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Preoperative evaluation of pediatric kidney stone prior to percutaneous nephrolithotomy: is computed tomography really necessary?

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Abstract The objective of the study was to investigate the precise role of computed tomography (CT) in preoperative radiologic evaluation and surgical planning of kidney stone in children prior to percutaneous nephrolithotomy (PNL). A total of 113 pediatric patients (aged ≤18 years) undergoing PNL for renal stone(s) in three referral hospitals between March 2010 and August 2012 were retrospectively evaluated. Depending on the preoperative radiologic evaluation, patients were divided into two groups. Those evaluated with CT were classified as group-1 ($n = 50$) and the remaining cases undergoing intravenous urography (IVU) examination were classified as group-2 ($n = 63$). Patient- and procedure-related variables and perioperative measures were compared between the groups. The mean age, stone size and localization were similar in both groups ($p = 0.07$, $p = 0.57$, $p = 0.6$, respectively). Although the postoperative hemoglobin drop was found to be significantly higher in group-2 (1.5 ± 1.3 vs. 0.9 ± 0.6 g/dL, $p = 0.005$), the mean operation time, fluoroscopic screening time, access number, overall success and complication rates were comparable ($p = 0.06$, $p = 0.94$, $p = 0.75$, $p = 041$, and $p = 0.41$, respectively). However, the mean hospitalization time was significantly prolonged in group-2 than in group-1 ($p = 0.03$). Our findings clearly demonstrate that, despite the key role of preoperative CT in particular patients with anatomically abnormal kidneys, IVU is a valuable alternative imaging modality with comparable radiation doses in children.

Keywords Kidney stone · Percutaneous nephrolithotomy · Children · Radiologic workup · Computed tomography · Radiation exposure

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Introduction

Recent studies have demonstrated an increase in the incidence of urolithiasis in children [1–3]. A 4 %/year increase rate in the incidence of nephrolithiasis in these cases throughout a 25-year period in a geographically defined population has been reported [3]. Although the exact causative factors for this increase is unclear, certain factors such as increased obesity, associated diseases (diabetes, etc.) and increased sensitivity of imaging techniques with the use of computed tomography (CT) have been claimed to be associated by some investigators [3–7].

Among the imaging modalities performed in the evaluation of kidney, CT examination has certain established advantages than the other modalities such as renal ultrasonography (US) and intravenous urography (IVU). It has been well established that, as the most sensitive and specific technique, CT examination can provide three-dimensional vision and additional information about the stone characteristics and anatomical factors [8, 9]. Therefore, CT has become the standard imaging for the identification of suspected urolithiasis, particularly in emergency clinics. Moreover, it is also important to use CT when a precise decision is needed for the treatment of stone disease such as in kidneys with certain structural and/or locational abnormalities [10]. However, its main limitation is that the higher radiation exposure restricts its routine use for diagnosis as well as follow-up of urolithiasis in children [11].

There is a limited number of studies studying the role of CT in evaluation of children with renal calculi prior to surgery [12, 13]. In one study with a small number of cases, the authors recommended the routine use of CT prior to PNL in children to prevent colon perforation [13]. In a recently published study, Johnson et al. [12] presented that, 76 % of CT did not contribute to the diagnosis or treatment regimen of pediatric cases who underwent surgery due to urolithiasis.

In this study, we aimed to evaluate and compare the outcomes of pediatric patients with renal calculi either evaluated with CT or IVU prior to PNL.

Materials and methods

We performed a retrospective analysis of 113 pediatric patients aged ≤18 years (67 boys and 56 girls) with renal calculi undergoing PNL in referral hospitals in Turkey between March 2010 and August 2012. The patients were classified into two groups according to the imaging modality used preoperatively. Patients who were evaluated with non-enhanced CT were classified as group-1 and with IVU as group-2. Patient- and procedure-related variables, perioperative and postoperative measures such as stone size, fluoroscopy, operation and hospitalization time, complication and success rates and hemoglobin drop were compared.

