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PAEDIATRIC RADIOLOGY

Imaging in childhood urinary tract infection

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Abstract
Introduction Urinary tract infection (UTI) is a common query in pediatric radiology. Imaging for and after UTI is still a heavily debated topic with different approaches, as thorough evidence to decide upon a definite algorithm is scarce.
Content and objective This review article tries to address the clinical rational of the various approaches (general imaging, top-down or bottom-up, selected and individualized imaging concepts…), describes the available imaging modalities and the respective findings in imaging children with UTI, and proposes an imaging algorithm for the work-up of children during and after UTI discussing the "pros and cons" of the different attitudes.
Conclusion In summary, imaging by US is generally considered for all infants and children with a febrile or complicated (upper) UTI, particularly without previously known urinary tract anatomy. The further work-up (searching for renal scarring and assessment of vesico-ureteric reflux) is then decided according to these initial findings as well as the clinical presentation, course, and scenario.

Keywords Childhood urinary tract infection · Imaging · Pediatrics · Ultrasound · VCUG · DMSA

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Introduction

Childhood urinary tract infection (UTI) is one of the most common conditions encountered in pediatrics and imaging for UTI is one of the most frequent queries in pediatric radiology.

UTI usually is a straight forward clinical diagnosis relying on urine samples and elevated inflammatory markers in blood samples; proper urine collection is essential for a reliable diagnosis—not only important for the respective treatment but also as this is the entrance point for potentially invasive imaging; therefore, particularly in infants, a catheter or puncture urine is mandatory [1–4]. Nevertheless, particularly in the first year of life the clinical presentation can be unspecific and diagnosis may be more difficult.

Treatment of UTI is based on antibiotics—the selection and duration of the antibiotic vary with bacteria characteristics and patient defined aspects such as age or co-existing malformation [2, 5].

UTIs per se occur at any age and with or without urogenital malformations; there are many other risk factors than just an anatomic or functional alteration of the urinary tract. However, there are some differences in age distribution and gender variations, and an associated urinary tract malformation poses a higher risk for developing long-term sequelae [2, 6–9]. These long-term sequelae are the most important reason for not only treating but also imaging neonates, infants, and children with UTI, as detecting treatable conditions will help prevent long-term damage and ensure proper long-term renal growth and function. All these potential implications, however, occur with "upper UTI"—i.e., renal involvement. Therefore, depiction of this renal involvement and the differentiation of upper versus lower UTI is of enormous importance, as this has therapeutic implications and as only those with either recurrent UTI and/or with renal involvement will need monitoring and follow-up.

What is the role of imaging in infants and children with UTI?

In general—whichever kind of imaging one applies, there must be a justifying indication, meaning that imaging will serve the patient in terms of impact on either therapy and management or prognosis. This so-called "diagnostic thinking efficacy" has increasingly become the most relevant paradigm of deciding on if and which kind of imaging should be applied, not only for economic reasons; avoiding unnecessary investigations helps reduce patient burden, potential side-effects from imaging or contrast agent application, and decreases the pediatric radiology workload—the latter becoming particularly important in these times when pediatric radiologist are becoming a rare species. As stated above, differentiation of upper versus lower UTI, detection of potentially associated malformations and of complications, and monitoring the further development in those with upper and/or recurrent UTI are questions where imaging is irreplaceable at present.

What can imaging provide in childhood UTI?

Imaging can aid establishing the diagnosis of UTI, particularly important with equivocal laboratory and clinical findings or atypical and unspecific clinical presentation as seen in newborns and infants. Imaging further helps with work-up of potential differential diagnoses.

Secondly, only imaging can provide information on potential urinary tract malformations that may increase the risk for a complicated course and long-term sequelae thus indicating a more intense treatment. The most common malformations associated with childhood UTI are vesico-ureteral reflux (VUR) or obstructive uropathies such as pelvi-ureteric junction obstruction and megaureter; rarer, but very important are also bladder outlet conditions such as posterior urethral valves. Increasingly, the importance of voiding dysfunction is being recognized as a major risk factor for developing (recurrent) UTI, secondarily leading to VUR or obstruction at the uretero-vesical or pelvi-ureteric junction by scarring or bladder wall thickening [2, 10–13].

The third task of imaging is the detection of atypical or severe diseases—such as lobar nephronia (=focal bacterial nephritis), granulomatous pyelonephritis, pyonephrosis, and necrosis/necrotizing pyelonephritis, of complications, such as abscess formation, and eventually also scarring and consecutive impairment of renal growth with secondary renal hypertension or (rarely) chronic renal insufficiency.

Finally, imaging is used for following-up children after severe UTI and/or with urinary tract malformations and dysfunctions associated with UTIs, to monitor the development of the malformation and its further evolution as well as renal growth, and to detect scarring with its implications. Sometimes imaging is also necessary to provide guidance for treatment such as percutaneous nephrostomy or abscess drainage.

Which imaging method is available and useful?

The most commonly used imaging modality is ultrasonography (US). Originally, this was considered just a first orienting step with compulsory additional imaging; today with the modern developments using sophisticated techniques such as high-resolution imaging with speckle reduction filters, harmonic imaging, broadband multi-frequency, and multi-focus transducers, and also applying (amplitude-coded) color doppler sonography [(a)CDS] and potentially contrast-enhanced US (ce-US), US has become the major and often—particularly initially—sufficient imaging in the diagnosis and the follow-up of childhood UTI [14–17]. However, to ensure the best yield of relevant information, the study must be performed in a standardized fashion with dedicated equipment using age-adapted transducers. Hydration must be granted (not to miss potential obstructive conditions), sufficient bladder filling is mandatory (not to miss VUR and bladder conditions), and a post-void evaluation is an essential part of every comprehensive urinary tract US examination [18, 19]. As kidney enlargement is one of the most useful and often the only sign for renal involvement, standardized measurements and volume calculations have to be performed. These numbers must not only be compared intra-individually (left and right side), but must also be related to age- or weight-adapted growth charts. Particularly in baby boys, a study of the urethra using a perineal approach during voiding enables depiction of all relevant urethral pathology, thus reducing the need for other studies [19–23]. And, by installing US contrast agents (UCA) into the urinary bladder via a bladder catheter, a reliable sonographic VUR detection by contrast-enhanced voiding uro-sonography (ce-VUS) has become possible and is an established alternative to fluoroscopic voiding cysto-urethrography (VCUG) or radionuclide cystography (RNC) [24–28].

