Postnatal imaging in fetally detected hydronephrosis

Riccabona Michael
Dept. of Radiology, Div. of Pediatric Radiology
University Hospital LKH Graz, Austria

Copenhagen 2012
Introduction

• Increasing number of neonatal urinary tract imaging requests
  – due to prenatally recognized hydronephrosis
    • fetal screening
    • family screening
Introduction

• Task of postnatal imaging
  – reassessment & confirmation & specification
  – diagnostic work-up
  – relieve of parents
    • doctors & nurses ...

**Aim:** reliable diagnosis

  – early enough
    • to prevent potential harm

  – not too early
    – not to miss pathology, one usually has time
Introduction

• Main questions
  – Whom?
  – How?
  – When?

• Economically feasible
• Therapeutically relevant
• Diagnostically reliable
  – no diagnostic overkill
  – without missing important conditions
Introduction

• Existing limitations & problems
  – quality of prenatal US
    • varying cut of values for “pathology”
      – standardization ...
      – information about when how big?
    • reports & images available?
    • other aspects than HN?
  – coverage of prenatal screening
    = postnatal screening necessary?
Introduction

• Existing limitations & problems
  – quality & coverage of prenatal US screening
  – new task of postnatal imaging = **efficacy**
    • new (conservative) treatment & management
    • as little invasive as possible (ALARA)
      – which method is diagnostically useful & reliable?
    • as early as meaningful and necessary
      – not too early to avoid unnecessary investigations
      – not too late to prevent avoidable deterioration
  = timely recognize kidneys that will need surgery
• socio-economic pressure
Plan

• How:
  = imaging methods
  + which conditions to be considered

• Whom:
  = selection criteria
  – entrance point
  – additional imaging

• When:
  = when is which kind of imaging useful
  + some image examples for typical developments...
How: imaging modalities

- **Ultrasound** (including modern methods)
- **VCUG**
  - ce-VUS?
- **MRU**
- **Scintigraphy**
  - DMSA static renal scintigraphy
  - MAG3 diuretic renography
  - radionuclide cystography
- **No role for CT** (and IVU, if MRI available)
US

• First investigations in all HN patients
  – proper quality essential
    – high frequencies, linear Tdx, HI, CDS ...
    – knowledge & device handling
  – when? which criteria?
US quality & requisites

• Detailed analysis of entire urinary tract
  – bladder: wall, content, size, bladder neck
  ostium, ureter, urachus, urethra ...
US quality & requisites

- Detailed analysis of entire urinary tract
  - bladder: wall, ostium, content, bladder neck ...
  - kidney: shape, position, size, parenchyma, cysts perfusion, dysplasia ...
US quality & requisites

• Detailed analysis of entire urinary tract
  – bladder, kidney
  – collecting system & ureter:
    • dilatation? content? peristalsis? ...
US quality & requisites

• Detailed analysis of entire urinary tract
  – bladder, kidney, collecting system & ureter
  – always look at
    • pre- & post-void situation
    • surrounding structures
    • genitalia
ESUR / ESPR procedural recommendation: pediatric urosonography

well hydrated patient, full bladder, adequate equipment & transducer & training ...

urinary bladder: size (volume), shape, ostium, wall, bladder neck
include distal ureter & retrovesical space/inner genitalia, urachus? ...
optional: CDS for urine inflow, perineal US, scrotal US ...

kidneys: lateral and/or dorsal, longitudinal & axial sections
parenchyma? pelvo-caliceal system?
standardised measurements in 3 dimensions & volume calculation
if dilated: max. axial pelvis & calix, narrowest parenchymal width, + UPJ
optional: (a)CDS & duplex-Doppler ...

post void evaluation
bladder: residual volume, bladder neck, shape & configuration
kidneys: dilatation of pelvo-caliceal system / ureter changed?
optional: contrast-enhanced urosonography, 3DUS ...

additional abdominal US survey recommended
US criteria

• Grading of dilatation = “HN scale”

⇒ HN: standardized grading
  – important for comparison
    • less measurement based
    • improves understanding
  – prerequisite
    • standardized US conditions
Pediatric HN grading system

