**Definitions**

<table>
<thead>
<tr>
<th></th>
<th>Pediatrics</th>
<th>Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal BP</td>
<td>SBP &lt;120, DBP &lt;80</td>
<td>SBP &lt;120, DBP &lt;80</td>
</tr>
<tr>
<td>Pre-hypertension</td>
<td>SBP 120-139, DBP 80-89</td>
<td>SBP 120-139, DBP 80-89</td>
</tr>
<tr>
<td>Stage 1 Hypertension</td>
<td>SBP &gt;140, DBP &gt;90</td>
<td>SBP &gt;140, DBP &gt;90</td>
</tr>
<tr>
<td>Stage 2 Hypertension</td>
<td>SBP &gt;160, DBP &gt;100</td>
<td>SBP &gt;160, DBP &gt;100</td>
</tr>
</tbody>
</table>

Classifications based off of the average of 2 or more readings taken at each of 2 or more visits following initial screening.

Portman 2005, Chobanian 2003

**Estimated Incidence of Pediatric Hypertension (HTN)**

<table>
<thead>
<tr>
<th>Time</th>
<th>HTN</th>
<th>Pre-HTN</th>
<th>HTN in Overweight Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>mid 1970s</td>
<td>1.5%</td>
<td>4.0%</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>18.7%</td>
<td>4.0%</td>
<td></td>
</tr>
</tbody>
</table>

Brady 2009, Flynn 2010

**Methods of BP Evaluation**

- **Auscultatory measurements:** sphygmomanometer and stethoscope
  - Sits for BP table
  - Patient should sit quietly for 5 minutes with his or her back supported, feet on the floor and right arm supported at heart level
  - Cuff size should be at least 2/3 distance from acromion to olecranon
- **Oscillometric (Dinamap)** measurements:
  - Automatic device that measures mean arterial BP and then calculates systolic and diastolic values
  - Measurements generally comparable to auscultatory
  - Oscillometric devices are convenient, have minimal observer error
- **Ambulatory BP monitoring (ABPM):** portable device worn by the patient to record BP over a specific period (usually 24 hours)
  - Enables calculation of:
    - Mean BP during the day, night and over 24 hours
    - Degree of nocturnal dipping
    - BP load (% readings >95%)
  - Useful to evaluate white-coat and masked HTN
  - Correlates better than office BP with CV complications (e.g. LVH)

NHBPEP 2004

**Causes of Pediatric Hypertension**

- **Primary/Essential Hypertension**
  - Most common form of HTN and is a diagnosis of exclusion
  - Common at all ages
  - More frequent in:
    - African American children
    - Family history of HTN
    - Overweight or obese

- **Secondary Hypertension**
  - For all age groups, renal parenchymal or renovascular causes together account for ~60-90% of secondary causes
  - More frequent in:
    - Younger children
    - Children with a greater degree of BP increase at the time of initial diagnosis

Portman 2005, Brady 2009
Differential Diagnosis of Secondary Causes of HTN

- Renal Parenchymal 80%
- Renovascular 10%
- Endocrine 5%
- Coarctation of Aorta 2%
- Malignancy 3%
- Miscellaneous 5%

Common Causes of HTN by Age

<table>
<thead>
<tr>
<th></th>
<th>Infants</th>
<th>Children</th>
<th>Adolescents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrombosis of renal artery or vein</td>
<td>Renal artery stenosis</td>
<td>Renal parenchymal disease</td>
<td>Essential HTN</td>
</tr>
<tr>
<td>Congenital renal anomalies</td>
<td>Renal parenchymal disease</td>
<td>Renovascular abnormalities</td>
<td>Renal parenchymal disease</td>
</tr>
<tr>
<td>Coarctation of Aorta</td>
<td>Wilms tumor</td>
<td>Endocrine causes</td>
<td>Endocrine causes</td>
</tr>
<tr>
<td>Bronchopulmonary dysplasia</td>
<td>Neuroblastoma</td>
<td>Coarctation of aorta</td>
<td>Essential HTN</td>
</tr>
</tbody>
</table>

Clinical and Laboratory Assessment of Children with HTN

- Important History Elements:
  - Symptoms suggestive of endocrine etiology (weight loss, sweating, flushing etc.)
  - History of prematurity and/or placement of umbilical artery/vein catheter; neonatal course; birth weight (all hypothesized to predict HTN)
  - History of UTI
  - History of Obstructive Sleep Apnea
  - Medications including steroids, decongestant/cold prep, OCP, NSAIDs, stimulants, β-adrenergic agonists, EPO, cyclosporine/tacrolimus, tricyclic anti-depressants, recent discontinuation of antihypertensive
  - Nutritional Supplements
  - Family history of HTN, early cardiovascular or cerebrovascular events, ESRD
  - Diet (caffeine, salt intake)
  - Smoking/drinking/illicit drugs
  - Physical Activity

