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Medizinische Universität Graz

Modern methods and approaches in pediatric uroradiology

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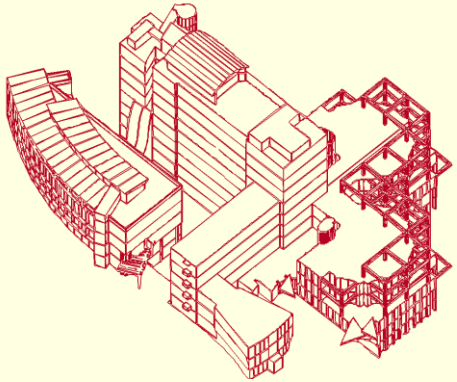


Objectives

- To revisit standard & modern imaging methods
  - applicable to the pediatric urogenital tract
- To describe new insights & imaging techniques
  - do these impacted imaging approach & task?
- To learn about new imaging options
  - how have they impacted imaging algorithms?
- To discover new potential of modern imaging
  - at reduced invasiveness
    - less radiation burden

Objectives

- To revisit established standards & methods
- To describe new insights a& imaging techniques
- To learn about new imaging options
- To discover new potential of modern imaging
- To give typical examples & suggestions
  - procedural recommendations & imaging algorithm
    - based on ESPR uroradiology task force
    - for common paediatric nephro-urologic queries

Basic considerations

Aim & task of imaging/paediatric uroradiology

- assess prenatally suspected finidings
  - screening?
- diagnose clinically manifest conditions
- follow-up diseases

⇨ ***impact on management & prognosis***

Basic considerations

Aim & task of imaging

- assess prenatally suspected changes
- diagnose clinically manifest conditions
- follow-up diseases

  ⇨ **impact on management & prognosis**

- less important (= "relative" indication):
  - reassurance of parents & relieve of doctors
  - "forensic imaging" – but often requested
- **Consider:** growing economic & legal pressure

First:

Imaging methods

all modern imaging approaches need solid base

=

fundamental established tools & rules need to be respected, performed properly and adapted towards today's standards & knowledge

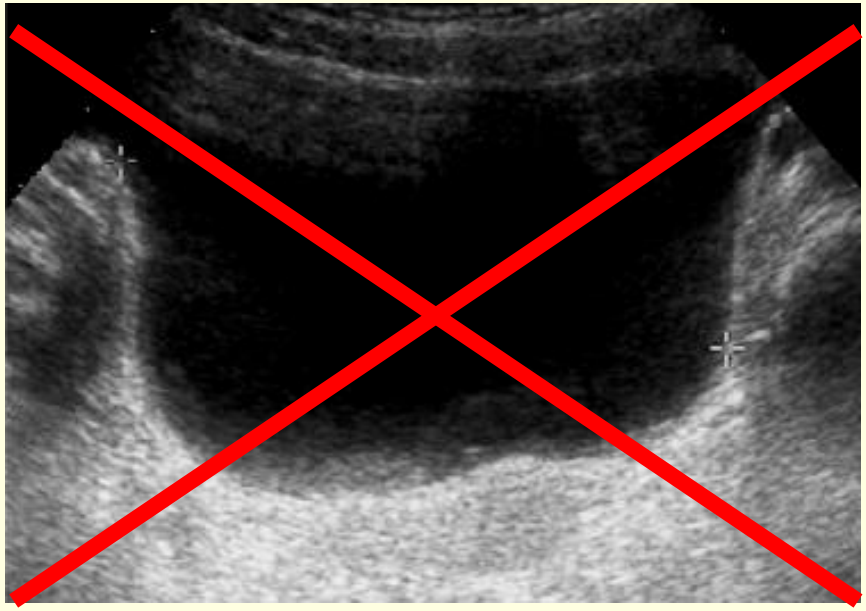
Imaging methods = requisites

- **US = mainstay of uroradiology**
  - dedicated equipment needs
    - high resolution & linear Tdx
    - high frame rate ...
    - modern US methods helpful
      - HI & compounding, HR ...

Imaging requisites: **US**

- **US = mainstay** of pediatric uroradiology
  - equipment needs
  - knowledgeable & engaged radiologist
    - training in pediatric US, comprehensive exam
    - proper timing

day 3



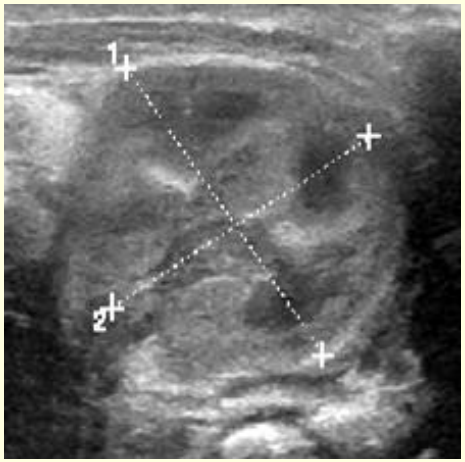
3 weeks

Imaging requisites: US

- Mainstay of uroradiology
  - equipment needs
  - knowledgeable radiologist
  - investigation technique
    - post void US, volumes assessment …
    - dorsal approach, documentation …

Imaging requisites: US

- Other requisites for good US results:
  - hydration
  - enough time
  - standardised investigation & report
  - heating, place for assisting persons
  - pacifier, swaddling facility ....
  - ergonomic setting
  - warmed US jelly
  - information, clear query
    - old images & reports?
    - present situation (medication, query ...)



ESUR / ESPR procedural recommendation: pediatric urosonography

well hydrated, 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

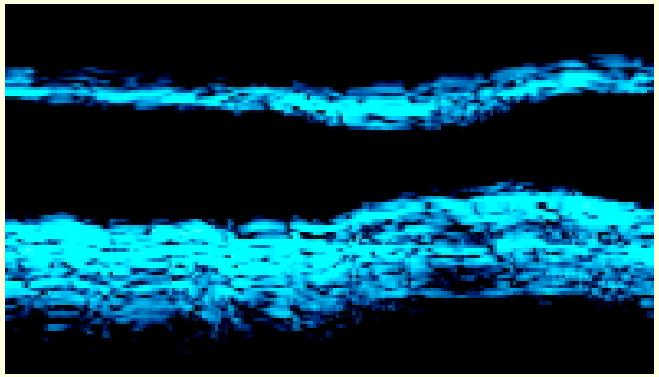
Pediatr Radiol 2008:38

Modern US

Improves US capabilities

- invasive/irradiating exams ↓
- helps to tailor further imaging

- e.g. perineal US, m-mode
  - unconventional approach or use
    - document ureteral peristalsis
    - visualise urethra during voiding
    - sonogenitography



Modern US

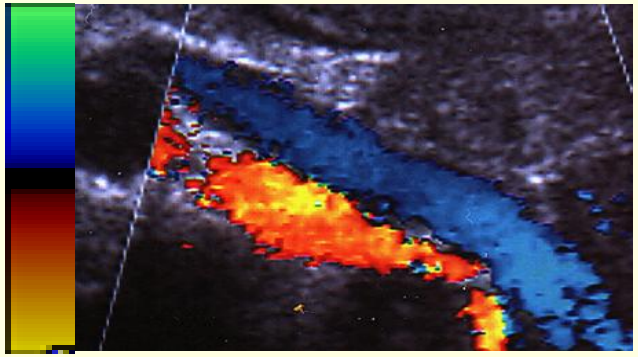
Improves US capabilities

- **e.g. extended field of view applications**
  - overview & improved measurements
    - sometimes essential, e.g. renal transplant
      - comprehensive & conspicuous illustration

Modern US

Improves US capabilities

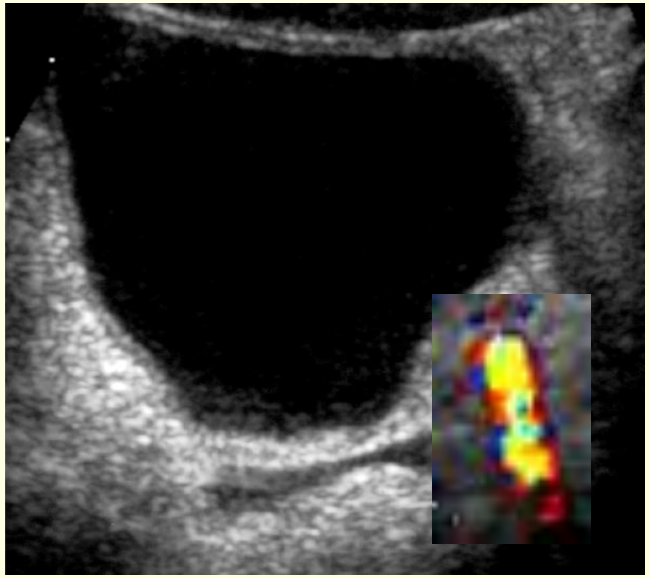
- **e.g. Doppler techniques** - many applications
  - information on perfusion
    - sometimes essential
    - spectral analysis …

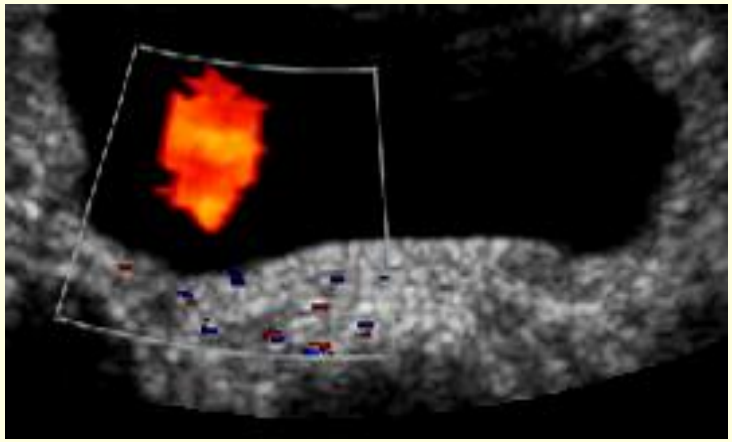


Modern US

Improves US capabilities

- **e.g. Doppler techniques**
  - information on perfusion
    - CDS valuable too, e.g.,
      - twinkling stone, ureteric jet
      - additional vessels …





