B mode renal US: Normal and pathological findings

14/9/2013

Dr Simon van Hooland
Nephrology dept, AZ St Lucas, Gent
Content of presentation

• Normal renal echo anatomy

• (Normal) anatomical form variants

• Renal echo pathology:
  - Renoparenchymatous diseases
  - Focal lesions:
    - lithiasis (hydronephrosis)
    - cysts
    - tumours
Kidney location and orientation

- Bean shaped (lateral convex and medial concave)
- Located retroperitoneally
- On both sides of the vertebral column
- Sliding on the m quadratus lumborum and psoas major

Fig. 10.1  The longitudinal and transverse axes of the kidneys

R kidney 1-2 cm more caudal than L

Loin lordosis -> lower pole more ventral
Visualisation of right kidney

• Patient on his back
• Sometimes better visualisation in left lateral position with R arm behind head
• Ask to take a deep breath (to see upper pole)
• Liver = acoustic window
• 2 approaches:
  - anterior axillary line (slim patients)
  - scan subcostally, at dorsolateral side
Visualisation right kidney

Ventrolateral

Posterolateraal
Visualisation of left kidney

- Often harder than R kidney
- Ptn on his back (or prone for biopsy)
- Or right lateral decubitus with L arm above head
- Deep inspiration often needed
- Subcostal, dorsolateral approach
- Position the TD very posterior
- Spleen = acoustic window
Visualisation of the left kidney
Documentation

3 longitudinal images (lateral/middle/medial)

3 transverse images (upper/middle (hilum)/lower pole)

Turn probe counter clockwise
Echo-anatomy  B mode

Parenchyma: cortex + medulla (8-20 pyramids)
Pelvicalicial system
Sinus
Hilus

Kidneys are enclosed by an adipose capsule (thickness varies with constitution)
Can have high or low echogenicity
Why is medulla darker than cortex?
Kidney surface

Smooth
= normal

Uneven:
DD:
- nephrosclerosis
- sequel pyelonephritis
- renal infarction
- persistent fetal lobulation
- ...
Kidney dimensions

- **Length**: 9-12 cm (L kidney slightly longer than R)
- **Width**: 4-7 cm
- **Height**: 3-5 cm
- **Resp. mobility**: 3-7 cm

Parenchymal width (cortex + medulla) = from tip of medullary pyramid (papilla) to the kidney surface = normal: 15 - 25 mm

Cortex width = 8-11 mm
Parenchym-pelvis ratio

- Alternative way to judge the parenchymal width
- Ventral + dorsal parenchymal width / width of pelvis
- Normal reference values (*):
  - < 30 y : > 1.6
  - 31-60 y: 1.2 – 1.6
  - > 60 y : 1.1

(*)Sono Grundkurs. Thieme. Matthias Hofer.
Female 35 y

Measure ant & post parenchymal width at level of the hilus

1.26 + 1.37 / 1.95 = 1.4
Do the kidneys have normal size?

Poor correlation renal length – body length
Better correlation renal volume – body weight

Normal renal size can best be estimated as renal volume (ml), which should be twice body weight (Kg)

Volume

• Formula ellipsoid:
  Length x width x height / 2

• Rule of thumb:
  Volume (ml) =
  Body weight (kg) x 2 ± 20%

• Fex Male 75 kg -> kidney volume: 150 ml (120-180 ml)
Echogenicity R kidney

Normally iso- to slightly hypoechogenic compared to the liver.
Echogenicity left kidney

Normally iso- to slightly hypoechogenic compared to the spleen.
Hyperechogenic right kidney

=sensitive but unspecific sign of renal disease.

Caveat: upto the age of 6 months, renal parenchyma is hyperechogenic compared to liver.
(Normal) anatomical variants

- Congenital a/ hypo genesis
- Hypertrophied column of Bertin
- Renal duplication (partial - complete)
- Dromedary hump
- Junctional fusion defect
- Horse shoe kidney
- Persistent fetal lobulation
- Ectopic kidney
Hypertrophied column of Bertin

X: medulla
Duplicated collecting system

- Most frequent congenital malformation (0.5-10%)

- Cave: Reflux/Obstruction

R kidney. There is a parenchymal bridge of cortex tissue (arrows) passing through the sinus, creating 2 separate sinuses (S). The kidney otherwise looks normal. Atlas of renal Ultrasonography (O’Neill)
Dromedary hump (splenic notch)