Fluoroscopic VCUG is the commonly used modality in the setting of (febrile, upper, or neonatal) UTI—not in the primary assessment but after the infection has been treated, to assess for VUR. However, due to new therapeutic regimes and algorithms, indications have become more restricted and the number of studies has significantly decreased over the last decade. Still it remains essential; a standardized technique with pulsed digital fluoroscopy and last image hold documentation should be applied to reduce the radiation burden [15, 17, 29, 30].

Renal scintigraphy in some countries is still regularly used for either depiction of acute renal involvement or for follow-up to monitor scaring and/or growth and function impairment. RNC is used less commonly and only in a few centers because of its reduced anatomic resolution and more restricted availability; in older children (i.e., after being toilet-drained), the indirect RNC is a non-invasive and reliable option to assess for VUR as well as urinary drainage problems. It offers a less invasive and most physiologic way (no bladder catheter is required) for VUR detection [as the study is performed after a normal diuretic renal scintigraphy (Tc^{99m} MAG3) [15, 31].

Intravenous urography has become outdated and obsolete in this clinical setting. Plain films are not useful in UTI except for rare cases with associated urolithiasis. The same accounts for (ce-)CT—even for assessment of renal complications such as abscesses and necrosis, modern US and MRI offer alternative radiation free options and thus have almost completely replaced ce-CT of the pediatric urinary tract in the setting of UTI.

MRI is performed also for assessment of underlying malformations or complications; but particularly using modern approaches such as diffusion weighted imaging (DWI) MRI has been shown to be excellent for detection of renal involvement and even scarring in and after UTI [32, 33]. Combining this approach with the potential of ce-MRI, a reliable evaluation of renal complications as well as assessment of potential differential diagnoses can be achieved—potentially even without the need for intravenous contrast administration. As for scintigraphy, also MRI can only be used for renal functional assessment (e.g., split renal function, urinary drainage and excretion…) well after the UTI—this assessment, however, should be avoided during the first months after such an UTI. Assessment of scarring should also be delayed at least for four to six months after the infection, and assessment of drainage impairment should only be performed after the neonatal kidney has maturated—i.e., preferably after the first months of life.

Imaging findings in childhood UTI

Typical findings in the acute infections are thickening of the bladder wall (best depictable with sufficient bladder filling) with potentially hazy margins and hyper-vascularisation on CDS. There may be floating particles in the urine (Fig. 1), bladder tension may be altered, and an open bladder neck may be observed. However, in the acute infection these findings should not be mistaken as a prove of a bladder or voiding function disturbance; only weeks after the UTI bladder function normalizes and then these indirect signs can be used for assessing dysfunction. The ureters may be lax and slightly widened, sometimes with thickening of the urothelium and echoes within the urine. Again in the acute infection, this does not necessarily indicate an obstructive or refluxing ureter. Of course if one depicts a lateralized/gaping ostium with a significantly enlarged ureter an underlying condition is obvious; the same applies for severe trabeculation indicating bladder outlet obstruction, bladder dysfunction, or VUR (Fig. 2).

The kidney can be affected focally or diffusely. This can be seen sonographically by focally or diffusely altered parenchymal structure with loss of cortico-medullary differentiation and increase or decrease of echogenicity (Fig. 3). There may additionally be focal swelling with sometimes even a pseudo-tumorous appearance (inflammatory pseudotumor—lobar nephronia = focal bacterial nephritis) (see Fig. 3a). (a)CDS may exhibit diffusely decreased

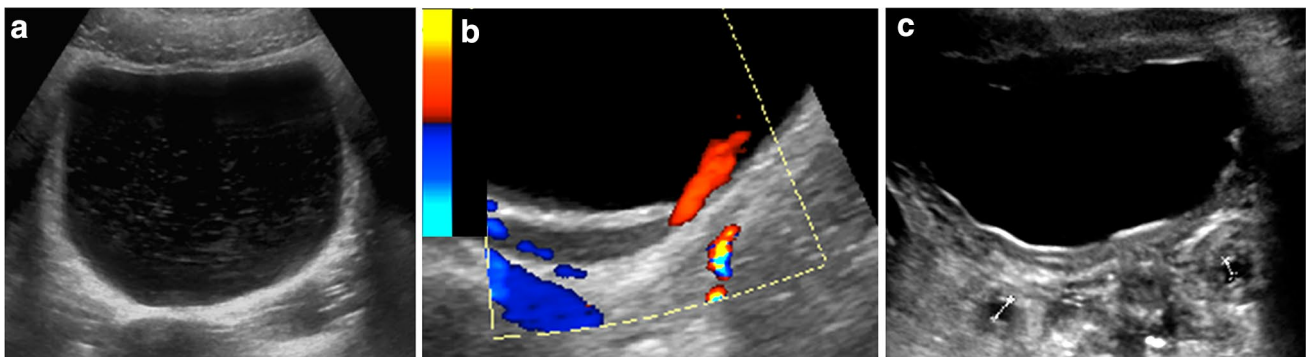

Fig. 1 Bladder and ureter findings in childhood UTI. **a** Urinary particles (cells, crystals…) producing floating echoes in the urinary bladder—in this case in a girl with acute UTI; note that this finding is unspecific, particularly if these particles have sedimented often other phenomena (e.g., concentrated urine, haematuria) are the reason for this appearance. **b** CDS shows an asymmetric strong ureteric inflow jet produced by echogenic urine from a kidney with acute pyelonephritis. **c** Axial section through the urinary bladder: bilaterally thickened ureteral wall and prominent ureters (+…+ indicating the ureteric lumen) visualized behind the bladder (note necessity to properly adapt the TGC-curve); only the left ureter was eventually refluxing, not the right one too (in spite of the wall thickening)—note that the wall thickening was obviously only due to the inflammatory swelling and resolved completely after the UTI