Modern US

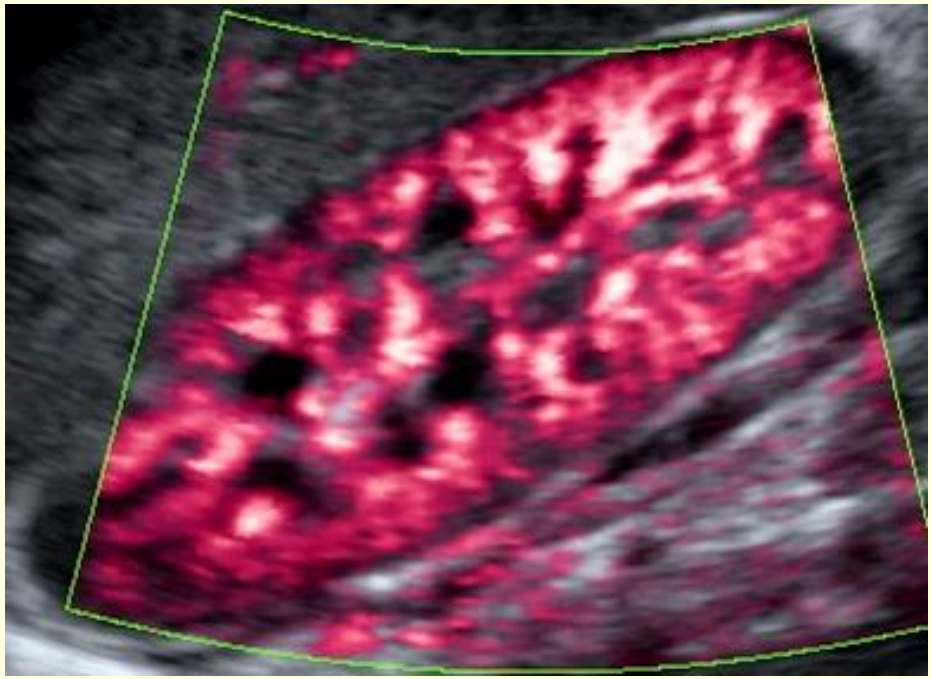
Improves US capabilities

- **e.g. aCDS**
  - sensitive for focal lesions
    - can visualise aPN
    - many other applications
      - trauma, infarction ...

Modern US

Improves US capabilities

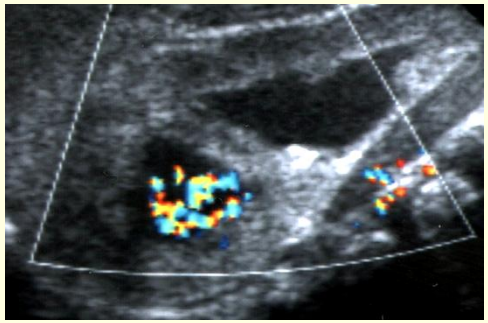
- **e.g. "B-flow"**
  - non-Doppler flow depiction
    - no angel dependency
    - lower MI



Modern US

Improves US capabilities

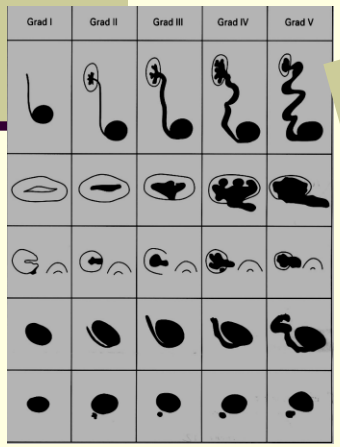
- **e.g. ce-VUS**
  - reliable & sensitive VUR detection
    - may visualize intra-renal VUR
    - potential to visualize urethra
  - no radiation
  - girls, screening, follow-up



ce-VUS

- Fill bladder with NaCl + US-CM
  - assess bladder, retrovesical space + kidneys
  - try to look at urethra during voiding perineally

➤ see also talk on UTI & VUR



Darge K. EJR 2002

ESPR / ESUR procedural recommendation

ce-VUS

No diet restriction or enema, urine analysis; AB as in VCUG …

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)

↓

Install US contrast medium, e.g., SonoVue ®, 0.5-1.0% of bladder volume
slow, US monitoring, fractional administration

↓

Peri-/ post-contrast US of bladder + kidneys: continuous, alternating
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

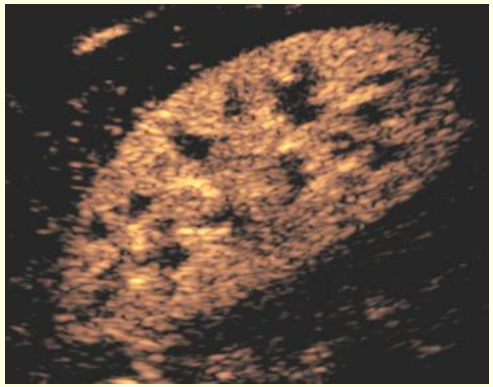
Assess urethra during voiding – perineal US

VUR diagnosis: echogenic micro-bubbles in ureters or renal pelves

Modern US

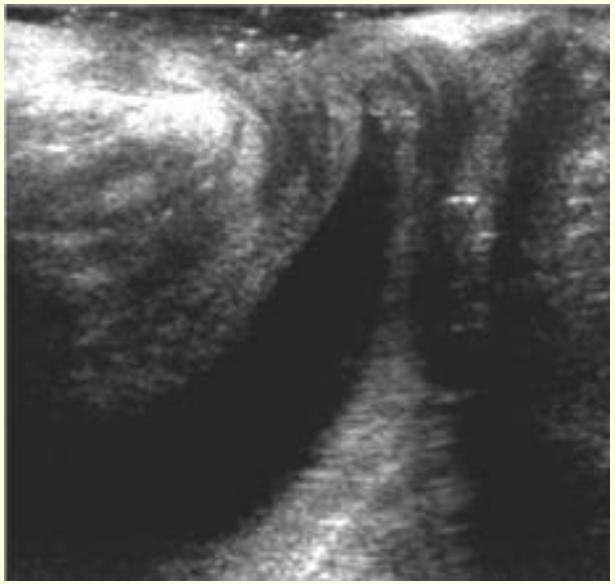
- **e.g. ce-US = intravenous/intra-cavitary CM**
  - reliable & sensitive
    - enhances US potential

      BUT: not licensed for pediatric use
  - native kidney lesions
  - transplant complications
  - drain position …



Modern US

- **e.g. US genitography**
  - in ambiguous genitalia, suspected malformation
  - fill vagina with NaCl
    - enhances genital US
    - perineal approach
      - may add US-CM, + fluoro …



Modern US

- **e.g. 3D/4DUS**
  - anatomic analysis …
  - accurate volume calculation
    - even in HN
  - comprehensive documentation

Modern US

- **e.g. 3D/4DUS**
  - anatomic analysis, volume calculation
  - comprehensive documentation
  - collecting system rendering
    - conspicuous visualisation
  - virtual cystoscopy

Imaging requisite: **VCUG**

- **VCUG = still essential in uroradiology**

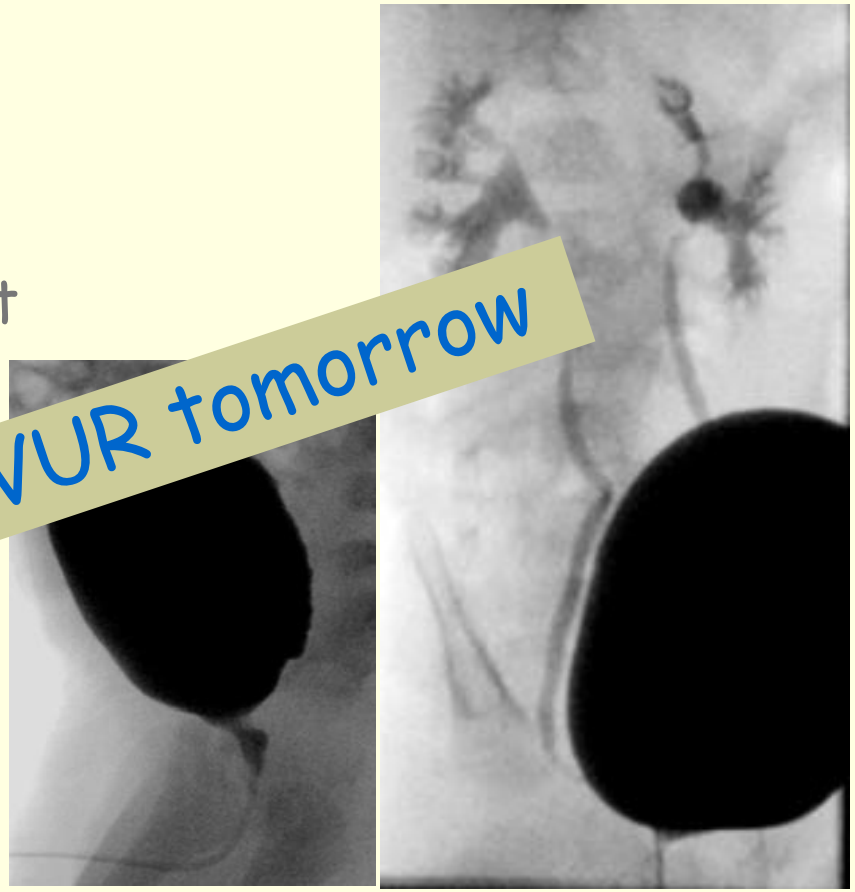
  BUT: adequate equipment & technique

  - some rules (also for genitography):
    - pulsed fluoroscopy
    - short screening
    - last image hold
    - no blind films

VCUG

- **VCUG = still essential in uroradiology**
  - BUT: adequate equipment & technique
  - some rules:
  - make utmost use of it
    - modified protocol
      = functional assessment

➢ talk on UTI & VUR tomorrow



ESPR / ESUR procedural recommendation

VCUG

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

catheterism: feeding tube, 4-8 french or suprapubic puncture
latex precaution: neuro tube defect, bladder exstrophy …

