Editorial

Imaging in pediatric urolithiasis—what's the best choice?

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Abstract: The incidence of urolithiasis increased dramatically during the last decades in adults as well as in children. Today, when a urinary stone is suspected, the imaging modality used most frequently is non-contrast enhanced computed tomography (NCCT). Due to the high sensitivity and specifity, NCCT is regarded as the gold standard. Its major drawback is the high dose of radiation administered with this examination. This is of special concern in children. Children with urinary stones are at high risk for multiple recurrences during their life. NCCT increases the risk for abdominal and pelvic cancer in children significantly. With respect to therapeutic success, however, conventional imaging modalities like ultrasound are not inferior and are without any harm. Therefore, ultrasound is recommended as the primary imaging technique in children by several guidelines. Nevertheless, as could be shown by Tasian *et al.*, ultrasound was the first imaging study in only 24% of children with urolithiasis. NCCT was the modality used most frequently (63%) in the USA between 2003 and 2011. There was a wide regional variation within the USA with highest CT use in the Northwestern and Southern and lowest in the New England states. It is hypothesized that engrained practice patterns and specific local medical resources as well as a lower confidence in ultrasound with its operator dependence are potential reasons. Regarding the fact that ultrasonography is highly reliable in the diagnosis of urolithiasis and is without any harm, it is essential to make all efforts to increase the adherence to the guidelines.

Keywords: Pediatric urolithiasis; renal stones; imaging; ultrasound; computed tomography

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The incidence of urolithiasis has increased dramatically during the last decades, not only in adults (1), but also in children (2). Due to climate changes, the incidence will probably rise during the next decades (3).

Nevertheless, urolithiasis is much less common in children when compared to adults. In industrialized countries, about 2-5% of urinary stone patients are children (4). This is probably the reason that many recommendations for diagnosis and therapy of urolithiasis are derived from adults.

Nevertheless, there are guidelines especially designed for diagnosing and treating urolithiasis in children (American Urological Association, European Association of Urology, and European Society for Pediatric Radiology).

In adults, the imaging technique most commonly used for urinary stones today is NCCT. The major draw-back, however, is the exposure to a relatively high radiation dose. This is even more important in children as they may need repeated examinations during their lives and the cumulated radiation dose may be harmful (5).

For proper choice of the best imaging technique in children, first one should consider the aims. In suspected cases of nephrolithiasis, the primary aim of imaging is to confirm or exclude a urinary stone. The secondary aim is to provide the basis for individual treatment.

Imaging modalities

Imaging techniques are used to exclude or substantiate the

diagnosis and to determine the size and location of a stone including assessment of the consequences of obstruction to the urinary tract and renal function. Knowledge of these parameters is necessary to plan therapy adequately.

Ultrasonography

Ultrasound has the advantages of being easily available, non-invasive and avoiding radiation. On the other hand, it is highly dependent on the skills of the doctor performing the examination.

B-mode ultrasonography can reveal stones in the kidney, in the proximal ureter at approximately the height of the lower renal pole and in the distal ureter. Generally, stones in the other ureter segments cannot be visualized due to intestinal gases.

Dilatation of the pelvi-calyceal system is an indirect sign of renal calculus (6). Sensitivity and specifity of ultrasound diagnosis of renal stones are approximately 61-93% and 95-100% respectively (7) The accuracy of ultrasound in pediatric urolithiasis is also quite variable. Stones could be detected in 33-100% The detection rate was much higher in the kidney when compared to the ureter (8).

Conventional radiology (KUB, intravenous urography)

Kidney-Ureter-Bladder (KUB)

The KUB film can only reveal radio-opaque calculi. Diagnostic sensitivity, respective specifity of KUB is 69%, respective 82% (9). Examination of the skeleton can provide evidence of other causes of pain (for example the vertebrae).

The radiation dose is about 0.5 mSv (10).

Intravenous urography

In general, films are taken at 7½ and 15 minutes following intravenous contrast medium infusion. Enhanced parenchymal contrast on early films (for example 3 minutes after contrast medium administration) can indicate obstruction on the affected side. However, early urogram films are generally not required as ultrasonography will have already been performed, thus, also reducing radiation dose.

To reduce exposure to radiation, further films should not be taken if the first film reveals all relative information. Often, it is adequate to concentrate radiography on the affected side. Delayed contrast medium excretion necessitates late films (for example after several hours).

The intravenous urogram is analyzed regarding renal function, dilatation of renal pelvi-calyceal system and ureter, location and area of the renal stone and radiological opacity. Non-opaque stones (generally uric acid stones) are noticed as contrast medium filling defects.

Sensitivity and specifity of intravenous urography in the diagnosis of ureteral stones is 92-98% and 59-100% respectively (11). The radiation dose is approximately 1.4-1.5 mSv.

Intravenous urography is contraindicated in acute ureteral stone colic (danger of fornix rupture), renal failure (creatinine ≥200 μmol/L), myeloma and similar diseases, contrast medium allergy, untreated hyperthyroidism.

NCCT

NCCT is the method with the highest sensitivity, respective specifity (91-100%, respective 95-100%) for examining a ureteral stone. A prerequisite is utilization of thin layers (<5 mm) to also detect small concretions. NCCT is superior to all other imaging techniques (11,12). Additionally, NCCT addresses to some extent other differential diagnoses. Density measurement (Hounsfield units) also facilitates estimation of stone composition. This is important for therapeutic planning (13). However, NCCT overestimates stone size by 30-50% (14).

The radiation dose is approximately 2.8-5.0 mSv (10,15), therefore being significantly higher than conventional radiology. As children affected by urinary stones are at high risk for multiple recurrences during their lifetime, they probably will need multiple imaging for stones during their life. Therefore, radiation exposure is an important issue. Kuhns *et al*. calculated that the ratio of the risk for abdominal and pelvic cancer due to a single NCCT for stones to the risk of a naturally occurring cancer over the lifetime of a child is estimated to be 2/1,000 to 3/1,000 (16).