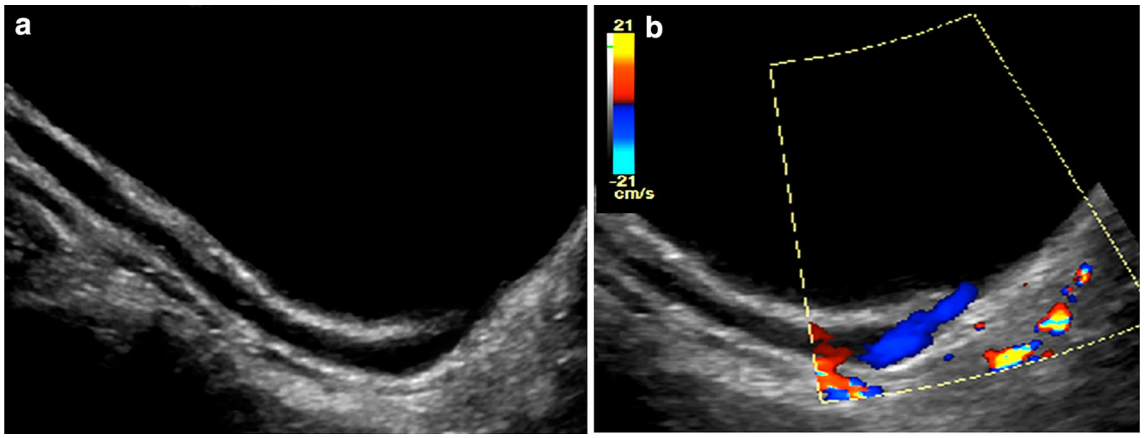

Fig. 2 Sonographic ostial and ureteral findings in/after childhood UTI. **a** A gapping ostium in child with recurrent UTIs, indicative for VUR. **b** VUR is additionally nicely shown by CDS visualizing the retrograde flow of urine through the ostium into the ureter (**b**)

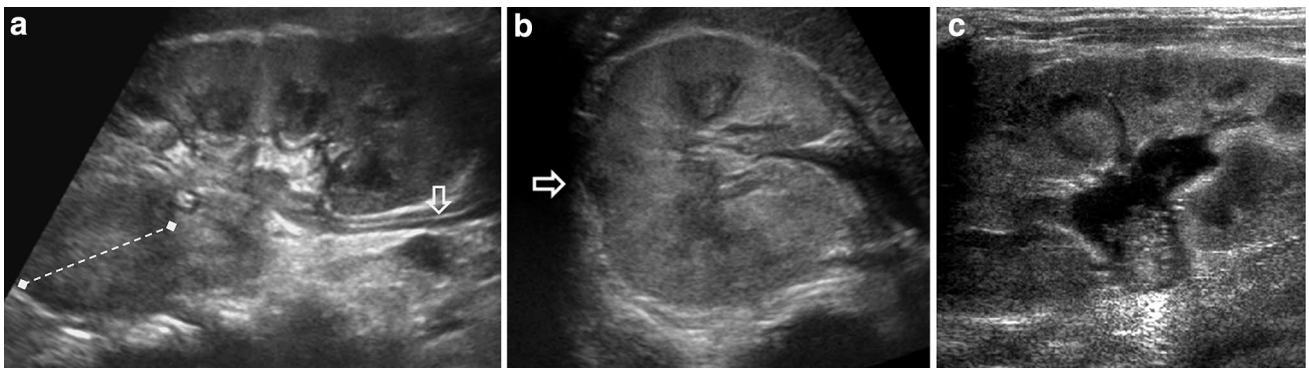

Fig. 3 Renal sonographic findings in childhood UTI. **a** Swollen right kidney with diffuse cortically increased echogenicity and focally inhomogeneously altered parenchymal echogenicity (+….+ nearly with a pseudo-tumorous appearance) and thickened urothelium (*arrow*) indicating severe renal involvement in upper UTI. **b** Regional subcapsular hypoechoic defect (*arrow*) in an area of altered parenchymal echogenicity of this diffusely swollen right kidney with acute pyelonephritis indicating a focal necrotic area (i.e., necrotizing aPN). **c** Neonatal kidney with sedimented "sludge" in the renal pelvis: this is an unspecific finding and is not indicative of pyonephrosis; note also the slightly echogenic distal medulla—a physiological transient phenomenon in neonates

parenchymal vascularity or focal perfusion defects (Fig. 4). These usually match diffusion positive focal renal lesions on MRI which also exhibit reduced contrast uptake on a Gadolinium-enhanced MR study (Fig. 5). On scintigraphy, these areas show up as a photogenic lesion—without additional underlying anatomic information scintigraphy, however, cannot differentiate between acute and chronic defects or other focal lesions such as cysts. On US urothelial thickening of the renal pelvis, the proximal ureter, and even in the intra-renal collecting system can often be seen (Fig. 1c, 3a, 6); additionally, floating particles in the urine may be present (see Fig. 1a)—in case of pyonephrosis echogenic particles, causing fluid leveling in potentially dilated calyces can be depicted ("Pyohydronephrosis").

