CONTEMPORARY MINIMALLY INVASIVE TREATMENT OF

UPPER URINARY TRACT STONES

Editors

Kemal Sarıca & Ümit Yıldırım

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Health Sciences

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Contemporary Minimally Invasive Treatment of Upper Urinary Tract Stones

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From the Editors;

Urolithiasis is a benign but painful disorder that places a heavy strain on the healthcare systems of all countries, especially those where it is endemic. The disease is becoming more common all over the world, and without medical intervention, the recurrence rate within 5 years of the first stone incident is rather significant, ranging from 35% to 50%. The condition can cause irreparable morphological/functional abnormalities in the affected kidneys if it is not detected and treated with proper medicinal and surgical treatments at the appropriate time. That is to say, there is evidence to suggest that it contributes to the development of chronic and terminal renal disease.

Thanks to significant developments in endovision and surgical instruments, numerous minimally invasive treatment options are now available. These techniques have allowed for effective stone treatment with minimal nephron loss after surgery. Miniaturizing the instruments also reportedly results in significant decreases in bleeding and other complications.

In this regard, extracorporeal shock wave lithotripsy continues to play an important role in modern medicine. However, progress in laser stone disintegration has surgeons leaning toward minimally invasive surgical procedures. Endoscopic combined intrarenal surgery, which has been shown to significantly increase postoperative stone-free rates, is rising in popularity and is now included in recommendations.

Our goal in writing this book was to provide a comprehensive overview of endoscopic stone removal (ESWL) and other minimally invasive surgical techniques currently employed to treat the stone disease of the urinary system in contemporary endourology.

Editors
Prof. Dr. Kemal SARICA
Dr. Ümit YILDIRIM

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CHAPTER I

EXTRACORPOREAL SHOCK WAVE LITHOTRIPSY

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1. Introduction:

The first kidney stone surgery in history was performed on a French prisoner in 1474, with the promise that he would be free if he lived after the operation. As a result of the operation's success, the prisoner gained his freedom. Milan Kardan performed the first demonstrable stone surgery in 1550 on a young girl with a lumbar abscess, and 18 stones were removed from her kidney. (1)

In parallel with technological development, new treatment methods have been discovered for urinary system stone disease. Extracorporeal shock wave lithotripsy (ESWL), retrograde intrarenal interventions, percutaneous nephrolithotomy (PNL), ureteroscopic interventions, laparoscopic treatments, and open surgical procedures. This section will talk about ESWL, a non-invasive approach for treating urinary system stone disease.

2. Development of ESWL and Technical Information:

Due to its simplicity of use, lack of invasiveness, ability to be administered as an outpatient procedure, and low morbidity rates, extracorporeal shock wave lithotripsy has emerged as the therapy of choice for urinary system stone disease. The first ESWL device, HM-1 (Human Model 1), was developed in 1980 by Dornier, an aircraft company. Chaussy et al. In 1982, they used this ESWL device on 60 dogs and 21 humans. (2) In 1984, Dornier HM-3 (Dornier MedTech, Wessling, German), which can perform ESWL in a water tank under general and spinal anesthesia, was developed and put into clinical use with FDA (Food and Drug Administration) approval. (3) Thanks to the second-generation lithotripters, low cost, painless application, easier use, and better focus are provided. Between 1990 and 1992, third-generation lithotripters with better focus and wider energy range were produced. These devices have become compact devices with single fluoroscopy, ultrasonography, or both. (4) Electrohydraulic, electromagnetic, and piezoelectric energy sources are the three energy systems employed in ESWL devices to produce shock waves. The device's generated shock wave is focused on the stone and creates small cracks in the stone. Small cracks coalesce, and breakage occurs. The main theories of stone fracture are pressure-induced crack formation (tear-shear forces), spallation, cavitation, acoustic compression (squeezing), and dynamic fatigue mechanisms. As a result of the studies on these theories, the critical factors that affect the breaking of the stone are the way of energy production and the width of the focus. (4–7)

After the development of communication methods, it is easier to reach people, and the accessibility of imaging techniques has increased the early diagnosis rates in urinary system stone disease. In this way, determining the size of urinary system stones before they grow has increased the applicability of ESWL treatment. The efficiency of the lithotripter, the size and placement of the stones (ureteral, pelvic, and calyx), the substance (hardness) of the stone, and the patient's physical state and cooperation are all factors that affect the success of ESWL. (8)

Stones with a density of more than 1000 Hounsfield units (HU) and high homogeneity in non-contrast computed tomography (CT) are less likely to be fragmented by shock wave lithotripsy. (8)

The optimum shock wave frequency is 1.0 to 1.5 Hz. Decreasing the shock wave frequency from 120 to 60-90 shock wave number/min reduces the residual stone rate, while when it is reduced to 30 shock wave number/min, the residual stone rate increases. Starting with low energy and gradually increasing the power causes vasoconstriction, reducing kidney damage and increasing patient compliance. In addition, in animal studies and a prospective randomized study, it was shown that increasing strength gradually increased the stone-free rate from 72% to 96%. (9)

For the energy to be transmitted best during the extracorporeal shock wave lithotripsy procedure, the generator head should be in complete contact with the body, and there should be no air in between. To achieve this, a gel layer is created by squeezing gel on the water pad and the patient so that there are no air bubbles. Ultrasound gel is the most commonly used substance. A 2% air bubble gap in the created gel layer will prevent the transmission of shock waves, reducing the success rate by 20% to 40%. (10)

Extracorporeal shock wave lithotripsy's effectiveness is operator-dependent. Therefore, better results are obtained in experienced clinics. Careful visualization of localization during the procedure contributes to the quality of the results. Visually checking the localization during the procedure adds to the quality of the results. (10)

3. ESWL Treatment in Kidney and Ureteral Stones:

Current kidney stone therapy options include ESWL, PNL, and retrograde intrarenal surgery (RIRS). Stone-free rates following ESWL and ureterorenoscopy (URS) are inversely related to stone size, but PNL efficacy is unaffected by stone size. Upper and middle calyx and pelvis stones can be treated with ESWL up to 20 mm (Table 1). The success rate with ESWL in lower calyceal stones is lower than in upper, middle calyx, and pelvis stones. Broken pieces in the lower calyx stones may remain and cause stone formation again. For lower calyceal stones, the stone-free rates following ESWL are 25–95%. The use of endoscopic procedures, even for lower calyceal stones less than 10 mm, is supported by current reports. RIRS or ESWL can be used to treat kidney stones larger than 20 mm if PNL is not an option. However, it should be kept in mind that the possibility of needing a ureteral stent will be higher in this case. (8,11)

Table 1. Treatment algorithm for renal stones (EAU 2022)

<table>
<tr><td>Location of the Stone</td><td>Stone Size</td><td colspan="3">Treatment Method</td></tr>
<tr><td rowspan="5">Renal Pelvis and Upper Calyx</td><td rowspan="2">> 20mm</td><td colspan="3">1.PNL</td></tr>
<tr><td colspan="3">2.RIRS or SWL</td></tr>
<tr><td>10-20 mm</td><td colspan="3">SWL or Endourology</td></tr>
<tr><td rowspan="2">< 10mm</td><td colspan="3">1.SWL or RIRS</td></tr>
<tr><td colspan="3">2. PNL</td></tr>
<tr><td rowspan="4">Lower Calyx</td><td>>20mm and <10mm</td><td colspan="3">Same as Renal Pelvis and Upper Calyx</td></tr>
<tr><td rowspan="3">10-20mm</td><td rowspan="3">Unfavourable factors for SWL</td><td rowspan="2">Yes</td><td>1.Endourology</td></tr>
<tr><td>2.SWL</td></tr>
<tr><td>No</td><td>1.SWL or Endourology</td></tr>
</table>

Extracorporeal shock wave lithotripsy's effectiveness is influenced by the following factors: a steep infundibulopelvic angle, a narrow infundibulum, a long calyx, hard stones (calcium oxalate monohydrate, brushite, or cystine), and a distance between skin and stone. For the treatment of proximal and distal ureteral stones greater than 10 mm, ESWL comes second to URS, whereas it comes first with URS for stones smaller than 10 mm (Table 2). (10)

Table 2. Treatment Recommendations for Ureteral Stones (EAU 2022)

Location of the Stone	Stone Size	Treatment Method
Proximal Ureteral Stone	>10mm	1.URS
		2.SWL
	<10mm	SWL or URS
Distal Ureteral Stone	>10mm	1.URS
		2.SWL
	<10mm	SWL or URS

The stone-free rate of URS was greater in the first four weeks when extracorporeal shock wave lithotripsy and URS were compared, but there was no discernible difference at the end of the third month. Less retreatment and new procedures are needed after URS. However, higher complication rates and longer hospital stays are observed after URS. (11,12)

3.1. Stent Placement Before ESWL Treatment

Because stenting does not affect the rate of stone-free patients after extracorporeal shock wave lithotripsy, it is not usually advised. In addition, it may cause dysuria, pollakiuria, urinary urgency, and suprapubic pain in stented patients. However, the stent can reduce stone street formation. It is advised to implant a stent before SWL since anuria in individuals with one kidney may develop after the surgery. (11,13,14)

3.2. Contraindications for ESWL Treatment

The following conditions are contraindicated for ESWL:

- Pregnancy due to potential effects on the fetus
- Bleeding disorders that must be compensated for at least 24 hours before and 48 hours after treatment
- Uncontrolled urinary tract infections

- Severe skeletal deformities and severe obesity that prevent stone targeting
- Arterial aneurysm around the stone
- Anatomical obstructions in the distal of the stone

ESWL in patients with uncorrected bleeding diathesis is a high-risk procedure for bleeding and perirenal hematoma. ESWL is safe and feasible after the correction of the underlying coagulopathy. Since ESWL is a procedure with a high risk of bleeding, it is recommended to discontinue antithrombotic therapy in consultation with an internist or cardiologist before the procedure and postpone it if it cannot be discontinued. (8,11)

3.3. Complications of ESWL Treatment

Some complications may also develop after extracorporeal shock wave lithotripsy. However, the number and frequency of complications of ESWL are low compared to PNL and URS. Complications related to stone fragments are renal colic, residual stones enlargement, and stone tract formation. Growth of residual fragments smaller than 4 mm has been demonstrated in 21-59% of patients undergoing ESWL. The gathering of broken stone pieces in the ureter is called stone street (steinstrase). The incidence of the stone tract after ESWL is 4-7%. In non-infective stones after ESWL, bacteriuria is seen at a rate of 7.7-23%, and sepsis is less than 1%. When ESWL is performed in staghorn stones, this rate increases to 2.7%. After ESWL treatment, bruising on the skin and bleeding in the urine can be observed. Considering the effects on the kidney, the incidence of asymptomatic hematoma is 11-59%, and the rate of symptomatic hematoma is less than 1%. Bleeding disorder, the use of antiplatelet medications, hypertension, obesity, diabetes mellitus, and the quantity and power of shock waves are all potential risk factors for hematoma formation. The incidence of dysrhythmia in patients who underwent ESWL is 11-59%. Morbid cardiac events, intestinal perforation, spleen, and liver hematoma are rare complications. It is uncertain whether ESWL and diabetes or hypertension are related. Conflicting data have been published. Taş kırılmasından sonra, yeni tanı konulan hipertansiyon vakalarının %8'inde görülür. Bu, genel popülasyonda yaklaşık %6 olan yeni gelişen hipertansiyon prevalansına benzer. (8,15)

3.4. Pain Control and Antibiotic Prophylaxis in ESWL Treatment

In the treatment of extracorporeal shock wave lithotripsy, patient compliance is an important factor for successful treatment. If the patient feels pain during the treatment, he will move, and the depth and frequency of breathing will increase. This, in turn, will cause focus problems and reduce the success rate of the treatment. In order to prevent problems with focus caused by discomfort during therapy, pain must be carefully controlled(10).

Antibiotic prophylaxis is not recommended as a standard before extracorporeal shock wave lithotripsy. However, prophylaxis is recommended if a stent has been placed in the patient before ESWL and there is an increased bacterial load (indwelling catheter, nephrostomy tube, or infection stones). Urine microscopy and urine culture should be performed while planning treatment before ESWL. (10)

3.5. Treatment and Follow-up After ESWL

Several meta-analyses and many randomized controlled studies support that medical expulsive therapy (MET) after ESWL for kidney and ureteral stones accelerates stone clearance and increases stone-free rates. MET can also reduce the need for painkillers. The stone passage following ESWL can be sped up, and stone-free rates can be greatly increased with mechanical percussion and diuretic therapy. In addition, patients can be advised to move, drink plenty of fluids for the broken stone particles to fall easily, and stand upside down at certain intervals in the lower calyx of the stone. (8,11)

Clinical experience has shown that repetition of ESWL sessions is possible. There has yet to be a consensus about the time between sessions. However, it is known that the sessions can be repeated on the same day for ureteral stones. (8)

The best time to determine residual stones after stone crushing is 4 weeks after the procedure. The imaging method with the highest sensitivity in detecting residual stones is computed tomography without contrast. However, in non-contrast computed tomography, Radiation dose and the detection of clinically inconsequential stones are increased when compared to direct urinary system radiography and ultrasonography. (8)

3.6. Presence of Pacemaker in ESWL Treatment

If the proper technical measures are taken, pacemaker patients can receive ESWL therapy. ICD (implantable cardioverter defibrillator) patients must be treated carefully (fire mode is temporarily reprogrammed during ESWL therapy). For newer models of lithotripters, however, this might be optional. However, a cardiologist should examine these patients before ESWL, and the physician’s recommendation should be taken. (16)

3.7. ESWL Treatment in Children

For most pediatric ureteral stones, extracorporeal shock wave lithotripsy is still the first line of treatment. However, in children, the chance of success is low if the stone is larger than 10 mm, if the stone is embedded, if the stone is calcium oxalate monohydrate or cystine, or if the stone localization is difficult and the kidney anatomy is not suitable. Studies show that the stone-free rate after ESWL in children is 70-90%, the retreatment rate is 4-5%, and additional procedures are needed in 4-12.5% of cases. It has been shown that the stone-free rate after ESWL is higher in stones smaller than 10 mm in children compared to stones larger than 10 mm, and the recurrence rates increase as the stone size increases. For the success of ESWL in children to be high, it should be performed under general anesthesia. However, with the developments in modern lithotripters, successful treatment can be applied with intravenous sedation, analgesia, or no medication in older children who can communicate. (11)