Adapted from Hofmann & SFU classification

HN 0 = collecting system not or minimally visible, considered normal
HN I = just renal pelvis visible, axial diameter <5(-7) mm, considered normal
HN II = axial pelvis diameter 5/7-10 mm, some calices with normal fonices visible
HN III = marked dilatation of calices, pelvis >10 mm, rounded papilla & fonices without parenchymal narrowing
HN IV = gross dilatation of collecting system + narrowing of parenchyma
HN V = used in some places to communicate extreme HN with only thin, membrane-like residual renal parenchymal rim

Pediatr Radiol 2008; 38
US “extended criteria”

- Grading of HN
- Other important features
  - indicating pathology
  - justifying further imaging
    - bladder pathology
    - ureteral abnormalities
    - renal parenchymal changes
    - urothelial sign

⇒ not only dilatation and/or mm matter!
VCUG

• Irreplaceable, but stricter indications
  – anatomy: diverticula, urethra, genitography ...
  – function, VUR
    • preoperative, DD of obstructive uropathy
VCUG

• Irreplaceable, but strict indications

• Technique: pulsed fluoroscopy
  – grids & filters, dose ...
    • age & size dependent
  – ALARA principle
    • no blind films
      ⇒ short screening time
      ⇒ spot films only if necessary
    • last image hold captures often suffice
  – cyclic filling, potentially modified technique
VCUG - ESUR recommendation

No diet restriction or enema, urine analysis, potentially antibiotics ...

Catheterism: feeding tube, 4-8 french or suprapubic puncture
Latex precaution: neuro-tube defect, bladder extrophy ...

Fluoroscopic view of renal fossae & bladder, initial + early filling

Bladder filling with radiopaque contrast
gravity drip = bottle 30-40 cm above table, watch dripping, AB?

Fluoroscopy: signs of increased bladder pressure, imminent voiding, urge ...
bilateral oblique views of distal ureters, include catheter
document VUR, include kidney (spot film => intra-renal reflux)

When voiding: remove catheter, unless cyclic VCUG = 3 fillings, 1st y(s)
female: spot of distended urethra (slightly oblique)
male: 2 spots during voiding (ap & high oblique / lateral)
include renal fossae during voiding, if VUR => spot film

After voiding: ap view of bladder & renal fossae
assess contrast drainage form kidney if refluxed

Note: VUR staging, minimize fluoroscopy time & spot films, no blind film
Contrast enhanced VUS

- Initial conventional US
- Fill bladder with NaCl
- Fractional CM instillation
  - 1% of filling volume (SonoVue)
- Constant evaluation of bladder + ureter + kidney
  - before & after CM
  - during & after voiding
Contrast enhanced VUS

- Usually good visualization of CM in kidney
  - using modern imaging techniques
    - based on non-linear sound properties
  - detection rate ce-VUS ≥ VCUG
    - grading achievable & established
    - recommended for girls & follow-up
ce-VUS: urethra?

- Urethra assessable
  - perineal approach
    - during voiding
    - repeated filling
    - as in VCUG

- Alejandro Maté, Eur Radiol 2003
- Theresa Berrocal, Radiology, 2005
How to do ce-VUS

No diet restriction or enema, urine analysis ...

- **Catheterism:** feeding tube, 4-8 french, or suprapubic puncture anaesthetic lubricant or coated plaste

- **Standard US of bladder & kidneys (supine, ± prone)**

- **Bladder filling with NaCl (only from plastic containers)**

- **US contrast medium,** e.g. Levovist® 300 mg/ml, 5-10% of bladder volume slow, US- monitoring, potentially fractional administration

- **Peri-/ post-contrast US of bladder & kidneys**
  
  **US modalities:** fundamental, HI, CDS, contrast specific methods

  alternate scans of right & left side during & after filling

- **During + after voiding: US of bladder & kidneys**

  supine ± prone, laying or sitting or standing

⇒ **VUR diagnosis:** echogenic micro-bubbles in ureters or renal pelves
DMSA scintigraphy

= static renogram

- Renal parenchyma assessment
  - tracer: Tc 99m DMSA iv
    - scan after 2-3 h
    - uptake only in normal renal parenchyma
DMSA scintigraphy