Following a detailed medical history and physical examination, urinalysis, urine culture, total blood count, serum biochemistry (including kidney and liver function tests) and coagulation tests were performed in all cases. The patients with (+) urine cultures were treated accordingly. The initial radiologic assessment was done with renal US and plain radiograph of kidney, ureters and bladder (KUB). Prior to surgery, IVU or non-enhanced CT was performed to obtain further information regarding the anatomical spaces of the involved kidney. The stone size (measuring the longest axis of each stone) was calculated in each case.

Operative technique

Prophylactic antibiotics were administered intravenously prior to the procedure in all patients. Following the placement of an open end ureteral catheter, percutaneous access was gained by using an 18 G access needle under C-arm fluoroscopy. The tract was dilated with Amplatz dilators (Cook Surgical, Bloomington, IN, USA) over the guidewire inserted through the needle to the collecting system with the aid of fluoroscopy. Dilation was performed up to 20 or 26 Fr in preschool children and in those aged 8–18 years, respectively. Stone fragmentation and retrieval was accomplished with the help of pneumatic or ultrasonic energy (EMS Swiss Lithoclast, Nyon, Switzerland) and grasping forceps through a 17 or 24 Fr nephroscope. Following the assessment of stone-free status with fluoroscopy and nephroscopy, a Nelaton catheter was placed as a nephrostomy tube in all patients.

Follow-up

All of the patients were evaluated with laboratory tests and KUB on postoperative day 1. The ureteral and Foley catheters were removed on the same day. Patients without fever, urine leakage and/or complaints were discharged on postoperative second day after the removal of the nephrostomy tube. Postoperative complications were classified according to the Clavien classification system [14]. Patients were recalled in 1 week and 1 month after the surgery. The assessment of final stone-free status with renal US, stone analysis and metabolic workup was routinely performed in all patients 4 weeks after the surgical procedure.

Statistical analysis:

Results were presented as the mean ± standard deviation. Data were processed using SPSS-16 for Windows (SPSS, Inc, Chicago, IL, USA). Continuous variables were compared with the Mann–Whitney *U* test. Proportions of categorical variables were analyzed for statistical significance using the Chi-square test or Fischer exact test. In all analyses, two-sided hypothesis testing was performed and probability values less than 0.05 were deemed significant.

Results

Following the initial evaluation with renal US and/or KUB, either non-enhanced CT (group-1, $n = 50$) or IVU (group-2, $n = 63$) was preoperatively performed to further outline the kidney and stone characteristics. The male/female ratio and mean age, along with the size and localization of stones were similar in both groups ($p = 0.89$, $p = 0.07$, $p = 0.57$, $p = 0.6$, respectively) (Table 1). Patients with previous renal surgery ($n = 5$), radiolucent kidney stone ($n = 4$), and contrast allergy ($n = 3$) were evaluated with CT. Retrorenal colon was incidentally detected in a 14-year-old boy evaluated with CT prior to surgery. A history of renal surgery or any other abnormalities such as horseshoe kidney or colonic distension was not present in this child.

The operative and postoperative outcomes are listed in Table 2. The operation and fluoroscopic screening time were found to be prolonged in group-2 which did not reach statistical significance ($p = 0.06$ and $p = 0.94$, respectively). The duration of hospitalization was significantly prolonged in group-2 ($p = 0.03$). The number of patients requiring multiple and single renal accesses was similar in both groups ($p = 0.75$). The number of patients treated through lower, middle and upper calyceal accesses was not significantly different in both groups ($p = 0.91$). Stone-free status was achieved in 42 (84 %) and 49 (77.8 %) of the patients in groups 1 and 2, respectively ($p = 0.41$).