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: if 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: 1-2 spots of distended urethra (slightly oblique)
male: 1-3 spots during voiding (ap & high oblique / lateral)
⇨ include renal fossae during voiding, if VUR => spot film of kidney

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

Note: VUR staging, AB-prophylaxis? …

Pediatr Radiol 2008:38

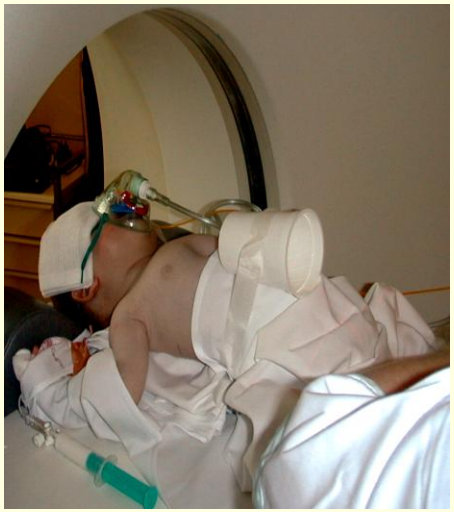
Imaging method: CT

- Huge potential
  - BUT: radiation! pediatric protocol? indication?
- General rule, particularly in infants:
  - try to avoid CT, use alternatives
    - extensive use of dedicated US, MRU …

Disclosure: Graz = Toshiba center for pediatric CT

CT

- If CT necessary - **never just try**
  - ✓ liberal use of immobilisation & sedation
    - high radiation risk (*Brenner 2001 etc …*)
      - particularly in infants
  - ✓ accept some image noise
    - don't use large detectors, no over-ranging ….
  - ✓ individually adapt protocol
    - dose, CM, technique
      - spiral, increment, timing …
    - corrected for weight, age & query
    - never use adult protocols
    - avoid multiphase CT



CT

Indications:

- Emergencies
  - severe & multiple trauma
  - acute hemorrhage
    - infarction
    - malformation

CT

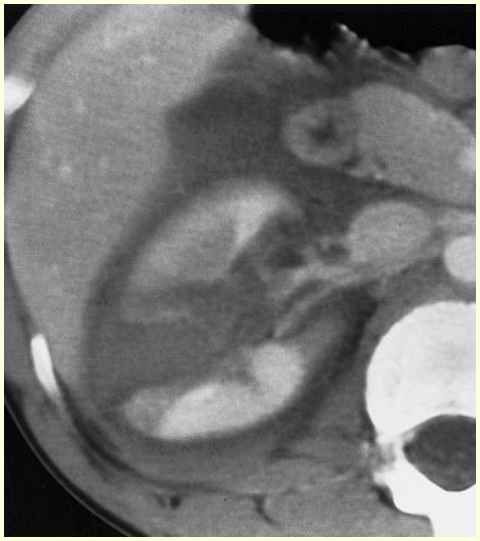
Indications:

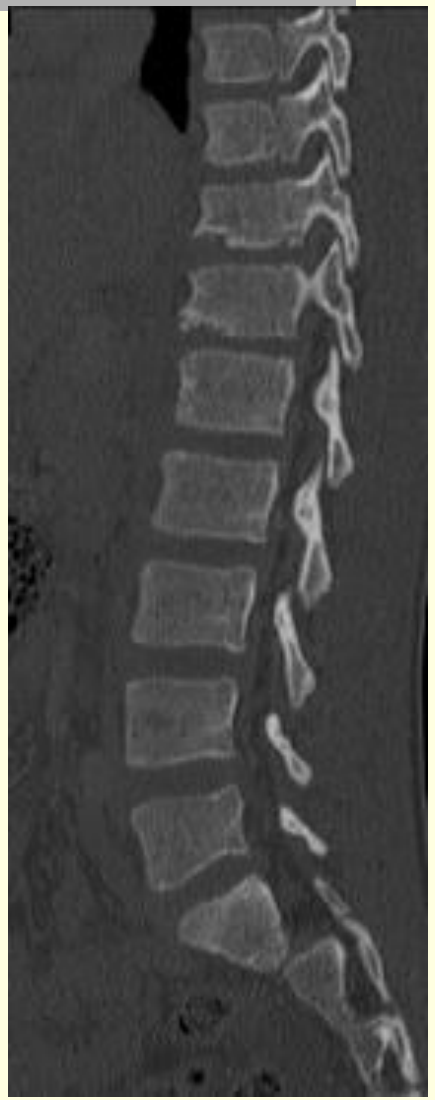
- Emergencies
  - severe multiple trauma
  - acute hemorrhage
  - infraction, malformation …
  - collecting system injury
    - split bolus technique?

CT

Indications:

- Emergencies
  - Severe, multiple trauma
  - acute hemorrhage
  - infraction, malformation …
  - collecting system injury
  - associated injury
    - spine & bone …
  - …

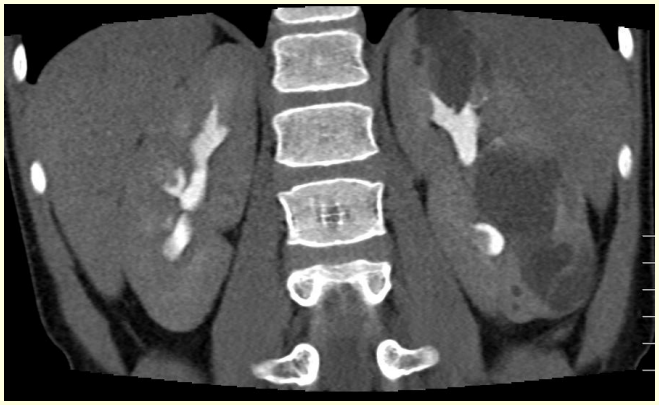


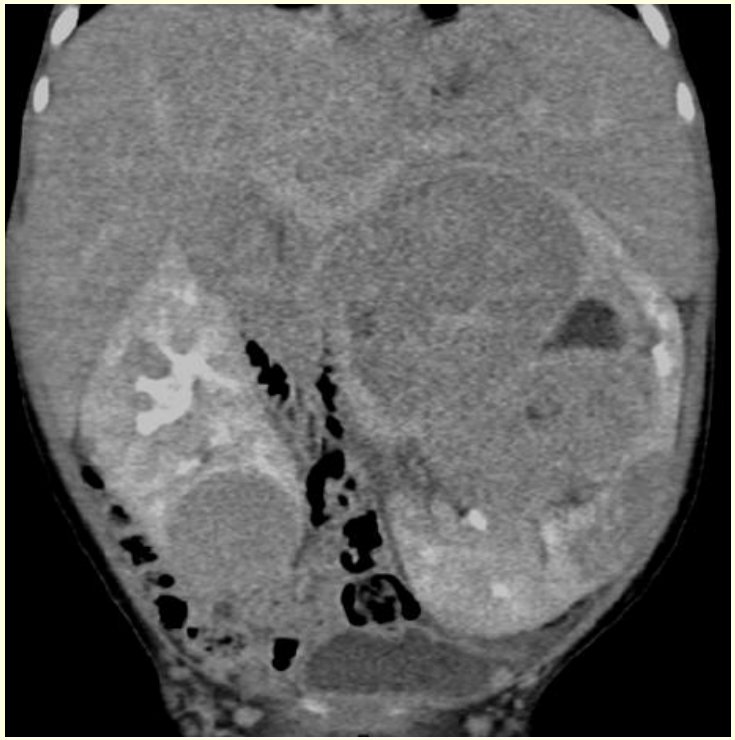


CT

Indications:

- Emergencies
- Tumor assessment
  - no MRI available
    - calcifications?
  - part of (lung) staging …
  - DDx …

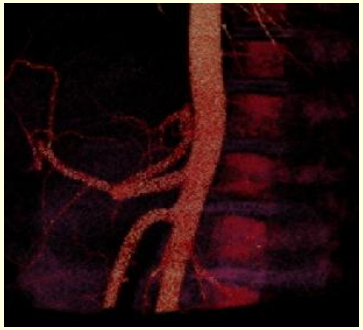


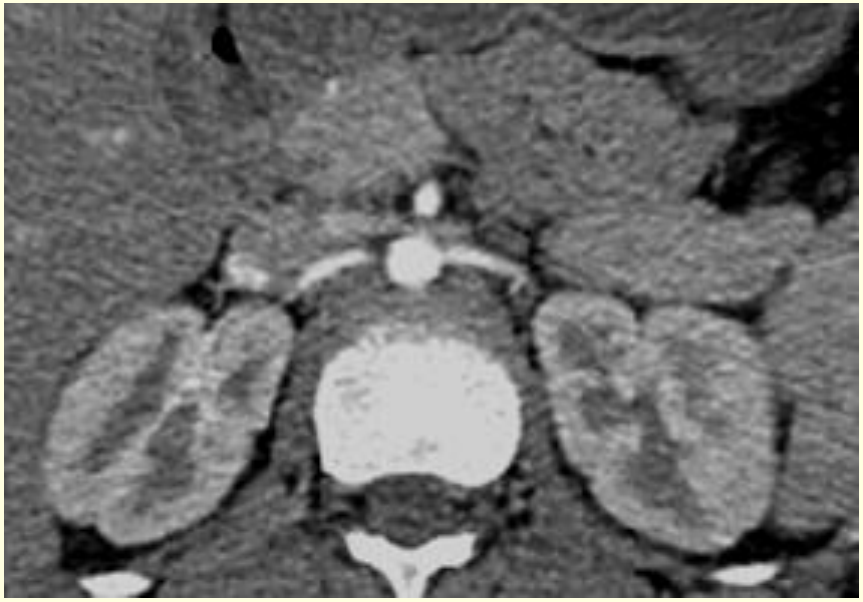


CT

Indications:

- Emergencies, tumors (?)
- CTA – renal artery stenosis
  - CT-DSA?
  - 80-100 kV?
  - flow?
  - bolus tacking?