- Left kidney
- Wide parenchyma in middle portion
- DD renal mass
Junctional fusion defect

- R kidney, upper pole
- Anterior
- Triangular, wedge shaped
- Hyperechogenic
- In continuity with sinus
- DD Scar, mass

The junctional fusion defect (arrowheads) is a wedge-shaped defect in the cortex that is filled with echogenic fat in continuity with the sinus fat (lower arrowhead). Caused by partial fusion of renunculi (embryonic parenchymatous masses). Atlas of renal ultrasonography (O’Neill)
Horse shoe kidney

Cave:
- VUR reflux
- lithiasis
- urinary tract obstruction

Fused lower poles
Horse shoe kidney
Persistent fetal lobulation

- Remaining signs of fetal lobulation
- More easy recognisable in the R kidney
Ectopic (pelvic) kidney
Renal B Mode US: pay attention to

• Size / volume
• Echogenicity
• Kidney shape / kidney surface
• Kidney location
• Signs of obstruction?
• Focal lesions?: stones/tumours/cysts

The 2 most important points of interest when looking a kidney
Renal echopathology

• Renoparenchymatous disease

• Focal lesions:
  - lithiasis (hydronephrosis)
  - cysts
  - tumours
Renoparenchymatous disease

- Unilateral vs bilateral disease
- Small vs enlarged kidneys

Some general rules of thumb:
- Small kidneys = chronic kidney disease
- Enlarged kidneys = acute (potentially reversible) kidney disease
- Diseased kidneys = often hyperechogenic aspect of parenchyma
Case 1: F, 50 yo, Guadeloupe

- Nocturnal presentation on ED
- Dyspnea, vertigo, tired, nauseae, cramps
- BP 210/160 mmhg; lungs: fine creps bibasally
- History: non treated AHT since 10 years
- Lab: s creat 12 mg% Ureum 256 mg/dl
- Chest X-ray: cardiomegaly + congested hili
- ECG: LVHT
Renal US
Bilateral small kidneys: DD

* Terminal stage of almost all renal diseases
* Chronic GNF
* Chronic PNF
* Analgetic nephropathy
* Bilateral RAS
* Nefrangiosclerosis (AHT)
Case 2 : 53 yo male

- Mixed dyslipidemia
- Heavy smoker: 40 py
- 10-2008: stent R common iliac artery
- 08-2009: idiopathic dilated CMP (EF 20%)
- AHT since 1980, since 08-2009 poorly controlled despite 4 antihypertensive R/
- A on CRF: s creat 1.33 mg% 08-2009
  s creat 2.74 mg% 12-2009
B mode renal US

R kidney

Left kidney

Clearly asymmetric!
Duplex R kidney

Tardus parvus wave form R intrarenally
AT 197 msec en RI: 0.44
95% stenosis R renal artery
Unilateral small kidney: DD

- Hypoplasia – agenesis
- Renal irradiation
- Chron. Pyelonefritis
- Renal artery stenosis
- TBC
Case 3: Male, 36 y

- Since 2 months diffuse edema (ankles; hands, face). More tired.
- BP 170/100 mmhg + pitting edema LL
- S creat : 1,01 mg% eGFR > 60 ml/min; Alb 1,8 g/dl, TG 398 mg/dl , Tchol 388 mg/dl
- Urine: EW/creat 8,8. RBC 19/field WBC 19/field
Weight = 80 kg  
Normal kidney volume = 160 cc + - 20%  
(128 – 192 cc)

Volume R kidney =  
\[
13 \times 7 \times 7.4 /2 = 336 \text{ cc}
\]
Volume L kidney = 
14 x 8 x 9 / 2 = 504 cc
DD Glomerulonephritis/vasculitis

- No definite diagnosis with US
- Only with kidney biopsy
- DD can be narrowed combining the history, clin ex, lab and US findings
Bilateral enlarged kidneys: DD

- All acute renal diseases
- Postvesical UT-obstruction
- Diabetes
- Amyloidosis
- Pregnancy
- Polycystic kidney disease
Diabetic nephropathy

- Very frequent cause of ESRD (40%)
- Almost always associated with large kidneys in the pre ESRD stadium (DD with hypertensive nephrosclerosis)
- The worse the renal function, the more hyperechogenic is the renal parenchyma
- Even in ESRD, the kidneys can still have a normal size.
Case 4 : Male 63 y