In a study, ESWL and mini percutaneous were compared in the treatment of radiopaque lower calyceal stones between 1-2 cm in children, and it was found that the stone-free rate of mini percutaneous was higher and the rate of retreatment was lower than ESWL. However, hospitalization, operation time, complication rate, and radiation exposure were found to be higher after mini percutaneous. (15)

3.8. ESWL Treatment in Special Patient Groups

ESWL is an effective treatment modality for small ureteral upper-end stones in patients with urinary diversion. However, in most cases, an endourological intervention is required to achieve stone-freeness. (8)

ESWL is an option for stones formed in transplanted kidneys. For small calyx stones, ESWL is a treatment method with minimal risk of complications, but the localization of the stone can be difficult, and the stone-free rate is low. (8)

ESWL can be applied in calyx diverticulum stones, pelvic kidney, and horseshoe kidney stones. However, due to the narrow calyx neck of the calyx diverticulum and the inappropriate position of the horseshoe kidneys, it may be challenging to shed the broken pieces. (8)

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CHAPTER II

SEMI-RIGID URETERORENOSCPY

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1. Introduction

Ureterorenoscopy was used for the first time in 1912 when a child's enlarged ureter orifice was accidentally inserted with a cystoscope. (1) Later in 1956, Hopkins was used with a cylindrical endoscopic rod lens with a narrower diameter and better light transmission. (2) In the lithotripsy of the first kidney stone, a 12F ureterorenoscopy produced by Castro and Storz was used in 1980. (3) The first semirigid ureterorenoscopy, on the other hand, quickly replaced the rigid model in 1989 because it allowed flexion up to 2 inches. (2)

The main indication for the use of semirigid ureterorenoscopy is the treatment of distal ureteral stones. Although the European Association of Urology (EAU) mentions the use of both URS and shock wave lithotripsy for ureteral stones below 1 cm in its current guidelines, it points out that URS is the first option for stones larger than 1 cm in the distal ureter. However, in changing age groups, kidney-ureter stone treatment is used in the diagnosis of the ureter and renal pelvis tumors, and urethral and ureter stenosis. (4,5) Ureterorenoscopes smaller than 8F are considered safe.

1. Preoperative Preparation

Every patient who will undergo URS should be adequately planned. The patient's history should be taken; routine preoperative examination such as physical examination, urine, analysis and urine culture, complete blood count, biochemical values including serum creatine, and non-contrast abdominal CT should be performed.

An informed consent form should be obtained from the patient and the patient's relatives. The patient should be informed about the case risks such as fever, infection, hematuria, inability to access/enter the ureter, ureter perforation and avulsion, renal hematoma, u, urethra, and ureter stenosis that may develop after the procedure and surgical revision may be required. (4,5)

Side marking should be done for all cases. Appropriate antibiotic therapy should be started according to the urine culture taken. If it is sterile, a single dose of intravenous antibiotic prophylaxis should be performed 1 hour before the case. Since no complications are expected during the use of antiplatelets and anticoagulants, it does not pose an obstacle for URS.

Considering that the patient will be positioned in the dorsal lithotomy position in the operating room, pressure points should be supported to prevent nerve and tissue damage. (6,7)

Although spinal anesthesia comes to mind as an option considering the risks, general anesthesia has advantages. Lithotripsy can be performed more easily because the procedure can be performed with smaller tidal volumes under general anesthesia, or even because mechanical ventilation can be temporarily stopped. (8) The other factor is the size of the stone. The duration of spinal anesthesia may be insufficient for large stones.

C-arm fluoroscopy should be available in the operating room and a radiation sign should be placed outside the room. (6) Fluoroscopy and endoscopic tower should be positioned opposite to each other in order to prevent them from interfering with each other in equipment installation. (9) The machine to which the laser fiber is attached must be positioned close so as not to restrict the use of URS and must be operated in accordance with the safety instructions.

Heated normal saline is the standard irrigation material. It should be used in conjunction with equipment that can generate active pressure when necessary. However, the pressure should not exceed 30cmH2O in order not to cause risks such as fornix rupture. (7)

All equipment that is likely to be used during the operation should be prepared before the operation and fixed in such a way as to prevent it from falling off. These include catheters that allow safe progression through the ureterorenal system. These guidewires, ureteral catheters, and stents should be maintained in a manner that allows reuse with minimal trauma. Various guide wires are available. It is important that they have a flexible tip and a rigid body with a hydrophilic coating, reducing friction. Stone removal equipment is made of nitinol-containing material that can maintain the shape of the device, prevent bending, and is suitable for stonework. (6) Since nitinol-containing instruments are thinner, they do not obstruct vision by allowing the passage of irrigation material. (10)

Although the pneumatic lithotripter is more effective during stone fragmentation with URS, laser lithotripters are preferred primarily because they are more useful than pneumatic lithotripters. (7,11) Because retropulsion to the kidney is more likely when delivered with a pneumatic lithotripter. (Up to 40%) As the size of the stone increases, dilation in the proximal ureter increases, and the placement of the stone approaches the proximal, the likelihood of migration increases even more, which increases the patient's morbidity and total cost. (12) Much nitinol-containing equipment has been designed, such as StoneCone, which prevents migration of the stone by placing it in proximal and helps to collect broken parts. Another option is to use a basket device that encapsulates the stone before lithotripsy. (11) Alternatively, equipment called BackStop, which forms a polymeric gel that forms a plug with thermosensitivity properties proximal to the stone, can also be used. The material that hardens at body temperature becomes liquefied again when irrigated with cold saline and can be removed from the ureter by washing. (10) Holmium YAG laser (Ho: YAG) is the most commonly used laser as it minimizes the risks such as stone retropulsion with semirigid URS. Ho: YAG can also be used for both ureter and kidney stones with semirigid URS.

Ureteral stenting before URS is not a routine procedure, but it may be preferred in patients with narrow ureters because it provides passive dilatation. In the same way, postoperative stenting may be associated with morbidity. However, stenting may be considered in patients with a history or risk of trauma, impacted ureter stone, ureter perforation, solitary kidney, and/or retroperitoneal fibrosis. (5,7,11) Although the ideal duration of the postoperative DJ stent is unknown, most urologists support a stent duration of 2 weeks. (5)

Figure 1: Preoperative Preparation

2. Surgical Technique

2.1. Imaging the Bladder and Ureteral Orifices

Regardless of the purpose of the operation, cystoscopy should be performed initially to exclude any malignancy and to be able to view the ureteral orifices. Alternatively, surgery can also be started directly with semirigid URS. In this case, it is recommended to place a 10-12F catheter in the bladder both to keep the system pressure low and to turn the system into a system that provides continuous flow.

It should be taken into account that urethral stenosis and an enlarged prostate gland may encounter obstacles on the way to the bladder of the semirigid ureterorenoscope, and it is necessary to protect the URS from excessive pressure. (13)

2.2. Ureteroscopy Steps

2.2.1. Ureteral Catheterization

After the ureteral orifices have been visualized, it is strongly recommended by the EUA to place a safety guide wire from the ureteral orifice to allow atraumatic access to the ureter and kidney. (5) Polytetrafluoroethylene (PTFE) wires are blacker-type wires that can be bent, while hydrophilic ones are resistant to bending but tend to slip. Taking into account the disadvantages, hydrophilic ones are recommended. Angled catheters and guide wires can be useful when faced with anatomical obstacles such as embedded stone, and ureteral stenosis.

Figure 2: Ureteral Catheterization

After the safety wire is fixed to the cover, the semirigid ureterorenoscope is inserted into the bladder again and a second guide wire is sent to the system in order to ensure that the ureterorenoscope moves safely through the ureter in accordance with the “railway technique”. (14) If retrograde pyelography is planned, an open-ended 5-6F thick catheter that will allow the passage of fluoroscopic substances can be placed through the wire. It can also be used to give dyestuffs or take a urine sample for cytology. (6) However, according to the ALARA principle, it is questionable to perform retrograde pyelography routinely to minimize radiation exposure to both the patient and the operator team. It should be performed when the scenario of the endoscopic procedure is not clear or sufficient data are not obtained from the Urogram-CT scan. Even if fluoroscopy is to be used, it is recommended to use it as a “flash” instead of continuous scanning. (7) In addition, in patients with distal ureteral stones, it may be more useful to perform distal URS before, as it may also cause stone migration. (2)

If the infective material in the ureter is drained after catheterization; a DJ stent can be placed simply to stabilize the patient until both the discharge of the infective material and the actual procedure are performed. (7)

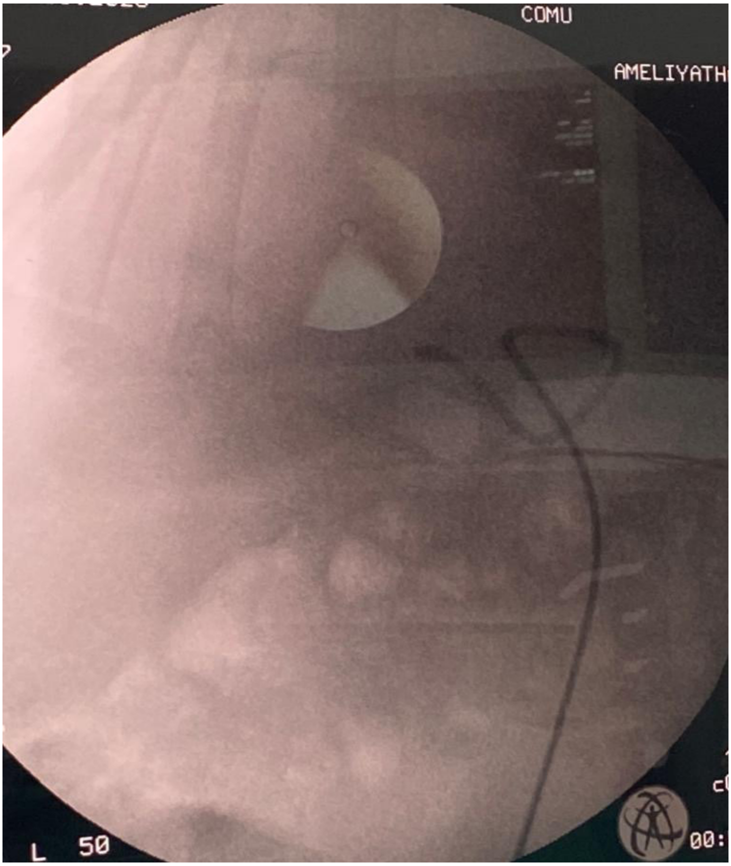

Figure 3: Ureteral Catheter Under Fluoroscopy

2.2.2. Ureteral Navigation

Modern endourology recommends changing the equipment according to the patient rather than adapting the patient to the equipment. The difficulties experienced in the placement of a semirigid ureterorenoscope due to stenosis in the ureteral orifice can be overcome with a balloon and Teflon coaxial dilatators. (5) Despite this, the first preference should be to try ultra-thin semirigid ureterorenoscopes in cases of strictures that cannot be overcome. Despite this, if the surgeon feels excessive resistance, the procedure should be stopped and a DJ stent should be temporarily inserted instead of repeatedly dilating the incompatible ureter, the procedure should be rescheduled after 2 weeks. Thanks to this procedure, the ureter will gradually dilate and allow maneuvering of the ureterorenoscope. (5)

Before starting URS, it is recommended to empty the bladder to avoid compression of the ureteral orifice. (7) The ureterorenoscope should be held in the dominant hand of the surgeon, with the other hand, the ureterorenoscope should be fixed in the urethral meatus. (14) It should be treated carefully to keep the ureterorenoscope straight and prevent unnecessary stress to be applied to the shaft. If it is difficult to enter the ureteral orifice, the URS can be rotated 90 or 180 degrees and the direction of the curved part can be changed. In addition to the first safety wire placed in the ureterorenoscope, the second navigation wire placed in the ureterorenoscope will facilitate the overcoming of obstacles.

The irrigation fluid flow rate should be adjusted by the assistant in order for the vision to be clear while advancing in the ureter. However, it is also necessary to be careful that the intrarenal pressure does not rise too much at this stage. If the URS cannot progress easily, the procedure should be stopped because the risk of ureteral perforation is high. The condition should be re-evaluated with fluoroscopic dye injection and the cause of the blockage should be investigated. (14) If the contrast agent goes beyond the blockage, progress can be tried with hydrophilic wires. Because Hydrophilic wires can overcome the obstacle more easily than PTFE wires. (7) For embedded stones that prevent the procedure from progressing, displacement can be attempted with light pushes of the catheter or ureterorenoscope (Billard Cue Technique), or with interventions with a ureterorenoscope after the stone is slightly broken down. However, these should be tried by experienced surgeons. If iatrogenic mucosal damage is detected at any stage, the procedure should be postponed and a DJ stent should be placed over the safety wire and the operation should be terminated. (7)

2.2.3. Stone Management and Lithotripsy

The Office of Clinical Research of the Society of Endourology (CROES) has found that semirigid ureterorenoscopes are used in most of the procedures applied for stone disease. (15) Semirigid URS was found to be successful in 95% of typical distal ureteral stones. (16) The reason for the use of semirigid URS is that it allows irrigation flow, which provides better vision during the procedure due to the wide channel opening, and allows the use of auxiliary equipment. The disadvantage is that you have to perform the operation again at a later date due to the higher probability of failure to progress to the desired point to be reached. (15) It should also be noted that in male patients with more developed muscles between the relatively rigid prostatic urethra and the renal pelvis, the semirigid ureterorenoscope is also likely to be broken or damaged. (7)

The rapid development of semirigid ureterorenoscopes in comparison with ESWL has provided a great advantage in the management of ureteral stones larger than 2 cm, which are considered to be too large for ESWL or larger than 15 mm that require stent placement before ESWL. (5,14) If the stone size and location allow, semirigid ureterorenoscopes can also be used in selected renal pelvic stones. (5,10,13) At the same time, semirigid ureterorenoscopes made it possible to break the stone in obese patients who were not suitable for ESWL due to the high stone-skin distance. (10)

