Section A-Research paper

Percutaneous Nephrolithotomy in Pediatric for Treatment of Renal Stones

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Abstract

The incidence of pediatric urolithiasis is increasing worldwide significantly. There are many aspects in which pediatric lithiasis differs from adult urolithiasis. Child's metabolic condition and anatomic structure contribute to medical planning and surgical planning respectively reducing the rate of surgical intervention repetition and protecting renal functions. In children, preventing the recurrence of stones has the same importance as removing them. Therefore, determination of the metabolic condition causing the stone formation is significant. The first step in treatment is increasing fluid intake, reduction of pain on diagnosis, by analgesics and antispasmodics. Asymptomatic small stones (<4–5 mm) may pass spontaneously. Medical expulsive treatment has been reported to increase the rate of stone passage, So medical expulsive treatments promoting stone passage (α-blockers) may be used in children. Supersaturation of calcium and oxalate or reduced levels of inhibiting citrate or magnesium are responsible for calcium oxalate stones formation. Calcium oxalate stones are common in children (70%). Minimally invasive surgical options that are highly effective in providing stone-free status reduced the interest in SWL; however, minimally invasive techniques and SWL have comparable stone-free rates. Moreover, the advantages of SWL include shorter post-procedural hospitalization, detection of less post-procedural readmission rates and is cheaper. Although SWL considered first line in treatment of pediatric renal stones, PNL can have a significant role in certain cases. According to the European Association of Urology guidelines, PNL is recommended as primary treatment option for large renal stones (> 20 mm). Also, for stones > 10 mm stones of the lower renal pole. SWL resistant stones as well

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The incidence of pediatric urolithiasis is increasing worldwide significantly. There are many aspects in which pediatric lithiasis differs from adult urolithiasis. Child's metabolic condition and anatomic structure contribute to medical planning and surgical planning respectively reducing the rate of surgical intervention repetition and protecting renal functions **(1)**

Various factors affect the incidence of stone disease, such as race, geographical region, socioeconomic conditions, and dietary habits.

Stone disease is endemic in the MENA region. High consanguinity and hot climate have been associated with the endemicity of urolithiasis, but it is accepted that genetic and racial characteristics affect the epidemiology**(2).**

Metabolic problems such as Hypercalciuria and hypocitraturia are the most noted risk factor associated with the development of pediatric stone **(3).**

Urinary tract infection is also a risk factor for stone formation which may develop secondarily to congenital anomalies of the urinary system. However, congenital obstructive anomalies (ureteropelvic junction stenosis,

posterior urethral valve, and duplication anomalies) can contribute to stone formation due to stasis even without presence of infection **(3).**

Stone formation is affected by dietary habits as well. Increased sodium intake predisposes to stone formation by increasing calcium excretion in urine. A high-protein diet increases the urinary excretion of uric acid, oxalate, and calcium, leading to decrease in urinary pH and precipitation of calcium oxalate. Urinary citrate level is the most potent inhibitor of crystallization, which is reduced by excessive intake of protein **(4).**

Many studies have focused on the effect of obesity on stone formation, but there is no consensus.

Risk factors for stone formation vary with difference in age groups. Neonatal period risk factors include a history of hospitalization in the neonatal intensive care unit, prematurity, and low birth weight. The use of nephrotoxic medications and diuretics is also a risk factor in this age group. Chronic bowel diseases become a risk factor later in life, due to increase in absorption of oxalate in the intestine (Baştuğ & Düşünsel, 2012). The use of anticonvulsant (topiramate) and ketogenic diet during childhood in children who suffer seizures, is known to increase urinary stone formation after 2 years **(5).**

Pediatric stone disease is frequently seen secondarily to monogenetic causes **(6).**

Nephrocalcinosis or stone recurrence within a year is the most significant sign associated with genetic stone disease. Delayed diagnosis and treatment of patients with stone disease with identified genetic predisposition represent a high risk of chronic renal failure. Therefore, it is important for clinicians to know the genetic epidemiological factors and make a diagnosis.

