International Journal of Surgery 36 (2016) 698–704

Contents lists available at ScienceDirect

International Journal of Surgery

journal homepage: www.journal-surgery.net

Review

Clinical effectiveness in the diagnosis and acute management of pediatric nephrolithiasis

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HIGHLIGHTS

- The incidence of pediatric nephrolithiasis is rising.
- Children/adolescents represent a unique patient population with higher risks from radiation exposure as compared to adults and high recurrence rate.
- Ultrasound is the first-line modality for diagnosing suspected nephrolithiasis in children.
- First line therapy for stable patients is most cases is observation/analgesics with alpha-blockers as MET.
- Surgical management of pediatric nephrolithiasis is similar to adults with ESWL and URS first-line for smaller stones and PCNL reserved for larger renal stone burden.
- Clinical effectiveness in children/adolescents with nephrolithiasis centers around ED pathways that limit CT imaging, adherence to ALARA principles and use of US during surgical procedures.
- Patient/Family education on the risks of repeat ionizing radiation exposures during follow up is essential.

ARTICLE INFO

Article history:
Received 17 October 2016
Accepted 10 November 2016
Available online 14 November 2016

Keywords:
Pediatrics
Nephrolithiasis
Urinary stone disease
Urology
Diagnostic imaging

ABSTRACT

The incidence of pediatric nephrolithiasis has risen over the past few decades leading to a growing public health burden. Children and adolescents represent a unique patient population secondary to their higher risks from radiation exposure as compared to adults, high risk of recurrence, and longer follow up time given their longer life expectancies. Ultrasound imaging is the first-line modality for diagnosing suspected nephrolithiasis in children. Although data is limited, the best evidence based medicine supports the use of alpha-blockers as first-line MET in children, especially when stones are small and in a more distal ureteral location. Surgical management of pediatric nephrolithiasis is similar to that in adults with ESWL and URS first-line for smaller stones and PCNL reserved for larger renal stone burden. Clinical effectiveness in minimizing risks in children and adolescents with nephrolithiasis centers around ED pathways that limit CT imaging, strict guidance to ALARA principles or use of US during surgical procedures, and education of both patients and families on the risks of repeat ionizing radiation exposures during follow up and acute colic events.

1. Introduction

The increasing burden of nephrolithiasis in the pediatric population has been brought to the foreground recently by several studies showing the rapid rise in the incidence of stone disease in children and adolescents [1–3]. As would be expected from this, the number of hospitalizations, emergency department visits, use of medical therapy and surgical interventions for children with nephrolithiasis have also seen a steady rise [1,3–6]. While the exact etiology for this increasing incidence rate is unclear, the morbidity associated with nephrolithiasis is especially concerning in the pediatric population. Risks from ionizing radiation, especially when repeated, and from surgical interventions may be magnified in children and adolescents both because of physiological differences from adults and because of the longer life expectancy and thus

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http://dx.doi.org/10.1016/j.ijsu.2016.11.030
1743-9191/

longer time period of exposure and follow up [7,8]. In addition to the impact on the pediatric patient, pediatric nephrolithiasis is estimated to cost the United States at least $375 million annually in hospital and emergency department costs [9]. This economic burden is likely even higher when considering outpatient visits, medical therapy and imaging study costs, and missed work/lost wages by caregivers. As a consequence, strategies and protocols to optimize the evaluation and clinical treatment of children and adolescents with nephrolithiasis are necessary. In this review, the clinical effectiveness of diagnostic imaging, medical therapy, and surgical interventions for pediatric nephrolithiasis will be explored, with specific emphasis on minimizing risk in this unique patient population.

2. Epidemiology

As mentioned above, pediatric nephrolithiasis is a growing public health burden with a 6–10% annual rise in incidence over the past 20 years [1,4]. Estimates of contemporary mean annual incidence of pediatric nephrolithiasis range from 36 to 57 per 100,000 children in US population-based observational studies [1,2,4]. In one recent study, the greatest increase in nephrolithiasis was noted among 15–19 year olds where the incidence increased 26% per 5 years from 1997 to 2012 [3]. In addition, this same study observed that annual incidence of stones increased most drastically among adolescent girls and African-Americans. This effect of gender on incidence of pediatric nephrolithiasis has been shown in other studies and interestingly, the risk of stones appears to be higher among boys in the first decade of life and among girls in the second decade of life [3,10]. The incidence of stone disease shifts towards a male predominance around 26 years of age, which is sustained throughout adulthood. The association between body mass index (BMI) and pediatric nephrolithiasis has been a controversial topic with the majority of studies showing no association between the two [2,11,12]. In fact, the prevalence of obesity in children and adolescents has remained constant from 1999 to 2010 while the incidence of kidney stone disease has doubled, suggesting other factors may be related to the rise in pediatric nephrolithiasis [13].

