEPH%2F104437&topicKey=PEDS%2F6088&rank=1~99&source=see_link&search=evaluation%20of%20pediatric%20hypertension
22. http://escholarship.org/uc/item/7mf6g290
References

27. https://www.uptodate.com/contents/image?imageKey=NEPH%2F71793&topicKey=NEPH%2F3825&rank=1~150&source=see_link&search=renovascular%20hypertension