Table 1 summarizes the genetic causes associated with pediatric stone disease **(3).**

Table 1

Hereditary causes of renal stones

Disease	Type	Inheritance	Gene and gene location	Metabolic Features
Cystinuria				
	Type A	AR	*SLC3A1*	Elevated urine cystine, cystine stone ± calcium stone
	Type B	AR-ID	*SLC7A9*	
Hyperoxaluria				
	Type 1	AR	*AGXT*	Elevated urine oxalate, Ca oxalate monohydrate stones
	Type 2	AR	*GRHPR*	
	Type 3	AR	*HOGA1*	
DENT Disease				
	DENT 1	X-LR	*CLCN5, Xp11.23*	Fanconi syndrome, hypercalciuria, glycosuria, aminoaciduria, phosphaturia, Nephrocalcinosis
	DENT 2	X-LR	*OCRL, Xq26.1*	Additionally, cataracts, mental retardation, muscular hypotonia, nephrotic proteinuria, metabolic acidosis
Batter Syndrome				
	Type 1	AR	*SLC12A1, 15q21.1*	Classical presentation; hypokalaemic metabolic alkalosis, renal salt wasting, hypercalciuria, increased renin, secondary hyperaldosteronism, nephrocalcinosis
Antenatal presentation; polyhydramnios, renal salt wasting, prematurity, hypercalciuria, nephrocalcinosis				
	Type 2	AR	*KCLJ1, 11q24.3*	
	Type 3	AR	*CLCNKB, 1p36.13*	
	Type 4a	AR	*BSND, 1p32.3*	
	Type 5	X-LR	*MAGED2, Xp11.21*	
Xanthinuria	AR	XDH	*Xanthine stones, hypouricemia*	

Disease	Type	Inheritance	Gene and gene location	Metabolic Features
Renal hypouricemia		AD or AR	*URAT1, SLC22A12, GLUT9, SLC2A9*	Hypouricemia, hypercalciuria, uric acid or calcium stone
Infantile idiopathic hypercalcemia		AR-ID	*CYP24A1*	Hypercalcemia, hypercalciuria, nephrocalcinosis, reduced calcitiriol metabolism, increased 1.25(OH)2D3 levels
Infantile hypercalcemia 2		AR	*SLC34A1, 5q35.3*	Hyperkalemia, hypercalciuria with nephrocalcinosis, hypophosphatemia, low PTH and increased 1.25(OH)2D3 levels
Autosomal dominant hypocalcemia hypercalciuria		AD	*CASR, 3q21.1*	Hypocalcemia, hypercalciuria, normal PTH level, calcium stone
Familial hypocalciuric hypercalcemia		AD	*CASR*	Hypocalcaemia, hypercalciuria normal to high PTH level
Autosomal dominant absorptive hypercalciuria		AD	*ADCY 10*	Hypercalciuria
Hereditary hypophosphatemic rickets with hypercalciuria		AR-ID	*NPT2c, SLC34A3*	Hypophosphatemia, elevated 1,25(OH)2D3 level
Primary distal renal tubular acidosis				
		AR	*ATP6V1B1, ATP6V0A4*	Impaired urine acidification, ± metabolic acidosis, calcium phosphate stones
		AD	*AE1*	
Primary proximal and distal renal tubular acidosis		AR	*CA2*	Impaired urine acidification, ± metabolic acidosis, calcium phosphate stones
Adenine phosohoribosyltransferase deficiency		AR	*APRT*	2,8-dihydroxyadenine stones
Familiar hypomagnesemia with hypercalcuria and nephrocalsinosis		AR-ID	*CLDN16, 3q28, CLDN19, 1p34.2*	Hypercalciuria, hypomagnesemia, hyperkalcemia, nephrocalsinosis
Calcium oxalate nephrolithiasis		Unknown	*SLC26A1*	Calcium oxalate nephrolithiasis
Phosphoribosyl pyrophosphate synthetase superactivity		X-LR	*PRPS1*	Hyperuricemia, uric acid stones
Hypophosphatemic nephrolithiasis/osteoporosis		AD	*NHERF1, SLC9A3R1*	Calcium stones, low bone density
Pseudohyperaldosteronism type two (PHA2 PHA2B)		AD	*WNK4, 17q21.2*	Hyperkalaemia, metabolic acidosis, ammonium excretion, hypertension

AR, autosomal recessive; AR-ID, autosomal recessive incomplete dominance; AD, autosomal dominant; X-LR, X-linked recessive [modified **(3).**

Non surgical treatment of pediatric renal stones

Prevention

In children, preventing the recurrence of stones has the same importance as removing them. Therefore, determination of the metabolic condition causing the stone formation is significant. The first step in treatment is increasing fluid intake, reduction of pain on diagnosis, by analgesics and antispasmodics. Asymptomatic small stones (<4–5 mm) may pass spontaneously. Medical expulsive treatment has been reported to increase the rate of stone passage, So medical expulsive treatments promoting stone passage (α-blockers) may be used in children **(7).**