Complications such as infectious urolithiasis can usually sufficiently be depicted by US as these stones are commonly seen either in the distal ureter (nicely accessible through the filled bladder) or the renal collecting system/the pelvi-ureteric junction; often they do exhibit not only shadowing but also twinkling on CDS. Complications such as abscesses or focal necrosis are seen as initially hazy, later on well-demarked focal, usually hypoechoic parenchymal defects, sometimes with a pseudo-tumorous aspect and with lack of perfusion (as well as lack of contrast enhancement on ce-MRI) (Fig. 5c, 7). The differentiation of an infected cyst from an abscess or a hemorrhagic cyst can sometimes be difficult, although this is relatively rare in childhood. Differentiation of a lobar nephronia from a renal tumor may also be challenging even by using MRI. However, usually they respond quickly to antibiotic treatment and thus monitoring during the course of disease will often solve the query.

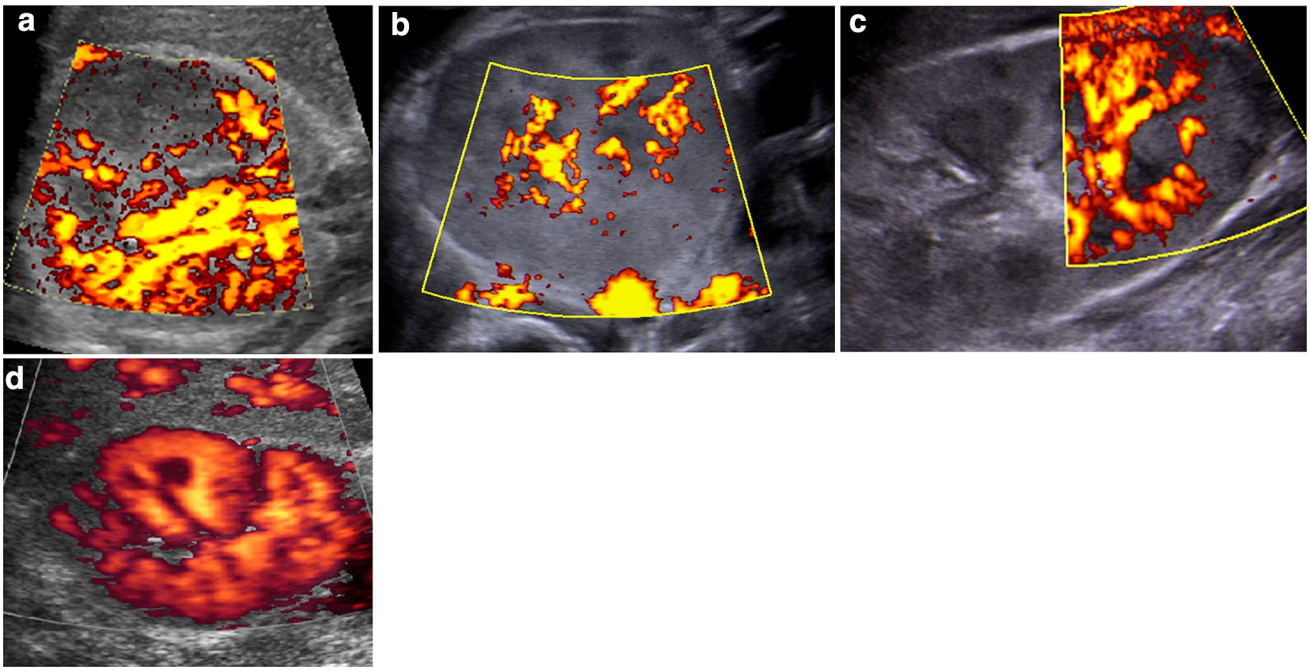

Fig. 4 Power Doppler findings in children with acute pyelonephritis. Focal perfusion defects either in regions with only little parenchymal changes (**a** rather regionally hypoechoic cortex with disruption of the normal cortico-medullary differentiation) or in kidneys with severely and even more diffusely altered parenchymal echogenicity due to acute pyelonephritis (**b** echogenic and hugely swollen appearance); in **c** the decreased vascularity of the hypoechoic cortical regions in the involved lower pole is nicely demonstrated. **d** Segmental linear minimal perfusion defect on Power Doppler (DDx: upper parenchymal junction line vs post-inflammatory scar) in a subacute residual perfusion deficit on the lateral aspect of this axial view of a right kidney 3 weeks after severe UTI with renal involvement (recurrent UTIs)

After UTI these changes gradually improve—however, the bladder and the kidney as well as the urothelium take time to normalize. Therefore, early follow-up usually is not beneficial unless there is a clinical suspicion for an unusually course, insufficient response to treatment, or a complication. Follow-up imaging (if necessary at all) should be delayed at least 4–6 weeks to allow for normalization of renal size and parenchymal structure, resolution of the urothelial swelling, and a pacified bladder with a normal function. Therefore, the best time for VUR assessment is also after this normalization has occurred—as residual laxity of the ureter, residual thickening and swelling of the bladder wall or the urothelium, as well as reactive para-inflammatory bladder and voiding dysfunction may impair depiction and grading of VUR. However, if for organizational or compliance reasons an earlier VUR assessment is necessary, VCUG (or ce-VUS) can be performed as soon as the urine is cleared from bacteria, keeping potential restrictions in mind. VUR assessment is commonly still performed by VCUG fluoroscopically after bladder puncture or catheterization using a standardized methodical approach with pulsed fluoroscopy, digital image amplifying, and last image hold documentation (see recommendations from the uroradiology task force) [19, 29]. Contrast-enhanced voiding uro-sonography (ce-VUS) has become an excepted alternative and in some centers even has nearly replaced VCUG, as it not only allows for a radiation free VUR assessment with a high sensibility and specificity, it also allows for grading, depiction of intra-renal reflux, and (by using a perineal approach with a dedicated filling cycle) urethral evaluation (Fig. 8) [20, 21, 23, 24, 29, 34].