= static renogram

- Renal parenchyma assessment
  - tracer: Tc 99m DMSA iv
  - uptake in normal renal parenchyma
    ⇣ (split) renal function
    ⇣ aPN, scaring ...
    ⇣ (regional) dysplasia
  - restricted use in HN & neonates
    • renal immaturity ...
    • needs good function
MAG3 scintigraphy

= diuretic / dynamic renography

• Dynamic assessment of renal function
  – arterial & parenchymal phase
  – excretion & drainage phase
  – diuretic stimulation
MAG3 diuretic scintigraphy

- Dynamic assessment of renal function
  - arterial & parenchymal phase
  - excretion & drainage phase
  - diuretic stimulation
  - “grade” obstruction
    - type I-IV°
    - relative function
**MAG3 diuretic scintigraphy**

- Dynamic assessment of renal function
  - arterial & parenchymal phase
  - excretion & drainage, diuretic stimulation
  - grade obstruction = type I-IV°
  - consider restrictions
    - needs sufficient renal function
      - not useful before 4 - 6 weeks, not in dysplasia ...
    - “Windkessel” effect - elasticity of renal pelvis
      - often equivocal findings - “type III b”, what to do?
  - standardized hydration
  - impact of positioning

Copenhagen 2012
MR-Urography: the method

- Different ways to do MR of urinary tract
  - “simple” anatomic imaging
  - functional imaging
    - visual semi-quantitative assessment
      - similar to IVU or CT
    - “area under curve”
      - single or multiple slice(s)
      - repeated acquisitions
    - “Patlok Plot” based assessment
      - 3d-sequence
      - dynamic assessment
MRU in infants: how

- Established
  - for anatomic assessment
- Basic imaging relatively easy
  - T2, T1 ....
    - challenges in infants
      - sedation, hydration, catheter?
    - add other sequences
      - fat saturation, HR? ...
      - IR, GRE, ...
      - MRA needed?
Basic MRU techniques

- **T2-MRU**: HASTE, TRUE-FISP, RARE, PACE..
  
  = heavily T2 weighted sequence, "T2 MR-urogram"

  ⇒ anatomic display of collecting system

  + overview
Basic MRU techniques

- **T2-MRU:** HASTE, TRUE-FISP, RARE, PACE ..
  = heavily T2 weighted sequence, "T2 MR-urogram"
  ⇒ anatomy of collecting system + overview
  + high resolution (HR)-3D views? thin slices!
  - isotropic volume ...
Basic MRU techniques

- Contrast-enhanced MRU
  - T1 weighted sequences (t)SE
    - pre- & post Gd, fs, serial ...
    + fast T1w-GRE sequences
Basic MRU techniques

• Dynamic diuretic (functional) MRU
  = dynamic imaging after contrast = “T1-MRU”
  – non-linear (cyclic) Gd iv.
    • NSF? GFR?
    • immaturity?
  – Furosemid iv.
    • hydration
  – serial acquisitions
    • delayed scans?
  – 3d views
    • MIP ...
Basic MRU considerations

• Challenges to be considered in infants
  – small field of view = little signal
  – small structures ⇒ ↑ spatial resolution
    • less fat – discrimination more difficult
  – no / less cooperation ⇒ ↑ temporal resolution
    • sedation? monitoring ...
    • diaphragmatic triggering / gating ...
    • “BLADE” / “PROPELLER” ...
  – functional & anatomic queries
    • physiological differences, immaturity ...

⇒ individually optimize protocol & sequence
Basic MRU considerations

• Challenges to be considered in children
  – small field of view, small structures
  – no / less cooperation, different queries

⇒ Use modern techniques
  – fast sequences
  – strong gradients
  – motion insensitive sequence
  – multi-canal coils
Basic MRU applications

- Practically has replaced IVU
  - non ionizing
  - anatomic information
  - non-functional units assessable
Basic MRU applications

• Practically has replaced IVU

Some examples:
✓ grading?
  - semiquantitative
  - visual impression
Basic MRU applications

- Has replaced IVU
  - duplex kidneys
  - complex anatomy
Procedural recommendation: Paediatric MR Urography [MRU]

INDICATION
Always previous US (+ reflux study, if indicated = VCUG, VUS, or RNC)
Queries: e.g. malformation, obstructive uropathy, complicated infection, tumour, post-traumatic, cystic disease, transplant ...