Medical therapeutic interventions

Supersaturation of calcium and oxalate or reduced levels of inhibiting citrate or magnesium are responsible for calcium oxalate stones formation. Calcium oxalate stones are common in children (70%) **(1).**

Hypercalciuria: Hypercalciuria is the most common problem associated with urolithiasis **(1).**

In idiopathic hypercalciuria, an underlying cause cannot usually be detected. Although 45% of patients have a family history of stones, specific genetic mutations are rarely detected. But in hypercalcaemic hypercalciuria, serum calcium levels are increased due to increased bone resorption or gastrointestinal hyperabsorption.Hypercalcemia might occur due to renal tubulopathies associated with Bartter syndrome and Fanconi syndrome **(8).**

The treatment includes restriction of calcium intake by keeping the daily calcium amount within the normal range. Another risk factor for stone formation is low calcium consumption **(1).** Hydrochlorothiazide and other thiazide diuretics may be initiated. However, the hypocalciuric effect may be reduced in long-term use. Furthermore, it may lead to disturbance in electrolytes as hypokalaemia, hypocitraturia, hyperuricemia, and hypomagnesemia. Monitoring blood and serum levels should be done at regular intervals. When citrate levels are reduced or when hypercalciuria persists despite other treatment protocols, citrate treatment may be considered **(1).**

Hyperoxaluria: Only 10% of oxalate is taken through diet. Hyperoxaluria can be caused by genetic disorders (primary hyperoxaluria), intestinal disease (enteric hyperoxaluria) or excessive consumption of foods high in oxalate (dietary hyperoxaluria). Primary hyperoxaluria is a rare and life-threatening genetic disorder caused by autosomal recessive enzymatic defects in glyoxylate metabolism in the liver due to mutations in the genes of AGXT, GRHPR, and HOGA1. Increase in calcium oxalate crystals may supersaturate in urine and kidney, leading to stone formation and chronic kidney disease **(1), (8).** Enteric hyperoxaluria is a distinct entity that usually occurs in the conditions of fat malabsorption, such as short bowel syndrome, inflammatory bowel disease, pancreatitis, and cystic fibrosis **(1)**. Treatment includes restriction of dietary intake of oxalate. Other dietary recommendations are low fat diet, maintaining an adequate calcium intake (RDA), and large fluid intake. Pyridoxine helps to reduce urinary oxalate levels, especially in primary hyperoxaluria. The addition of citrate to the treatment is beneficial for increasing the inhibitory activity **(1) (2).**

Hypocitraturia: Citrate exerts its inhibitory effect by directly binding to calcium or inhibiting the growth and/or aggregation of the calcium oxalate and calcium phosphate crystals. Low urinary citrate level is one of the main reasons for the formation of calcium stones in children (30%–60%). Hypocitraturia is asymptomatic and not associated with a metabolic problem. It may accompany metabolic acidosis, distal tubular acidosis, or diarrhoea syndromes. Excessive protein and salt consumption cause a reduction in citrate levels.

Potassium citrate is used in hypocitraturia treatment. The side effects of potassium citrate include nonspecific gastrointestinal symptoms. Dosing should be performed with caution in patients with hyperkalaemia and chronic renal failure **(1).**

Cystinuria: This is an autosomal recessive disease characterized by cystinuria due to defective tubular absorption of dibasic amino acids, namely, cystine, lysine, arginine, and ornithine. Cystinuria is seen in 2%–6% of all children with urinary tract stone disease. The solubility of cystine in urine is low and pH dependent (pH<7). It may accompany hypercalciuria, hypocitraturia, and hyperuricosuria, leading to the formation of mixed-type stones. Imaging of the cystine stones in plain X-rays is difficult due to its semiopaque structure, and SWL treatment is difficult due to its hard structure **(1).** These children have a high risk of stone recurrence **(9).**

Treatment includes increasing fluid intake to increase the solubility of cystine by reducing its saturation and urine alkalinisation. The goal is to maintain the pH level above 7.0–7.5 using potassium citrate. In case of treatment failure, second-line agents include α-mercaptopropionyl glycine and D-penicillamine. The medications' side effects include mild gastrointestinal complaints (reduced taste and smell), fever, and rash. However, caution should be exercised for serious side effects, including bone marrow suppression, nephrotic syndrome, and epidermolysis **(1).**