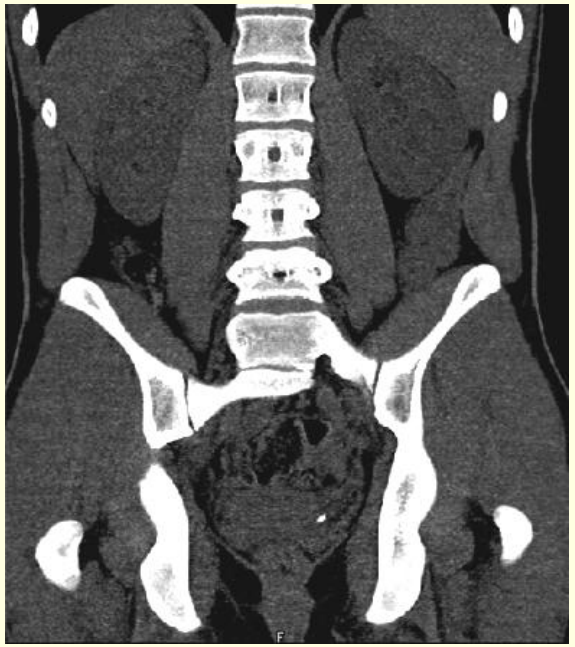


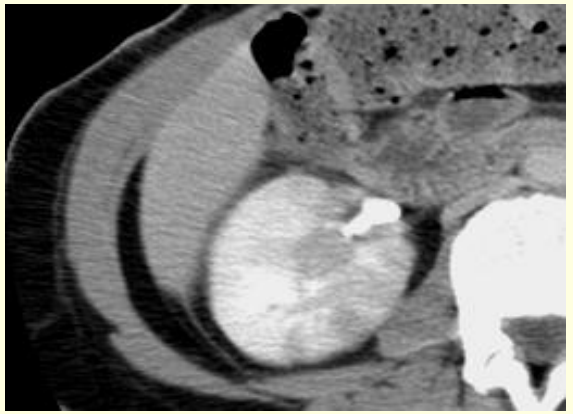


CT

Indications:

- Emergencies, tumors, CTA
- Rare others
  - UTI complications
  - stone CT
  - DDx (no MRI)
  - …

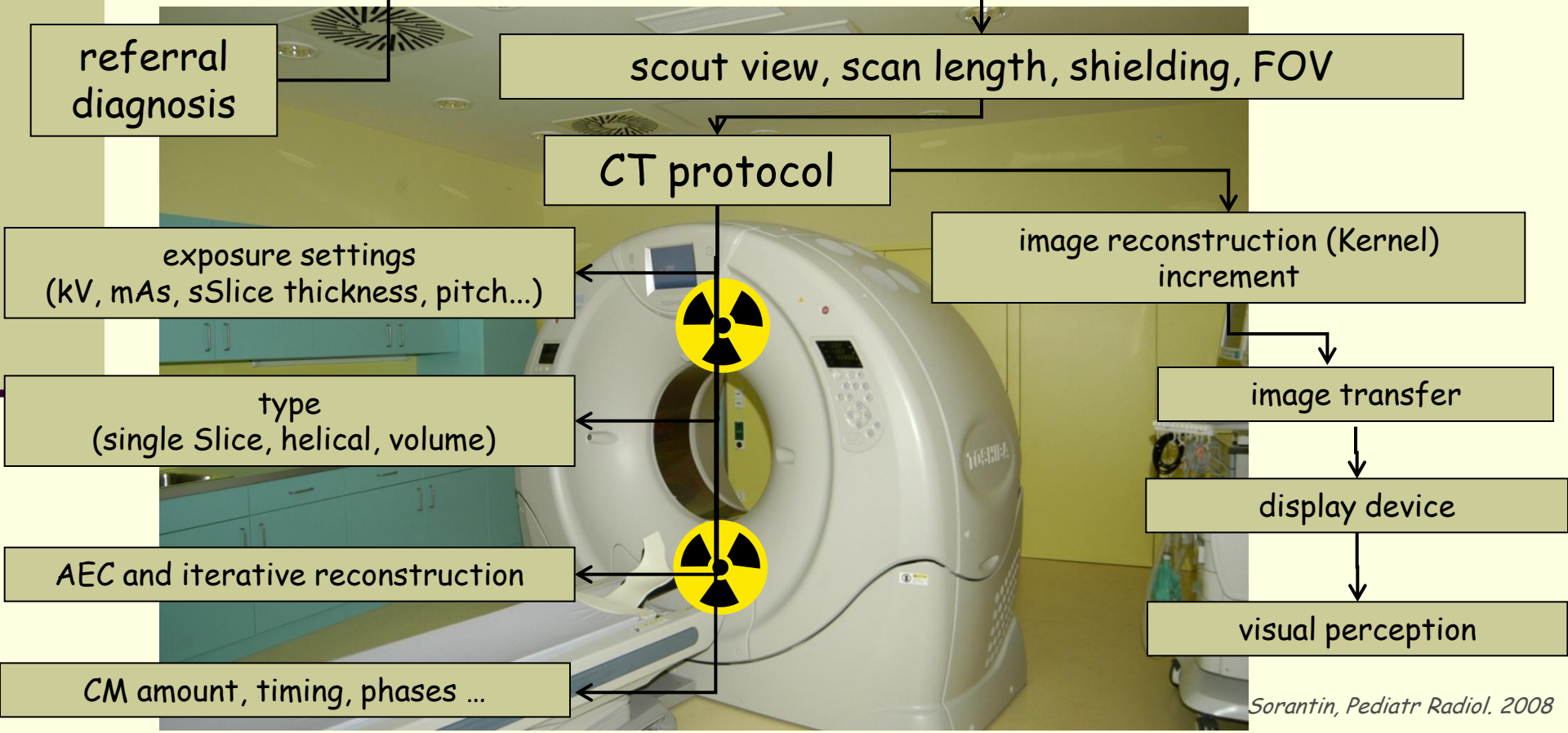




CT

Some rules for adapting protocols

- age, weight, query … - look at entire imaging chain



Sorantin, Pediatr Radiol. 2008

CT - How

Some rules for adapting protocols

- kV & mA:
  - mAs – linear relation ⇨ 2x mAs = 2x dose
  - kV – exponential relation ⇨ 2x kV = 4x dose
- CM: 2,5 – 1 ml/kg (300mg/ml), flow? …
- ALARA
  - US before planning CT?!
  - usually 1 phase sufficient
  - timing critical
  - NOTE: resolution? ⇨ small increment = dose ↑ …

CT - How

- How to reduce dose
  - DLP? effective dose? noise level?
  - tube current modulation / AEC
  - reconstruction filters & algorithms
  - consider using focused CT
  - rise arms, protective devices
  - ***rule of thumb*** (abdomen)

age	mAs reduction factor
	120 kV
newborn	0.43
1 year	0.51
5 year	0.59
10 year	0.66
15 year	0.76
slim adult	0.90
normal adult	reference value
obese adult	1.27

$$mAs = [weight(kg)+5] \times 1.5$$

for 120 KV

Rogalla / Stöver

SPR recommendations / image gently campain

ESPR / ESUR procedural recommendation

Uro-CT in children

Indications

- severe urinary tract trauma, complicated/equivocal urolithiasis & infection, tumour & DD, renovascular disease

  NOTE: **only** in case high level US (+ KUB) not conclusive, ***always consider alternatively MRU, if available***

Preparation

- avoid pain, decrease anxiety, local protection device, generous immobilisation & sedation
- for CM administration - previous line placement, measure creatinine, hydration

  NOTE: *age dependent different normal creatinine values in infants & children*

Contrast application

- 2,5-1,5 ml/kg (weight dependent); generally 2 ml/kg, injection speed 1 - 2ml / sec (if power injector applicable)
  - age adapted injection rate & scan delay time, hand or - depends on:
    - location/size/type of IV access, child size/weight, underlying disease & query

Protocols

NOTE: ***always use age-/weight-adapted paediatric settings,*** *restrict acquisition area*

keep age corrected effective dose < 2mSv
tailor protocols to query (according to clinical indication & result of previous US)
avoid multi-phase acquisitions

= perform CT study according to query / clinical indication, including **one** ("or rarely more") of the following:

unenhanced, arterial, nephrographic, and excretory phase

Nephrolitiasis
- unenhanced scan
- consider to further **reduce mAs**

Renovascular disease/ vascular malformation
- arterial phase / CTA

Trauma
- arterial phase: suspected vessel injury
- nephrographic phase: often sufficient, always informative
- urographic phase: suspected injury of collecting system

Tumour & DD, infections
- nephrographic phase: usually sufficient, mandatory
- urographic phase: in selected cases to assess involvement or pathology of collecting system

Pediatr Radiol 2010:40

Modern imaging: **MRI & MRU**

= the future method of pediatric uroradiology

- T2-MRU = "T2 MR-urogram"
  - anatomic display, cysts ...
- availability?