When to do what: the imaging algorithm

There is an ongoing discussion about when to do imaging, which kind of imaging, if to image at all, and what conditions to "hunt" [2, 15, 35–38]. While initially VUR was considered the most important condition associated with scarring and UTI, the focus now has shifted towards the kidney and renal parenchymal damage. These two different approaches—bottom-up or top-down—have let to numerous discussions and various partially differing imaging recommendations [1, 12, 38–42]. In 2008, the ESPR Uroradiology Task Force has published a recommendation primarily based on evaluating the kidney in the early phase and assessment of VUR in the later phase only in those where either renal involvement or damage has been depicted or other sonographic signs remained obvious that hint towards VUR. Just recently, at the Task Force Session

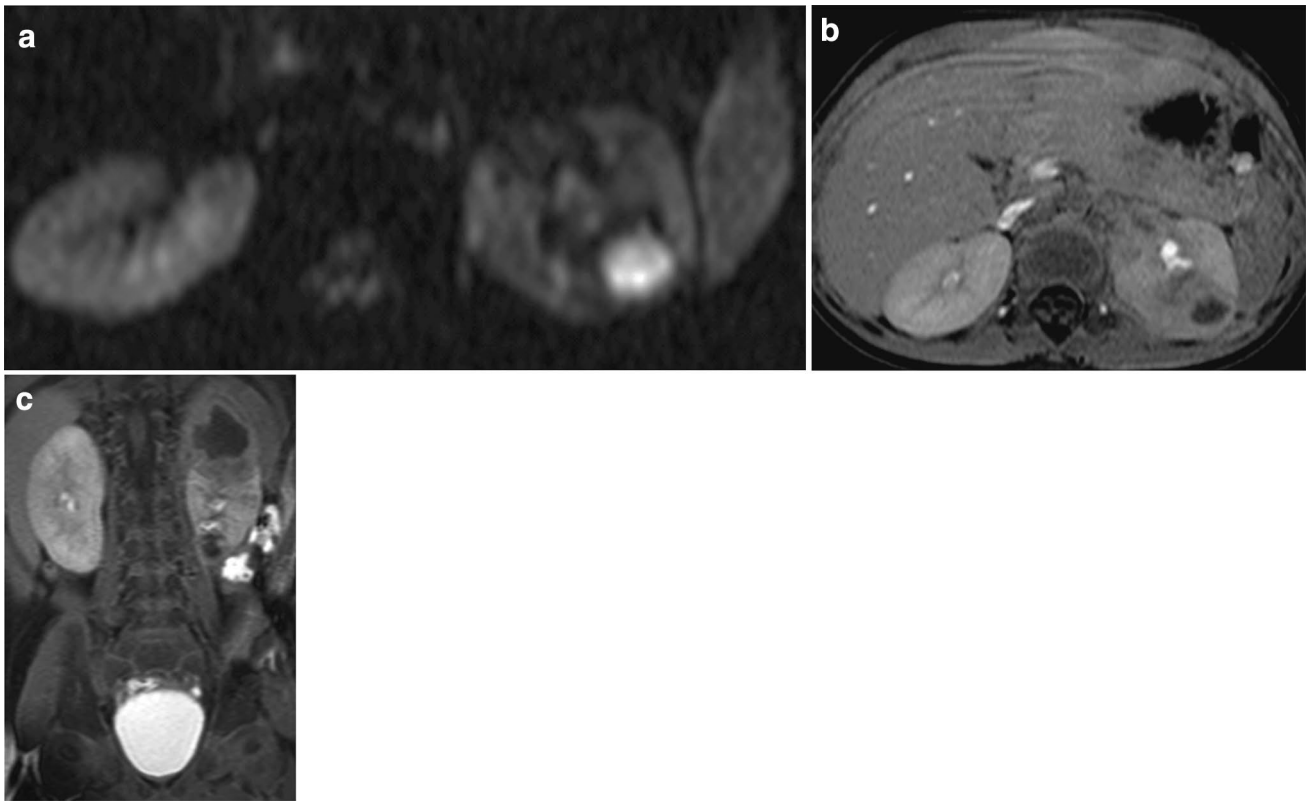

Fig. 5 MRI in acute pyelonephritis. **a** Diffusion weighted imaging, axial section, depicts a focally restricted diffusion in the left kidney consistent with pyelonephritis. **b** Contrast-enhanced T1 weighted axial image showing the reduced enhancement of the same left renal lesion as shown in **a**—consistent with a central necrosis in a focal lesion in acute pyelonephritis. **c** Contrast-enhanced coronal T1-weighted image depicts a large abscess in the upper third of the left kidney, in a girl with recurrent and multifocal pyelonephritis; note that the remaining kidney also shows multifocal inflammatory foci