Uric acid stones: Uric acid is the end-product of purine metabolism. Uric acid is not soluble in acidic urine (pH<5.8); therefore, it precipitates, leading to uric acid stone formation. Serum uric acid levels are usually normal in familial or idiopathic hyperuricosuria. However, pathologies characterized by excessive uric acid

production (e.g., myeloproliferative diseases and pathologies associated with cell destruction) are accompanied by hyperuricemia. Hyperuricosuria is also associated with a high-protein diet and purine intake. Uric acid stones are nonopaque. USG and/or low-dose, nonenhanced CT examination is used for diagnosis and treatment planning **(1).**

Citrate preparations are used for the treatment. The goal is to maintain the urinary pH at 6–6.5. In case of treatment failure or in myeloproliferative diseases, allopurinol is initiated. Rash, diarrhoea, and eosinophilia may develop during allopurinol use **(10).**

Infection stones: These account for 5% of the pediatric urinary tract stone diseases. Urinary tract obstruction or functional anomalies may lead to the development of *Proteus, Klebsiella*, and *Pseudomonas* (known as urease enzyme-producing bacteria) infections. These microorganisms increase urinary pH, causing struvite (magnesium ammonium phosphate) and calcium phosphate apatite supersaturation and leading to the formation of infection stone(Wein, Kavoussi, Novick, Partin, & Peters, 2011). The main principle of the treatment is treating the urinary tract infection and removing the stone from the system. The anatomic or functional reason causing urinary tract infection should be eliminated **(1).**

Invasive treatment of paediatric renal stones

Shock wave lithotripsy

According to the EAU/ESPU guidelines, SWL is the first-line treatment protocol for the majority of the renal and proximal ureteral stones **(1).** The success rate is between 59% and 94%. Out of the many factors that affect the outcome of the process, stone size is considered the most important one. The larger the stone, the lower the success rate and the higher the rate of retreatment. A general observation on the relation between stone localization and stone-free rate is that SWL is more effective in stones localized in the renal pelvis and proximal ureter than the calyceal stones **(11).** Many factors affecting success are evaluated together using nomograms. In their nomogram, **Onal et al. (12)** reported the factors increasing the success rate as being under 5 years of age, stone load being <1 cm, localization of the stone (pelvic or upper calyceal stone; only in females), absence of a history of stone treatment in the same side and having a single stone. Other than the factors included in this nomogram, a history of open stone surgery has been reported to reduce the success rate of SWL, especially in lower calyceal stones. In a similar nomogram developed by **Dogan et al (13),**the size of the stone, age, sex, localization, and history of stone treatment in the same side have been reported as factors determining the stone-free success rate. Subsequent studies demonstrated that both nomograms are useful in determining the stone-free rate of SWL in the population in which they are developed and in other endemic populations **(13).**

The complication rate after SWL is between 1.5% and 35% **(14).** The most frequent complications are renal colic and stein Strasse. Stein Strasse is usually seen in children with a high stone load, and the treatment is performed using SWL. pre-SWL stenting decreases the formation of stein Strasse. Other than this, urinary tract infection, subcapsular hematoma, and renal parenchymal injury are rarely seen. The information on the long-term effect of SWL on the kidneys in children is lacking. A small number of studies indicate that overall, it does not affect renal development; there is a study reporting that longitudinal kidney growth is affected negatively **(12).**

Minimally invasive surgical options that are highly effective in providing stone-free status reduced the interest in SWL; however, minimally invasive techniques and SWL have comparable stone-free rates. Moreover, the advantages of SWL include shorter post-procedural hospitalization, detection of less post-procedural readmission rates and is cheaper **(1).**

Percutaneous nephrolithotomy in pediatric for treatment of renal stones

Indication of PNL in children

Although SWL considered first line in treatment of pediatric renal stones, PNL can have a significant role in certain cases. According to the European Association of Urology guidelines, PNL is recommended as primary treatment option for large renal stones (> 20 mm). Also, for stones > 10 mm stones of the lower renal pole. SWL resistant stones as well **(15).**

The main indications for PNL could be grouped
as follows:

1. Stone
    a. staghorn calculus
    b. multiple calculi
    c. renal pelvis stone >2 cm
    d. Lower pole stone >1 cm
    e. stone plus a foreign body
    f. composition (cysteine, calcium oxalate monohydrate)
2. Anatomic abnormalities
    a. UPJ obstruction
    b. ureter obstruction
    c. infundibular stenosis
    d. calyceal diverticulum
3. Patient
    a. obesity
    b. scoliosis
    c. vascular malformation
    d. preference
4. Treatment failure
    a. ESWL
    b. ureteroscopy **(3)**

