Figure 1: Intravenous urography (IVU) in childhood

**Preparation**
- age: minimum 4-6 weeks
- infants: before next meal
- NPO, hydration, creatinine, venous line ...

**Procedure**
- adapt exposure & contrast agent
- proper use of filters, grid, shutters
  - renal area, or KUB (include symphysis)
- initial KUB only if indispensable (e.g., urolithiasis)
- reduced number exposures:
  - one early renal view at 5 min
  - single late KUB at 15-20 min
  - additional focused images, if needed for treatment
- diuretic IVU: Furosemide iv. 1 mg/kg BW (max. 20 mg) 20 min before view
  - inject 5 min before, with, or 5-10 min after CM application

**Indications**
- restricted access to MRU/CT
- pre- or/and p0st-operative
- urolithiasis, (trauma)
- caliceal diverticula
- ureteral & subtle caliceal pathology

**NOTE:**
- previous dedicated US mandatory

**IV contrast dose**

<table>
<thead>
<tr>
<th>Age [year]</th>
<th>ml/kg BW</th>
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<tr>
<td>1</td>
<td>2.5</td>
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<tr>
<td>2</td>
<td>2.0</td>
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<tr>
<td>3</td>
<td>1.5</td>
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<td>&gt;4</td>
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**Goal:** answer specific query with minimal radiation (ALARA)

⇒ *avoid multiple, unnecessary or particularly tomographic views*
Abbreviations: CM = contrast media, CTA = CT-angiography, DD = differential diagnosis, KUB = kidney – ureter – bladder radiograph, kV = kilovolt, mAs = milli-ampere second, mSv = Milli-Sievert, US = ultrasound.
Figure 3: “Anatomic” paediatric MR-urography (MRU)

INDICATION
Always previous US (+ reflux study, if indicated = VCUG, ce-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 [maximum 1]), empty bladder before entering the magnet
- Sedation: priority to immobilization (feed & wrap), or no (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 with dynamic queries
  - Polyethylene 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 0, 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: from above both diaphragms to below symphysis
  - potentially SSFP axial & coronal (+ sagital)
Heavily T2-weighted sequences coronal (e.g., T2-3D TSE fs or 2D-thin & -thick slice [3D-URORAG], 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 GRE fs (for functional assessment continuously for 3-5min.)
  - NOTE: subtraction helpful - particularly for MRA, if achievable; for MRA use motor pump & flow of 1 ml/sec
T1 axial & coronal (fs), + sagital if needed
Final coronal T1-3D GRE fs; or additional delayed imaging up to 20(-30) 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
*2 non-cyclical compounds can be used in older children according to approval
for various queries tailored protocols are essential
  - e.g., MRA, diffusion, additional sagital acquisition
  - Gd-dose as recommended by manufacturer

Abbreviations: 3D = three dimensional, ce-VUS = contrast enhanced voiding urosonography, CM = contrast media, DD = differential diagnosis, F = Furosemide, FOV = field of view, fs = fat saturation, GFR = glomerular filtration rate, GRE = gradient echo (sequence), Gd = Gadolinium, IR = inversion recovery (sequence), iv. = intravenous, mg = milligram, min = minutes, MRA = MR-angiography, NaCl = physiologic saline, NSF = nephrogenic systemic fibrosis, p.i. = after injection, RNC = radionuclide cystography, SSFP = steady state fast precession (sequence), TSE = turbo spin echo (sequence), US = ultrasound, VCUG = voiding cystourethrography, VUR = vesico-ureteral reflux.