3. Acute management

3.1. Diagnostic imaging

In contrast to adults where use of computerized tomography (CT) is widely considered the first-line diagnostic study for the evaluation of suspected nephrolithiasis, ultrasound (US) is recommended as the initial imaging modality [14,15]. The reason for this is that while noncontrast CT has a nearly 100% sensitivity and specificity for detecting nephrolithiasis, there are concerns for cumulative and long-term effects of ionizing radiation including increased risk of cancer [16]. Cancer risk may be even greater in the pediatric population because of the longer life expectancy and the greater sensitivity of developing tissues/organs (ie, higher mitotic rates) to radiation effects.

Although US is less specific and sensitive than CT in detecting urinary tract stones, it does allows direct visualization of urinary stones and of signs of urinary tract obstruction such as dilation of the ureter and/or pelvicalyceal system, increased renal echogenicity, or increased renal size. When compared to the gold-standard of CT, one study noted that ultrasound had a 70% sensitivity, 100% specificity, 96% positive predictive value, and 62% negative predictive value for the detection of urinary tract stones in patients younger than 18 years. Furthermore, the stones that were missed on ultrasound were in most cases clinically insignificant (ie, small in size or non-obstructing) [17]. The use of additional criteria such as renal resistive indices, gray-scale acoustic shadowing and the "twinkling artifact" on color Doppler evaluation have been investigated in adults to help improve the diagnostic accuracy of ultrasound for nephrolithiasis [18–20]. However, to date, no studies have evaluated the use of any of these criteria in children with stones and therefore their validity in the pediatric population is unknown. In particular, the role of renal resistive index in children with urinary tract obstruction is complicated by the fact that RI is age dependent – highest at birth and decreases gradually to adult levels at about 4–5 years of life [21]. Future studies are warranted to help shed light on what role these criteria may play in pediatric nephrolithiasis.

Given the concerns of ionizing radiation exposure with CT and the relatively high sensitivity and specificity of ultrasound in detecting nephrolithiasis of clinical importance, both the American Urological Association (AUA) and the European Society of Pediatric Radiology (ESPR) recommend obtaining a renal and bladder ultrasound as the first-line imaging in children and adolescents, with CT scans reserved for equivocal or non-diagnostic US results in which the clinical suspicion for stones is high [14,15]. Likewise, the European Association of Urology (EAU) guideline for the diagnosis of urolithiasis recommend renal and bladder ultrasound as the primary diagnostic imaging tool in all patients [22]. In addition to these national and international organizations, the Alliance for Radiation Safety in Pediatric Imaging, which includes the Society for Pediatric Radiology and American College of Radiology, started the Image Gently® campaign in 2007 to decrease the use of ionizing radiation in pediatric patients undergoing diagnostic imaging [23].

Despite these various recommendations and guideline statements, one recent review of a commercial insurance claims database found that ultrasound was only obtained as the initial imaging in 24% of children and adolescents with suspected nephrolithiasis [7]. Conversely, 63% of children underwent initial CT imaging with substantial regional variation within the United States [7]. This inappropriate use of initial CT imaging in children has been confirmed by other studies. Johnson and colleagues performed a retrospective cohort study of the Nationwide Emergency Department Sample from 2006 to 2010 and found that 87% of pediatric patients with suspected nephrolithiasis underwent CT alone [24]. Factors associated with use of CT alone included older age of patient, evaluation at a non-teaching hospital, visit on a weekend and visit EDs that serve smaller proportions of pediatric patients [24]. On the other hand, children who presented at EDs that utilized clinical care pathways emphasizing the use of US as the first-line imaging in children were found to have lower odds of undergoing initial CT [25] (see Fig. 1).

At the Children's Hospital of Philadelphia (CHOP), we have utilized an ED clinical pathway for the evaluation and treatment of children with suspected nephrolithiasis since 2009. The clinical pathway is accessible online by all clinicians in the hospital system and was developed in collaboration between the pediatric emergency medicine, pediatric radiology and the pediatric urology departments. The goals of the pathway are to standardize patient evaluation, expedite appropriate radiologic studies with US as first-line, and to reduce the time to disposition. Use of the clinical pathway at CHOP has led to lower rates of CT use in children suspected of nephrolithiasis compared to other regional EDs with no clinical pathway [25].

3.2. Immediate urinary decompression

Similar to the evaluation of the adult with nephrolithiasis, the initial step in the acute management of the child is determining the need for immediate urinary decompression. Emergency decompression of the obstructed urinary system by a ureteral calculus can