MRU

= the future method

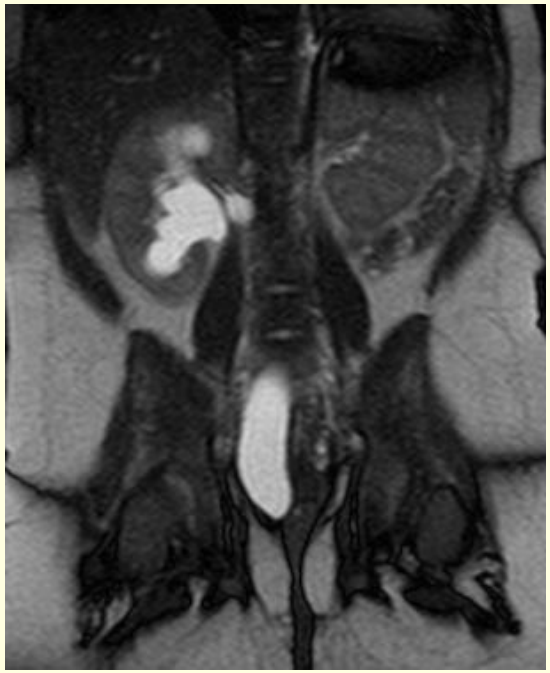
- T2-MRU = "T2 MR-urogram"
- ce-T1 MRU, dynamic/diuretic

MRU

- Practically has **replaced IVU**
  - ✓ non ionizing, dynamic information
  - ✓ assess collecting system + parenchyma + genitalia

MRU

- **Indications**
  - obstruction & malformation
  - inflammation, scars, complications
  - cysts & tumors

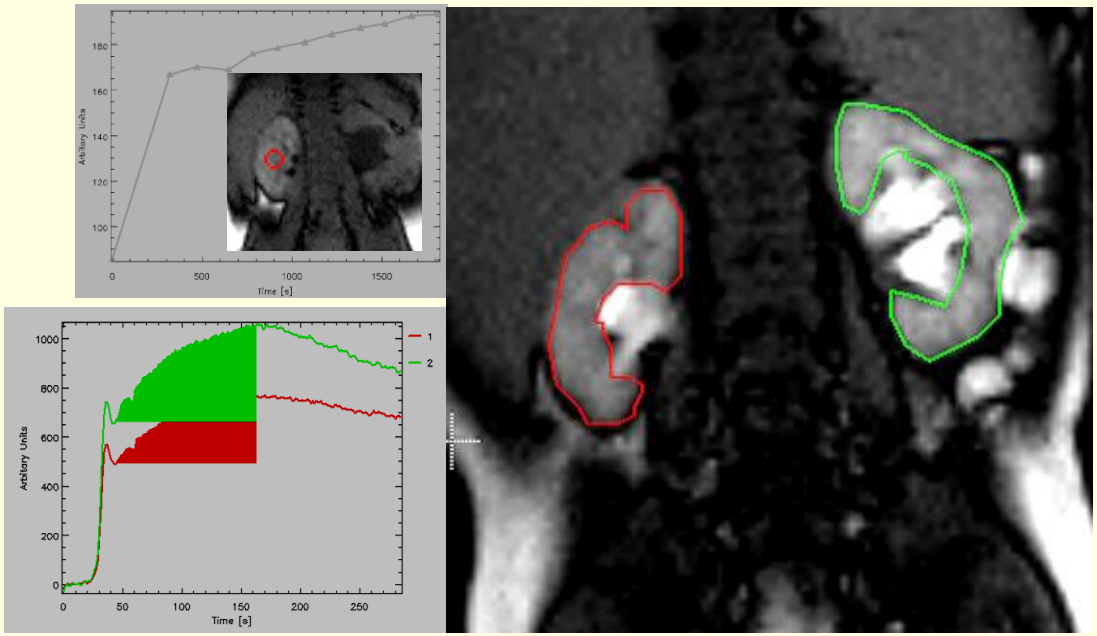


MRU

- **Indications**
  - obstruction & malformation
  - inflammation, scars, complications
  - cysts & tumors
  - helpful established tool for DDx

MRU

- **Modern MRU**
  - allows to quantify function & drainage
    - various methods, diuretic stimulation ...



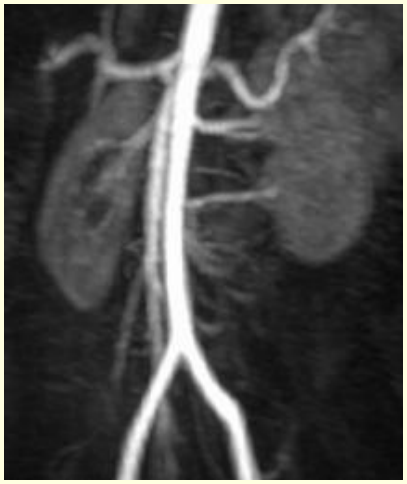
Rohrschneider, Radiology 2002 ,
Grattan-Smith Pediatr Radiol 2008,
Images from Riccabona, EJR 2008 ...

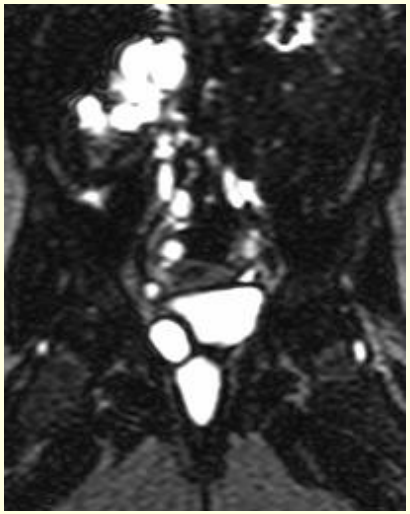
BUT: needs sedation & Gd

MRU

- Modern MRU & MRI
  - allows to quantify function & drainage
    - various methods, diuretic stimulation ...
  - HR imaging
  - MRA & MRV (also pre-transplant ...)

⇨ "one stop shop" imaging





MRU

- Modern MRU
  - allows to quantify function & drainage
    - various methods, diuretic stimulation ...
  - HR imaging, MRA
  - future potential by new applications
    - perfusion imaging
    - MR-spectroscopy
    - DWI
    - BOLD
    - non-enhanced MRA (ASL ...)
    - new contrast agents
    - MR-VCUG

Then:

modern applications

adapt imaging algorithm to impact

=

imaging must have impact on patient management (= efficacy)

sometimes less (e.g., detailed US, but performed properly) is more

⇨ *properly select when to do what and how*

Modern applications

= **use of imaging today**

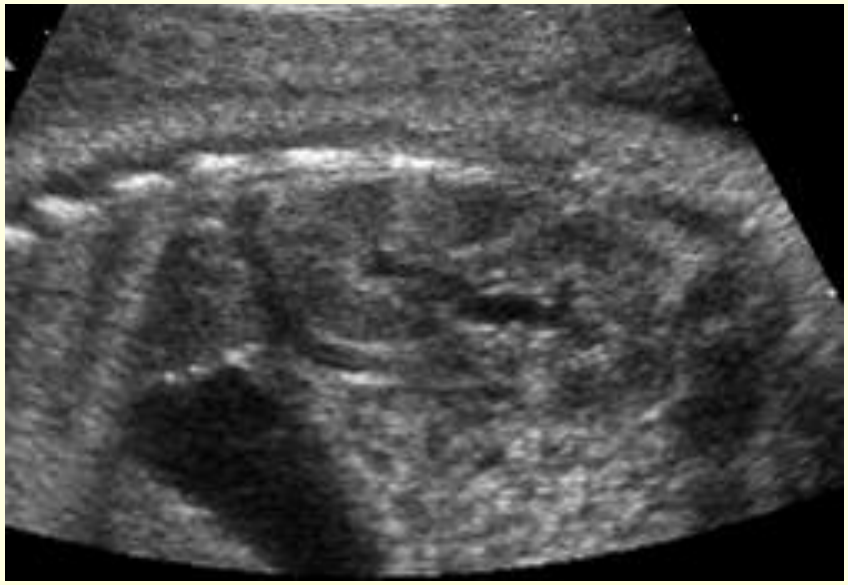
+ imaging algorithms
  - affect many & common queries in infancy

based on new tasks for imaging

➢ talk on UTI = tomorrow

e.g.,

imaging in infants with fetally detected HN



Imaging in infants with fetal HN

- **Aim of imaging**
  - detect malformations & urinary tract conditions
    - before they cause renal damage
- If disease present
  - **differentiate** entity
    - obstructive versus refluxing uropathy
      - obstruction common with high grade HN
  - **grade** disease
    - need for treatment
      - follow-up?
    - timing of investigations?

Imaging in infants with fetal HN

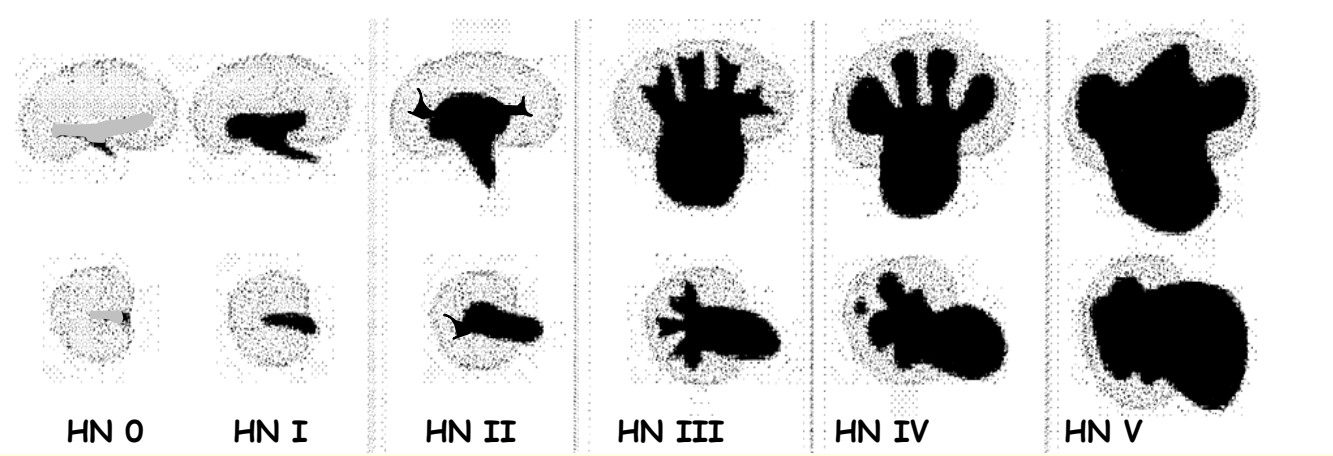
- **Aim of imaging**
  - detect malformations
- If disease present
  - differentiate obstructive vs. refluxing uropathy
  - grade disease
  - **define need for further imaging**
    - different for severe vs. minimal abnormalities
    - different for obstruction or VUR or others

⇨ comparison with prenatal US essential

⇨ standardised HN grading

US: HN grading system

Derived from Hofmann & fetal SFU classification (Fernbach et al)



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 fornices visible

HN III = marked dilatation of calices, pelvis > 10 mm, rounded papilla & fornices 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