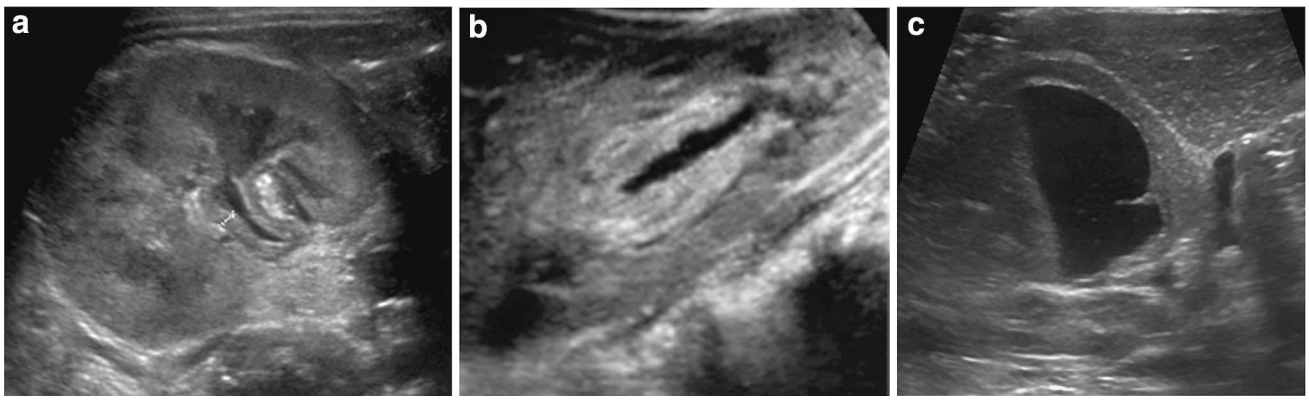

Fig. 6 Urothelial thickening and sedimentations. **a** The pelvic wall is diffusely swollen and thickened (+…+) in this axial section of a right kidney with acute pyelonephritis; also note the diffuse increased echogenicity of the widened peripelvic tissue in the renal hilus. **b** On this longitudinal section through the central kidney the huge and echogenic thickening of the entire pelvic wall and peripelvic tissue is obvious—this was due to hemorrhage due to drug intoxication, demonstrating that the "urothelial sign" is an unspecific finding. **c** Pus sedimentations and fluid level in a child with an infected renal cyst; note that in cysts usually no "urothelial sign" can be seen even in severe and long standing infection

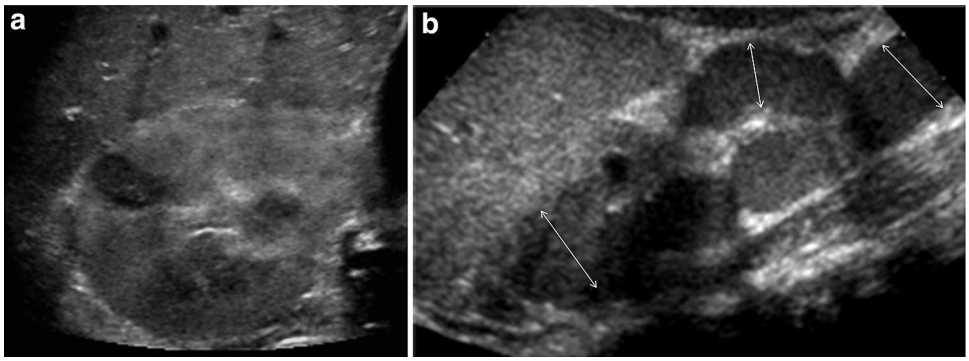

Fig. 7 Complicated and unusual renal inflammatory conditions. **a** Focal ovaloid hypoechogenicity with some central echoes—indicating a renal abscess in this child with multiple septic emboli due to valvular vegetation in endocarditis. **b** High-grade urinary tract dilatation (pelvicaliceal system and ureter)—these structures (<->) are completely filled with echogenic material (=pus). Note that in spite of clinically obvious (uro-) sepsis, the urine analysis was nearly normal (due to the lacking drainage from the infected urinary tract)

during the annual ESPR Congress in Graz in June 2015, this topic has been re-addressed and re-discussed under the aspect whether we need to change and adapt—however, at present no real new convincing evidence has been published that would alter these suggestions or rectify a new imaging algorithm. The much more restrictive indications for imaging proposed by the NICE guidelines a couple of years ago are still discussed controversially; it has also been shown that by applying these criteria some children with significant malformations and thus a considerable risk for renal damage would have been missed if these criteria would have been applied and no imaging would have been performed [43, 44]. This demonstrates that economically driven recommendations are potentially dangerous, and that the absence of evidence for a certain measure does not necessarily imply that there is no benefit for children as there usually is also any evidence that not performing the study is safe.

Bearing all these considerations in mind, it seems reasonable—*during the acute stage*—to at least image all neonates, infants, and young children with the first UTI usually by US, if there has not been any previous imaging study that has shown a normal urinary tract anatomy (e.g., by fetal or neonatal screening, by a US examination for other reasons…). As potentially existing urinary tract malformations may pose the kidney at risk, these investigations should be done during the first days of the UTI and should be performed thoroughly in a standardized fashion. Furthermore, at least a detailed US study should be performed in the acute setting in all children, when the differentiation of upper versus lower UTI is not achievable clinically. This objective may also be achieved by using DMSA scintigraphy or renal MRI with DWI. Definitely all children with a prolonged or complicated course, no proper response to treatment, or known urinary tract malformations have to undergo imaging—usually US is sufficient in the acute setting. Further imaging may be indicated—which then is performed best by MRI, such as differentiation of pseudotumorous lesions from real tumors, or evaluating the extent of a huge abscess with perinephric involvement. Sometimes imaging will be able to support treatment by guiding interventions, e.g., for draining an abscess or an obstructed pyonephrosis [45]. In rare cases, a CT may become necessary particularly if infectious stones are associated or for assessing conditions that go along with calcifications such as xanthogranulomatous pyelonephritis or renal tuberculosis—in these instances, dedicated pediatric CT protocols have to be applied.