- Important Physical Exam Elements
  - Four extremity pulses and BP
  - Moon facies, truncal obesity, buffalo hump
  - Retinopathy
  - Thyromegaly
  - Skin lesions (café-au-lait spots, neurofibromas, adenoma sebaceum, striae, hirsutism, butterfly rash, purpura)
  - Evidence of CHF
  - Abdominal mass, abdominal bruits
  - Edema

- Laboratory Evaluation:
  - Specific tests may vary by clinic location and patient population
  - To rule out renal disease and chronic pyelonephritis:
  - Basic metabolic panel (electrolytes, BUN, HCO3, creatinine)
  - Urinalysis
  - Urine Culture
  - CBC to rule out anemia which could be consistent with CKD
  - Fasting lipids and glucose
  - Thyroid function tests
  - Plasma renin activity: very young with Stage 1 and children with Stage 2
  - Imaging:
    - Renal ultrason with Doppler examination of the renal vasculature
    - Echocardiography including measurement of LVMH
    - Renal arteriography: severe HTN or failure to control BP with one drug
  - Other Tests:
    - Retinal Exam: severe cases
    - Assessment of catecholamines: United States NO versus Europe YES

Clinical and Laboratory Assessment of Children with HTN

- Brady 2009
- Rodríguez-Cruz 2011
**Yield of Diagnostic Testing for Mild-to-Moderate HTN in children**

<table>
<thead>
<tr>
<th>Test</th>
<th>% of test w/Sig Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholesterol &gt; 170</td>
<td></td>
</tr>
<tr>
<td>ABPM* DBP&gt;95%</td>
<td></td>
</tr>
<tr>
<td>Cholesterol &gt; 200</td>
<td></td>
</tr>
<tr>
<td>ECHO</td>
<td></td>
</tr>
<tr>
<td>Plasma Renin Activity</td>
<td></td>
</tr>
<tr>
<td>Renal Sonography</td>
<td></td>
</tr>
<tr>
<td>Urinalysis</td>
<td></td>
</tr>
<tr>
<td>Serum Electrolytes</td>
<td></td>
</tr>
<tr>
<td>Spot Urine Catecholamines</td>
<td></td>
</tr>
<tr>
<td>Thyroid Function Test</td>
<td></td>
</tr>
<tr>
<td>BUN/creatinine</td>
<td></td>
</tr>
</tbody>
</table>

*ABPM = Ambulatory BP Monitoring

Wiesen 2008, Baracco 2012

**Making the Differential Diagnosis**

**General Therapeutic Recommendations for Pediatric HTN**

- All healthy children 3 years of age and children younger than 3 with certain comorbid conditions (e.g. prematurity, low birth weight, kidney disease, congenital heart disease) should have their BP measured at all physician visits
- If either SBP or DBP is elevated (≥90th percentile or SBP ≥120mmHg or DBP ≥80mmHg if these values are lower than the 90th percentile), the BP should be measured 2 additional times on 2 separate visits
- ABPM can expedite determination of BP status

Portman 2005

**Practice Guidelines for Pediatric BP Monitoring**

- All healthy children 33 years of age and children younger than 3 with certain comorbid conditions (e.g. prematurity, low birth weight, kidney disease, congenital heart disease) should have their BP measured at all physician visits
- If either SBP or DBP is elevated (≥90th percentile or SBP ≥120mmHg or DBP ≥80mmHg if these values are lower than the 90th percentile), the BP should be measured 2 additional times on 2 separate visits
- ABPM can expedite determination of BP status

Brady 2009

**Non-pharmacological Interventions**

- Suggested for all patients with prehypertension and hypertension
- Most patients with pediatric primary HTN should have a trial of non-pharmacologic management prior to starting drug treatment
- Loss of 10-15 lbs (4-7 kg) is sufficient to achieve a meaningful reduction in BP
- Physical activity with increased HR for 30-40 minutes, 3-4x/wk can lead to a demonstrable drop in BP