Contraindication PNL in children

1. Infection
2. High blood pressure
3. Bleeding disorders

PNL is contraindicated during anticoagulant use, untreated urinary tract infection and mass in the kidney **(16).**

Technical aspects of PNL in children

Standard & Mini PCNL

Classical (standard) PCNL in children required a 30FG Amplatz sheath and employed a 24FG nephroscope. The advantage of such generous access was very high (>90%) stone clearance rates in a single session but was not easily applicable in small children, where there was the risk of renal damage or excessive bleeding requiring blood transfusion.

The miniaturization of equipment for PCNL in pediatric patients has facilitated its use in all age groups and has also provided an opportunity to treat smaller stones that would otherwise be candidates for ESWL or RIRS. PCNL remains the gold standard treatment for large renal stone >2 cm and complex stones (Chen, Deng, Duan, Zhu, & Zeng, 2019; Radmayr et al., 2018).

Retrospective comparative studies have indicated that mini PCNL provides at least similar stone-free rate for moderate-size stones in comparison to RIRS (Pelit et al., 2017). (ElSheemy et al., 2016) also demonstrated superior results with mini PCNL (14FG) for renal calculi of 10–25 mm in preschool children in comparison to ESWL with comparable complication rates but a longer hospital stay .

In a large retrospective multi-institutional cohort including 1,205 pediatric renal units who underwent PCNL, the use of a sheath size >20FG was an independent predictor of complications and bleeding necessitating transfusion (Bülent Önal et al., 2014), and the association between a larger tract and greater blood loss has been confirmed in several other reports (Guven et al., 2013), (Unsal, Resorlu, Kara, Bozkurt, & Ozyuvali, 2010), (Celik et al., 2017)). Consistent with these reports, it was demonstrated that PCNL with a smaller tract <24FG results in lower blood loss without a decrease in success rate (Mesrur Selcuk Silay, Jonathan S Ellison, Thomas Tailly, & Paolo Caione, 2017).

Similarly, in our study of 1,135 renal units, we have also observed that blood transfusion requirement was significantly less in all age groups when <20FG sheath was used. Blood transfusion rate was higher in children with larger stone burdens and in younger children with lower allowable blood loss (Rizvi et al., 2016).

The other important factors to prevent bleeding are an understanding of the pelvicalyceal and intrarenal vascular anatomy and the skilled application of a proper technique. The selection of the puncture site should be according to the stone location. The puncture is performed through the fornix, in the direction of the infundibulum to avoid trauma to the blood vessels adjacent to the infundibulum. In addition, while manipulating the nephroscope during stone fragmentation and retrieval, it is important to avoid excessive torque and the creation of false passages which traumatize the parenchyma.

There is still no strict standardized nomenclature for PCNL. Various classifications have been proposed and published in the literature, which include standard/conventional PCNL (22–30 FG), mini PCNL (11–22 FG), minimally invasive PCNL (MIP) (9.5–26 FG), Chinese mini PCNL (14–20 FG), ultra mini PCNL (11–13 FG), micro PCNL (4.8 FG), mini micro PCNL (8 FG), and super mini PCNL (10–14 FG). The first documented mini PCNL was by Jackman using an 11 FG peel away vascular access kit (95). Since then with the growing diversity of the miniaturized PCNL, the terminology mini PCNL has been loosely used for tract size 11–22 FG, and thus, mini PCNL is poorly defined (Janak Desai et al., 2013; Jones, Bennett, Aboumarzouk, Griffin, & Somani, 2017; Sabnis et al., 2013; Wright, Rukin, Smith, De la Rosette, & Somani, 2016; Zeng, Zhu, & Lam, 2018).

We also initially started off with adult-sized nephroscopes (27 and 24FG) and gradually reduced it to 20, 18, and 15FG. Currently, we routinely use mini PCNL utilizing a 12FG nephroscope with a straight channel and offset lens or a 9.8FG cystoscope through a 16FG working sheath in most situations (Rizvi et al., 2016).

We occasionally employ rigid pediatric cystoscopes 6/7.5–10.5FG through a 12FG Amplatz sheath. These may be called an ultra mini PCNL. These scopes are readily available in most pediatric urology units and are sturdy, rigid, and reusable and, therefore, cost-effective. These ‘scopes have an added advantage for use in the narrow and difficult anatomy of small children and could be an economic compromise to microperc.

