Kidney & Urinary Tract Ultrasound

Fatina Fadel
Hafez Bazaraa
Ultrasonography
Ultrasound

- Available
- Rapid
- Inexpensive
- Painless & no sedation needed
- No adverse effects/ complications
- Can be repeated
- Useful for screening
Ultrasound

- Ultrasound has advanced from a specialized imaging technique to a bedside test & clinical examination supplement
- Ultrasound is the principal imaging modality for visualization of the kidneys & urinary tract
In a patient with renal failure ....
In a patient with AKI ...
Role of US

- Confirm normal anatomical position of kidneys
- Exclude structural anomalies.
- Assess size of the kidneys and collecting systems
- Exclude renal cortical scarring.
- Exclude renal or suprarenal masses (cystic or solid)
- Assess bladder filling and emptying
Common Neonatal & Pediatric Pathology

- **Fusion Anomalies.** (horseshoe, ectopia, cross-fusion)
- **Hypoplasia or agenesis.**
- **Duplication anomalies.** (supernumerary or variants of the collecting system and uterers)
- **Congenital structural disease** (Juvenile PCKD, MCDK, dysplasia)
- **Solid tumours**
Limitations

Co-operation is the biggest challenge with any pediatric study.

- If scanning a neonate, try to time the scan after a feed for best compliance.
- Full bladder if cooperative, bladder 1\textsuperscript{st} (before void) if not.
- Use WARM gel

Ultrasound \textbf{CANNOT} exclude vesico-ureteric reflux.
EXAMINATION TECHNIQUE
Equipment & position

- **5+MHz curvilinear probe**
  - 3.5 MHz for larger adolescents
  - High frequency (superficial) linear probe 8-12 MHz ↑ resolution

- **Supine position**
  - Essential for bladder
  - May use contra-lateral with caregiver support, posterolateral imaging, for kidneys
  - Prone (if gases preclude visualization)
Scanning: Kidneys

- Confirm normal position
- Measure renal length
- Cortical thickness & echogenicity, CM differentiation, pyramids
- Cortical scars, cysts, NC
- Assess pelvis, calyces

*Scan entire kidney in LS & TS, may use higher freq. probe for detailed scan of cortex & med. Pyramids*
<table>
<thead>
<tr>
<th>Age</th>
<th>Mean length (cm)</th>
<th>Range (±2 SD in cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term newborn</td>
<td>4.48</td>
<td>3.86–5.10</td>
</tr>
<tr>
<td>2 months</td>
<td>5.28</td>
<td>3.96–6.60</td>
</tr>
<tr>
<td>6 months</td>
<td>6.15</td>
<td>4.81–7.49</td>
</tr>
<tr>
<td>1.5 years</td>
<td>6.65</td>
<td>5.57–7.73</td>
</tr>
<tr>
<td>2.5 years</td>
<td>7.36</td>
<td>6.28–8.44</td>
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<tr>
<td>3.5 years</td>
<td>7.36</td>
<td>6.18–8.54</td>
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<tr>
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<td>7.87</td>
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<td>8.09</td>
<td>7.01–9.17</td>
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<td>7.14–10.66</td>
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<td>9.5 years</td>
<td>9.20</td>
<td>7.40–11.00</td>
</tr>
<tr>
<td>10.5 years</td>
<td>9.17</td>
<td>7.53–10.81</td>
</tr>
<tr>
<td>11.5 years</td>
<td>9.60</td>
<td>8.32–10.88</td>
</tr>
<tr>
<td>12.5 years</td>
<td>10.42</td>
<td>8.68–12.16</td>
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<td>13.5 years</td>
<td>9.79</td>
<td>8.29–11.29</td>
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<td>14.5 years</td>
<td>10.05</td>
<td>8.81–11.29</td>
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<tr>
<td>15.5 years</td>
<td>10.93</td>
<td>9.41–12.45</td>
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<td>16.5 years</td>
<td>10.04</td>
<td>8.32–11.76</td>
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<tr>
<td>17.5 years</td>
<td>10.53</td>
<td>9.95–11.11</td>
</tr>
<tr>
<td>18.5 years</td>
<td>10.81</td>
<td>8.55–13.07</td>
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</tbody>
</table>
Renal length

- Supine measurement (prone underestimates)
- 2x
- Size correlates with pt height/ length more than age
- Lt kidney slightly larger (-5mm) in most cases
Normal kidney

Longitudinal section

Cross section

Renal capsule: echogenic line

Renal parenchyma: outer cortex & inner medulla pyramid

Central sinus complex: high echogenicity (vessels, fat, fibrous tissue)
Features

- The renal cortex in patients older than 6 months of age is nearly always hypoechoic relative to the adjacent liver or spleen.

- The normal medullary pyramids are (minimally) hypoechoic. The identification of these pyramids is easier with hydration of the patient and diuresis.