PREPARATION:
- **General:** Place line in advance, creatinine for CM-studies (GFR calculation - NSF), mock unit / visit to magnet
- **Hydration:** NaCl or Ringer’s solution (20 ml/kg for 1 hour [max. 1l]), empty bladder before entering the magnet
- **Sedation:** priority to immobilization (feed & wrap), or no (or minimal) sedation. Deep sedation only if necessary
- **Bladder catheter:** deeply sedated patients who cannot empty the bladder (particularly after Furosemide)
  - potentially also in high grade VUR patients with dynamic queries
  - Polyethlene catheter without balloon, urine bag, below level of MR table
- **Diuresis:** Furosemide 1 mg/kg IV (max. 20 mg), 15 min before to beginning of morphologic investigation
  - timing may vary in dynamic-diuretic functional protocols (F -20, F -15, F +10, F +15, F +20)

MRU examination*1:
**Positioning:** Supine position with arms above the head
**SCOUT:** Sagittal important for correct oblique coronal plane, FOV: above both diaphragms to below symphysis
  - potentially SSFP axial & coronal (+ sagittal)

Heavily T2-weighted sequences coronal (e.g., T2-3D TSE fs, 2D-thin & -thick slice [3D-urogram], HASTE/RARE/PACE, ...)?
**T2-IR sequence, non-enhanced T1-weighted & GRE sequence**
  - NOTE: 3 slices anterior + posterior of kidneys for GRE; adjust FOV

**CM-Application** - cyclic Gd compounds*2 iv. in first year of life (renal immaturity ...) & bilateral uropathy, or GFR ↓
**Repeated serial coronal T1-3D sGRE fs**, for 3 - 5 min.
  - NOTE: subtraction helpful - particularly for MRA, if achievable; for MRA use motor pump & flow of 1(-2)ml/sec
**T1 axial & coronal (fs), + sagital if needed**
**Final coronal T1-3D sGRE fs; or additional delayed imaging up to 20 min p.i.**
  - potentially changing to prone position or post void scan (when delay in CM washout)

*1 functional MRU not yet standardised and not addressed
  - Furosemid timing, contrast dose & application may need adaptation for various queries tailored protocols are essential
  - e.g., MRA, diffusion, additional sagital acquisitions

*2 non-cyclic compounds can be used in older children according to approval
  - Gd-dose as recommended by manufacturer

Pediatr Radiol 2010: 40
Functional diuretic MRU

• Different approaches
  - single slice, area-under-curve
  - 3D sequence, Patlok-plot ...

• Essential features:
  - diuretic stress
  - standardised hydration
  - (semi)quantitative
    • (split) renal function
    • urinary drainage
      - sedimentation issues
      - T2* effects...

Copenhagen 2012

Rohrschneider et al, Radiology
Functional diuretic MRU

Area-under-curve method
- observe & quantify signal over time
- fast 3D sequence or single slice

• Essential features:
  - signal linear to Gd-concentration
    • lower dose (0.05 mg/kg)
  - first 3-5 minutes
    • fast acquisition
  - late phases

Concentration CM [mmol/l]

Signal [normalized]

Riccabona, Pediatr Radiol & EJR ...
Functional diuretic MRU

Area-under-curve method

• unsolved aspects:
  - motion correction
Functional diuretic MRU

Area-under-curve method
- unsolved aspects:
  - motion correction
  - 3d-coverage

⇒ DMSA versus MRU - split renal size & function

single slice ± 3.1%

multi slice ± 1.7%
Functional diuretic MRU

- **Patlok plot method**
  - 2 compartment model
    - subtract arterial inflow (aorta)
- **Essential features:**
  - fast 3d sequence
    - dose = 0.1 mmol/kg
    - slow injection (0.1 ml/sec)

Sequence: TR = 3.2, TE = 1.1 msec
flip angle ≥30°

Functional diuretic MRU

• Potential
  - “one stop shop” imaging
  • entire anatomy (including vessels)
  • all functional information, including GFR & split size
    - perfusion, transit & excretion, urinary drainage
    - peristalsis, vitality ...
Functional diuretic MRU

- Restrictions
  - drainage?
    - sufficient function?
    - $T2^*$ effect, sedimentation
    - Patlok function for drainage?
    - single slice - proper section?
  - standardization
    - validation missing
    - restricted availability
  - DTPA versus MAG3
    - only glomerular filtration...