Microperc

The term microperc refers to a system in which the telescope, working channel, and irrigation are combined in a needle, which can be as small as 4.8FG and requires only a single puncture, thereby avoiding the need for tract dilatation (Bader et al., 2011). The main advantage of microperc in children is to minimalize bleeding.

The technique may only be used in very selected cases, but it allows direct puncture into the relevant calyx via the all-seeing needle and direct fragmentation/powdering of the stone in situ. With no need for tract dilatation, less radiation exposure, and, consequently, less operating time, it should result in lower complication rates.

There are certain limitations of the microperc; first, the vision gets compromised more quickly with the slightest bleeding and stone dust. The vision may not be as good as in mini PCNL because the irrigation fluid is pushed intermittently, and there is no regular outflow passage. Necessary precautions should be taken to control the intrarenal pelvic pressure at every step of the procedure by placing a large caliber ureteric catheter in the renal pelvis, and saline irrigation should be carefully monitored during the procedure. It has been demonstrated that the intrarenal pressure is significantly higher in the micro PCNL compared to the standard PCNL(Tepeler et al., 2014).

Secondly, if the stone fragments migrate into a different calyx, it becomes impossible or difficult to access them. Thirdly, microperc instruments are costly and meant to be disposable (Wright et al., 2016), making their universal use in emerging economies, where much of the stone burden in children lies, extremely difficult.

The use of very small tracts has to be individualized on the basis of stone location and burden and balanced against the limitation of low irrigation fluid flow, impaired visualization, and limitation in the use of disintegration technology and grasping forceps.

The complications of PCNL in children have been reported from 9 to 27.7% (Jones et al., 2017; Bülent Önal et al., 2014). Studies on micro PCNL (tract size <10 FG) reported a complication rate of 9% with a higher incidence of renal colic. Studies on ultra mini PCNL (tract size 10–14 FG) reported 14% complications with higher incidence of hematuria, renal extravasation, or renal pelvic perforation. A multi-institutional study of 1,157 children treated with PCNL (nephroscope 17 FG to 26 FG and URS 9.5 FG) reported a complication rate of 27.7%, where 7.7% were intraoperative and 20% were postoperative complications. The majority of the complications were Clavien grade I and II, and there were no grade IV and V complications (Bülent Önal et al., 2014) (Jones et al., 2017). Most of the series have limited numbers; therefore, risk factor analysis is difficult.

Guidance for percutaneous puncture

1- Fluoroscopic antegrade approach:

The high-quality of current C-arm fluoroscopic equipment and the familiarity among urologists of fluoroscopic imaging has led to its preferred use in percutaneous renal access, particularly in the operating room. Surgeons prefer fluoroscopy for guidance due to the clear visibility of the needle and guide wire. For percutaneous renal surgeries such as PCNL or endopyelotomy, fluoroscopic monitoring is very important for the entire procedure during renal access, guide wire manipulation, tract dilatation, residual stone evaluation, and post-procedural nephrostogram. The renal collecting system opacified with contrast following retrograde ureteral catheter placement, the C-arm is rotated approximately 30º towards the surgeon once the preferred calyx has been selected. With this technique, the axis of the C-arm is in the same central posterior plane as the kidney and therefore provides a direct end-on view of the posterior calyces. The needle is advanced in the plane of the fluoroscope beam with the C-arm in the 30º direction. The appropriate direction of the needle is confirmed by obtaining a 'bull's eye sign' on the fluoroscopic monitor, which is, due to the needle hub, superimposed on the needle shaft, and the plane of the needle is the same as that of the X-ray beam (Resorlu et al., 2012)

2- CT guided approach:

Computed tomography (CT) guidance is another alterative for management of complex cases. This imaging guidance is essential in patients with specific medical conditions such as morbid obesity, splenomegaly, hepatomegaly, severe skeletal anomalies like scoliosis or kyphosis, or who have had previous major intra-abdominal surgery, and in patients with minimal or no dilatation of renal pelvis (Duty, Okhunov, Smith, & Okeke, 2011)

CT-guided puncture may provide a better mapping for a supracostal PCNL approach(Ravi Munver, Fernando C Delvecchio, Glenn E Newman, & Glenn M Preminger, 2001) .