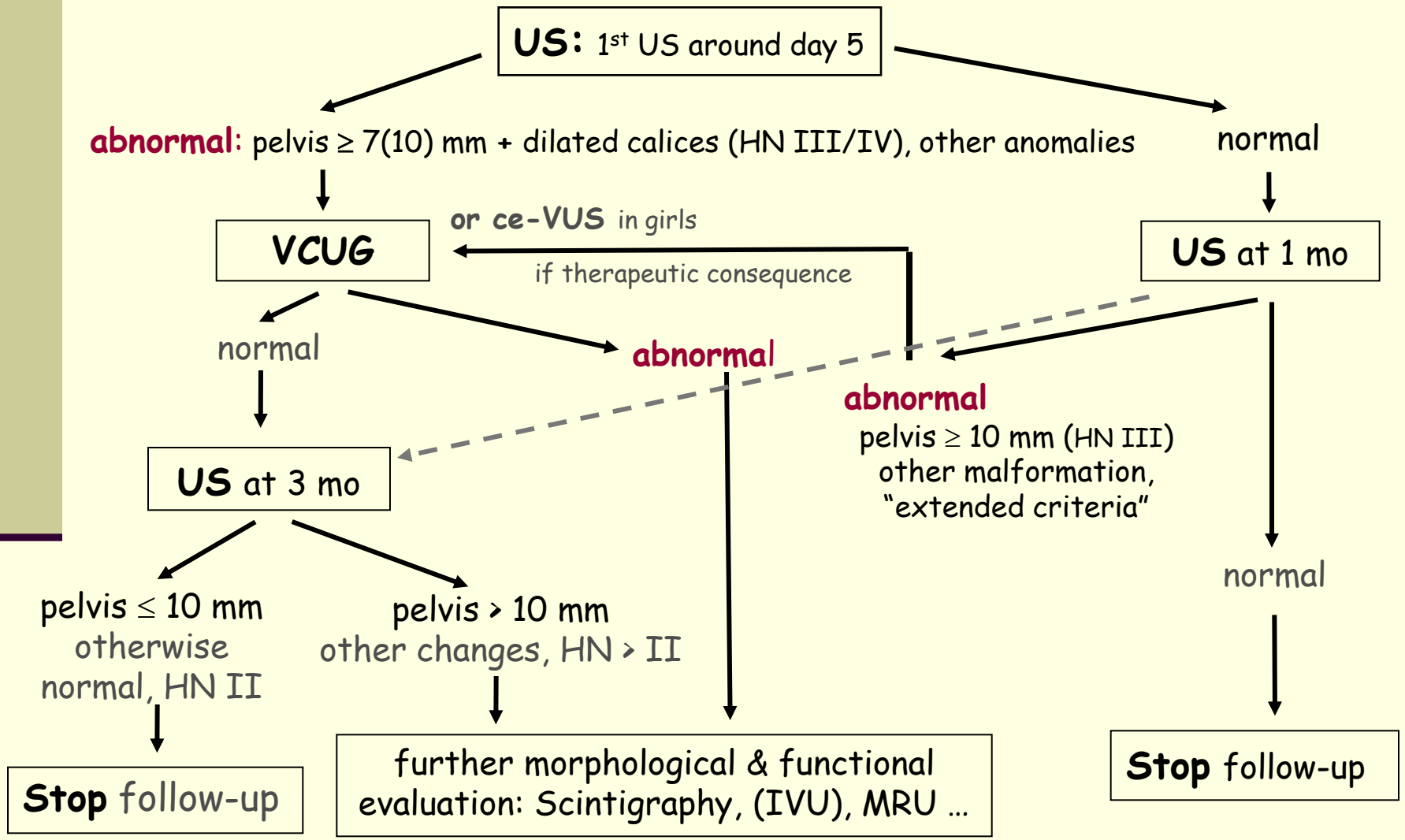
Pediatr Radiol 2008; 38

Imaging in infants with fetal HN

- **Aim of imaging**
  - detect malformations
- If disease present
  - differentiate obstructive vs. refluxing uropathy
  - grade disease & define further imaging
- Essential question
  - *Whom to image how & when?*
    - not too invasive
    - not missing important conditions
    - without diagnostic overkill = economic approach
    - in the light of new knowledge & treatment concepts

Postnatal imaging in newborns with fetally diagnosed moderate (= mild to moderate) HN

⇨ new adapted imaging algorithm



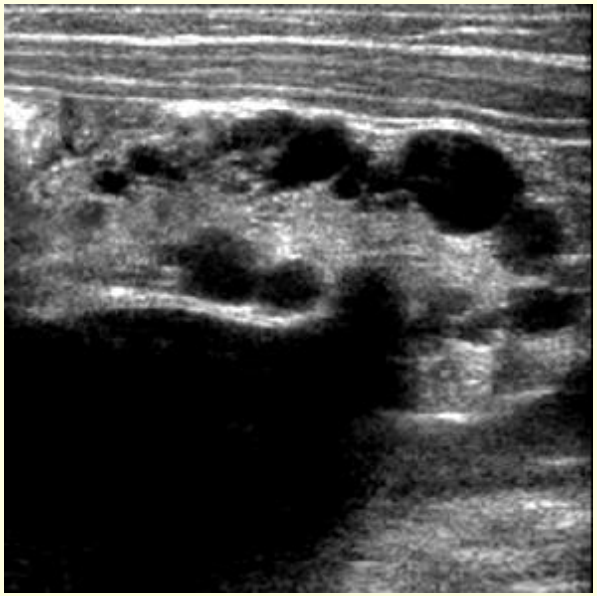
Pediatr Radiol 2008; 38

Imaging in infants with high grade HN

- Different_than for low degree HN
  - findings: obstructive uropathy/high grade VUR
    - beware of PUV (in boys)
      - earlier imaging mandatory
      - VCUG

Imaging in infants with high grade HN

- Different_from low degree HN
  - obstructive uropathy, PUV …
- Consider DDx
  - duplex systems
    - obstructive/refluxing moiety
  - cystic disease
    - PCKD, MCDK
    - cystic tumour …



Imaging in infants with high grade HN

- Different_from low degree HN
  - obstructive uropathy, PUV …
- Consider DDx
  - duplex systems, cystic disease
  - complex malformation
    - creative imaging approach

Imaging in infants with high grade HN

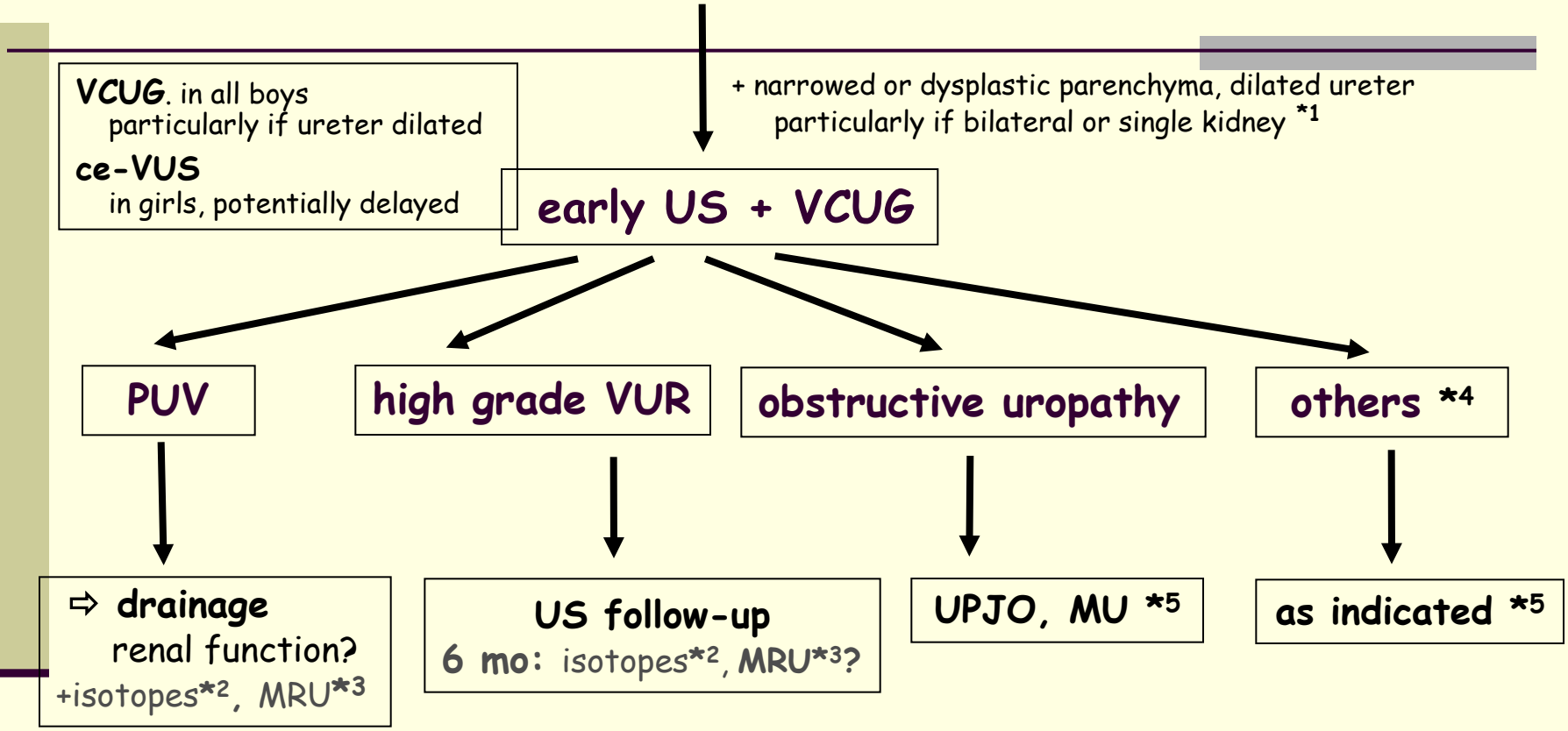
- Different from low HN
  - obstructive uropathy, PUV
- Consider DDx
  - cystic disease
  - duplex systems
  - complex malformations

⇨ different imaging needs than in low grade HN

- different entities & risks

But: also consider immaturity & therapeutic options

Postnatal imaging in newborns with fetally diagnosed high grade HN (= gross dilatation = HN ≥ IV)