Grattan-Smith, Pediatr Radiol 2008, 2010
Functional diuretic MRU

• Restrictions
  - drainage? standardization, DTPA vs MAG3
  - sedations needs & options
  - still need high quality US
  - still may need VCUG
  - catheterism?
  - costs & availability
  - impact on treatment & outcome?
Which indications for MRU?

• **UPJO, UVJO / MU**

• **Duplication**
  - ectopic ureteral insertion, ureterocele
  - relative function upper vs. lower moiety
    • even non-/poorly functioning units assessable

• **Single & ectopic kidneys**
  - associated genital anomalies
  - cystic kidney remnants ... 

• **Complex malformation, function**
When to image whom how?

- Usually post-natally confirmation by US
  - quality essential
    - just assess renal pelvis? bladder? ureter?
    - prone or supine?
    - diuresis? hydration? - age dependent!
  - timing depends on prenatal finding
    - bilateral HN? renal insufficiency?
    - degree of HN at which gestational age?
- other aspects: availability & access
  - equipment & expertise
  - physiologic renal immaturity, compliance ...
Postnatal imaging in newborns with fetally diagnosed mild hydrenephrosis

Antenatal diagnosis of mild to moderate HN

US: 1st US around day 5

Abnormal: pelvis ≥ 7(10) mm + dilated calices, or other anomalies

VCUG

Normal: pelvis ≤ 10 mm, otherwise normal

Stop follow-up

Abnormal

US at 3 mo

Normal: pelvis ≤ 10 mm, other changes

Further morphological & functional evaluation: scintigraphy, (IVU), MRU...

Abnormal

pelvis ≥ 10 mm, other malformation, “extended criteria”

US at 1 mo

Normal

Stop follow-up

Pediatr Radiol 2008; 38
Postnatal imaging in newborns with fetally diagnosed high grade hydronephrosis

Prenatal US: gross dilatation = HN≥IV°

VCUG, in all boys particularly if ureter dilated
ce-VUS in girls, potentially delayed

early US + VCUG

PUV

high grade VUR

obstructive uropathy

others *4

⇒ drainage renal function?
+ isotopes*2, MRU*3

US follow-up
6 mo: isotopes*2, MRU*3?

UPJO, MU *5

as indicated *5

*1 (US) genitography: in patients with single kidney, MCDK, ectopic kidney, suspected genital anomaly ...

*2 MAG3: better than DMSA in dilated systems and neonates, not before 6 weeks;
   + open bladder catheter to avoid VUR induced errors; DMSA preferably after 3 months

*3 MRU: complex anatomy, function, obstructive component ...

*4 e.g. MCDK, cystic dysplasia, duplex or horseshoe kidney, other malformation, non-obstructive HN, cysts/cystic tu ...

*5 see respective algorithm

Pediatr Radiol 2009: 39
Imaging algorithm in infants & children with suspected obstructive uropathy

- **US (+ DDS/CDS)**
  - **mild (HN <3°) x1**
  - **US follow-up hydration! CDS! diuretic US (?)**
  - **VUR/PUV x1**

- **HN ≥ III°**
  - **VCUG (ce-VUS?)**
  - **<6 weeks old**
  - **>6 weeks old**
  - **no VUR**
  - **clinical symptoms x3**
  - **potentially diuretic US(?)**