The *follow-up and work-up of children after UTI* depends on the initial situation. A child with a single potentially not febrile "normal" UTI without renal involvement or scarring, with an also otherwise normal urinary tract sono-anatomy, will not always have to undergo a VUR study—here the indications have become much more rigid, and far less VCUGs are being performed to avoid unnecessary investigations with a low yield, high costs, and significant invasiveness as well as radiation burden to quite a number of children [2, 12, 15, 38, 46–48]. It is different for children with UTI and renal involvement particularly if with scares, altered urinary tract anatomy, significant urinary tract malformations, or sonographic signs which indicate the existence of a VUR such as a gaping ostium, a duplex system with dilated lower pole ureter and collecting system (thus being highly suspicious for VUR), persisting urothelial thickening, or varying dilatation of the renal pelvis during the course of the disease. In these children, a VUR test should be performed—optimally around 4–6 weeks after the infection, when alteration of the bladder wall and the urothelium has ceased and the ureter will have recovered his normal peristalsis and tonus. This then can be performed by which ever method—increasingly, ce-VUS is used for radiation protection issues; in children

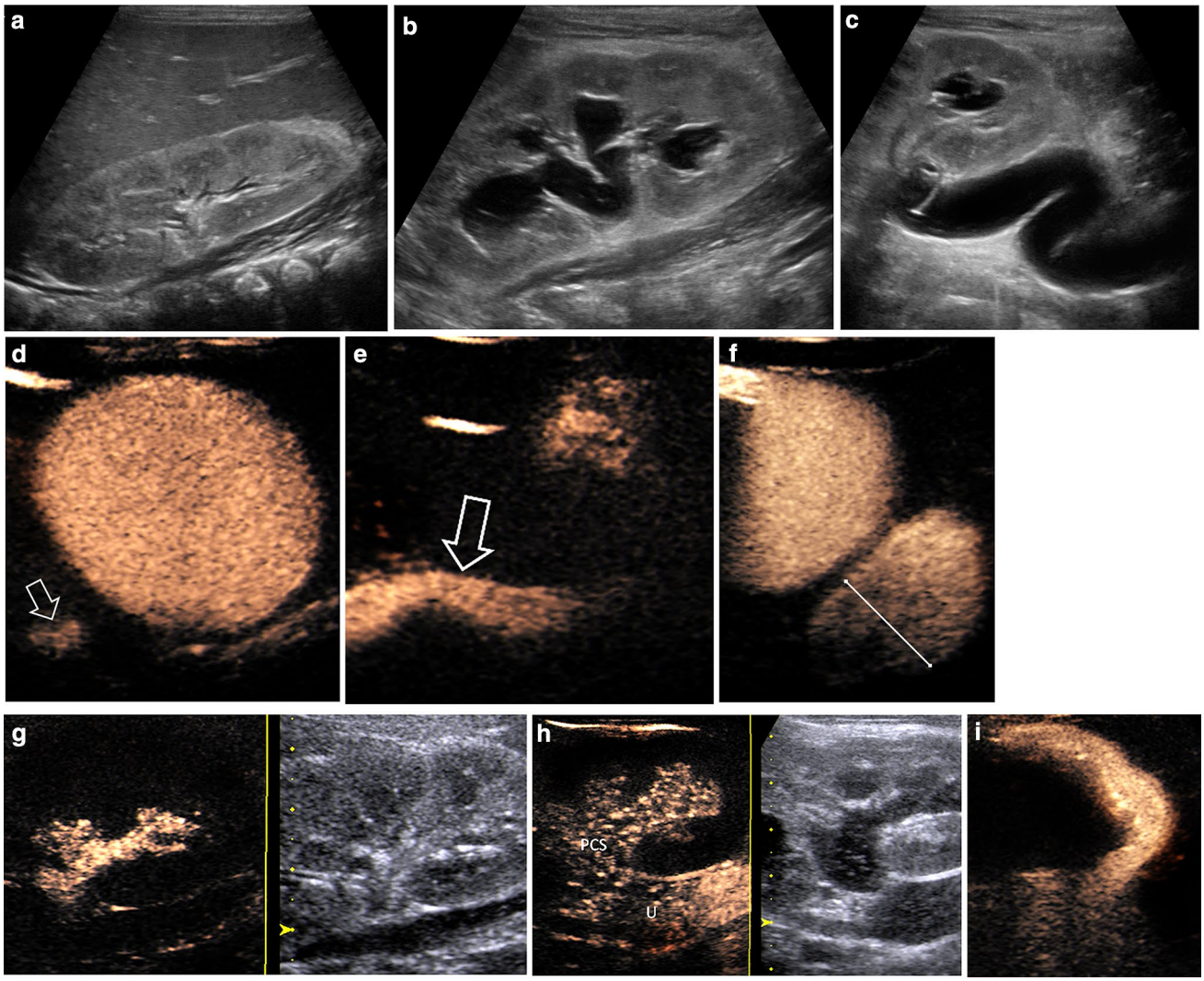

Fig. 8 Ce-VUS in VUR First the native images of the relatively normal right kidney (**a**) and the left kidney with gross distention of the pelvicaliceal system (**b**) as well as of the corresponding ureter (**c**). After filling of the urinary bladder with saline infusion using a bladder catheter and fractionated instillation of US contrast agent (SonoVue®, Bracco/Italy), VUR into the non-dilated right ureter (**d** axial view, **e** parasagittal oblique section, *arrow*) and the dilated left ureter (**f**, +–+) is seen. Using a split image technique for orientation (left is the contrast image, right is the native image—used for orientation and correlation), VUR into the non-dilated right collecting system (**g** VUR II-III°) and—with a dilution effect—into the dilated left ureter (U) and pelvicaliceal system (PCS) is depicted (**h**). During voiding the urethra is clearly visible—without any outflow obstruction, using a perineal access (**i**)

