INTRODUCTION TO RENAL SYSTEM IN PEDIATRICS
ANATOMY & PHYSIOLOGY OF KIDNEY

- Same as that of an adult but with few differences;
  1. Length approx. 6 cm and weight 24gm in a full term newborn as compared to 12 cm and 150gm in an adult.
  2. Formation of nephrons is complete at birth but functional maturation continues
  3. GFR of children does not approximate adult values until end of 3rd yr of life
4. Normal urine output in children:

- **Newborn production**—approx 2-3 mL/kg/hr
- **Child production**—approx 1 mL/kg/hr

5. Blood pressure according to percentile charts (not fixed)
COMMON PRESENTING SYMPTOMS

- Dysuria
- Frequency of micturation
- Polyuria/oliguria/Anuria
- Fever
- Urinary retention
- Edema
- Hematuria
- Abdominal pain
- Abdominal mass
- Failure to thrive / Anemia / short stature
Renal System Assessment

- **History**
  - Symptoms and their details
  - Meds: antibiotics, anticholinergics, antispasmodics
  - Urologic instrumentation
  - Urinary hygiene
  - Family history

- **Physical assessment**
  
  Inspection, Palpation, percussion, auscultation
Diagnostic studies
- Renal scan
- Cystogram
- Retrograde Pyelogram
- U/S
- CT
- MRI
- Renal arteriogram
- Urine Examination
- Urine C&S
- BUN
- S.Creatinine
- X-ray KUB
- IVU
- MCUG / VCUG
Normal Urinalysis

- pH: 5.0-9.0
- Sp Gr: 1.001-1.035
- Protein: <20 mg/dL
- Urobilinogen: up to 1 mg/dL
- None of the following:
  - Glucose
  - Ketones
  - Hgb
  - WBCs
  - RBCs
  - Casts
  - Nitrites
Normal Characteristics of Urine

- Color range
- Clear
- Newborn production—approx 1-2 mL/kg/hr
- Child production—approx 1 mL/kg/hr
HYPERTENSION IN PEDIATRICS
Definition

- Pediatric hypertension is defined as a blood pressure greater than the 95th percentile blood pressure for age, sex and length for patients without comorbidities.
- Patients with comorbidities are defined as hypertensive when the blood pressure is greater than the 90%.

Comorbidities

- Diabetes, Renal disease, Cardiac disease, Obesity, Family history
Preventive Medicine

- Treatment of pediatric hypertension is actually preventive medicine.
- Patients don’t die of heart attacks or strokes in their pediatric years.
- Likely will have cardiovascular events at a younger age than expected.
Diagnosis of Hypertension

- 3 blood pressure readings greater than the upper limit of normal
- 20 mm Hg higher than the limit on any one reading is considered diagnostic of hypertension
White Coat Hypertension

- Defined as a normal blood pressure at home but elevated in the office.
  - Increased sympathetic tone
  - No evidence of increased cardiovascular mortality
## Causes of Hypertension

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Most Common</th>
<th>Less Common</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants and Neonates</td>
<td>Renal artery thrombosis after umbilical artery catheterization</td>
<td>Bronchopulmonary Dysplasia</td>
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<tr>
<td></td>
<td>Coarctation of the aorta</td>
<td>Patent ductus arteriosus</td>
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<tr>
<td>Congenital renal disease</td>
<td>Renal artery stenosis</td>
<td>Intraventricular hemorrhage</td>
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<td></td>
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<td>Neurogenic tumors</td>
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# Causes of Hypertension

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<tr>
<td>1-10</td>
<td>Renal Disease</td>
<td>Renal artery stenosis</td>
</tr>
<tr>
<td></td>
<td>Coarctation of the aorta</td>
<td>Hypercalcemia</td>
</tr>
<tr>
<td></td>
<td>Essential</td>
<td>Neurofibromatosis</td>
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<tr>
<td></td>
<td></td>
<td>Pheochromocytoma</td>
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<tr>
<td></td>
<td></td>
<td>Primary hyperaldosteronism</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$11\beta$ hydroxylase deficiency</td>
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<tr>
<td></td>
<td></td>
<td>$17\alpha$ hydroxylase deficiency</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apparent mineralocorticoid excess</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Liddle’s syndrome</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Glucocorticoid remediable hypertension</td>
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<tr>
<td></td>
<td></td>
<td>Hypertension induced by immobilization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sleep apnea associated hypertension</td>
</tr>
<tr>
<td>11 and older</td>
<td>Renal Disease</td>
<td>All diagnosis listed above</td>
</tr>
<tr>
<td></td>
<td>Essential hypertension</td>
<td></td>
</tr>
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</table>
Pediatric Hypertension: History