Although the mean postoperative hemoglobin drop was found to be significantly higher in group-2 than in group-1 (1.5 ± 1.3 vs. 0.9 ± 0.6 g/dL, $p = 0.005$), overall complication rates were similar in both groups (10 vs. 15.9 %, $p = 0.41$). The complications observed in group-1 are listed as: bleeding requiring blood transfusion ($n = 1$, Clavien grade 3), pleural effusion requiring thorax tube placement ($n = 1$, Clavien grade 2), urinary tract infection requiring additional antibiotic treatment ($n = 1$, Clavien grade 2), urine leakage treated with stent insertion ($n = 1$, Clavien grade 3) and pelvis perforation requiring intraoperative stent placement ($n = 1$, Clavien grade 3). On the other hand, bleeding requiring blood transfusion ($n = 6$, Clavien grade 3) and postoperative transient fever ($n = 4$, Clavien grade 1) were the main complications observed in group-2 (Table 2). Transient fever (<38.5 °C) was observed on postoperative day 1 and managed with antipyretics. Urine and blood culture were negative and hemodynamics was stable in these patients. On the other hand, additional antibiotics were administered according to the urine culture in patient with UTI in group-1.

Percutaneous renal access to the upper calyx was safely performed with the combined guidance of fluoroscopy and US in the patient with retrorenal colon. Any colonic injury or related symptoms were not observed postoperatively. However, pleural effusion occurred in a patient after upper calyx access and has been managed with placement of a thorax tube.

The information about stone analysis and composition was available in 91 (80.5 %) patients (Table 2). Metabolic workup was available in 85 patients (75.2 %) of whom 50 (58.8 %) had one or more predisposing disorders identified. Of those; 27 had hypocitraturia, 11 hypercalciuria, 11 hypomagnesuria, 2 cystinuria, 3 hyperoxaluria and 2 had hyperuricemia.

Table 1 The demographic values of the patients in group-1 (patients evaluated with CT) and group-2 (patients evaluated with IVU)

	Overall	Group-1 (CT)	Group-2 (IVU)	*p*
n	113	50	63	
M/F	67/56	28/22	39/24	0.89
Mean age (years)	9.7 ± 4.4 (1–18)	8.8 ± 4.5 (1–17)	10.5 ± 4.2 (2–18)	0.07
Stone size (mm)	26.2 ± 13.4 (8–70)	24.0 ± 9.4 (8–50)	28.1 ± 15.9 (10–70)	0.57
Stone location				0.6
Pelvis	29	12	17	
Lower calyx	36	15	21	
Upper calyx	3	2	1	
Middle calyx	13	8	5	
Pelvis + calyx	20	8	12	
Staghorn	12	5	7	

Discussion

Radiologic imaging is the most crucial step in the diagnosis and planning of a proper treatment strategy and for the follow-up of patients with urolithiasis. The European Association of Urology (EAU) guidelines suggest the use of US as the first choice of imaging modality in the evaluation of pediatric patient with urolithiasis [10]. However, further functional information is required in a considerable percent of the cases before making any decision for a proper treatment modality or performing an intervention for kidney stones in this specific population. Recently published EAU guidelines recommend contrast studies (enhanced CT or IVU) in patients in whom a procedure is planned for stone removal [10].

IVU is the traditional imaging modality used in the diagnostic workup of patients with urolithiasis. However, with the increased availability and high specificity and sensitivity, CT has been the most popular and widely used imaging modality in the evaluation of stone disease [8, 9]. IVU gives information about the grade of hydronephrosis, renal function and anatomic abnormalities of the collecting system such as calyceal diverticula, duplex systems and medullary sponge kidney [8, 9]. However, it provides only two-dimensional imaging and does not give any additional information about the adjacent organs and three-dimensional configuration of pelvicalyceal anatomy. Additionally, to accurately define which calyx is located posteriorly might be difficult with IVU. Some authors [15, 16] suggest