Before starting the stone-breaking process, all the auxiliary equipment mentioned earlier should be kept ready on the table. The equipment should be selected appropriately according to the size and position of the stone. The laser settings should be adjusted according to the stone, and the correct size and thickness should be selected because the size of the auxiliary equipment, such as a basket, will block the flow of irrigation fluid and restrict the surgeon's vision. (7,11)

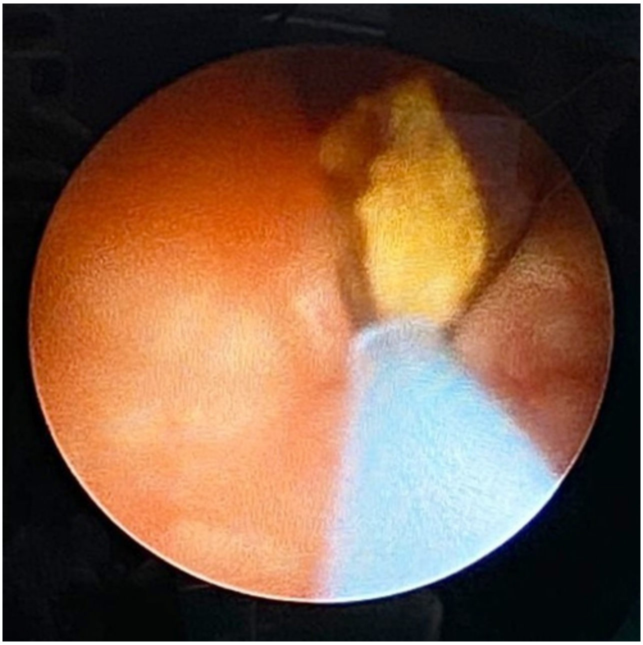

Figure 4: Trapping the Stone In a Basket Catheter

In general, it is recommended to trap the stone in a basket before starting lithotripsy to prevent retropulsion of stones or to use anti-retropulsion devices such as StoneCone, N-Trap, and Xen-X distally to the stone. When such agents were not used, the irrigation liquid pressure was reduced or the ballistic-laser lithotripter fall was reduced to prevent retropulsion. This prolongs the operation time, increases the cost, and may require additional operation as a result of retropulsion. (18) Thanks to these agents, better stonelessness rates could be achieved and the use of semirigid ureterorenoscopes became widespread. (19,20)

Although lithotripsy is performed with ultrasonic and ballistic energy in many developing countries, the Holmium laser is the golden standard. The adjustment of the laser is extremely important. It is possible to reduce the risk of retropulsion by using low energy and high frequency. The lithotripsy strategy is also very important. Unlike the one performed in the renal pelvis, in the ureter; instead of peripheral ignition, an ignition in such a way as to create a gap in the center of the stone also eliminates the risk of mucosal thermal damage. After the formation of stone fragments, it is recommended to use baskets to clean the stone. In semirigid ureterorenoscopy, endless nitinol baskets are recommended. Low-wire baskets are used for removing large fragments, while multi-wire baskets are indicated for cleaning small fragments formed after extensive lithotripsy.

After the lithotripsy and litholopaxy procedure are completed, the integrity of the ureter is evaluated endoscopically at the exit. This is an important step because; as shown in randomized controlled trials and meta-analyses, routine stent placement is not indicated after non-concomitant URS cases. (21)

Stone management is difficult in certain patient groups, such as pregnancy, obesity, pediatric patients, and patients with bleeding diathesis. While ESWL is contraindicated during pregnancy and in patients with bleeding diathesis, its effectiveness is low in obese patients. In the pediatric age group, general anesthesia is required in order to apply ESWL. In these patient groups, the approach with semirigid ureterorenoscopy has high success rates in the treatment of ureteral stones. (22,23)

2.3. Ureteral Stenosis

Ureteral stenosis can be defined anatomically or functionally as a narrowing of the entire ureter or a segment. (13) They may be congenital, idiopathic, or acquired. Ureterorenoscopy can be both an agent used in the treatment of urethral stenosis and can cause urethral stenosis.

While the gold standard was an open surgical repair in the treatment of ureteral stenosis until recently, today's treatment can be performed endourologically with developing ureterorenoscopic techniques.13 Open surgical methods in ureteral stenosis vary depending on the location of the stenosis. Distal ureteral stenosis requires re-implantation, while proximal and middle ureteral stenosis can be treated with a boari flap, ureteroureterostomy, or ileal transposition. (24) If it is planned to use a ureteroscope for the treatment of ureteral stenoses, options such as balloon dilatation, consecutive rigid endoscopic dilatation, or laser endoureterotomy can be used.

Balloon dilation is a procedure whose success Deceleration varies between 48% and 82%. The technique starts with the placement of the balloon in the stenotic area over the safety wire under the guidance of fluoroscopy. The balloon is gradually inflated to widen the stenosis. After the procedure, the final state of the section with stenosis should be checked with URS. Then, a stent should be placed in the ureter and a stent should be left for controlled dilatation between 1 and 8 weeks, depending on the surgeon's preference. (13)

Laser endoureterotomy offers similar long-term results to open surgery with lower morbidity rates and shorter recovery times. (22) As with stone disease, Holmium laser is preferred in this procedure due to the low complication rates. (26) However, it is safer to apply balloon dilatation to the extent that it allows the passage of the semirigid ureterorenoscope at the beginning. Thus, the ureterorenoscope can be passed forward of the stenosis segment through the safety guide and the endoureterotomy procedure can be performed directly under the vision. The stenosis area is excised with a laser. The adequacy of the depth of the procedure can be determined by the appearance of the extra ureteric fatty area and extravasation of the contrast agent under fluoroscopy. (27) It is recommended to place a stent after surgery because it accelerates the healing of the ureter, prevents the escape of urine from the ureter, and prevents re-constriction. (13) Ureterorenoscopic treatment is not recommended in strictures longer than 1.5cm, in patients with eGFR less than 25, and in severe dilatation of the renal pelvis.

2.4. Urothelial Masses

Semirigid ureterorenoscopy allows direct imaging of any pathology in the ureter or kidney lumen. The introduction of ureterorenoscopy for mass diagnosis has paved the way for the development of equipment that makes it easier to take large tissue samples, such as BIGopsy. (10) It is recommended to secure the operation with a guide wire to reduce the iatrogenic mucosal damage, such as in the approach to the stone. Ureterorenoscopy can be used both as a visual diagnostic equipment and can also be used to take histological tissue samples and cytological fluid samples. (11) It is one of the least invasive methods that can be done for this purpose. There are 2 main methods for obtaining a ureteral biopsy. One is the cold-cutting technique using stone baskets and the other is the sampling process using biopsy forceps. Caution should be taken when performing the tissue removal procedure, taking into account the risk of ureteral perforation.

Although nephroureterectomy is the standard treatment for ureteral tumors, it is recommended to choose more preventive methods in patients with a solitary kidney or chronic kidney disease. (6,28) Cold-cutting techniques or the Holmium laser evaporation technique can be used to reduce the tumor mass in patients who are treated with a semirigid ureterorenoscope. (6)

3. Postoperative Process

If a DJ stent is inserted in patients who do not develop complications during the operation and complications are not expected during follow-up, its duration can be kept short and it can be discharged within a maximum of 1 day.

In case of fever, antibiotic therapy should be continued, the urethral probe should not be removed until the fever subsides to avoid vesicourethral reflux and to keep the collector system pressure low.

4. Conclusion

In a study conducted by the Clinical Research Office of the Society of Endourology (CROES) in almost 10 thousand patients, it was reported that the most common and most uncomplicated procedure for ureteral stones at all locations is semirigid ureterorenoscopy. The stone absence rate increases from 76% to 94% as it goes from proximal to distal in the ureter. Intraoperative complications were reported in 4% and postoperative complications in 3%. (29) To conclude, semirigid ureterorenoscopy is a procedure with a low risk of complications in almost the entire tract, including the ureter and renal pelvis, a high success rate, and a low cost that can be performed repeatedly.

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CHAPTER III

RETROGRADE İNTRARENAL SURGERY

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1. Introduction:

Although there have been great achievements in the surgical treatment of urinary stone disease in the last 2 decades, surgical treatments cannot produce a permanent solution for the episodes of stone diseases, due to their genetic and recurrent nature. According to the results of studies conducted in developed countries, the incidence and prevalence of stone disease increase from year to year all over the world. (1)

Over the past 25 years, the holmium: yttrium-aluminum-garnet (Ho:YAG) laser has been the most preferred type of laser modality for laser lithotripsy. Similarly, retrograde intrarenal surgery (RIRS) performed with flexible accompaniment has also been considered the most effective and safe surgical procedure for <2 cm kidney stones. In this section, both the operational process, the laser technology, the important and preliminary things to be done before and after the RIRS operation (Prestenting, urine culture, antithrombotic agents, operative parameters, follow-up period), and the recent related literature will be mentioned.

2. Preoperative Measures:

Before giving the details of the procedure, let's touch on the preoperative points that need to be emphasized. Today, urine culture is evaluated before most of endourologic interventions. Preoperatively, sterile urine culture results are awaited. Among all other interventions, the one for which a negative urine culture will be expected most is endoscopic intrarenal surgery. Unfortunately, even if the patients are administered preoperative broad-spectrum antibiotics according to the urine culture results, bacteria may still exist in and on the infected stones of the patients after the antibiotheraphy. (2)

Before talking about our main topic flexible ureterorenoscopy (fURS), just to mention, direct urinary system radiography and urinary ultrasonography are used for the diagnosis of stone disease today, but the gold standard diagnostic modality is non-contrast computed tomography with 98% sensitivity and 97% specificity. It has no obvious weakness except that it may not visualize some very rare stone types and it may cause 10 mSv ionizing radiation exposure per shot. (3)

What should be done about antithrombotic therapy before fURS is also controversial. RIRS operation is considered one of the operations with low bleeding risk. However, some authors stated that anti-coagulation therapy (Warfarin, low molecular weight heparin, direct oral anticoagulants) increases the probability of bleeding associated with the procedure, but anti-platelet therapy (Aspirin, clopidogrel) is more reliable. (4) RIRS procedures can be performed under either general anesthesia or regional anesthesia. The most preferred patient position is the lithotomy.

Ureteroscopy (URS) and Percutan nephrolithotomy (PCNL) play a more necessary role in the treatment of urinary stones, with the help of advancing technology, and by creating easier and more successful access to the ureter and kidney in the last 2 decades. Generally, in PCNL operations which are normally applied to kidney stones larger than 2 cm, the stone can be seen and fragmented easily after successful access if there is no significant intrarenal hematoma or bleeding. After that point, the most important criterion is if the lithotripter can fragment the stone safely and effectively. However, when ureteroscopy is planned with flexible ureteroscopes, size, and flexibility are the most important factors. In other words, it doesn't matter how efficiently the lithotripter fragments the stone if the hard-to-reach stones can't be accessed. Therefore, it is desired that the technology evolves to produce more flexible, more efficient, and more miniaturized ureteroscopic devices.

Figure 1/a: Flexible ureteroscope, 1/b: Head of fURS,
1/c: Tip of fURS(Channels of light, water and guideline or laser)

3. Laser technology:

Laser definition is light amplification as a result of the excitation of radiation emission. The generation of high-energy electrons as a result of the excitation of an atom with an external energy source leads to the production of laser energy. The energy of high-energy electrons is released in the form of light or photons. Its unique properties such as being coherent (Photons in one phase), collimated (Photons parallel), and monochromatic (Same wavelength) help to transmit laser energy in a highly concentrated manner. In and after the electric current, one of the emitted protons hits the other stimulated atom, creating a cycle called stimulated emission, which will continue until the electricity is cut off, this stimulated emission continues until the operator releases the pedal and cuts off the energy. (5) It is very helpful to have a good understanding of the parameters that will affect the possible performance of the laser. Lasers over 35 W are considered high power. The total laser power is expressed in watts(W) and is measured by multiplying the pulse energy by the pulse frequency. Pulse energy is the amount of energy released in each pulse and is expressed in Joules (J). Pulse frequency is the number of pulses released per second and is expressed in hertz (Hz). As an example, if 2 J of energy and a frequency of 8 Hz have opted for, the total power will be 16 W. New lasers can increase the pulse width as well as increase the pulse frequency. The pulse width does not affect the total energy output, but it may ensure efficacy by distributing the energy over a longer period. (6)

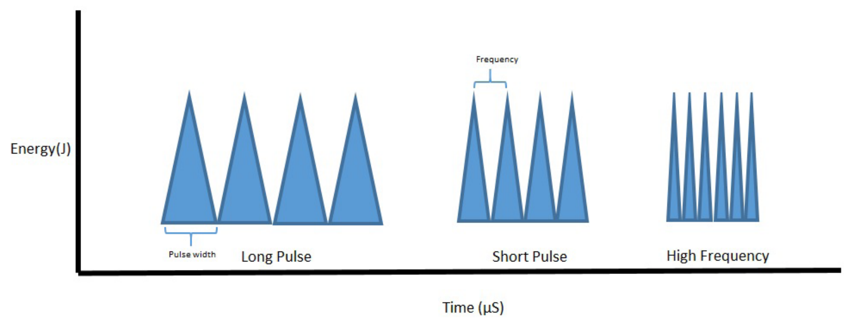

Figure 2: Energy, frequency, and pulse width relations.

Since 1960, different types of lasers have been introduced with different technologies. Ruby laser, one of the first to come out, heated the stone with a continuous wavelength until vaporization occurred, which caused excessive heat production above the melting point of the stone. This has led to its limited clinical use. Alternatively, the pulsed energy that was developed later, provided high power density and minimal spread or dissipation on the stone surface (pulsed-dye laser, coumarin pulsed-dye laser). (7)

Ongoing technological advances have allowed the development of the Ho:YAG laser. Holmium laser is used extensively in urology clinical practice, its wavelength is 2140 nm in pulsed mode, its pulsed duration is between 250 and 350 microseconds, and it is intensely absorbed by water superficially. As a result of this situation, it creates superficial cutting and ablation, creating a superficial thermal injury that usually ranges from 0.5 to 1.0 mm. The long pulse duration of the Ho:YAG laser only produces a long cavitation bubble that generates a weak shock wave. This system creates a photothermal mechanism to vaporize the stone. (8)

The Ho:YAG laser can transmit its energy through a flexible fiber that can easily perform lithotripsy throughout the entire collection system. With the advantage of having a low penetration depth, the holmium laser can be safely activated at a distance of 0.5-1 mm from the ureteral wall. Another important advantage of the holmium laser over the coumarin pulsed-dye laser due to its technology is that it can fragment all stone types regardless of their composition. Holmium laser is one of the most reliable, effective, and sophisticated technology compared to its competitors. The holmium laser produces a weak shock wave that reduces the possibility of the stone or stone fragments' retropulsion. Holmium laser has multiple soft tissue treatment applications, therefore, it offers the opportunity to intervene in pathologies such as prostatic enlargement, urethral stenosis, and tumors in the lower urinary system. In recent years, thulium laser has also emerged as an important therapeutic option to holmium laser, with finer fibers and better endoscopic deflection possibility.