who are toilette-drained, an indirect RNC (after a MAG3 diuretic renal scintigraphy) is probably the least invasive and most physiological way to assess for the existence of VUR at low radiation burden without the need for a bladder catheter. Particularly in older children (after the bladder has matured), the importance of voiding and bladder dysfunction is increasingly recognized—these have to be detected and treated, as even surgery for VUR is eventually not successful in some of those children; if the dysfunction is left untreated, a high re-occurrence rate of operated VUR is observed. These children are depicted by a detailed history specifically asking for symptoms of voiding disorders and observing indirect US signs such as a constantly open bladder neck, wall thickening and trabeculation even without VUR, atypical bladder capacity, and pathological post-void residual urine—or by direct visualization of the dysfunction on VCUG when using a modified protocol allowing for functional assessment [11–13, 17, 38, 49]. On the long run, development of scarring and monitoring renal growth is of outmost importance. This usually is achieved by a US follow-up (best done not before 6–8 weeks after the infection) and—if there is a high suspicion for scarring or after a severe infection—a DMSA static renal scintigraphy at 6–9 months after the infection. The latter can be replaced

by MRI if available at reasonable costs—particularly when applying functional MR that allows for assessment of split renal function and glomerular filtration rate.

So what imaging should be practically performed practically in neonates, infants, and children with UTI? Still there is no ideal universal imaging algorithm available for imaging infants and children with or after UTI. Discussion on imaging following UTI is based on the correlation of UTI with renal scarring, VUR, other malformations of the kidneys and the urinary tract, and non-neurogenic bladder-sphincter dysfunction [2, 12, 15, 35, 37–39, 41, 46, 50, 51]. VCUG is still the central point of discussion; it is an invasive investigation with radiation burden, discomfort, and a small risk of causing UTI. More than a decade ago, the American Academy of Pediatrics and a Swedish state-of-the-art conference recommended US and VCUG in all infants and young children up to two years of age with UTI to detect VUR [39, 52]. This imaging policy is no more accepted nowadays and the American Academy of Pediatrics changed their attitude, too [1]. Even according to these recommendations, the number of investigations can be reduced and VCUG not necessarily has to be performed in all children with UTI, only those with indirect signs on US or complicating clinical circumstances. In infants with febrile UTI an US investigation of the bladder and the kidney should be performed during the first two days of treatment to identify serious complications such as pyonephrosis or abscesses (or an underlying malformation that poses a high risk for renal damage or a complicated course)—particularly when the clinical situation is severe or if there is no improvement. Nuclear scanning with DMSA is not recommended as part of routine evaluation in (the first) febrile UTI. RNC with low-dose radiation or ce-VUS without radiation are alternatives to conventional fluoroscopic VCUG, but both also require catheterization of the bladder. As stated above, it is the ultimate goal to recognize and to prevent renal damage, even if renal scarring without VUR is frequent. Conversely, detecting VUR is not a good predictor of renal damage after UTI and cannot serve as a screening investigation for renal damage [7]. Taking all this into account, it appears reasonable to perform an early comprehensive US study in all infants with (febrile) UTI—particularly those with severe clinical symptoms, clinically equivocal situations, and yet unknown urinary tract anatomy. In all patients with significant renal involvement or obvious scaring a VUR test and, after four to nine months, a DMSA scan (or in future potentially an MRI) are recommended; in older patients also a basic assessment for functional voiding/bladder disturbances should be considered.

Discussion

Urinary tract infection is one of the most common indications for imaging work-up in pediatric radiology. In the past everybody was hunting VUR as it was considered to be the main cause for long-term sequelae and renal damage. Therefore, numerous studies and VCUGs have been performed. With new insights into pathogenesis, the focus has changed towards the kidney and many other factors that pose a risk to renal involvement and scarring after UTI have been identified; thus, VUR has become less important. This as well as refinement of imaging methods impacted imaging algorithms where new developments have widened and changed the imaging armamentarium.

Today still a rather generous indication for a US study of the urinary tract is advocated in infants, neonates, and children with UTI particularly if with complicated course or without information on the urinary tract anatomy from previous studies. However, this should be a dedicated study with proper equipment and trained examiners. Indications for some sort of VUR assessment are much more restricted and well chosen based on clinical and imaging information—usually VCUG and (if available) ce-VUS are used; in older children, an indirect RNC is a very good and non-invasive alternative, whereas MR-VCU has not been established probably for cost reasons, availability, and technical challenges. The main focus, however, will remain on those children in whom renal damage and scarring is detected and those with significant urinary tract malformations associated with (recurrent) UTIs: they will need long-term monitoring of renal health, growth, and function—mostly achieved by US, scintigraphy, and/or MRI. The regular follow-up of a potential VUR has also become less important, and intervals between follow-up studies are being prolonged as well as antibiotic prophylaxis is partially being replaced by cystoscopic VUR treatment using injection of bulging agents. However, the story and the discussion is not yet over, and I am sure we will see new proposals coming up again.

Summary and conclusion

US remains the mainstay for imaging in febrile (recurrent) childhood UTI. The task of pediatric radiology is to provide high-quality imaging, particularly, to guarantee high-quality US and make it available 24/7 to help selecting patients for VUR studies properly, using the proper technique at the lowest possible radiation burden—trying to avoid invasiveness whenever possible. But it is also important to suggest a useful urinary tract imaging adapted to the clinical situation and presentation (and individual patient) by US,

potentially VCUG (or RNC/ce-VUS), and/or scintigraphy/MRI, if potential information from the study will influence patient management, morbidity, and outcome—avoiding invasive and/or irradiating studies in all where there is no impact on therapy, management, or prognosis/outcome.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Disclosure No relevant items to declare in connection with this topic/review article.

Ethical standards This article does not contain any studies with human participants or animals performed by any of the authors.

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