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

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

*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 …

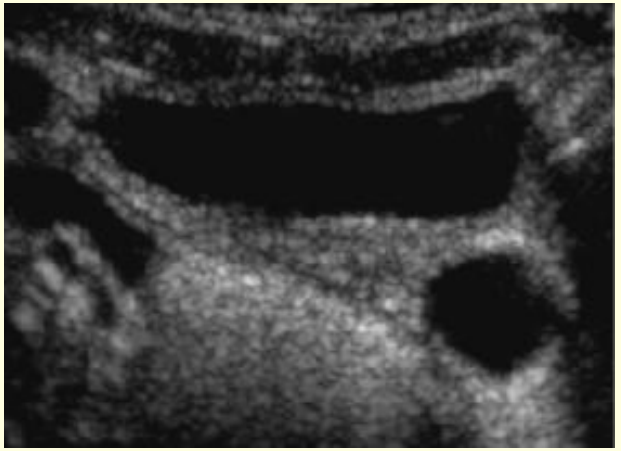
*5 **see respective algorithm**

Pediatr Radiol 2009:39

Imaging in infants with fetal HN

The only clinically important question =

- ***which kidney needs treatment?***
  - which only needs monitoring, which nothing?
  - ⇨ reliable prospective assessment?
    - deterioration without surgery?
    - function, growth …
  - approach & treatment varies with condition
    - MU / ureterocele
    - ectopic insertion
    - PUV, UPJO …



Imaging in infants with fetal HN

The only clinically important question

- *Which kidney needs treatment?*

And then: ***Which imaging should be used?***

Imaging options:

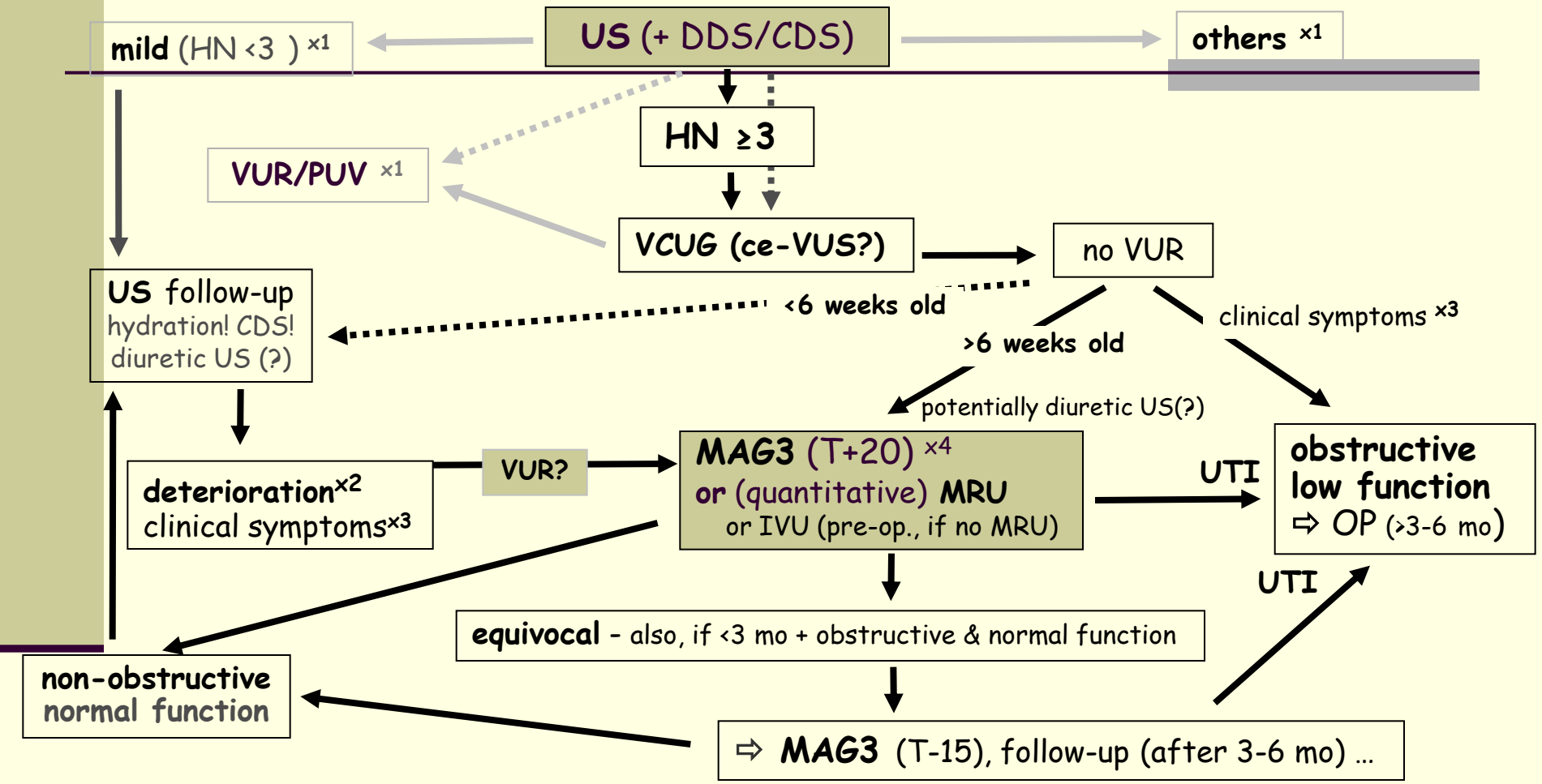
- US (incl. diuretic US, CDS / DDS ...)
- IVU (outdated)
- MAG 3 (split function + drainage)
- MRU (anatomy + function)

⇨ at present no reliable *a-priori pro-futuro* assessment

= serial investigations using various methods necessary

- to monitor disease, intervene in deterioration

Imaging algorithm in infants with suspected obstructive uropathy



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 vascularisation (on aCDS), asymmetrically elevated 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

Other examples

Imaging in other urinary tract conditions & symptoms based on modern imaging potential

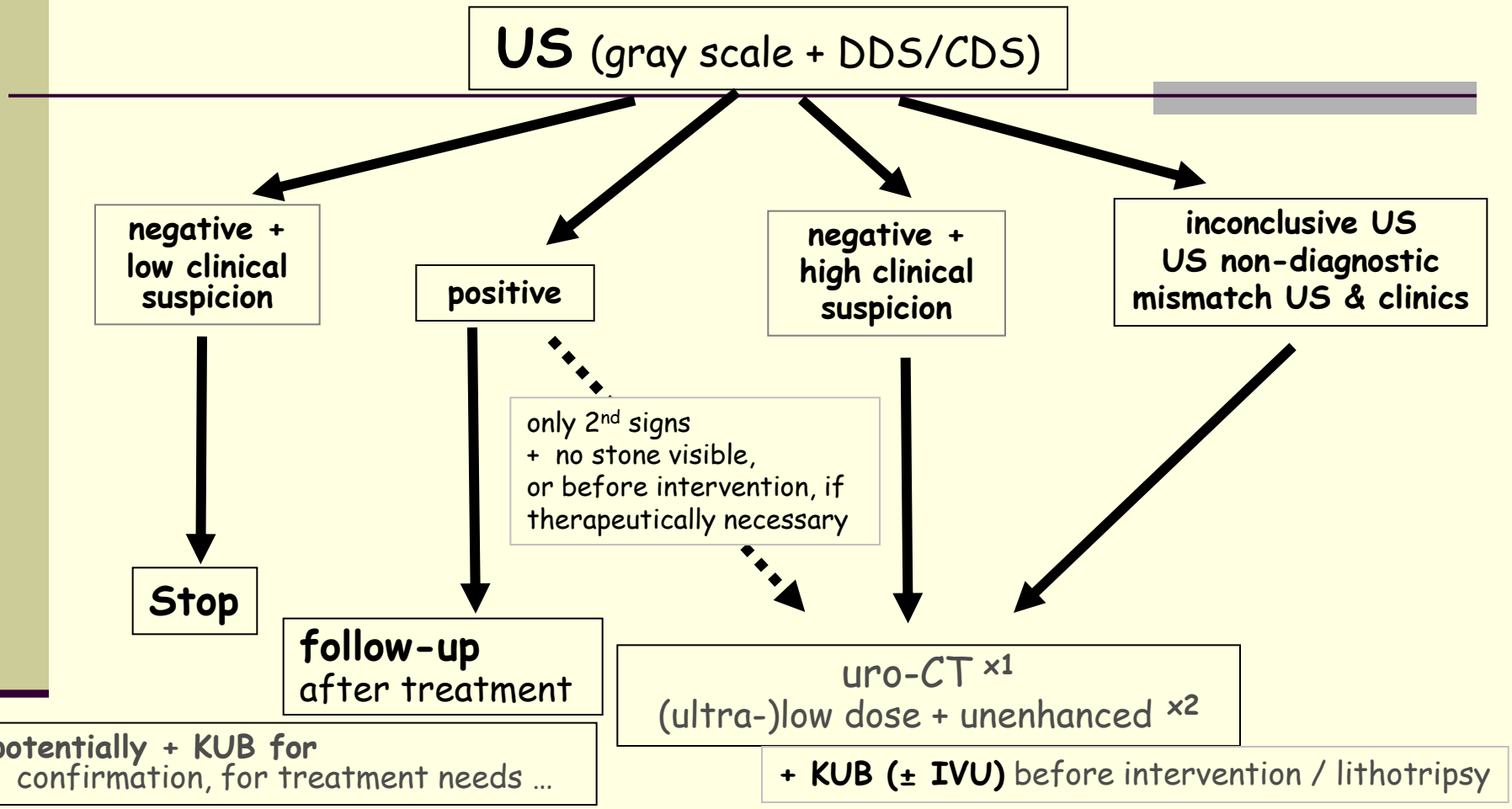
Imaging in urolithiasis

- Do we need to apply all modern options?
  - CT for all?
    - urolithiasis
    - nephrocalcinosis
    - haematuria

Imaging in urolithiasis

- Do we need to apply all modern options?
  - CT for all?
  - US + KUB / IVU?