- **MAG3 (T+20) x4**
  - or (quantitative) **MRU or IVU (pre-op., if no MRU)**

- **deterioration x2**
  - **clinical symptoms x3**

- **non-obstructive normal function**

- **equivocal - also, if <3 mo + obstructive & normal function**

- **⇒ MAG3 (T-15), follow-up (after 3-6 mo) ...**

- **obstructive low function ⇒ OP (>3-6 mo)**

---

**x1 as appropriate, see respective algorithm**

**x2 proposed imaging criteria for deterioration:**
- on **MAG 3:** decreased (split) renal function & drainage, contra-lateral hypertrophy
  - on **US:** increasing dilatation, decreasing parenchymal width, echotecture, contra-lateral hypertrophy
  - decreased vascularity (on cCDS), asymmetrical RI (on PW-DDS), reduced peristalsis (in MU) or ureteric jet (asymmetrically in unilateral disease)

**x3 Clinical criteria for deterioration:** pain, infection, haematuria, (kidney) growth failure, hypertension

**x4 assess drainage pattern and (split renal) function**

*Pediatr Radiol 2009: 39*
Image and case examples

Typical findings and conditions
"When to do what"

... if we still have time ...
What are the challenges

- Can we know fetally or neonatally which kidney will need surgery?

Lessons we learned in the past:
- the grade of fetal HN does not always correlate with neonatal findings
What are the challenges

• Can we know fetally or neonatally which kidney will need surgery?

Lessons we learned:

➢ fetal HN grade ≠ neonatal finding
➢ low grade neonatal HN does not exclude future obstructive uropathy that may need surgery
What are the challenges

• Can we know fetally or neonatally which kidney will need surgery?

Lessons we learned in the past:

➢ fetal HN grade ≠ neonatal finding
➢ low grade HN does not exclude future severe HN
➢ established alternate non-obstructive diagnosis (VUR) does not rule out future obstruction
What are the challenges

- Can we know fetally or neonatally which kidney will need surgery?

Lessons we learned in the past:
- fetal HN grade ≠ neonatal finding
- low grade HN does not exclude future severe HN
- established alternative non-obstructive diagnosis (VUR) does not rule out future obstruction
- low grade neonatal HN does not allow reliable prediction of future development
  - particularly if US done relatively early
What are the challenges

• Can we know fetally or neonatally which kidney will need surgery?

Lessons we learned in the past:

- fetal HN grade $\neq$ neonatal finding
- low grade HN does not exclude future severe HN
- established alternative non-obstructive diagnosis (VUR) does not rule out future obstruction
- low grade neonatal HN does not allow reliable prediction of future development
- HN may persist unchanged without deterioration
What are the challenges

- Can we know fetally or neonatally which kidney will need surgery?

Lessons we learned in the past:

- Fetal HN grade ≠ neonatal finding
- Low grade HN does not exclude future severe HN
- Neonatal HN does not predict future development
- Established alternative non-obstructive diagnosis (VUR) does not rule out future obstruction
- Neonatal HN may persist unchanged
- Neonatal high grade HN does not necessarily mean future surgery
Discussion

• Postnatal imaging in prenatal HN
  – depends on many factors
    • prenatal findings
    • local postnatal management
      – compliance ...
    • availability
    • health system
      – prenatal screening? socio-economic situation ..

• **Goal:** recognise relevant conditions
  – therapeutically necessary, without overkill
    • without missing important disease, prevent damage
Conclusion

• Postnatal imaging heavily relies on US + knowledge of prenatal findings
  • high quality US & proper timing essential
  • VCUG, MAG3, MRU irreplaceable, IVU outdated

• Additional imaging tailored according too
  – US result
  – therapeutic consequence
  – clinical query & situation
    • ALARA
    • avoid unnecessary exams
      – only assess relevant conditions
Any questions -

Yes, please, ... ??
Thank you!
ÖGUM-DEGUM recommendations

Minimaldokumentation: Anforderung für die Standarduntersuchung

Erweiterte Dokumentation: Wie Normalbefund + gezielter Zusatzschritte + weitere Zugangswege und Methoden

Bei Erstvorstellung ist die Untersuchung des gesamten Abdomens empfohlen (abdominelle Übersichtssonografie) – siehe "Standarddokumentation der Sonografie des kindlichen Abdomens".

http - www.oegum.at