- Neonatal history
- Onset of Symp: headaches, vomiting
- Symp of underlying kidney disease
  - dysuria, polyuria, nocturia, previous UTI’s
- Symp of CT disease
  - joint pain, edema, rash, fever
- Medication history
Pediatric Hypertension: Hist.

- F/H of hypertension, renal diseases
- F/H of early complications of HTN
- and atherosclerosis

- Symp of rare causes of HTN:
  - wt loss, sweating, flushing, palpitations
  - onset of menarche, sexual development
Pediatric Hypertension: Exam.

◆ General
  ◆ Dysmorphic features - syndromes
  ◆ pale, edematous

◆ Vitals: BP (4 limb), HR, ht, wt. percentiles

◆ fundoscopy

◆ CVS: absent or delayed femoral pulses,
  • low leg pressure relative to arm BP, heart
  • sounds murmurs
Pediatric Hypertension: Exam.

- **GI:** abdominal bruit, palpable masses; **GU:** pubertal development

- **CNS:**
  - Hypertensive retinopathy
  - Bell palsy
  - Neurologic deficits (ie. hemiparesis)

- **Skin:**
  - cafe-au-lait spots, rashes
Pediatric Hypertension

Rule of thumb: BP on 3 occasions

Pre-term: $BP > 80/45$

Term infants: $BP > 90/60$

2-5 years: $BP > 125/80$

6-11 years: $BP > 130/85$

>11 years: $BP > 140/90$
Clin Manifestations of Severe Hypertension

Hypertensive Retinopathy 27%
Hypertensive Encephalopathy 25%
Convulsions 25%
LVH 13%
Facial Palsy 12%
Visual Symptoms 9%
Hemiplegia 8%

Deal et al, Arch Dis Child 1992;67:1089-92
Typical Workup

- Renal function tests
- Plasma Aldosterone/Renin
- Urine analysis
- Urine protein/creatinine
- Renal ultrasound
- 4 point blood pressure readings
- CBC
- TSH
Renal Function

- Normal Values
  - 1 – 5 years old: 0.3-0.5 mg/dL
  - 6-11 years old: 0.5-0.7 mg/dL
  - Girls > 11 years: 0.7-0.9 mg/dL
  - Boys > 11 years: 0.7-1.2 mg/dL

- Normal creatinine is determined by the muscle mass of the patient and their renal function
Urine Analysis

- Hematuria
  - Glomerular disease

- Pyuria
  - Interstitial nephritis

- Proteinuria
  - Glomerular disease
  - Hyperfiltration syndrome
  - Reflux nephropathy
Urine Protein/Creatinine

- More sensitive than albustix in detecting proteinuria
- Microalbumin detection sticks can be used
Renal Ultrasound

- Urologic abnormalities
  - Ureteropelvic junction obstruction
  - Multicystic dysplastic kidneys
- Polycystic kidney disease
- Renal scarring
- Discordant kidney size
  - Reflux nephropathy
  - Renal artery stenosis
4 Extremity BP

- Screen for coarctation
- Not 100% sensitive
- Echocardiogram is the diagnostic test of choice
If Workup is Negative?