Table 2 The perioperative outcomes are listed

	Overall	Group-1 (CT)	Group-2 (IVU)	*p*
Operation time (min)	89.3 ± 39.7 (20–240)	80.8 ± 31.0 (25–180)	96.7 ± 44.6 (20–240)	0.06
Fluoroscopy time (min)	4.4 ± 3.2 (0.2–18)	4.3 ± 2.9 (0.2–12)	4.5 ± 3.4 (0.1–16)	0.94
Hemoglobin drop (g/dL)	1.3 ± 1.1 (0.1–5.4)	0.9 ± 0.6 (0.1–3.4)	1.5 ± 1.3 (0.1–5.4)	0.005
Access number *n* (%)				0.75
Single	103 (91.2)	45 (90.0)	58 (92.1)	
Multiple	10 (8.8)	5 (10.0)	5 (7.9)	
Access location				0.91
Lower pole	80	35	45	
Middle pole	29	13	16	
Upper pole	14	7	7	
Hospitalization time (days)	4.1 ± 2.2 (1–10)	3.7 ± 2.0 (1–10)	4.5 ± 2.2 (1–10)	0.03
Success rate *n* (%)				0.41
SF	91 (80.5)	42 (84.0)	49 (77.8)	
Rest	22 (19.5)	8 (16.0)	14 (22.2)	
Complication rate *n* (%)	15 (13.3)	5 (10.0)	10 (15.9)	0.41
Bleeding	7	1	6	0.13
Fever	4	0	4	
Pleural effusion	1	1	0	
UTI	1	1	0	
Urine leakage	1	1	0	
Pelvic perforation	1	1	0	
Stone analysis				0.77
Ca oxalate	41	18	23	
Ca phosphate	24	11	13	
Mixed	12	5	7	
Uric acid	4	–	4	
Cystine	2	1	1	
Struvite	7	2	5	
Unknown	23	13	10	

that posterior calyces that are appropriate location for lower pole access are located medially. Eissner et al. [17] advocated the opposite the second lateral to the medial one is most likely the posterior calyx. In another study, Lipkin et al. [18] used air pyelogram to define the posterior calyx for proper percutaneous access under fluoroscopy during procedure. The definition of the posterior lower calyx is of utmost important in that it is accepted as an optimal access site that allows the greatest maneuverability of the rigid nephroscope and prevents vascular injury [17, 18]. Therefore, the imaging method used preoperatively plays a key role in the final outcome of the PNL as well as the decision making of the treatment modality. In the present study, the factors related to postoperative hemoglobin drop such as stone size, duration of operation, number of accesses, and dilation technique and size were not significantly different in both groups. The hemoglobin drop was significantly higher in the IVU group than the CT group (0.9 ± 0.6 vs. 1.5 ± 1.3 g/dL, $p = 0.005$). However, the rate of patients requiring blood transfusion was similar in both groups (1/50 vs. 6/53, $p = 0.13$).

CT delineates the abnormalities of the adjacent organs of the kidney. The retrorenal colon is regarded as a risk factor for colon perforation during PNL. In a recently published study, the incidence of retrorenal colon was reported as 1.7 % in 1,000 consecutive abdominal CT scan series [19]. Although many studies have been reported regarding colon perforation related to PNL in adults [20–23], there are only two studies on this nasty complication in the pediatric population [13, 24]. Gedik et al. [13] reported two (4.17 %) cases with retrorenal colon in a series of 48 patients with a mean age of 11.5 years. In this study, open conversion was required because of colon perforation in a patient with retrorenal colon who was evaluated with IVU preoperatively. Retrorenal colon was detected with CT prior to PNL in another child with Hirschsprung disease. In this study, the authors advocated that CT should be performed routinely prior to PNL to avoid any complication related to retrorenal colon. In another study, a colon perforation that was diagnosed during PNL was managed conservatively by Goger and associates [24] The authors underlined that CT was not used to prevent the additional radiation exposure in that patient, but he was referred to their clinic with IVU. In the present study, one patient was diagnosed incidentally with retrorenal colon during preoperative CT evaluation. Percutaneous renal access to the upper pole was safely performed with the guidance of US and fluoroscopy.