3- Sonar guided percutaneous nephrolithotomy

Performing mini‑PNL under the guide of ultrasonography (US) can be a feasible, harmless and effective alternative to fluoroscopy when used by experienced surgeons. Using US also decreases the radiation exposure to the surgeon and patient. (Hosseini, Hassanpour, Farzan, Yousefi, & Afrasiabi, 2009)

Technique starts with ureteral catheter 3–4 Fr insertion into the kidney and tapping it to urethral Foley catheter after insertion. The patient's position changes to a prone position. Then, visualisation of the pelvicalyceal system (PCS) under the Colour‑Doppler US guide. Using a one‑shot dilatation technique, passing an 18G access needle into the targeted calyx by attaching the needle to the curved US probe.

Removal of stylet and 0.035‑inch J‑tipped guidewire introduction into the targeted calyx. Incision of the skin and an 8 Fr polyurethane dilator first dilated the nephrostomy tract. Then, the replacement with Alken guide, and a single 18 Fr Amplatz dilator passing on the Alken guide, on which an Amplatz sheath introduction into the PCS follows. The Amplatz sheath and working guidewire are left in place.

After that, rigid nephroscopy performance.

During renal access, all the processes is monitored under the guidance of US without using fluoroscopy. Lithotripsy is done with pneumatic lithoclast, and its particles are removed by forceps.

Stone‑free status is checked at the end of the operation by the US. If no significant perforation occurred, no stone residue is seen, bleeding is minimal and access is done with a single tract, tubeless mini‑PNL is an option. After 12–24 h, both ureteral stent and urethral Foley catheter are removed.

In cases of any inflammatory ureteric polyp due to stone obstruction, pelvic ureteric junction obstruction, significant residual stone and concurrent lithotripsy of ipsilateral ureteric stone, Double‑J stent insertion is an option

Complications of PNL: divided into

I Complications related to the access*:*

1 Parenchymal bleeding*:* A common source for a bleeding during **PNL** is the tract itself, this bleeding can be prevented by puncture in lower calyx with limited movement and angulation of dilatation system ***(20).***

If bleeding impairs the endoscopic view significantly, the procedure should be terminated and a nephrostomy should be placed and clamped for 40-60 minutes to provide a tamponade within the collecting system to provide hemostasis. The second procedure can be carried out after 24 or 48 hours. However, in case of persistent significant bleeding, renal angiography should be performed with the possibility of a superselective embolization ***(20).***

Lesions of the vascular system can also lead to late bleeding complications arising from pseudoaneurysm or arteriovenous fistulas and usually need therapeutic intervention.

a) Pleural injury:

When supra-11th rib access is performed, the incidence of intrathoracic complications increases to 23.1% while it is 1.5% to 12% with above-12th rib approach and 0.5% for subcostal access **(21).**

b) Colonic perforation:

Colonic perforation is a rare complication during **PNL(22)** found that only 2% of the patients had a retrorenal colon when in the supine position that increased to 10% in the prone position, resulting in a 0.2% to 0.5% rate of colonic injury during **PNL**. The diagnosis of colonic injury is usually elusive owing to the variability of symptoms and signs, which can occur immediately or several days after the procedure. Unrecognized colonic injury can lead to abscess formation and nephrocolic or colocutaneous fistula **(23).**

Intraperitoneal fecal soiling may also develop peritonitis **(23).**

The identification of a retrorenal colon is of outmost importance in the prevention of colonic perforation during establishment of the percutaneous tract. Preoperative abdominal **(CT)**, especially with the patient in the prone position, can determine the relation between the colon and kidney(Skoog, Reed, Gaudier Jr, & Dunn, 1985). Preoperative CT is helpful in patients with a high risk of retrorenal colon such as those with previous renal surgery, horseshoe kidneys, chronic colonic distension, spinal cord injury, and myelomeningocele **(24).**

c) Hepatic and splenic injury:

The liver and spleen may also be at risk of being injured during percutaneous access. In the absence of splenomegaly or hepatosmegaly, injury to these organs is extremely rare with subcostal and lower pole punctures. The risk may be somewhat greater with upper pole punctures **(25).**

II Complications related to the stone removal:

A) Septicaemia:

Following **PNL**, fever is significantly higher and more frequent in patients with infected urinary stones than in those with sterile stones ***(20).***

In cases where septicemia has occurred, the patient should receive intensive care therapy including forced diuresis, antibiotic treatment, optimal renal drainage, and electrolyte control ***(20).***

e**B) Extravasation and fluid absorption:**

The common source for extravasation and fluid absorption is a perforation of the collecting system. Methods of prevention include manipulation only under X-ray or endoscopic control, use of an open or continuous flow system, and use of normal saline as irrigate.