- Start treatment with antihypertensive medication under the following circumstances
  - Comorbid conditions
  - Evidence of end organ damage
    - Echocardiogram with LVH
  - Systolic blood pressure 10 mm Hg greater than 95%
  - Failure of lifestyle modifications
Lifestyle Modifications

- Salt restriction
- Exercise 20 minutes 5 days a week
  - HR should achieve 85% of maximum
- Weight loss
When to Perform More Testing

- Any abnormality of primary screening
  - Aldosterone/Renin > 30
    - Hyeraldosteronism
  - Abnormal Urine analysis
  - Discordant kidney size
  - Severe hypertension
  - Family history
    - NF, MEN
    - Early strokes in family
Hypertension in clinic

Correct size cuff
Wait 5 minutes and repeat
Still high Check 2 more visits

Home BP Monitoring

Ambulatory BPM

BP Normal

White Coat HTN

BP Abnormal

Family History
Physical Exam CBC
Urine Analysis Renal Panel
Aldosterone/Renin Urine
Protein/creatinine

Comorbid Conditions
Diabetes,
Renal Disease,
Cardiac Disease,
Obesity

Workup Negative

No Comorbid Conditions
Consider Echocardiogram
LVH Present
LVH

Treat with Antihypertensives
HTN after 1 year

No LVH
Lifestyle Modifications

HTN Resolved
BP check every 6 months

Workup Positive Treat
Calcium Channel Blockers

- **Amlodipine**
  - Studied in children
  - 54 hour half life
    - Missing a dose is not an issue
  - Once a day dosing
  - Drops BP effectively

- **Cardizem**
  - Once daily dosing
  - Negative ionotrope
ACE Inhibitors

- **Lisinopril**
  - Generic - 7 dollars a month
  - Once daily dose
  - Pediatric studies

- **Captopril**
  - 3 times a day

- **Vasotec**
  - 2 times a day
ACE Inhibitors Caution

- Nephrogenesis occurs until 2 years of age
- ACE Inhibitors decrease TGF-β and TNF-α expression
- This may lead to a decrease in nephron mass
- Consider not using ACE Inhibitors until after 2 years of age
Angiotensin Receptor Blockers

- All have been studied in children
  - Irbesartan
  - Candesartan
  - Losartan
  - Telmesartan
## Treatment of Hypertensive Emergencies

<table>
<thead>
<tr>
<th>IV Meds</th>
<th>Dosage</th>
<th>Pharm</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labetalol</td>
<td>0.2-1 mg/kg/dose 0.5-3 mg/kg/hr</td>
<td>Onset 5 min 2-3hr</td>
<td>Asthma,↓HR, CHF</td>
</tr>
<tr>
<td>Na Nitropruss</td>
<td>0.5-0.8 mcg/kg/min</td>
<td>Onset sec t/2 s-min</td>
<td>↓BP, ↑HR, cyanide toxicity, ↑cerebral BF</td>
</tr>
<tr>
<td>Nicardipine</td>
<td>1-3 mcg/kg/min</td>
<td>Onset min t/2 10-15m</td>
<td>Unpredictable ↓BP, ↑cerebral BF</td>
</tr>
<tr>
<td>Hydralazine</td>
<td>0.1-0.5 mg/kg</td>
<td>Onset 10-20m</td>
<td>↑HR, h/a, flushing, fluid ret</td>
</tr>
<tr>
<td>Enalapril</td>
<td>0.005-0.01 mg/kg 8-24 hr</td>
<td>Onset&lt;15m t/2 24 hrs</td>
<td>Don’t use if suspect bilat RAS</td>
</tr>
</tbody>
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## Treatment of Severe Hypertension

<table>
<thead>
<tr>
<th>PO Meds</th>
<th>Dosage</th>
<th>Pharm</th>
<th>Complications</th>
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<tr>
<td>Nifedipine (bite and swallow)</td>
<td>0.25-0.5 mg/kg/dose</td>
<td>Onset 20-30 min Up to 6 hours</td>
<td>Can cause profound hypotension, especially with underlying cardiac disease</td>
</tr>
</tbody>
</table>

For asymptomatic patients

- drug must be bitten and swallowed (better and more predictable absorption vs. sublingual administration)


Conclusion

- Hypertension in children is increasing in incidence
- Most children have essential hypertension
- The workup is simple and inexpensive
- Angiogram indicated for severe hypertension
- Plasma metanepherssines is the best screen for pheochromocytoma
- Once a day medications for compliance