Imaging algorithm for **infants & children with suspected urolithiasis**



x1 **or KUB (+** adapted **IVU,** particularly if low-dose CT unavailable)

x2 potentially **contrast-enhanced CT,** if other DD or complication; **MRU in selected cases**

Pediatr Radiol 2009, 39

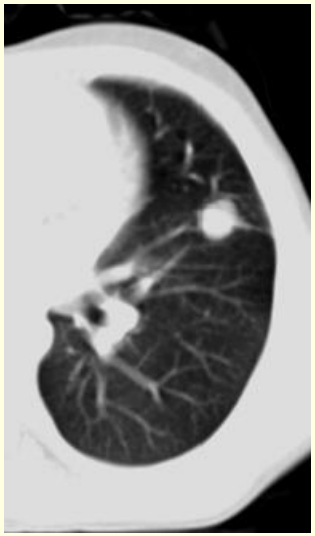
Imaging in other conditions

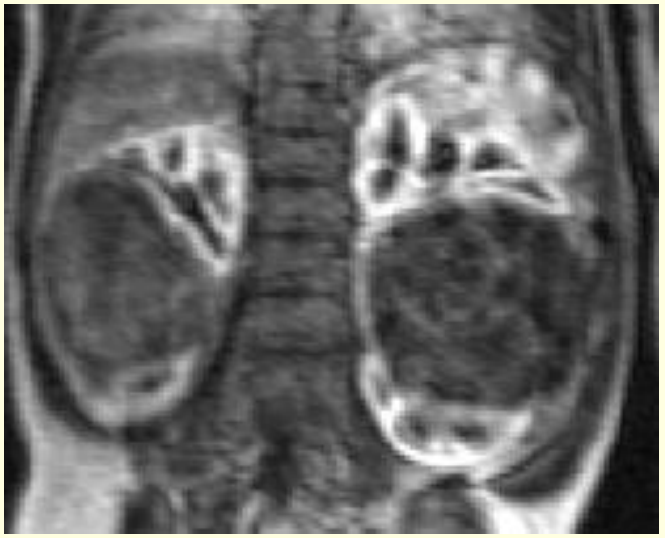
- What about tumors?
  - US + CT or MRI?
    - depends on entity

      = age matters!
      - + symptoms ..

Imaging in other conditions

- What about tumors?
  - US + CT or MRI?
  - increasingly shifted towards US + MRI
    - use modern MR tools: MRA, DWI, WBMRI …
    - lung MRI?





Summary & conclusion

- US = mainstay of uroradiology in infants
  - provided proper equipment & application
- VCUG = indicated more restrictively
  - proper technique essential, partially ⇨ ce-VUS
- IVU & CT = hardly used in infants
  - except CT for severe trauma, …
- MRU = the ideal one stop shop imaging in
  - obstructive uropathy
  - complex malformations
  - tumor, complicated infection …

Summary & conclusion

- Procedural recommendations exist
  - help to standardise high quality imaging
- Imaging algorithms exist
  - suggestions for optimal use of imaging methods
- Individual responsibility remains
  - adapt to patient & local needs / options
- Remember: Aim of imaging =
  - diagnose disease & maintain renal function
  - help prevent harm to the kidney

Any questions -

Yes, please, … ??

Thank you !

Imaging algorithm for hematuria in infants

Clinical & laboratory evaluation *
= **presumable diagnosis** in most situations

Note: malignancy much rarer than in adults

+ basic imaging:

US + DDS/(a)FDS

abscess, pyohydronephrosis, severe haemorrhage …
⇨ **intervention** *1

diagnosis evident
=> further imaging as appropriate, if necessary

US normal

US inconclusive
mismatch US & clinics

Stop imaging

potentially further imaging
depends on clinical course & query*3

UTI *2
UPJO, VUR, MU *2
Tumour*3
Trauma*2,3
Vascular*2,3.
Urolithiasis*2
GN & nephropathies*3
Bladder-, urethral- , ureteral pathology*3

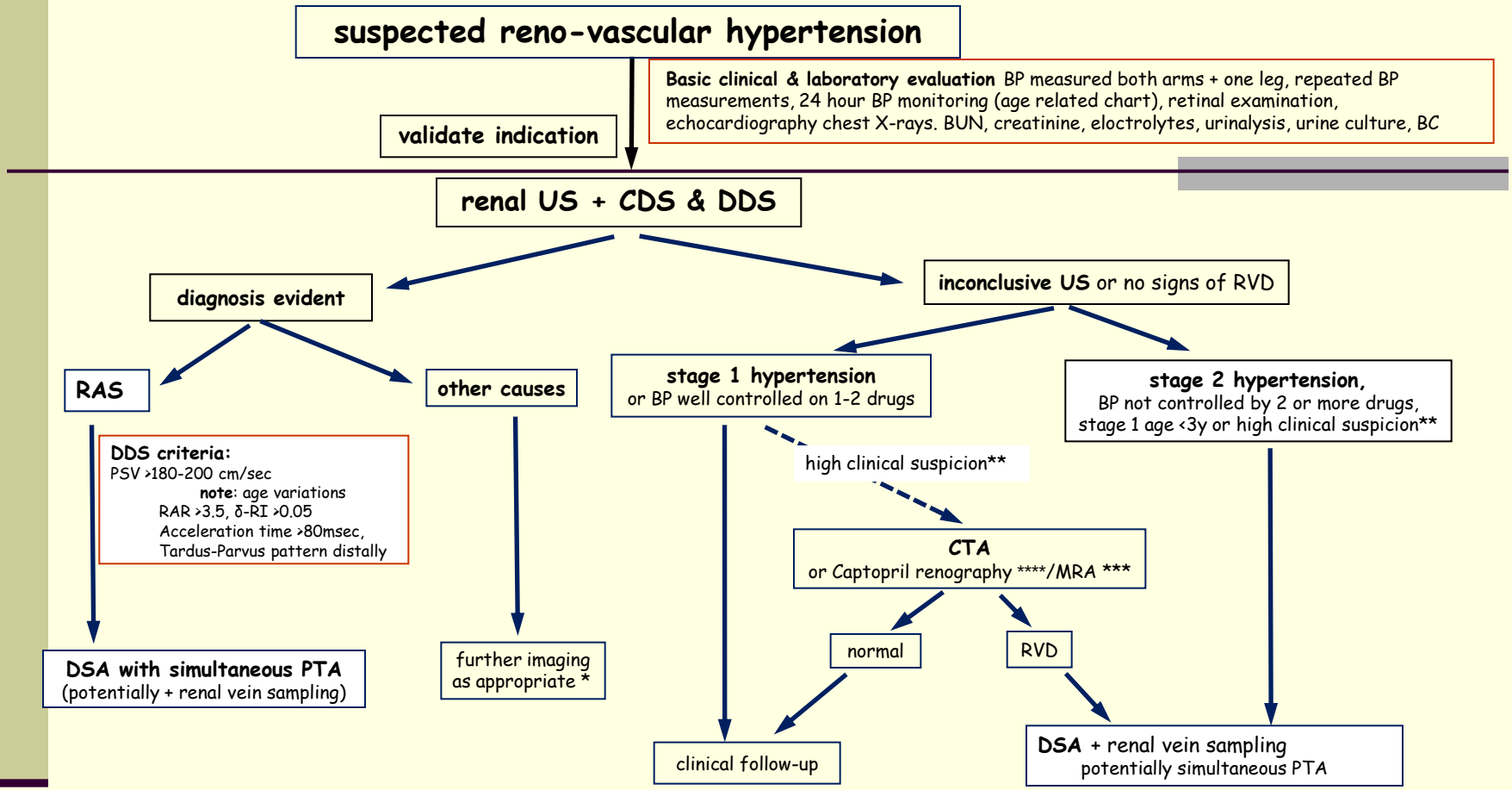
*1 DD: Tu, haemorrhage, complicated UTI
e.g., XPN, Tbc, abscess … => MRI/CT

*2 see respective dedicated imaging algorithm

*3 proceed to next imaging step (CT, Angiography, VCUG …)

* **clinical & laboratory evaluation:** variation (day time, position, activity …)? vaginal/rectal discharge? duration? recurrent? undulating symptoms? pain or colic? trauma? fever? dysuria? age (foreign body …)?, blood pressure? microscopic or macroscopic haematuia? family history? urinalysis (erythrocyte morphology, isolated hematuria? …), renal function? blood count / CRP …

Imaging algorithm in infants with potential reno-vascular hypertension



* **Further imaging** as appropriately indicated (see existing recommendations …)

** **High clinical suspicion**: history of renal trauma or radiation, umbilical artery catheterization, renal vascular thrombosis, bruit over renal arteries, high renin levels, presence of disease associated with renovascular pathology (e.g., neurofibromatosis, Williams' syndrome, tuberous sclerosis …)

*** **MRA:** potentially & increasingly ce-MRU for large vessels & infarcted areas, non-enhanced MRA techniques?

**** **Captopril scintigraphy:** potentially prior to PTA for function, particularly in doubtful situations or neonates until old enough for PTA, note: local variations

Abbreviations: BC = blood count, BP = blood pressure, BUN = blood urea nitrogen, CDS = color Doppler sonography, cm/sec = centimeters per second, CTA = CT-angiography, DSA = digital subtraction angiography, DDS = spectral duplex Doppler, MRA = MR angiography, PSV = peak, systolic velocity, PTA = percutaneous transluminal angioplasty, RAR = renal aortic ratio, RAS = renal artery stenosis, δ-RI = Resistive Index difference, RVD = renovascular disease, US = ultrasound, y = year

„Anatomic" **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. 1000 ml), 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
- Polyethlene catheter without balloon, urine bag, below level of MR table

Diuresis: Furosemide 1 mg/kg IV (max. 20 mg), 15 min before 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: Sagital 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-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 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

- Furosemide timing, contrast dose & application may need adaptation

for various queries tailored protocols are essential

- e.g., MRA, diffusion, additional sagital acquisition

*[2] non-cyclic compounds can be used in older children according to approval

- Gd-dose as recommended by manufacturer

Pediatr Radiol 2010; 40