However, even with these precautions a high-fluid volume syndrome may develop. Therefore, if the fluid discrepancy (inflow/outflow) exceeds 500 ml, the procedure should be stopped and a nephrostomy placed. Monitoring of the serum electrolytes is mandatory ***(26).***

III Late post operative complications:

A) Renal function impairment:

An early follow-up study showed no renal function deterioration on split 131I hippuran clearance studies one year following **PNL** ***(27)***.

B) Urinomas:

Small-asymptomatic-urinoma are absorbed without late sequel. Larger and symptomatic urinoma require ultrasound- or CT-guided drainage ***(28)***.

Most important factors to prevent complications during PNL:

Preoperative radiological evaluation, optimal puncture through the calyx, ultrasound control if possible, a traumatic dilation under continuous X-ray control, minimal angulation of nephroscope, use of a flexible pyeloscope for stone parts in upper calices and Know when to stop and when to retreat ***(20).***

Classification of PNL comlications:

Stratifying complications of **PNL** as major and minor ones, ***(29).*** reported major complications (death, bleeding necessitating intervention, significant infection, urinary tract injury, and injuries to adjacent organs) in 6% of patients and minor complications (postoperative fever, bleeding necessitating transfusion, extravasation, tube dislodgment, pneumonia, prolonged urine drainage from the flank, in > 50% of patients undergoing PNL.

(Clavien, Sanabria, & Strasberg, **(30)** proposed general principles to classify complications of surgery, and recently the same group modified this classification focusing on life-threatening complications and long-term disability.

Classification of surgical complications according to the Modified Clavien system (30) :

Grade 1: Any deviation from the normal postoperative course without the need for interventions whether they were in the form of pharmacologic treatment or surgical, endoscopic, and radiologic. Allowed therapeutic regimens are drugs as antiemetics, antipyretics, analgesics, diuretics, electrolytes, and physiotherapy. Wound infections opened at the bed side are also included in this grade as well.

Grade 2: Complications requiring pharmacologic treatment with drugs other than such allowed for grade 1 complications. Blood transfusions and total parenteral nutrition are also included.

Grade 3: Complications requiring surgical, endoscopic, or radiologic intervention.

Grade 3a: Intervention not under general anesthesia.

Grade 3b: Intervention under general anesthesia.

Grade 4: Life-threatening complications (including central nervous system complications) requiring intensive care unit stay.

Grade 4a: Single organ dysfunction (including dialysis).

Grade 4b: Multi-organ dysfunction.

Grade 5: Death of the patient.

Complications of percutaneous nephrolithotomy classified according modified Clavien system: ***(31).***

Grade 1*: Fever and transient elevation of serum creatinine*

Grade 2*: Blood transfusion, urine leakage* <12hours ,infections requiring additional antibiotics(instead of prophylactic one)
,wound infection ,urinary tarct infection and pneumonia

Grade 3:

Grade 3a: Double stent placement for urine leakage >24hours, double J stent placement for UPJ and pelvis injury, urinoma, pneumothorax and retention/cloic due to blood clots

Grade 3b: Ureter-bladder stone, calyx neck stricture, UPJ obstruction, AV fistula, perirenal hematoma needing intervention, perinephritic abscess and perioperative bleeding requiring quitting operation.

Grade4:

Grade4a: Neighboring organ injury, myocardial infarction, nephrectomy and lung failure

Grade4b: Urosepsis

Grade5: Death of patient.

The most frequently seen PNL complication is haemorrhage, and blood transfusion becomes necessary in 10% of the patients.

Other PNL complications include fever and persistent urine leaks from the nephrostomy area **(32).**

PNL complication rate in childrenis 27%.(2-) Operative time, sheath size, mid-calyceal puncture, and partial staghorn stone formation are factors affecting complication rates **(12).**

Moreover, multiple punctures are necessary for cystine and infection stones, but stone composition does not affect the success rate **(32).** PNL is also an effective treatment method in children with a history of open surgery for stones. However, because the risk of colon injury is increased in this group, preoperative CT is essential for anatomical evaluation **(12).** Clinical classifications can be used to evaluate many factors before PNL. The Guy's stone scoring system is one of these classifications. This system is useful in estimating the success rate in children. High Guy's stone score is associated with a reduced success rate **(33).**

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