- The renal sinus appears as a central echogenic area. (may be minimal-decreased vs adult)

- The renal pelvis, when visible, should be 10 mm or less in AP diameter.
Neonatal kidney; 3 features

1. Echogenicity ↑↑↑ (↑↑↑ no of glomeruli).

2. Prominent hypoechoic renal pyramids (larger medullary volumes, ↓↓ CM diff). Don’t misinterpret as dilated collecting system.

3. Renal sinus echogenicity ↓ ↓ (paucity of echogenic pelvic/ medullary fat).
Scanning: Kidneys

- Confirm normal position
- Measure renal length
- **Cortical thickness & echogenicity, CM differentiation, pyramids**
- Cortical scars, cysts, NC
- Assess pelvis, calyces

*Scan entire kidney in LS & TS, may use higher freq. probe for detailed scan of cortex & med. Pyramids*
Echogenicity

### Cortical echogenicity

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 0</td>
<td>Less than normal liver</td>
</tr>
<tr>
<td>Grade I</td>
<td>Equals normal liver</td>
</tr>
<tr>
<td>Grade II</td>
<td>Exceeds liver; less than renal sinus</td>
</tr>
<tr>
<td>Grade III</td>
<td>Exceeds liver; equals renal sinus echo</td>
</tr>
</tbody>
</table>

*Pyramids should be hypoechoic*

↑ echogenicity suggests nephritis

Echogenic lines throughout ➔ severe PN

Renal parenchymal disease eg GN, Nephrotic present as ↑ echogenicity
Scanning: Kidneys

- Confirm normal position
- Measure renal length
- Cortical thickness & echogenicity, CM differentiation, pyramids
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- Assess pelvis, calyces urolithiasis

Scan entire kidney in LS & TS, may use higher freq. probe for detailed scan of cortex & med. Pyramids
Collecting system
- Pelvicalyceal without ureteric dilatation ➔ PUJO
- Intrauterine HN ➔ post-natal scan 4-5 d not before (dehydration & low GFR may give false –ve early)
### Grading of hydrenephrosis

<table>
<thead>
<tr>
<th>Grade</th>
<th>U/S</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No hydrenephrosis</td>
</tr>
<tr>
<td>1</td>
<td>Only renal pelvis is seen</td>
</tr>
<tr>
<td>2</td>
<td>Renal pelvis &amp; few calyces are seen</td>
</tr>
<tr>
<td>3</td>
<td>Virtually all calyces are seen</td>
</tr>
<tr>
<td>4</td>
<td>Virtually all calyces are seen + parenchymal thinning</td>
</tr>
</tbody>
</table>
Partial Duplex Kidney
Pyelonephritis

- Normal
- ↑ size & echogenicity
- Thickening of the wall of renal pelvis & calyceal distortion
Cortical scar

KEYPOINTS:
Scar- linear echogenic line from the cortical edge in towards a pyramid

1. Smooth transition with the capsule
2. Continue with the perirrenal fat
3. Does not cause mass effect
In both the neonatal and paediatric kidney, the foetal cortical lobulations are pronounced and should span the pyramids.
If a lobulation dips into a pyramid, it is likely to be a cortical scar.
Pyonephrosis
(dilated system & echogenic content)
Stones
highly echogenic + acoustic shadowing
Stones
highly echogenic + acoustic shadowing

Stone in pelvis
Acoustic posterior shadow
Nephrocalcinosis

- Calcium deposition in the renal parenchyma
- Medullary ➔ hyperechoic pyramids
- Diffuse ➔ ↑ cortical & medullary echog.
Nephrocalcinosis

Causes:
• Idiopathic hypercalciuria
• Long term furosemide therapy in neonates esp. premature
• Hypervitaminosis D
• Hyperparathyroidism
• Renal tubular acidosis
• Hyperoxaluria
• Medullary sponge kidney

Other causes of hyperechoic medullary pyramids:
• Tamm Horsfall proteins
• Vascular congestion
• Papillary necrosis.
• Transient in neonate with oliguria & perinatal anoxia.
Clinical and ultrasonographical characterization of childhood cystic kidney diseases in Egypt

Neveen A. Soliman1,2, Marwa M. Nabhan1,2, Hafez M. Bazaar1,2, Ahmed M. Badr1,2, and Mohamed Shaheen3

1Department of Pediatrics, Center of Pediatric Nephrology & Transplantation, Kasr Al Ainy School of Medicine, Cairo University, Cairo, Egypt, 2Egyptian Group for Orphan Renal Diseases (EGORD), Cairo, Egypt, and 3Department of Radiology, Kasr Al Ainy School of Medicine, Cairo University, Cairo, Egypt
Renal Cystic disease

- AR polycystic Kid
- AD polycystic Kid
- Glomerulo Cystic Disease
- Cysts associated with multiple malformation syndrome (e.g.) Turner syndrome Tuberous sclerosis.
- Cystic disease of renal medulla

Bilateral

- Simple Cyst.
- Multi Cystic Dysplasia.
- Multilocular Cystic nephroma

unilateral
Polycystic Kidney Disease

A.R.