Brady 2009, Trachtman 2011

**Pharmacological Intervention: Who Should Get Drugs?**

- The 2004 NHBPEP guidelines indicate pharmacological therapy in children with one or more of the following conditions:
  - Symptomatic HTN (e.g. headaches, seizures, changes in mental status, focal neurological complaints, visual disturbances, CV complaints)
  - Stage 2 HTN
  - Stage 1 HTN (without any evidence of target-organ damage) that persists despite a trial of 4-6 months of non-pharmacologic therapy
  - Hypertensive target-organ damage, most often LVH
  - Stage 1 HTN with diabetes mellitus or other CVD risk factors such as dyslipidemia
  - Stage 1 HTN with family history of premature CVD
  - Prehypertension in presence of comorbid conditions, such as chronic kidney disease or diabetes mellitus

NHBPEP 2004
**Stage 2 Acute HTN Crisis**

**Treatment Principles**

- Blood pressure above the 99th percentile or more than 4 SDs above the mean is considered severe, however any BP in the presence of neurological symptoms is an acute emergency and requires urgent attention.
- Target of treatment is not to normalize the BP but to lower the mean arterial pressure by 20% so that a regular regimen can be started.
- Children are less likely to have atherosclerosis and therefore can tolerate sudden drops in BP without the risk of vital organ ischemia, MI or stroke.

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**Stage 1 Chronic HTN**

**Treatment Principles**

- Choice of medication should be guided by underlying condition and the presence of other comorbidities.
- Patients with HTN and migraine headaches should receive β-blockers or CCBs, while children with diabetes and HTN should receive ACEI or angiotensin II receptor blockers (ARBs).
- Because of their metabolic effects, such as lowering TGF-β and Angiotensin II, ACEI and ARBs are indicated for patients with end-organ damage such as cardiac hypertrophy.
- Prescribe drugs that do not cause adverse effects on QoL in order to prevent non-adherence to drug regimen.
- It is advisable to use the fewest of agents possible and to prescribe once-daily dosing regimens.

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**Stage 1 Chronic Primary HTN**

**Pharmacologic Therapy**

- Drug therapy is warranted if non-pharmacologic options fail to be effective or if the child is symptomatic, has other cardiovascular (CV) risk factors, family history of premature CVD, diabetes mellitus, or target-organ damage.
- Diuretics alone will work in 50% of pediatric patients with HTN while additional drugs will be needed to control the other half.

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**Stage 1 Chronic Secondary HTN**

**Pharmacologic Therapy**

- All patients with secondary HTN should be started on antihypertensive medication.
- The underlying cause of HTN should be treated if possible.
- Child with HTN caused by renal disease should be prescribed drugs that block the synthesis/action of angiotensin II and aldosterone due to their renoprotective effects. These include:
  - ACEI, e.g., enalapril, lisinopril, ramipril and trandolapril.
  - Note: Patients may experience a marked decline in kidney function when they start ACEI.
  - ARBs, e.g., losartan, valsartan, irbesartan.
  - Recently developed renin inhibitors, aliskiren.
  - Aldosterone antagonists, e.g., spironolactone, eplerenone.

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**General Schematic of Work-Up and Treatment of Pediatric HTN**

[Diagram of HTN treatment]

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**Stage 2 Acute HTN Crisis**

**Pharmacologic Therapy**

<table>
<thead>
<tr>
<th>Line</th>
<th>Drug</th>
<th>Route</th>
<th>Category</th>
<th>Dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Labetalol</td>
<td>IV</td>
<td>α/β Blocker</td>
<td>0.25-1 mg/kg per dose administered by rapid transfusion</td>
</tr>
<tr>
<td>2nd</td>
<td>Isradipine</td>
<td>IV</td>
<td>CCB</td>
<td>0.1 dose mg/kg per dose</td>
</tr>
<tr>
<td>3rd</td>
<td>Nitrendipine</td>
<td>IV</td>
<td>CCB</td>
<td>0.1-0.3 dose μg/kg per minute</td>
</tr>
<tr>
<td>4th</td>
<td>Enalapril</td>
<td>PO</td>
<td>ACEI</td>
<td>0.05-0.1 mg/kg per hour</td>
</tr>
</tbody>
</table>

[Trachtman 2011]
**Prognosis**

- There is very little data available on the natural history of primary HTN in children so it is impossible to predict the long-term outcomes of untreated HTN in children and adolescents.
- One small study in Iceland demonstrated a correlation between childhood SBP and the development of coronary artery disease in adulthood.
- LVH occurs in ~33% of children and adolescents with mild, untreated HTN.
- Preventing end organ damage including vascular changes, cardiac damage and renal effects should be the goal of treatment for pediatric hypertensive patients.

**References**


Trachtman H. Short- and long-term physiologic and pharmacologic control of blood pressure in pediatric patients. Integ Blood Pre ss Contr 2011; 4:35-44.