4. Procedure and fiber:

Kidney stones may be located in the pelvis, middle zone, upper and lower poles of the kidney. Extracorporeal Shock Wave Lithotripsy (ESWL), PCNL, and fURS are the most popular methods known and applied for years in terms of the treatment of kidney stones. fURS is a technique that can be performed on kidney stones less than 2 cm in size, without any percutaneous intervention, with retrograde access, and with excellent efficacy and reliability. After the appropriate and effective access to the kidney by the access sheath, the technique of fragmenting the stone is relatively easy and effective, following the holmium laser probe advancement through the flexible ureteroscope. The laser fiber must be properly positioned on the stone surface before the laser activation. During the laser lithotripsy procedure, a blizzard effect may occur as time passes. Emerging and floating stone fragments can be removed with endoscopic irrigation. A guidewire may also be present in the system for safety purposes while lithotripsy is performed on the stone. Basket catheters suitable for intrarenal use can be used to extract some separated stone fragments. Care must be taken when firing the laser, as it has the ability to break and cut metal structures. Again, in order not to damage the working channel of the ureteroscope and the lens, the laser fiber should be about 2 or 3 mm further from the tip of the ureteroscope. (Practically speaking, the transparent part of the fiber should be farthest forward, and the remaining blue part of the fiber should be protruding enough from the ureteroscope to be visible on the screen.)

Holmium laser fibers are produced in different sizes ranging between 200 μm and 1000 μm. Fibers of 200, 272, and 365 μm are suitable as they can pass through the working channel of the flexible ureteroscope. Of course, as the fiber gets thicker, the flexion of the flexible ureteroscope becomes more difficult. The device, which is shown to be able to flex up to 270 degrees invitro in practical terms, can make relatively limited flexion in real operation, when there is a laser fiber inside. Therefore, in our practice, we use 272 μm most frequently for fURS. On the other hand, 550 μm laser fiber can be used with high efficacy and reliability, accompanied by a semi-rigid ureteroscope, more often in cases of ureteral stones.

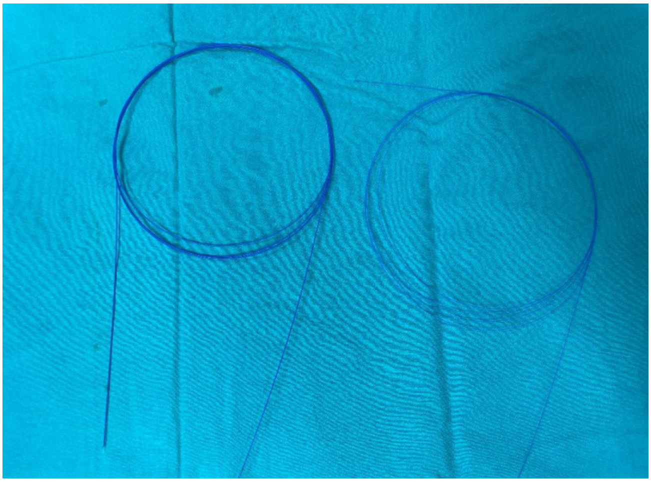

Figure 3: 272 and 550 μm laser fibers in the operating room.

The ability of the laser comes to the fore at the stage of fragmenting the stone. Conditions such as high/low pulse energy, pulse duration, fragmentation efficiency, and retropulsion amount are significantly affected by each other, either positively or negatively during stone fragmentation. For example, low pulse energy produces smaller fragments and causes less retropulsion, but it needs a longer time because it does this with less efficiency. On the other hand, a longer laser pulse duration was tried in stone fragmentation, and it was expected that in this way the stone would be better crumbled, the tip of the laser would be less damaged and the retropulsion of the stone would be less. However, in summary, it is still controversial how to approach a urinary stone scenario with which energy, power, or frequency.

5. Fragmentation + extraction or dusting styles:

In terms of the crushing style for kidney stones, 2 main styles have been adopted, the first is fragmentation with extraction and the second is dusting. For the first method, it is an accepted approach to interfere with the stone in the 0.6-1.0 J power and 6-10 Hz frequency range. Although it is recommended to approach the stones from the middle or edge, the reason for the suggestion of fragmentation from the middle first may be to prevent possible damage to the kidney mucosa by staying inside the stone. When the stone fragments are small enough, they can be extracted by a type of basket catheter suitable for intrarenal use. Thanks to this fragmentation method, stone analysis is possible. Performing stone analysis allows the patient to be more accurately guided and protected from subsequent stone episodes. Unfortunately, we observe that many patients have undergone 5-10 times URS and RIRS procedures without any stone analysis or 24-hour urine analysis. When Chew et al. evaluated the natural course of asymptomatic residual stones that remained after URS in their study, they found that re-intervention was required in 44% of the patients. (9)

On the other hand, the purpose of the dusting method is to fragment the kidney stone to the smallest possible size and to allow spontaneous passage. As the technology of laser consoles progressed, it became possible to increase the laser pulse rate and reach higher frequencies. In this way, the possibility of working with relatively lower pulse energy and higher pulse frequency has been developed during kidney stone fragmenting. It has become possible to operate at frequencies of 15-20 Hz in standard laser consoles, and 50 Hz and above in newer technology systems. The method of completely breaking the stone into much smaller fragments without the need to extract it has become quite popular.

Since there is no need for active stone extraction specific to the dusting method and the use of a basket to remove stones is not required, the reduction in basket-related complications can be considered an advantage. In terms of the dusting technique, the main aim should be to advance the laser from one end of the stone to the other with regular movements, to go back and forth between the different ends of the stone as if painting, without deepening the middle region and without fragmenting the stone into large fragments. In kidneys that move a lot due to respiration, an image will appear as if the stone is going back and forth with the kidney. It is an option to continue fragmentation by keeping the laser slightly back and adapting to the movements of the kidney and stone. When the stone volume is relatively large, it will be easily fragmented by the laser with the fragmentation style mentioned above. However, when a small stone fragment remains, the power of the laser will be relatively high. In such cases, instead of trying to catch the stone, assuming we are in a calyx, we can fire the laser fiber by fixing it in the middle of the calyx and wait for the existing stone fragment to come to the tip of the fiber frequently. This method is called popcorning. Stone fragments create an image on the screen, like popping popcorn. Fragments small enough to pass the ureter on their own are usually 1-2 mm in size. The size of the remaining residues can sometimes be misleading and can be observed as larger or smaller than they really are. In such cases, comparing the stone with the laser fiber on the screen in terms of size will give us a healthy vision.

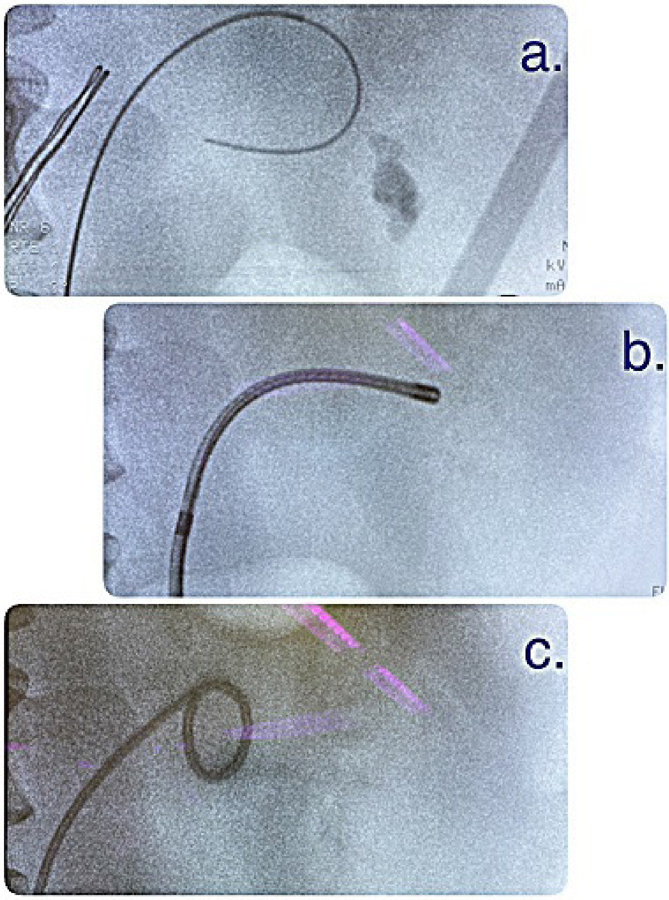

Figure 4: In the section, there is the left kidney stone and the guidewire; in the b section, after the stone fragmentation and the clearance, we see the flexed flexible ureterorenoscopy, and in section c, we can see the placement of JJ stent in the renal pelvis.

6. Discussion:

We tried to examine the scientific studies on intrarenal surgery in the last 5 years and to make inferences in light of them. Let's continue the topic on this aspect.

First of all, I would like to talk about the vital importance of keeping intrarenal pressure low in intrarenal surgeries and endoscopic surgeries performed on the entire urinary system. In the review published by Croghan et al. in 2022, in 52 studies, 21 in vitro and 32 in vivo, in the last 70 years, URS, fURS, PCNL, mPCNL (Mini percutaneous nephrolithotomy) operations were reported, intrarenal pressures were examined. (10) In this review, it was stated that intrarenal pressure usually exceeds 40 cm H2O during upper urinary system endoscopic interventions, and intrarenal pressure may be related to various factors. It has also been stated that the placement of a ureteral access sheath (UAS) significantly reduces intrarenal pressure, although opening and closing the irrigation manually during flexible ureterorenoscopy creates a variable situation. Similarly, in the absence of UAS, it has been demonstrated that instantaneous intrarenal pressure can be >100 cm H2O as a result of manual pumping. In the review, it was stated that as a result of excessive intrarenal pressure elevation, postoperative pain, and pyrexia will occur. (10) Again, the lower the position of the UAS, the less water it will drain, and the higher the intrarenal pressure will remain, as already known, and discussed in the review. In the study of Farag et al., mentioned in this review, compared to constant pressure irrigation (<150 mm Hg or 204 cm H2O) during the fURS procedure, hand-assisted irrigation with constantly varying pressure was associated with post-operative febrile urinary tract infection, flank pain, and fever in the emergency room. It has been suggested that it significantly increases the cases of admission and systemic inflammatory response syndrome. (11) In summary, in the review published in the World Journal of Urology by Tokas et al. in 2019, it was argued that uncontrolled very high intrarenal pressures can be reached in intrarenal surgery, especially in manual irrigation, and UAS placement is the most effective method to prevent this. (12)

Figure 5: Ureteral access sheath inner and outer parts

Another important and debatable issue is what the benefits or harms of pre-operative stenting are, if necessary, and on this subject, Fahmy et al. published a meta-analysis in 2022 that included 20 studies and 5852 patients. In the study, kidney stone patients who were not presented, that is, who had direct lithotripsy, were excluded. According to the results of the study, lower complication rates, especially ureteral damage, higher stone-free rates, and higher access sheath usage rates were observed in patients who underwent presenting. (13) Again, in the review published by Law et al. in the World Journal of Urology in 2022, higher access sheath placement success, lower ureteral injury rate, and overall higher stone-free rate were reported in patients who underwent presenting .(14)

Endourologists know in their practical life that some factors can affect the endourological procedure positively or negatively before the procedure. Among these, the prominent factors are gender, preoperative stent placement, negative preoperative urine culture, and the presence of diabetes mellitus. (DM) In the meta-analysis published by Ma et al. in 2020 based on 16 different studies and

12357 patients, they suggested that female gender, DM, presenting, operation time longevity, and preoperative urine culture positivity cause negative results in terms of infectious complications. (15) This analysis contrasts the view on presenting with that of Fahmy et al. Based on this study, it may be necessary to evaluate the review of Bhanot et al. on appropriate strategies to prevent mortality after ureteroscopy. This review mentions 72 cases of mortality that occurred between 1990 and 2020 in the 15 studies evaluated, in the 10 countries mentioned. And from this point of view, they stated that >65 age, female gender, presence of additional comorbidities, longer operation time, and absence or positivity of preoperative urine culture are associated with worse prognosis in intrarenal and intraureteral surgeries. (16) The study of Bhanot et al. is valuable in terms of emphasizing the issue of mortality in endourological interventions. Because endourological interventions, especially intrarenal surgeries, are never innocent surgeries when proper conditions are not provided!

There is also a meta-analysis published by Talso et al. in 2019, in which reusable and disposable flexible URS systems are mainly analyzed in terms of cost. As a result, it was stated in this study that reusable fURS are more cost-effective than disposable fURS even when all costs are included in high-volume centers. In terms of performance, it has been suggested that comparable results can occur between both devices. (17) Of course, there are differences between studies while making this comparison. The factors that ensure the longevity of reusable fURS are correct to use in experienced hands, storage in the right conditions, and optimum service opportunities in case of damage. Although officially reusable fURS is registered as unused in more than 15-20 cases, in real practice it is used in many centers until it falls below the required minimum efficiency and safety limit, and it can be said that it is quite durable when used in the right and knowledgable hands. Here, of course, it is also important to use the laser probe correctly and to schedule the service of the laser device correctly. As the number of unexpected repairs needs to increase, the cost-effectiveness of reusable fURS will decrease. Disposable fURS systems have been frequently produced, promoted, and offered for sale in the industry in recent years.