The risk factors associated with colon perforation during PNL have been evaluated by some authors. The presence of horseshoe kidney, female sex, chronic colonic distension, previous renal surgery, lower pole calyceal access, extreme laterally originated renal puncture and left side localization constitute a higher risk for colon perforation [20–24]. In the study of El-Nahas et al. [20] which aimed to identify the risk factors of colon injury, the presence of horseshoe kidney and advanced patient age were found to be significant risk factors. Therefore, CT is recommended as an imaging modality prior to PNL in patients with renal and anatomical abnormalities, previous renal surgery and chronic colonic distension. While five patients had previous renal surgery ($n = 5$) in the CT group, none of the patients had a renal surgery history in the IVU group.

Although the advantages of CT have become prominent in special circumstances such as anatomical abnormalities ($n = 1$), radiolucent kidney stones ($n = 4$), contrast allergy ($n = 3$) and renal insufficiency [8, 9], routine use of CT in the preoperative evaluation of kidney stone(s) in pediatric population is a controversial issue because of the risks related to radiation exposure. It is well known that pediatric patients are more sensitive to the hazardous effects of radiation because of the presence of actively dividing and growing cells. The mean radiation dose of abdominal CT is measured to be 5 mSv that equals the radiation dose of 250 chest X-rays [25]. The radiation doses increase up to 25–35 mSv in an enhanced CT [10]. On the other hand, the estimated radiation dose for IVU is 1.3–3.5 mSv that is lower than the regular-dose CT [10]. Brenner et al. [11] investigated the fatal malignancy risk related to radiation exposure in children. They underlined that a single abdomen CT would lead to 1 CT-related death per 550 scans in a 1-year-old child. Therefore, the ALARA principle should be meticulously applied to children. With technical improvements, the dose of radiation exposure related to CT has been decreased to 0.5–3.5 mSv and named low-dose CT [10]. However, there are concerns about the lack of implementation of pediatric settings of CT in radiology units especially in developing countries and lack of awareness about the effects of radiation exposure among urologists who order the imaging methods [26].

The group of Alliance for Radiation Safety in Pediatric Imaging that attempt to reduce the radiation exposure suggests using imaging modalities only when necessary [27]. In a recently published study, Johnson et al. [12] presented that, in 76 % of the cases, CT evaluation did not add any additional information both for the diagnosis as well as for the planning of the proper treatment regime in children with symptomatic urolithiasis undergoing surgery. Similarly, Ripolles et al. [28] underlined that all of the cases where the US was not successful in detecting the calculi did not require any surgical intervention. Therefore, we suggest that low-dose CT should be used in special circumstances, such as in patients with anatomical abnormalities, and history of previous abdominal or renal surgery. With the lack of pediatric settings of CT, a combination of IVU and renal US leads to lower doses of radiation exposure.

This study is limited by its retrospective nature, lack of information about the radiation exposure, the wide range of pediatric cases enrolled in the study and the fact that the study was designed at three different tertiary hospitals. The vast majority of patients were referred to our departments after an initial radiological evaluation by the primary or secondary care centers. In addition, the variations of institutional CT protocols lead to difficulty in assessing the dose of radiation exposure.

Conclusion

Children suffering from stone disease are prone to be exposed to higher dose of ionizing radiation because of repeated radiologic examination procedures, either during the evaluation or follow-up phase of the management throughout their life. CT is the best imaging modality in making diagnosis and decision of the treatment modality in patients with urolithiasis. Although CT plays a key role especially in patients with renal and anatomical abnormalities, radiolucent kidney stones, contrast allergy and renal insufficiency, IVU might be considered as an alternative imaging modality considering the lack of special situations with comparable radiation doses. The results of our study clearly presented similar postoperative success and complication rates in patients evaluated with either CT or IVU prior to PNL in pediatric cases with kidney calculi.

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

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