- Presentation ED
- Nausea, weakness, dysuria since months
- R/ NSAIDs (back pain)
- S creat 8,8 mg% (09-2010)
- Renal US : Unique R kidney
  Hydro-ureteronephrosis
  Enlarged prostate
  Irregular bladder wall
Urological consult:

- Cystoscopy: enlarged prostate, trabeculated bladder, not suspected for carcinoma
- TURP -> APO: BPH
- Partial recovery of renal function (s creat 2.5 mg%; 04.2011)
Unilateral enlarged kidney DD

- UT-obstruction
- Acute pyelonephritis
- Renal vein thrombosis
- Single kidney
## Classification hydronephrosis

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Only pyelectasia, no caliectasia, normal parenchyma</td>
</tr>
<tr>
<td>II</td>
<td>Pyelectasia, only a few calices are dilated, normal parenchyma</td>
</tr>
<tr>
<td>III</td>
<td>Pyelectasia, extensive caliectasia – normal parenchyma</td>
</tr>
<tr>
<td>IV</td>
<td>As grade III, thin parenchyma</td>
</tr>
</tbody>
</table>

*Fernbach et al. 1993  Pediatr Radiol;23:478-80*
HYDRONEPHROSIS

• Unilateral or bilateral?
• Do you see lithiasis?
• How do bladder + prostate look like?
  -> Globus vesicalis?
  -> Irregular bladderwall lining?
  -> Enlarged prostate?
• Repeat US after miction
  -> postmictional residu? Disappears hydronephrosis after miction?
• (Measure the intrarenal art RI)
• Cave hydronephrosis w/o obstruction: pregnancy, diabetes insipidus, tx kidney
Lithiasis

- Similar ultrasonic appearance regardless of stone type.
- Size determines ease of detection.
- Stones > 5 mm can be reliably detected with US.
- More easy to find with a higher frequency probe.
- Are hyperechogenic with retro-acoustic shadow.
- Twinkle artefact.
- Are harder to find and evaluate than gallbladder stones.
- CT à blanc = better examination than US to look for stones
Twinkle or comet tail artefact

Tips to better visualize the comet tail artefact:
1. Set a low color doppler frequency
2. Increase the colour scale (elimination of the normal frequency shifts)
Cysts

- Most frequent observed renal lesion
- Most are trivial (« simple cyst »)
- Prevalence increases with age (20% at 50 y)
- Autopsy studies: up to 50%!
- 2x as frequent in males than in females
Ultrasound = less sensitive than CT to detect a renal mass

But the value of US =

To distinguish

- A benign cyst

From

- A more complex cyst / solid mass
# Classification of renal cystic disease

## Table 8. Kidney Congenita

<table>
<thead>
<tr>
<th>I. Abnormalities</th>
<th>I. Renal dysplasia</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Deficient c.</td>
<td>a. Bilateral</td>
</tr>
<tr>
<td>b. Unilateral</td>
<td></td>
</tr>
<tr>
<td>c. Renal hypertension</td>
<td></td>
</tr>
<tr>
<td>II. Anomalies of</td>
<td>I. Polycystic kidney</td>
</tr>
<tr>
<td>A. Renal ecto</td>
<td>a. Simple</td>
</tr>
<tr>
<td>b. Crossed</td>
<td></td>
</tr>
<tr>
<td>C. Anomalies of</td>
<td>a. Cystic</td>
</tr>
</tbody>
</table>

## Table 10. Classification and Segregation

<table>
<thead>
<tr>
<th>I. Polycystic kidney disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Autosomal-dominant polycystic kidney disease (ADPKD)</td>
</tr>
<tr>
<td>2. Autosomal-recessive polycystic kidney disease (ARPKD)</td>
</tr>
</tbody>
</table>

## Table 11. The Liapis and Weigl Classification of Renal Cysts

<table>
<thead>
<tr>
<th>I. Polycystic kidney disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Autosomal-dominant polycystic kidney disease (ADPKD)</td>
</tr>
<tr>
<td>2. Autosomal-recessive polycystic kidney disease (ARPKD)</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>I. Polycystic kidney disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Autosomal-dominant polycystic kidney disease (ADPKD)</td>
</tr>
<tr>
<td>2. Autosomal-recessive polycystic kidney disease (ARPKD)</td>
</tr>
</tbody>
</table>

---

Bonsib S. Arch Pathol Lab Med – Vol 134, April 2010
## Bosniak Classification:

<table>
<thead>
<tr>
<th>Category (Bosniak)</th>
<th>US Features</th>
<th>Workup</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 1: Simple cyst</strong></td>
<td>Round, anechoic, thin wall enhanced through transmission</td>
<td>None</td>
</tr>
<tr>
<td><strong>Type 2: Mildly complicated cyst</strong></td>
<td>Thin septation, calcium in wall</td>
<td>CT or US follow-up</td>
</tr>
<tr>
<td><strong>Type 3: Indeterminate lesion</strong></td>
<td>Multiple septae, internal echos mural nodules</td>
<td>Partial nephrectomy, biopsy</td>
</tr>
<tr>
<td></td>
<td>Thick septae</td>
<td>CT follow-up if surgery is high risk</td>
</tr>
<tr>
<td><strong>Type 4: Clearly malignant</strong></td>
<td>Solid mass component</td>
<td>Nephrectomy</td>
</tr>
</tbody>
</table>

Based on the CT graphic appearance of renal cysts
Acquired cystic kidney disease

- Dialysis patients
- Non enlarged kidneys
- Despite multiple cysts
- Cysts of different size
- Hyperechogenic parenchyma irt liver/spleen
- Distal wall enhancement
Lithium nephropathy: sonographic findings

- Lithium-> nephrogenic DI, RTA, TI nephritis, nephrotic S
- Observational series of 10 ptn/36.000 US exams/4 years)
- Numerous microcysts & punctate echogenic foci (microcalcifications, predominantly in the cortex)
- Punctate echogenic foci better seen on US than on CT and MRI
- Kidney size : 7.5-13.9 cm (mean 11.2 cm)
- Probably rather rare finding
  Unknown how many lithium pts who don’t show these findings
Medullary sponge kidney (MSK) is a developmental abnormality occurring in the medullary pyramids of the kidney. MSK is characterized by cystic dilatation of the collecting tubules in 1 or more renal pyramids in 1 or both kidneys (asymptomatic/kidney stones/hematuria/UTI)

- Medullary calcifications
- Reversed CM differentiation
Nephrocalcinosis

- Deposits of CaP (& CaOx) in renal parenchyma and tubuli
- Nephrocalcinosis involves the renal medulla or, much less often, the cortex
- « Reversed corticomedullary differentiation »
- Sometimes with retro-acoustic shadow
- Not specific for 1 condition
Diseases associated with nephrocalcinosis

- 30-40%  Hyperparathyreoidism
- 20%     Renal tubular acidosis
- 10-15%  Medullary sponge kidney
- 6%      Hypercalciuria, idiopathic
- 5%      End stage renal disease
- rest    Sarcoidosis, malign tumors, Vitamin D intox, Papillary necrosis…
Autosomal dominant polycystic kidney disease

• Diagnosis can be made by US alone
• Positive family history and:

  15-30 years: 2 cysts in 1 kidney or 1 cyst in each kidney

  30-60 years: 2 cysts in each kidney

  > 60 years: 4 cysts in each kidney
Renal tumours

- Benign vs malignant
- Sensitivity of US to detect tumour depends on its size
- Tumours > 3 cm: in 100% detected
- Tumours < 2 cm: in 50% detected
Benign renal tumours

- Angiomyolipoma
- Oncocytoma
- Multilocular cystic nephroma
Angiomyolipoma

- Most frequent benign kidney tumour
- Autopsy studies: 0.3%
- Female/male: 3/1
- 95% fat
- Round hyperechogenic, «white» tumor
- Usually rather small (1 cm)
- No blood flow detectable with CF mode
- 1/3: retro-acoustic shadow
- Check after 3 months -> idem aspect: diagnosis is confirmed

If bilateral:
Think of tuberous sclerosis (Bourneville)
Malignant renal tumours

- RCC (80-85%)
- TCC (8%)
- Lymphoma
- Metastases
- Other: e.g. sarcoma, ...
Renal Cell Carcinoma

- 80% of the malignant renal tumors
- APO: clear cell – papillary - chromophobe
- Frequently hyperechogenic
- But can also be hypo or iso echogenic
- Color doppler: hypervascularisation with low RI
- Central necrosis
- 5% Multilocular cystic aspect
Papillary renal cell carcinoma
R lower pole

No vascularisation shown with colordoppler, doesn’t exclude malignancy!
Thank you for your attention!