During the last decade, examination protocols with lower radiation doses have been developed (so called ultra low dose NCCT). This term, however, is not standardized. Using those protocols, the radiation dose can be reduced to approximately 1-2.2 mSv (17,18). However, resolution also suffers especially with respect to stone composition (measurement of Hounsfield units), thus compromising therapeutic planning.

Aspects of differential indication of imaging techniques

Sensitivity and specifity are of great importance when comparing imaging methods. In this respect, native computed tomography is superior to all other techniques.

The conventional imaging modalities (ultrasound, X-ray),

however, are not so bad. A large study, recently published, demonstrated that in case of clinical suspicion of urolithiasis there was no difference between patients primarily diagnosed by NCCT and those primarily examined by ultrasound with respect to diagnoses and therapy results (19). As shown by Johnson *et al*. (20), nearly 90% of children treated for urolithiasis could have completed their work-up and therapy without undergoing CT.

On the other hand, almost 75% of children undergoing NCCT for suspected urolithiasis did not have a stone (21).

Additionally, other criteria must be taken into consideration: radiological protection, side effects, estimation of renal function, follow-up examinations, therapeutic relevance and cost.

Radiological protection

The 2004 report from the German government ministry for radiological protection describes consistently higher radiological dosages in Germany than in other countries. Radiological dose increased 12% from 1996 to 2001. Increased use of CT was primarily responsible. In the USA, the frequency of NCCT for suspected urinary stones increased tenfold during the last decade (22). Indeed, the dosage for this technique is significantly higher than in conventional radiology, even employing ultra low dose protocols. This has to be considered especially in children.

Kuhns *et al*. calculated that ratio of the risk for abdominal and pelvic cancer due to a single NCCT for stones to the risk of a naturally occurring cancer over the lifetime of a child is estimated to be 2/1,000 to 3/1,000 (16).

NCCT offers only a relatively small increase in sensitivity and specifity (see above). Follow-up investigations have to be considered as well. It could be shown that about 80% of stone patients initially diagnosed by NCCT scan will receive further NCCT scans for follow-up (23).

Untoward effects

Except for radiological dosage, NCCT and plain renal films have no adverse effects. When contrast medium is employed (contrast enhanced CT and contrast medium infusion urography), contrast medium incidents and renal function deterioration can occur.

Assessment of function

Ultrasonography, plain renal films and native computed tomography do not assess renal function. Renal function is only evaluated by contrast medium infusion urography and contrast enhanced tomography.

Follow-up examinations

Principally, it is possible to perform follow-up examinations of ureteral colic with all described imaging techniques. Radiological dose and availability are significantly problematic regarding computed tomography. It could be shown that about 80% of stone patients initially diagnosed by NCCT scan will receive further NCCT scans for follow-up (23). Sometimes conventional radiology is performed following initial computed tomography diagnostics. However, comparability often suffers due to change of method.

Therapeutic relevance

Therapeutic planning is a major aim of imaging techniques. Many interventional methods (extracorporeal shockwave lithotripsy, ureterorenoscopy, percutaneous nephrolithotomy) are managed with conventional radiology. Comparability is definitely at best when the same imaging method is used for diagnosis and therapy. Ultra low dose protocols in NCCT are hampered by reduction of differentiation between non-opaque uric acid stones and other concretions. However, as uric acid stones can be dissolved by medication, this differentiation is of therapeutic relevance

Costs

Recently, it could be shown that ultrasonography is much cheaper than NCCT in the diagnosis of urolithiasis (19).

Conclusions

NCCT is the method with the greatest accuracy. However, conventional diagnostics are not significantly worse in this respect. Smith-Bindman *et al*. recently demonstrated that in case of clinical suspicion of urolithiasis there was no difference between patients primarily diagnosed by NCCT and those primarily examined by ultrasound with respect to diagnoses and therapy results (19).

Radiation dose, costs and availability promote primarily the use of conventional diagnostics. As shown by Johnson *et al*. (20), nearly 90% of pediatric stone patients treated for urolithiasis could have completed their work-up and therapy without undergoing CT.

Presently, we recommend the following diagnostic approach in children: ultrasonography is imaging technique to be used first. This is in accordance with the guidelines for diagnosing urinary stones in children

When the stone cannot be visualized by ultrasound or when anomalies of the urinary tract have to be examined, techniques using contrast media are required. Although the

sensitivity of CT is highest, we favor conventional radiology with respect to radiation doses (24).

Clinical reality today

However, this pathway has not been adopted by the majority of colleagues treating children with urolithiasis. Tasian *et al*. (25) performed a cross-sectional study on the use and regional variation in initial imaging in children with urolithiasis in the USA between 2003 and 2011. Contrary to the guidelines and good clinical practice, the majority of children (63%) underwent CT scan as the first imaging study. Ultrasonography, recommended by the guidelines, was the first-line modality in only 24%. There was a wide regional variation within the USA with highest CT use in the Northwestern and Southern and lowest in the New England states. It is hypothesized that engrained practice patterns and specific local medical resources as well as a lower confidence in ultrasound with its operator dependence are potential reasons. Nevertheless, one should be aware that the radiation exposure by CT scans is associated with an increased risk in children, especially in girls. Regarding the fact that ultrasonography is highly reliable in the diagnosis of urolithiasis and is without any harm, it is essential to make all efforts to increase the adherence to the guidelines. Only by sustained propagation of these guidelines it will be possible to avoid unnecessary radiation exposure in children with all its consequences for lifetime.

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Footnote

Conflicts of Interest: The author has no conflicts of interest to declare.

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