When asked what the developments regarding the innovations in laser technology are, Enikeev et al.'s recent review evaluated the ablation rate, stone-free rate, and safety parameters of thulium fiber laser. Most of the studies used the conventional Ho:YAG laser, and 13 studies evaluated the thulium fiber laser. As a result, it has been shown that the thulium fiber laser is effective and safe in stone fragmentation and causes very little retropulsion. However, in many studies mentioned in this review, a direct comparison between the two systems could not be made. Therefore, although the thulium fiber laser is promising, it has been emphasized that comparisons with the conventional Ho:YAG laser are still limited. (18) In the review published by Lildal et al. in 2021, a holistic approach was made to fURS and the laser technologies used, and it was cited that there is no limit to the technology. With the development of ureterorenoscopes and the advancement of laser technology, it was emphasized that positive progress is expected in the areas such as efficiency, fragmentation, urinary system injury, intervention for larger stones, stone-free rate, reduction of retropulsion, and intrarenal pressure. (19) In support of this, Corrales and Traxer stated in 2022, in a review that included 5 thulium studies and compared Ho:YAG and Thulium Fiber, thulium showed more effective results against a similar safety profile. (20) In another review published by Falagario et al., it is stated that RIRS is catching up with PNL in terms of both efficiency and reliability day by day in light of technological developments. (21)

In the “International Alliance of Urolithiasis guideline on retrograde intrarenal surgery”, an important group of academics who have made a great effort in stone disease, came together and created all kinds of recommendations about performing RIRS effectively and safely. (22) To emphasize the additional points that we consider important here, they emphasized that RIRS has a higher first intervention success and lower retreatment rate compared to ESWL, even though first-line treatment with ESWL is used in kidney or proximal ureteral stones <20 mm. Again, it was emphasized that the RIRS procedure is contraindicated in cases such as acute symptomatic urinary infection, obstructive fever, and urosepsis, and that nephrostomy or JJ stent should be placed first. Concerning preoperative stenting, although the panel argues that it improves stone clearance and reduces the rate of ureteral injury during the actual procedure, it does not recommend routine stenting prior to RIRS, and routine pre-stenting is recommended, especially in infectious/obstructed cases. There are many suggestions in terms of the way the operation is performed. In most cases, it is recommended that the safety guidewire be placed at the beginning of the operation. Most surgeons believe that UAS insertion provides easy access to the collecting system, comfortable fluid drainage, and easy stone extraction, but there are no studies supporting this as a panel view, on the contrary, UAS may increase the risk of ureteral injury and therefore must be placed carefully into the ureter under x-ray imaging support in difficult cases. The panel made recommendations also about the ureteroscope and the method. Comparing fiber optic and digital flexible systems, it is stated that fiber optic systems have better tip deflection and lower caliber. When disposable and reusable flexible URS systems are compared, reusable fURS can be preferred in high-volume centers and highly experienced hands. It has been stated that the preference for single-use flexible ureterorenoscopes in patients or resident training centers may be more convenient and more cost-effective. One of the issues detailed by the panel is the working channel of ureteroscopes. It is expected that dual-channel ureteroscopes will provide additional benefits in terms of irrigation and visibility compared to single-channel ureteroscopes. The disadvantage of dual-channel ureterorenoscopes is that they require a thicker diameter ureteral access sheath, which is relatively more likely to cause a ureteral injury. Apart from this, the thinner diameter of the flexible ureteroscope will also provide better fluid drainage, lower intrarenal pressure, and a better view when the same thickness access sheath is used. Lastly, robotic systems have been mentioned about the ureteroscope, and it is stated that robotic systems are not widely accepted due to the high cost and the need for additional space in the operating room, compared to the benefits of reducing radiation exposure and reducing the need for manpower. It has been emphasized that thulium fiber laser can be a good alternative to Ho:YAG laser in terms of efficiency and safety, it can be preferred with low retropulsion rates, but more studies are needed on this subject. It was stated that there was no RCT supporting any difference between dusting or fragmentation methods in terms of post-op stone-free rates, and which method to choose was left to the current intraoperative conditions and the experience of the surgeon. At the end of the procedure, the removal of the access sheath was required to be under direct view, and the reason for this was to observe potential ureteral injuries. Ureteral stenting after the procedure is highly probable for most urologists. Although it may cause LUTS(Lower urinary tract symptoms), stenting is often preferred for ureteral safety reasons and alpha-blockers and anticholinergics may be used if necessary. According to the panel opinion, ultrasonography, kidney-ureter-bladder x-ray or low-dose computed tomography can be used in post-operative follow-up. However, if small residual fragments or stone clearance are being investigated, then low-dose computed tomography should be preferred. Post-op complications are generally mild, with 67.7% of Clavien-Dindo being Grade I and 98% of them being Grade I-II-III. Post-operative haematuria is common but largely self-limited. If it continues as severe, causes such as collecting system perforation, sudden decompression, perforations due to anticoagulant therapy, misuse of access sheath, and AV fistula come to mind. Treatment is given according to the cause. Intrarenal pressure and operative time should always be considered to avoid infectious complications. Post-operative fever is a common symptom with a rate of 4.9%. Preoperative mid-stream urine culture negativity is the rule for intrarenal stone surgery. Special attention should also be paid to ureteral injuries, according to the International Alliance of Urolithiasis Panel. It is believed that ureteral injuries occur at a higher rate than predicted since they are not particularly observed at the end of the operation. Minor injuries are often overlooked, as most cases are stented. (22)

Again, the European Association of Urology Section of Urolithiasis and International Alliance of Urolithiasis Joint Consensus, led by Zeng and Sarıca and composed of 209 participants, has a very valuable list of recommendations put forward at the same time. Let's add what we have in mind here. In general, all antiplatelet drugs are blocked for a few days before surgery, with only aspirin generally allowed if it is absolutely necessary. It was stated that it is a necessity to visualize the ureter by performing a ureteroscopy before the UAS is placed. If the patient is going to have a 2-stage RIRS for various reasons, there should be a period of 4 weeks between the two operations. The 3rd month was preferred as the appropriate time for imaging in the evaluation of post-operative stone clearance. The total time from the urethra to the urethra was determined as 90 minutes as the ideal operation time. It was emphasized that when ureteral stenosis is encountered and ureteroscope or UAS does not pass, ureteral stent placement should be preferred without forcing it. In particular, this point is the point where the principle of "First not harm" in medicine should come to mind the most. It may be life-saving for inexperienced urologists to remember this recommendation and not force the ureter, immediately place a stent and leave the case for the second session. Again, the RIRS procedure should not be preferred for stones larger than 2 cm unless there is an obvious necessity. Here again, it should be kept in mind that there is an 8-fold difference in volume, not 2 times, between the stones, which are called 1 cm and 2 cm, because the volume is calculated, and 8 times more operation time may be required. The consensus stated that post-operative ureteral stent placement may be preferred in most cases, but 1-2 weeks would be sufficient in standard cases .(23)

How is the situation with children? A recent review included 51 studies evaluating RIRS in children. It has been stated that RIRS is superior to ESWL in stones of all sizes and locations, both in children and adults. The literature has support for the use of UAS in cases, but the long-term effects in children are not yet fully known. It was also emphasized that as the surgeon's experience increased over time, stone-free rates increased and complications decreased in cases performed in children. (24) In the review published by Tekgül et al., it is seen that the approach to pediatric stone disease is not very different from that in adult patients. While spontaneous passage of stones with an average size of 4-5 mm is expected, as the stone size increases, ESWL, RIRS, PCNL, and open surgical methods come into play, respectively. The surgeon's experience is one of the most important factors in which method to use. It has been stated that pediatric intrarenal interventions have become easier with the advent of endourological devices with a tip of 4.5 Fr and a shaft of 6.5 Fr. Prestenting is still controversial. Medical expulsive therapy (MET) therapy with alpha-blockers is permitted in children aged 2-15 years, with a controlled dosage per kg of weight. (25)

Another important issue is the question of whether or not to perform fURS for a stone larger than 2 cm, which is always in minds of the urologists. In the review of Alcalde et al., which included 5 studies and compared the safety and efficacy of fURS with PCNL in stones in the 2-3 cm range, complication rates were similar, but PCNL was reported to be significantly superior in stone-free rate. In the review, it was reported that fURS is more advantageous in terms of hospital stay and the degree of hemoglobin decrease, but ultimately, fURS would require at least 2 sessions to achieve stone-freeness as effectively as PCNL in >2 cm stones. (26)

I mentioned dusting and fragmentation methods. These two methods are not separate and far from each other in terms of efficiency and safety. Comparing these two methods, Gauhar et al.'s review compiled from 10 studies and 1141 patients in 2022 states that there is no statistically significant difference between the two techniques in terms of safety and efficacy. (27)

Last but not least, another featured area where fURS can be used is their adjunctive and supportive work with each other in complex and difficult cases with percutaneous access. It is called endoscopic combined intrarenal surgery (ECIRS), where antegrade and retrograde approaches combine their strengths. We can consider it as a new approach to standard PCNL. It promises better irrigation, hence better visibility, better and through-through access, more successful stone-free rate. (28)

7. Conclusion:

The RIRS procedure is performed more effectively day by day due to the development of laser technology and flexible ureterorenoscopes. The development of ureteroscopes that provide better fluid drainage and better flexibility, and the increase in the efficiency and reliability of laser technology over time, will shorten the operation times, thus providing the opportunity to intervene in larger stones, and perhaps one day the indications for percutaneous nephrolithotomy will be questioned again. I tried to summarize the endoscopic intrarenal surgery, which has a very important place in the treatment of renal stone disease, by compiling information from various sources. I hope it will be useful to the literature and my colleagues.

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CHAPTER IV

STANDARD PERCUTANEOUS NEPHROLITHOTOMY

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1. Introduction:

Percutaneous access to the kidney was first accomplished in 1976. The approach's primary objective was pyelolithotomy. Previously, it was only used to drain an obstructed urinary system.

Today's indications are more diverse. Minimally invasive surgery is becoming increasingly popular as a safe way to access the upper urinary system. The primary reason for percutaneous upper urinary system access is to perform intrarenal surgery. Antegrade treatment of large ureteral stones, percutaneous resection of urothelial tumors, and treatment of fungal bezoars.

Every day, the number of percutaneous attempts to treat urinary stone disease rises. Percutaneous nephrolithotomy (PCNL) is currently recommended as the first treatment option for kidney stones measuring 2cm or larger. Along with evolving technology, the devices and instruments used in percutaneous stone surgery vary due to a variety of factors such as the patient or the clinic's available technical opportunities. To reduce bleeding and other potential complications, surgeons can use 9.5F pediatric age group instruments instead of the 30F nephroscope used in adult patients. The procedure steps are as follows: entry and dilatation, fragmentation and extraction of the stones, and urinary system catheterization. (1,2)

2. Entry And Tract Formation

2.1. Needles and guide wire

The formation of an entry and tract is critical as the first step in preparing for kidney intervention. The needle is primarily inserted into the kidney while the preferred viewing method is active. A guide wire is inserted into the needle. Once the guide wire is confirmed to be in the pelvicalyceal system, the tract is expanded through the guide wire until the lumen width is appropriate for the procedure.

The most commonly used needles for entry are 21 gauge (G) and 18 gauge (G), both of which have blunt tip outer shafts and sharp tip inner obturators. Although the 21G needle may cause minor injuries while passing through the tissue, multiple entries can be made due to the low risk of bleeding. The ability of the needle to enter and exit multiple times is advantageous because the most difficult aspect of percutaneous entry into the upper urinary tract collector system is ensuring that the needle strikes the correct point in the kidney. Multiple entries should be avoided with the 18G needle because it is more traumatic than the 21G needle. The 18G needle›s hardness is advantageous in cases where the 21G needle cannot be properly inserted into the kidney, such as in obese patients. Furthermore, for further stages of dilation and catheter applications, the 0.018-inch guide wire can be replaced with a 0.035-inch guide wire. (3)

A 0.035-inch PTFE-coated J wire is the safest guide wire to use for percutaneous entry into the upper urinary system. Perforation in the collector system is reduced as a result. The goal of percutaneous procedures is to move two guide wires down the bladder, one very hard (for working purposes) and the other soft or J-type PTFE coated. (3)

Although many operators believe that passing the guide wire through the ureter is unnecessary, different techniques have been developed for this purpose. Using a coaxial or dual lumen catheter, the safest technique is to insert a rigid hydrophilic guide wire with an angled tip next to the first inserted (angled-type) rigid hydrophilic guide wire (double lumen catheter). (4,5)

2.2. Dilatators and Access sheaths

Plastic access sheaths with an internal diameter of 30Fr and an outer diameter of 34Fr are commonly used in percutaneous kidney surgery. In some cases, smaller sheaths with diameters ranging from 12 to 24 Fr may be preferred for the procedure. The access sheath has a sloped end structure, which allows one side of the access sheath to move into the collector system and assists the surgeon in changing position within the collector system. Depending on personal preference, the sheaths can be opaque or transparent. (6–11)

Metal dilatators, first introduced in 1985, are coaxial stainless steel rods that gradually increase in size over 8 Fr guided rods. The mass of the 0.035-inch guide wire is forwarded by an 8 Fr rod during the first stage of dilation. The knob at the rod›s end prevents the first dilator from moving any further, allowing the depth of dilatation to be determined. Following the advancement of the first bar, successive metal rods are moved over each other until the desired tractor width is achieved. A 30/34 Fr plastic access sheath is placed over the last 30 Fr. rod. The rigid metal dilatator system has the advantage of being reusable and very effective on perineal scar tissue. The disadvantage is that obtaining the correct dilatation depth can be difficult, especially in hard scar tissue. (6–11)

2.3. Amplatz dilatators (Semirigit plastic dilatation set)

It is made up of an 8 Fr PTFE catheter that can be advanced over a 0.035-inch guide wire and a series of plastic (polyurethane) dilators that can be applied over this catheter. It has the advantage of causing less trauma to the collecting system than rigid metal dilators. The disadvantage is that bleeding may occur during the removal of both dilators. The semirigid plastic dilators that are currently available are only for single use. As a result, the cost per patient is higher than with rigid metal dilators. (6–11)

Balloon dilatators have been developed to reduce the amount of time lost and the risk of bleeding when repeating dilatations with rigid metal and semi-rigid plastic dilatators. It is now the most commonly used dilation method in percutaneous kidney surgery. The working cap of the bubble-dilating catheter is advanced through the guide wire until it reaches the intended dilatation depth of the radiopaque signal. A measurable injector inflates the dilator bubble pressure. (6–11)

It is common for the balloon to form a «waist» in the most resistant areas, such as the abdominal wall fascia and the kidney capsule. When the balloon is fully inflated, the working sheath is wrapped around it. In dense scar tissue, disposable balloon dilatators are less effective than rigid metal and semi-rigid plastic dilatators, but they are more useful in hypermobile kidneys. According to some studies, balloon dilatators have lower bleeding and transfusion rates than rigid metal and semi-rigid plastic dilatators. In the pediatric age group, a surgeon's preference for access calibration is especially important. Mini percutaneous nephrolithotomy is almost standardized in percutaneous stone surgery in this age group. As a result, thinner access sheaths were used. (4–6,11)

3. Nephroscopes

The basic instrument of PCNL is the nephroscope, which provides endoscopic vision with 30-degree optics and has a channel for the working elements to pass through. All steps taken from the time of percutaneous stone surgery intervention are to enter the pelvicalyceal system with a nephroscope with appropriate calibration and lumen width. (guide wire manipulations, dilatation steps) The size of the nephroscope to be used is the main determinant of how wide the dilatation will continue. As a result, because stone disease requiring surgical intervention can have an age distribution ranging from adulthood to the neonatal period, the instrument used should be directly proportional to the patient's dimensions. There are two types of nephroscopes based on their practical application: rigid and flexible. The calibration range of the more commonly used rigid nephroscope ranges from 9.5Fr to 30Fr. A mini nephroscope is required, especially in the pediatric age group, but it can be difficult to obtain. In our clinic, we prefer to use pediatric ureteroscopy for this purpose (4,5).