- Multiple small cysts 1-2mm (dilated collecting tubules)
- Congenital hepatic fibrosis (presented later).

By ultrasound
- Bilateral enlarged echogenic kidneys with poor delineation of the renal sinus, medulla, and cortex.

Presented in neonatal.
- Period with ↓ kidney function

A.D.

- Large cysts are present in both kidneys.
- Congenital hepatic fibrosis is rare.

By ultrasound
- In neonates the same as A.R. polycystic kidney.
- In old child: multiple large cysts in both kidneys

Presented in 4th or 5th decade with hypertension or hematuria.
- Rarely in neonate presented with Abd. Mass.
ADPKD

CRITERIA
3+ total @15-39y
2+ each kid. @40-59y
4+ each kid. @60y+
<2 @40y + EXCLUDES
ARPKD

Complete medullary involvement
No cortical involvement

Mildly enlarged kidney
Preserved cortex
Significant echogenic renal medulla
ARPKD
Multicystic-Dysplastic Kidney

*kidney replaced by anechoic masses of variable size with:
- no communication between cysts
- no identifiable renal pelvis
- no normal (dysplastic) renal parenchyma

*Scan  No uptake
Bladder

- Urine
- Wall thickness (3mm full, empty: 5mm but may give false impression of ↑)
- Chronic ↑ pressure or infection
- Defects, stones, focal thickening, etc
- Lower ureter
Scanning: Bladder

- Begin in transverse with a slight caudal angle. Sweep through the bladder for any structural defects or focal wall thickening.
- Distal ureteric dilatation, Ureteroceles, ureteric jets by Doppler.
- Post-voiding residual urine
Thick Bladder Wall
Bladder hematoma (post-biopsy)
Cystitis

- Diffuse thickening of bladder wall
- With extensive involvement, the inflammatory lesion can protrude into bladder lumen → mimicking Rhabdomyosarcoma of bladder

Diff by → cystoscopy or follow up after treatment of infection
PUV

The most common cause of urethral obst in boys.

By ultrasound ➔ ➔ ➔

Bilateral hydronephrosis & Hydroureter

Thick bladder wall
Ureterocele

Congenital or infl. Obstruction ureter near trigone ➔ ballooning just proximal ➔ ‘intravesical’ mass with thin sonolucent wall
Mega ureter

Non obst Non refluxing
Primary

Obst non refluxing
Primary
Secondary

Non obst. refluxing
Primary
Secondary

Structure stenosis

Calculi ureterocele

Short or absent intranvesical ureter

D.I

Idiopathic Ureteric dilation

Neurogenic bladder ureterocele
Special techniques

- Doppler imaging
  - Renal vessels
  - Ureteric jets
- Voiding urosonography (contrast/ Doppler)
- Post-voiding residual urine
Doppler imaging

*Arterial  *Venous  *Perfusion

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSV</td>
<td>&lt; 180 cm/sec</td>
</tr>
<tr>
<td>Renal Aortic Ratio (RAR)</td>
<td>&lt; 3</td>
</tr>
<tr>
<td>Resistive index (RI)</td>
<td>&lt; 0.70</td>
</tr>
<tr>
<td>Δ RI (right – left)</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Acceleration Time (AT)</td>
<td>&lt; 0.07 sec</td>
</tr>
<tr>
<td>Acceleration Index (AI)</td>
<td>&gt; 3.5 m/s²</td>
</tr>
</tbody>
</table>
RVT: enlarged echog (oedema)

Resistance index = $1 - \left( \frac{V_{\text{min}}}{V_{\text{max}}} \right)$
Ureteric jets by Doppler
Other roles of U/S

- Interventional Nephrology
  *Biopsies, CVCs, etc*
- Critical care nephrology
Therefore ...

- Ultrasound is the principal imaging modality for visualization of the kidneys & urinary tract
- Clinical examination & diagnostic tests are increasingly being integrated
  
  *Remember ABG, CBG, dipstick, POC-testing, CXR, ....*

- A basic ultrasound examination can add a lot to a nephrology assessment
  
  *And can guide further imaging/ investigation if needed*
1. Multicystic dysplastic kidney is usually associated with

A multiple communicating renal cysts
B liver cysts
C polyhydramnios
D no uptake on isotopic scan
2. A neonate with unilateral hugely dilated renal pelvis without ureteric dilatation is most probably having

A. vesicoureteric reflux
B. pelviureteric obstruction
C. posterior urethral valve
D. ureterocele
3. Compared to older children, neonatal kidneys generally feature

A  larger size
B  increased echogenicity
C  highly echogenic renal sinus
D  absent renal pyramids