4. Stone fragmentation

4.1. Pneumatic Lithotriptor

Today, because of its low cost, it is the most commonly used device in percutaneous nephrolithotripsy. It first appeared in 1992. It works by transferring the shock wave created by compressed air pushing the metal cylinder inside the lithotripter to the stone with the probe. Hard stones can be fragmented very effectively using the mechanical effect of compressed air. Direct contact between the probe and the stone is required for proper fragmentation in the pneumatic system. One disadvantage is the lack of aspiration features, as well as the development of bleeding and perforation due to direct contact with the tissue. (1,2,5)

4.2. Laser Lithotriptor

When compared to percutaneous kidney surgery, it is more commonly used in ureteroscopic lithotripsy. Lasers are rarely used in standard PCNL. Because, when compared to others, it is quite slow and expensive when evaluated for PCNL. Desai et al. described micro percutaneous nephrolithotomy surgery for the first time in recent years as an exception to this rule. The use of a laser in this surgery is required for stone fragmentation. (2,4,5)

Coagulation and ablation can also be performed using the laser source. To date, three types of stones have been used in practice: Coumarine Dye (504 nm), Alexandrite (755 nm), and Holmium YAG Laser (2100 nm). The most commonly used laser for this procedure is the Holmium YAG laser. It is extremely effective against hard stones, but it can also easily damage guide wires, baskets, and similar devices. (4)

4.3. Ultrasonic Litotriptor

Its operation is based on the ultrasonic waves produced by electrically stimulating piezoceramic crystals and transmitting them to the stone via the probe. The ability to aspirate stone fragments from the working channel gives this lithotriptor an advantage over others. (1,2,12)

5. Stone forceps

After the stone has been fragmented in the pelvicalyceal system with an appropriate lithotripter, small pieces can be removed by irrigation or aspiration, but the pieces that cannot be removed from the kidney with this method should be removed one at a time. For this purpose, forceps are frequently used. Foreign body forceps with two or three legs can be used, depending on the size of the fragment or the lumen width of the sheath being studied. They are fragile instruments. They are easily broken if not handled with care. Perhaps the most important factor influencing the cost of stone forceps is attempting to remove large stone pieces in a hurry without good fragmentation or applying a high force to remove the stone stuck in the tissue/nephroscope. (1,2,4,12,13)

6. Placement Of The Drainage Tube

6.1. Nephrostomy Catheters

6.1.1. Balloon Catheter (Council)

16-24 Fr catheters are commonly used as nephrostomies following percutaneous surgical intervention. Calyceal obstruction may occur if the balloon is drawn into the infundibulum. Because the contrast medium may prevent the balloon from emptying while the catheter is being removed, it is recommended that the balloon be inflated with water or an isotonic solution.

The Council catheter has the advantage of allowing small-caliber catheters to be advanced from the tip to the ureter, allowing for safer access to the upper urinary tract while maintaining ureteral patency. Even if the nephrostomy tube is resistant to removal, it must be secured to the skin with sutures or other means. Fixing the drainage tube to the skin does not completely prevent it from moving inside. The distance between the skin and the collecting system may change with the patient's movement in some cases, and the tube attached to the skin may come out of the kidney. Because of the risk of tube dislocation, catheters with extensions descending from the ureter can be used in addition to the part of the tube inside the kidney. (1,14,15)

6.1.2. Malecot Catheter (Re-entry)

The Malecot catheter's wings expand in an appropriate environment to provide a non-traumatic and non-obstructive attachment mechanism.

This modified catheter is known as a 're-entry' catheter because it allows the guide wire inserted through the Malecot catheter to pass through the ureter and into the bladder. Malecot catheters are suitable for renal use and have a wide lumen in sizes ranging from 16-30 Fr, but they are also available in sizes as small as 8 Fr. (1,2,4)

6.1.3. Cope Catheter

Cope nephrostomy tubes have a more secure attachment mechanism. A thread emerges a few centimeters from the catheter's tip and then re-enters near the catheter's tip. When the thread is stretched, a secure spiral forms that prevents the thread from easily exiting the renal pelvis. The rope is wrapped around the tube's outer end or the tube with a locking mechanism and secured to the tube with a rubber clamp. Cope catheters are designed in the same spiral shape as pigtail ureteral stents. Cope catheters have largely replaced pigtail catheters in many percutaneous procedures due to the strength of the tensioned helix of the string, which provides a more secure attachment than the unstretched helix of a pigtail catheter. Cope nephrostomy tubes with diameters ranging from 6 to 14 Fr can be used for simple upper urinary tract drainage and instillation, as well as following percutaneous surgery. (1,2,4,5)

6.1.4. Nefroureteral Stent

The mechanism of attachment is similar to that of the Cope catheter, but the tube continues with a ureteral extension and ends with a passive free-standing pigtail inside the bladder. The ureteral portion may be the same or smaller in diameter than the nephrostomy portion. The nephroureteral stent is inserted percutaneously through a wire that extends to the bladder. When one end of the bladder is loosely released and folds within the bladder, fluoroscopy can reveal perforations on the sides of the renal fold. A Cope attachment spiral is formed within the renal pelvis by stretching the rope while moving the catheter back and forth and rotating the outer portion of the tube clockwise. Nephroureteral stents are available in thicknesses ranging from 8.5 to 10.2 Fr, with standard lengths ranging from 20 to 28 cm. (5,8)

6.1.5. Circle Catheter

The last one we'd like to discuss is nephrostomy tubes, which are safe, easily replaceable, and can guide their placement. The external drainage of the circle nephrostomy tube is provided by the circle nephrostomy tube. The Circle nephrostomy tube requires two percutaneous access points to the kidney and is very useful when irrigating the renal pelvis or performing secondary nephroscopy. Following the entry from two distant calyces, the wire is captured from the other entrance using a flexible nephroscope or flexible ureteroscope sent over the wire. When the endoscope is removed, the wire residual circle nephrostomy tube causes minimal trauma, rarely occludes and requires excellent drainage as well as an irrigated Y-connector of the renal pelvis.

After a PCNL procedure, a Foley catheter (by cutting the balloon inflation channel) or nelaton may be used for drainage. Furthermore, we prefer it, especially when performing ultra mini PCNL, and we routinely use the feed tube. Stents with a curved proximal and distal tip J are another option for post-percutaneous drainage. Stents of varying widths are used in practice, depending on the manufacturer's calibration. Height options may be available at ka-light temperatures ranging from 3 Fr to 7 Fr, which are appropriate for children. The stent used in the adult population is 4.8 Fr wide and 26 cm long. (4,5)

6.2. Dj stents

Another option is to use stents with J-shaped proximal and distal ends for drainage following percutaneous surgery. After considering the calibration of the ureter in the pediatric age group, 3 Fr to 7 Fr stents with various length options can be selected. In the adult age group, 4.8 Fr or 6 Fr D-j stents with a length of 26 cm are commonly used. (2,4,5)

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CHAPTER V

MINI, ULTRA-MINI, MICRO PERCUTANEOUS NEPHROLITHOTOMY

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1. Introduction:

Percutaneous Nephrolithotomy (PCNL) was first described by Fernström and Johansson in 1976, about 50 years ago. It was later accepted as the first-line treatment method in treating kidney stones larger than 2 cm by American and European Urology guidelines. (1) Many studies have proven that percutaneous nephrolithotomy is an effective and reliable method widely used worldwide. However, like almost every surgical procedure, some complications have been described in the standard percutaneous nephrolithotomy method. These include postoperative sepsis, fever, adjacent organ injury, bleeding, and the need for transfusion. (2,3) Advances in technology and the industrial field have been reflected in the surgical area in time to reduce the complications caused by the procedure and, thus, morbidity. Miniaturization, use of laser technology, and improvement of optical systems have been made in surgical instruments to reduce bleeding, operation time, hospital stay, and postoperative analgesic requirement and simultaneously increase the stone-free rate. (4)

Studies have shown that complications after standard percutaneous nephrolithotomy are caused mainly by tract dilatation and insertion of the accessory sheath. It has been shown that decreasing the calibration of the instruments used and thus reducing the width of the tract reduces the most common bleeding, adjacent organ injury, the need for postoperative analgesics, and the duration of hospital stay in correlation. (4)

One of the advantages of miniaturization is that retrograde intrarenal surgery provides direct access to kidney stones that cannot be reached due to access sheath, ureteral stenosis, or infundibulopelvic angle-related problems. Moreover, since JJ stent application is lower than retrograde intrarenal surgery (RIRS) applications after percutaneous surgeries, lower urinary system symptom complaints due to JJ stent in the postoperative period are less common. (4)

As a result of miniaturization over time, the reduction in the size of the accessory sheath used in PCNL surgery has brought new definitions. The diameter of the accessory sheath is defined as mini PCNL if it is between 14-20 F, Ultra-Mini PCNL if it is between 11-13 F, and Micro PCNL if it is 4.85 F.

2. Mini PCNL

Although ESWL(Extra Corporeal Shock Wave Lithotripsy) took the lead in the treatment of kidney stones from the 1980s to the beginning of the 2000s, fURS (Flexible ureterorenoscopy) and Miniaturized PCNL became the main treatment modalities in the following years. Current Urology is looking for ways to relieve patients with 10-20 mm kidney stones, with the lowest complication rate and the highest stone-free rate, without the need for additional treatment sessions. Although the aim of miniaturizing the devices used in percutaneous surgery for kidney stones is to reduce the morbidity caused by standard PCNL(sPCNL), none of them can be said to replace sPCNL in terms of effectiveness yet. Discussions on efficacy and safety continue at full speed.

Currently, sheath sizes in the range of 11-20 Fr are included in the mini-PCNL (mPCNL) class by different authors. The procedure is not very different from sPCNL, in that the expected calyx is targeted with an access needle, a guidewire is sent, a sheath is advanced under the scope, and the stone is fragmented with appropriately fine ureteroscopes and laser energy after optimum calyx access is achieved. The key is miniaturization. The most suggested debate is that mPCNL causes less bleeding and fewer post-operative complications than sPCNL, provides efficacy close to sPCNL, and is significantly superior to RIRS in efficacy and cost-effectiveness. (5) The PCNL calibration classifications of the different groups mentioned in the review published by Kallidonis (6) et al and the classifications of Schilling et al (7) and Tepeler et al (8), which are also mentioned in the review, are shown in Table 1.

Table 1: Classifications of PCNL according to different groups:

PCNL classification according to different investigating groups	
Procedure	**Sheath outer diameter**
Standard PCNL	>22 Fr
Mini-PCNL	≤22 Fr
MIP	18 Fr
UMP	13 Fr
SMP	10–14 Fr
Superperc	10–12 Fr
Micro-PCNL	<5 Fr (4.8 Fr)
Mini-micro PCNL	8 Fr
PCNL classification proposed by Schilling et al.[3]	
Size	**Sheath outer diameter**
XL	≥25 Fr
L	20–24 Fr
M	15–19 Fr
S	10–14 Fr
XS	5–9 Fr
XXS	<5 Fr
PCNL categorization proposed by Tepeler et al.[4]	
Size of percutaneous access indicated as superscript:	PCNL+30, PCNL+20, PCNL+12

PCNL: percutaneous nephrolithotomy; MIP: minimally invasive PCNL; UMP: ultra-mini PCNL; SMP: super-mini-PCNL

The mPCNL technique was first planned by Jackman et al in 1998 for adult patients with stones smaller than 2 cm. 18 gauge needle and outer sheath in caliber up to 13 Fr are used. Images were obtained with ureteroscopes between 6.9 and 7.7 Fr and a holmium laser or ultrasonic lithotripter was used as a lithotripter. (9) With the increasing interest in the application of the mPCNL technique, new techniques have been introduced with devices of various sizes. Nagele et al. advocated the same principles as the first mPCNL technique, additionally used a 16 Fr metal dilator and an 18 Fr metal sheath, and reported that a 12 Fr nephroscope manufactured by Karl Storz was used. It has been stated that advances in sheath and nephroscope dimensions allow lower-pressure irrigation and better stone clearance. (The vacuum cleaner effect) The system defined by Nagele et al is defined as Minimally Invasive PCNL (MIP) and the advantage of this system is better pressure control due to single-step dilatation and low-pressure irrigation system. (10)

In the study of Kallidonis et al, which referred to the studies we have just mentioned, some studies that made detailed comparisons on mPCNL and sPCNL were evaluated and it was found that mPCNL is advantageous over sPCNL in terms of post-op bleeding, nephrostomy time and hospital stay; on the other hand, it is highlighted as disadvantageous in terms of operation time and intrarenal pressure. (6) In the 2020 review of Ather et al., rather than the use of the sPCNL (≥22 Fr), the use of mPCNL (12-20 Fr), ultra-mPCNL (11-13 Fr), mini-micro PCNL (8 Fr), and micro PCNL (<5 Fr), the technique is said to be increasing. It was emphasized that this situation limits the indications for ESWL use. It has also been stated that miniaturized PCNL has a higher stone-free rate than fURS, but may have very few high hemorrhagic complications. Again, fURS is a 1-day procedure, while PCNL may require 2-3 days of hospitalization; On the other hand, it was stated that stent use will be required for a few weeks in fURS, while there is no such need in PCNL(11). Again, according to the opinions of different authors, the potential of mPCNL was defined and the method was positioned between sPCNL and fURS. Traditionally, stones between 1.5-3 cm and >1000 Hounsfield Units are the ideal indication for mPCNL. Chinese authors have stated that mPCNL is close to sPCNL, even in staghorn stones, depending on the surgeon's experience. Again, mPCNL by novice urologists during the sPCNL learning curve period, with a smaller caliber dilator, creates a relatively safe environment for bleeding. (12) Kidney The location of the stone in the lower calyx may make mPCNL advantageous over RIRS. Again, after sPCNL, mPCNL may be preferred in the intervention of residual stone residues.

3. Ultra Mini and Super Mini PCNL

The term "ultra mini PCNL," abbreviated as "UMP," is a relatively new addition to the PCNL lexicon and usually denotes an access sheath size of 11-13Fr. At first, a fluoroscopy-guided puncture with an 18-gauge needle is administered. The needle is withdrawn, a guidewire is inserted, and the 11Fr or 13Fr access sheath with an obturator is advanced over the guidewire. Then, a small nephroscope with a 6Fr optic is utilized to observe the kidneys. Stone is fragmented under direct vision using a Holmium laser, the only practical energy source gave the size of the devices. The use of an endoscopic pulsed perfusion pump helps the patient keep their eyes open. Due to the 'vortex' effect, stone pieces are flushed out when the endoscope is quickly removed. There have been reports of sepsis (6%), urinary extravasation (3%), and fever (2%), all of which occurred after using this method on calculi smaller than 2 centimeters (8 percent). (13) For an estimated price of £8,800, equipment from manufacturers like LUT (Leben and Technologie) is worth looking into. Although the equipment may be used again and again, the cost of the laser fiber for a single surgery will be significant. Costs per procedure may be decreased in clinics that recycle laser fibers, but this method has a limited lifespan that is affected by the amount of energy utilized and the sorts of stones that have already been treated.

Cross-sectional surface area is reduced to roughly 1/8 of the original tract size utilized in conventional PCNL (30 Fr) because of the decreased tract size, lowering the potential for bleeding and tissue damage. The tiny UMP sheath nevertheless manages to progress without inflicting considerable harm to the infundibulum, even when UMP is performed on kidneys with a narrow infundibulum. The UMP system's working sheath is fitted with a tiny tube of 3 Fr that is soldered to the inside and leads to an exterior port. The working sheath's unique construction has the benefit of allowing stone pieces to be retrieved without the need for baskets or graspers. Low rates of complications, high SFRs, and the need for further treatments are all related to UMP (14) and are particularly useful in the treatment of stones <20 mm in diameter in lower pole calyx. However, UMP has been shown to be more effective than ESWL for treating lower calyx stones with long, narrow calyces and a steep angle, making it difficult for pieces to pass. (15) According to a matched study done by Wilhelm et al., both UMP and RIRS are effective in reducing the size and frequency of complications associated with the removal of renal stones of 10–35 mm in diameter. However, in the UMP group, both surgical and hospital stays were longer. (16)

Recent technological advancements in the realm of miniature PCNL techniques are extremely astonishing. These unique techniques, characterized by small percutaneous tract widths, reduce hemorrhage while maintaining a high SFR. (17–20) However, it is essential to be aware of the limits of these techniques, such as lower irrigation flow, decreased endoscopic vision, a decreased capacity to recover stone pieces and an increased risk of developing high renal pelvic pressure. Zeng et al. created Super Mini PCNL (SMP) to improve the safety and effectiveness of existing PCNL technology by using a novel micro endoscopic device. (21) The SMP system consists of an 8.0Fr nephroscope and a brand-new irrigation-suction sheath. Utilizing SMP offers several advantages. It is feasible to effectively recover both stone dust and stone pieces as a first step. With continual irrigation, there is no fog or mist to obscure the view. This is because the new watering strategy decreased both the "dust storm" and the quantity of blood lost. Thirdly, the negative pressure aspiration that facilitated irrigation drainage maintained the average renal pelvic pressure low during the whole surgical procedure. (22) This indicates that SMP may significantly minimize the risk of sepsis, which is often caused by intraoperatively elevated kidney pressure. In research by Liu et al., 111 children had SMP. All of the kidney stones, which averaged around 1.4 centimeters in size, were located in the lower calyx of the kidney. The ultimate SFR was 90,1%, while problems were seen in 15.3% of patients. The two complications were levels I and II on the Clavien scale. The cold temperature was the most pervasive negative impact. After getting symptomatic treatment, everyone recovered health. There may be some benefits for pediatric patients utilizing SMP as compared to RIRS. (23)

4. Micro PCNL

Desai et al. described a variant of mzPCNL, which they named micro-PCNL, in 2011. They used a 4.85 f tool they called the all-seeing needle. The 3-piece All-seeing needle (PolyDiagnost, Pfaffenhofen, Germany) consisted of a 0.9 mm micro optic with a 120-degree angle of view and a resolution of up to 10,000 pixels and a 1.6 mm (4.85F) outer diameter needle. The fiber optic telescope had a flexible structure that could be bent on itself. An endoscopic camera system and a Xenon light source with a power of at least 100 W are connected to the fiber optic telescope. A 3-channel connector is connected to the post-access needle. A 200 µm laser fiber is connected through the central channel, a pressure irrigation connection, and a fiber optic telescope from the side channels. (24)

The micro-PCNL satellite technique can be described as follows. In the dorsal lithotomy position, a 6 Fr open-ended ureteral catheter is inserted under cystoscopic supervision. The patient is then positioned prone, and the appropriate calyx is accessed with a 4.8 Fr (16 Gage) all-seeing needle (PolyDiagnost, Pfaffenhofen, Germany). After the stone has appeared, the inside is removed, and a three-way connector is affixed to the shaft’s outer end. Optical fibers are inserted through the center connector’s side port. Other ports are utilized for an irrigation system and a 272 m laser fiber to pulverize the stone (Quanta System, Spa OAF, Solbiate Olona VA, Italy). The ureteral catheter is retained in place until the first postoperative day or is replaced with a JJ stent if there is a substantial stone load or residual stone. (25)

The most significant benefit of micro-PCNL is decreased bleeding. In micro-PCNL, single-step access under direct visualization aids in the prevention of potential difficulties during access and dilation of the tract and reduces the risk of intraoperative hemorrhage. In fact, intrarenal hemorrhage can result in the premature end of an operation, organ loss, or even death. According to studies, the nephroscope and the size of the tract affect intraoperative bleeding. Kukreja et al. demonstrated that technique-related variables, such as the method of access (fluoroscopy vs. ultrasonography), number of tracts, method of tract dilatation, size of tracts, and rate of surgical complications, have an important impact in predicting total blood loss. (26,27) In the first micro-PCNL trial, the mean decrease in hemoglobin was determined to be 1.4 mg/dL 5, however, later investigations did not report the requirement for postoperative transfusion. (28–30)

Another difference between micro-PCNL from conventional PCNL is that there is no need for stone removal. Although similar to SWL in this respect, the advantage of micro-PCNL is that the stone localization is precisely focused directly under the image and allows complete fragmentation of the stone by laser, regardless of stone density. (31) Also, SWL is a relatively less invasive procedure. However, its success depends on several variables, such as the density, location of the target stone(s), and the distance between the stone and the skin. (32)

Compared with PCNL, intrarenal surgery (RIRS) has good efficacy and a low complication rate, such as severe bleeding or infection in patients with small kidney stones, but has a lower fragmentation rate. The steep learning curve is another limitation of RIRS. On the other hand, any surgeon capable of performing PCNL can learn micro-PCNL procedures relatively easily. (31) In a prospective randomized study, Desai et al. compared micro-PCNL and RIRS to treat renal stones smaller than 1.5 cm. Their results concluded that micro-PCNL is a safe and effective alternative to RIRS, with similar stone clearance and complication rates. The disadvantages of these procedures are that micro-PCNL is associated with higher analgesic requirements due to increased pain and higher hemoglobin loss. At the same time, RIRS has a higher rate of JJ stenting . (32,33)

Previous studies have reported success rates ranging from 85 to 93% for micro-PCNL. Although complete removal of small residual stone fragments is facilitated by serial saline irrigation during the procedure, stone fragments may cause postoperative renal colic pain and steinstrasse formation, especially in patients with large Stones. (28–30)

Drainage of the collecting system during micro-PCNL is provided by a large ureteral catheter (6Fr). In the absence of an external access sheath used as in conventional PCNL, an increase can be observed in intrarenal pelvic pressure, especially in buried pelvic stones that have prolonged operation time and prevent drainage. In one study, the authors reported a case of abdominal distension due to fluid extravasation as a complication of micro-PCNL. The authors attributed this nasty complication to an embedded pelvic stone, which led to impaired renal drainage. (28)

The main limitation of the technique is the low resolution of the micro-optics, and the thin and small size of the micro-sheath can affect the result. The image may be affected by minimal bleeding. Reaching other calyces containing scattered stone fragments may be restricted due to limited maneuverability. Conversion to mini-PCNL is a solution to overcome these limitations of the micro-PCNL technique. In the limited literature available, conversion to intraoperative mini-PCNL was required in 4.8-8.57% of cases. (28–30)

Previous studies have shown that tubeless procedure is the most important factor affecting the shortening of hospital stay after percutaneous nephrolithotomy. In addition to the advantages described above, the hospital stay is shortened due to the totally tubeless technique and smaller incisions in micro-PCNL. (34)

5. Conclusion

Surgeons and patients alike benefit greatly from the downsizing of technology and the gradual improvement of PCNL techniques throughout time. This is a promising area of endourology that needs further research.

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CHAPTER VI

SUPINE PERCUTANEOUS NEPHROLITHOTOMY

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1. Introduction:

In the treatment of stones smaller than 2 cm, shock wave lithotripsy (SWL) is generally recommended as the first-line treatment method. Percutaneous nephrolithotomy (PCNL) is the first choice in the treatment of kidney stones larger than 2 cm, according to the urolithiasis guideline of the European Association of Urology. (1) Traditionally, the most commonly used method is the prone position in the world. The prone position is preferred because it has a wide working area. This position theoretically offers the possibility of performing renal access in the direction of the Brödel line without significant bleeding. (2) Initially, urologists' knowledge of perirenal anatomy remained limited due to the lack of use of modern imaging methods. During the percutaneous intervention, PCNL was performed in the prone position to reduce risks such as injuries to the colon and other nearby organs. However, with the widespread use of pre-operative computerized tomography imaging, it has been realized that this possibility is less likely in the supine position. (3) The prone position is also associated with higher complications in patients with morbid obesity and cardiopulmonary disease. (4)

Over the last decade, PCNL has undergone gradual changes, including advances in access techniques, endoscopic instrumentation and miniaturization, lithotripters, and exit strategies. Modification of the prone patient position is also part of development. (5) Various modified prone and supine positions have been proposed over the years. According to the British Association of Urological

Surgeons (BAUS) data, 6% of percutaneous kidney surgeries were performed in the supine position in 2010. This rate increased to 20% in the Clinical Research Office of the Endourological Society (CROES) global study in 2015. (6,7) This significant change reveals that supine PCNL has become a more accepted and preferred technique among endourologists over the years. Reasons for position changes are; providing retrograde access, comfortable and safe procedures in terms of anesthesia, optimal airway control, and less risk of endotracheal tube displacement.

Supine PCNL was first described by Valdivia Uria in 1987. (8) It was later performed by Dr. Iberluzea for a long time in Spain. (9) Many different supine position modifications have subsequently been described to improve surgical outcomes. According to the review of Kumar et al., no superior advantages of any supine position were identified to the others. (10) With the elevation of the flank region, a wider working space can be obtained. Today, the Galdakao modified Valdivia position, which allows simultaneous retrograde access, is the most preferred supine PCNL position in the world.

Supine and prone PCNL have now been compared in many studies and meta-analyses. Stone-free rates were reported to be similar in both types of operation. (11-13) Advantages of supine PCNL over prone PCNL are; no need for repositioning, short surgery time, less radiation exposure, low risk of colon injury, low-pressure working environment, easy spontaneous stone passage, retrograde accessibility, and ease of access to the airway in terms of anesthesia. (5) The ergonomics provided by the surgeon's ability to work in a sitting position is another advantage of the supine PCNL. In addition, since there is no conflict between the surgical instruments and the fluoroscopy device, the C-arm does not need to be taken out. (5)

In the urolithiasis guideline of the European Urology Association, both supine and prone PCNL is stated to be safe. It has been shared that the supine position is advantageous for retrograde access, while the prone position is advantageous for upper pole entry and multiple accesses. (1)

The technical features, advantages, and disadvantages of the supine PCNL operation are discussed in this chapter. Endoscopic combined intrarenal surgery is not covered as it is the subject of another chapter.

2. Surgical Technique

In supine PCNL, the design of the operating room and the placement of the instruments vary according to the patient's position and the chosen access method (figure 1). Considering the need for endoscopic combined intrarenal surgery, instruments should be readily available. It is essential that the operating table is radiolucent and compatible with the C-arm fluoroscopy device. The operating table should have appropriate extremity footrests so that the lower extremity can be ipsilaterally extended and contralateral flexed. All possible pressure points should be supported with soft materials and all necessary efforts should be made to protect the patient. If ultrasound-assisted or ultrasound-guided access is to be made, an ultrasound device should also be available.

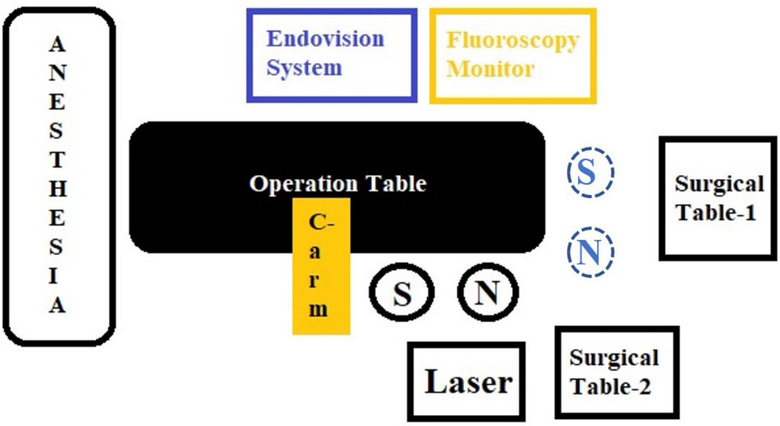

Figure-1 Operation room settings for 0-90 degree technique for supine PCNL: Surgeon and nurse temporarily stand in place marked with blue dotted lined circle for retrograde ureteral catheterization. C-arm has to be placed on the same side of the surgeon in this method

2.1. Patient Position:

Over the years, the supine position has undergone various modifications, and complete supine, lateral supine, and modified supine positions such as Barts' flank-free modified supine position, Giusti's position, and Modified Double-S supine position have been described. We prefer the Galdakao modified Valdivia position in our daily routine practice.

In the Galdakao modified Valdivia position, the patient is laid on the side very close to the edge of the operating table. In this position; the lower extremity on the side of the stone is extended, and the contralateral lower extremity is abducted and flexed. (14) Thus, retrograde interventions can be performed simultaneously. The ipsilateral upper extremity is taken to the opposite side by crossing the rib cage and removed from the operation area. The ipsilateral lumbar region is elevated by approximately 20 degrees. (14) Thus, the lower calyx is displaced more laterally and becomes perpendicular to the operating table. (14) The triangular area to be accessed is determined by marking the posterior axillary line anteriorly, the 12th rib cranially, and the iliac crest caudally (figure 2). In obese patients, the fat falling on the opposite side is corrected and straightened by sticking with bands. Particular attention is paid to adjusting the position of patients with skeletal deformations in order to avoid pressure damage.

Starting with cystoscopy, the ureteral catheter is placed on the operation side with fluoroscopic control. Retrograde pyelography is performed through the ureteral catheter.

Figure-2 Anatomical landmarks: The posterior axillary line, the 12th rib, and the iliac crest

2.2. Renal Puncture and Tract Dilatation:

Bull's-eye and triangulation techniques are commonly used access methods in prone PCNL. In supine PCNL, ultrasound-assisted, ultrasound-fluoroscopy combined, fluoroscopy-assisted, and endoscopy-controlled access methods have been described. The cephalad tilting methods described by Hoznek et al. and the methods described by Gökçe et al. are the most commonly used fluoroscopy-assisted access methods. (15,16)

We routinely perform the biplanar 0-90◦ fluoroscopic puncture technique described by Manzo et al. in daily practice. (14) When the C-arm fluoroscopy device is at 0◦, the appropriate calyx to be punctured is selected. Then, the calyx depth is identified by rotating the device to the 90◦ position. (figure 3). An 18-gauge percutaneous access needle is passed into the desired calyx under fluoroscopic guidance. A 0.038-inch guidewire is passed anterogradely across the renal pelvis and into the ureter, upper or lower calyx. The track is dilated sequentially using fascial and Amplatz dilators. Appropriated size Amplatz sheath is inserted. The nephroscope is advanced through the sheath. If endoscopic combined intrarenal surgery (ECIRS) is planned for multiple calyceal stones, the procedure is started with a diagnostic ureterorenoscopy. A fiber uretero-renoscope is used for URS. Then, a flexible uretero-renoscope is inserted into the renal pelvis over the guidewire. In cases where the flexible URS can be advanced, percutaneous access is performed under endoscopic direct vision. In cases without ECIRS, flexible antegrade pyelo-ureteroscopy is performed if the rigid nephroscope can not able to reach to stone. Stone-free status is confirmed with flexible URS in those who underwent ECIRS.

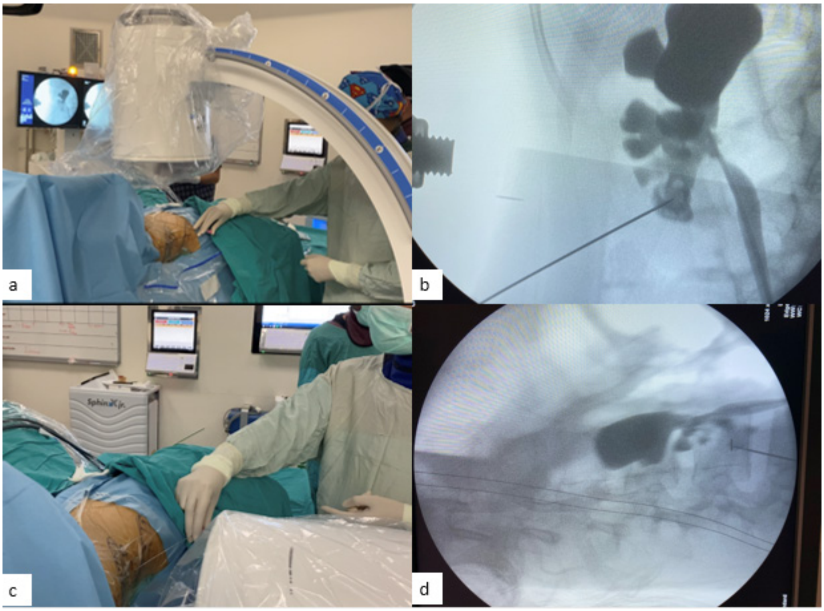

Figure-3 biplanar 0-90◦ fluoroscopic puncture technique **a,b:** 0 degree position- identifying the calyx to puncture **c,d:** 90 degree position-identifying the depth of the calyx

2.3. Lithotripsy:

Stone disintegration is achieved using a laser, ballistic, ultrasonic or combined lithotripters. There is no difference in terms of lithotripters between prone and supine PCNL. Spontaneous passage of stone fragments is easier in supine PCNL with the help of gravity.

2.4. Exit Strategies:

Similar to prone PCNL, the procedure can be terminated with a nephrostomy tube or a double J stent or can be done totally tubeless. A nephrostomy tube can be placed if there is a need for second-look surgery or suspicion of a perforation of the pelvicalyceal system. If there is no bleeding or perforation in patients who are thought to be stone-free, the procedure can also be terminated totally tubeless.

3. Advantages and Disadvantages of Supine PCNL

One of the important advantages of supine PCNL over the prone position is the benefits of anesthesia. Easy and effective access to both the pulmonary and cardiovascular systems in the supine position is very important for anesthesiologists, especially in emergency situations. The supine position is also more advantageous for obese patients. (17) Turning the intubated obese patient into a prone position requires excessive force and may increase the risk of complications. Intubation tube dislocation may occur during repositioning. Less irrigation fluid absorption in the supine position is important in terms of both avoiding cardiac overload and reducing the risk of infection. (18)

The risk of complications due to central and peripheral nervous system damage increases in prone position surgeries. (19) Position-related ophthalmic complications can be seen in the prone position (20). There are risks of direct pressure injury in prone position surgeries. (19) Theoretically, one of the advantages of the supine position over the prone is avoiding additional repositioning time which causes a loss of time of 20-25 minutes time until the final position. And also as another advantage, the entire surgical procedure can be performed with a single surgical field cover. (21)

Other advantages of the supine method are (22);

- More comfortable for a surgeon who performs the procedure in a sitting position

- Less radiation exposure for the surgeon
- Low intrarenal pressure, avoiding cardiac overload and reducing the risk of infection
- Easier spontaneous passage of fragments
- Ability to perform ECIRS for complex stones
- Reducing the need for multiple access

The disadvantages of supine PCNL can be listed as follows (21);

- Difficulties in access and dilation due to renal hypermobility,
- Longer tract length due to more lateral access, insufficient access sheath, and nephroscope length especially in morbidly obese patients
- Low intrarenal pressure, the occasional collapse of the collecting system, and limited vision
- Simultaneous bilateral PCNL cannot be performed

4. Conclusion

In conclusion, although supine PCNL has started to be performed in an increasing number of centers in recent years, prone PCNL is currently being performed more frequently. Supine PCNL compared to prone PCNL, has become an increasingly popular procedure with its shorter operation time, similar stone-free and complication rates. Supine PCNL is preferred as a recommended intervention in patients with morbid obesity, cardiovascular disease, and a high risk of anesthesia. One of the most important advantages of supine PCNL is that it allows simultaneous ureterorenoscopy.

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CHAPTER VII

ENDOSCOPİC COMBINED INTRARENAL SURGERY

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1. Introduction:

Over the past 30 years, advancements in surgical technology and endoscopic methods have revolutionized the treatment of urinary stones. Because of these advancements, urinary stone removal by surgery is now more feasible. (1) Minimally invasive methods, such as extracorporeal shock wave lithotripsy (ESWL), flexible ureteroscopy (fURS), and percutaneous nephrolithotomy (PCNL), have essentially replaced open surgery because of their high success rate and low risk. (2) Treatment of large stones (>20 mm) in the upper urinary tract with the minimally invasive procedure percutaneous nephrolithotomy (PCNL) has been shown to have a much higher stone-free rate (SFR) than traditional approaches. Treatment recommendations for urolithiasis published by the European Association of Urology (EAU) say that PNL is still the treatment of choice for stones greater than 20 millimeters in diameter. (3)

The term "ECIRS" stands for "endoscopic combined intrarenal surgery," and it was introduced in 2008 to standardize the use of rigid and flexible endoscopes in performing combined retrograde and antegrade approaches to treating large and/or complex cases of urolithiasis. (4) According to the available literature, this aids in overcoming the constraints and problems of PCNL, particularly when dealing with huge stone volumes. PCNL and fURS have separately acquired traction as first-line minimally invasive therapies for urolithiasis depending on stone size thanks to developments in endourology, downsizing, and technology. (5) When dealing with a kidney stone that is more challenging, PCNL alone isn't enough. Hydronephrosis makes percutaneous access easier; without it, it may be necessary to use numerous tracts to reach all calyces. Fragments of stones often go to the ureter, and even after treatment, some of these stones may remain in the ureter. Since the introduction of the holmium: yttrium aluminum garnet laser system in the 1990s, RIRS has seen tremendous growth(6). It is hypothesized that the optimal surgical result for renal lithiasis can be attained by combining these two in ECIRS. ECIRS's main benefit is that technique allows for dynamic and concurrent optimization of antegrade and retrograde access using flexible and semirigid tools by two surgeons, who may adapt the treatment to the stone burden/location and anatomical complexity of each patient. (7)

2. Surgical Technique

The organization is crucial in an ECIRS operating room because of the large number of people and pieces of equipment present. Two urologists, an anesthesiologist, a nurse, and an additional nurse who oversees the facility's machinery make up the medical staff. The usual operating equipment for both the antegrade and retrograde surgeons should be arranged on their respective scrub nurse tables, with any backups located nearby. Dual-viewing, also known as image splitting or picture-in-picture viewing, allows for the simultaneous display of both antegrade and retrograde images on a single high-definition monitor. The operating table must be radiolucent and mobile to free the abdomen of radiopaque obstacles while using the C-arm of fluoroscopy and the cushioned leg stirrups for the modified lithotomic position.

2.1. Position:

In the late 1980s, a Spanish surgeon named Josè Gabriel Valdivia Ura began routinely conducting PCNL in a supine-modified posture in which the operated side was raised. Gaspar Ibarluzea, another Spanish urologist, later advocated adding an asymmetrical lithotomic configuration of the lower limbs to the Valdivia supine posture to combine the benefits of supine decubitus for anesthesia with the convenience of retrograde access to the collecting system. Our preferred posture for ECIRS is a variation of the supine Valdivia position called the Galdakaomodified supine Valdivia (GMSV) position. A wide range of oblique, flank, total supine, and modified prone postures have been documented by several urologists to facilitate ECIRS and facilitate smooth anesthesiological intraoperative care. Patients have better hemodynamic and pharmacokinetic circumstances, less danger of pressure injuries and ischemia, and a lower chance of inadvertent extubation and tracheal tube kinking when the patient is turned prone, as proven by the anesthesiologists themselves. It is important to note the drawbacks of the supine positions as well, including the increased mobility of the kidney, which may necessitate additional assistance to stabilize the kidney and the smaller working space compared to the prone position's expansive field of view, although elevating the flank does help to enlarge the working space. A sample of the GMSV position that we routinely prefer in our clinic is presented in Figure 1.

Figure 1: Demonstration of the position used for ECIRS

2.2. Retrograde approach:

Under fluoroscopy guidance, a 0.038 Fr guide wire is inserted through the semirigid ureteroscope into the renal pelvis. Retrograde pyelography can be used to examine the pelvicalyceal system. A ureteral access sheath (UAS) is placed over the guide wire under fluoroscopy. A fiberoptic flexible ureteroscope should be used to access the collecting system.

2.3. Antegrade Approach:

An 18-gauge cutaneous access needle is inserted under biplanar fluoroscopy at a dictated angle and depth in the selected and ultrasonically controlled plane. The ureteroscope is inserted into the preferred calyx, preferably filled with contrast-enhanced saline, and then used to detect the definitive image of a needle entering the calyx via the trans-papillary route. It is common for the 0.038 Fr hydrophilic rigid guidewire to descend into the ureter, roll helically in the bladder lumen, or be removed from the external urethral meatus under fluoroscopic and endoscopic guidance (also called through-through) as shown in Figure 2. First, an incision is made in the skin and subcutaneous tissue using 8F and 10F fascial dilators, and then a 24F Amplatz sheath is placed on the balloon dilator to provide more comfortable and effective dilation of the tract. Only in hourglass-shaped tracts, complete balloon dilation can be evaluated with fluoroscopy; all other stages can be controlled endoscopically. As a result of the size difference between the Amplatz sheath and the nephroscope, a good irrigation flow is achieved by inserting the 18F nephroscope.

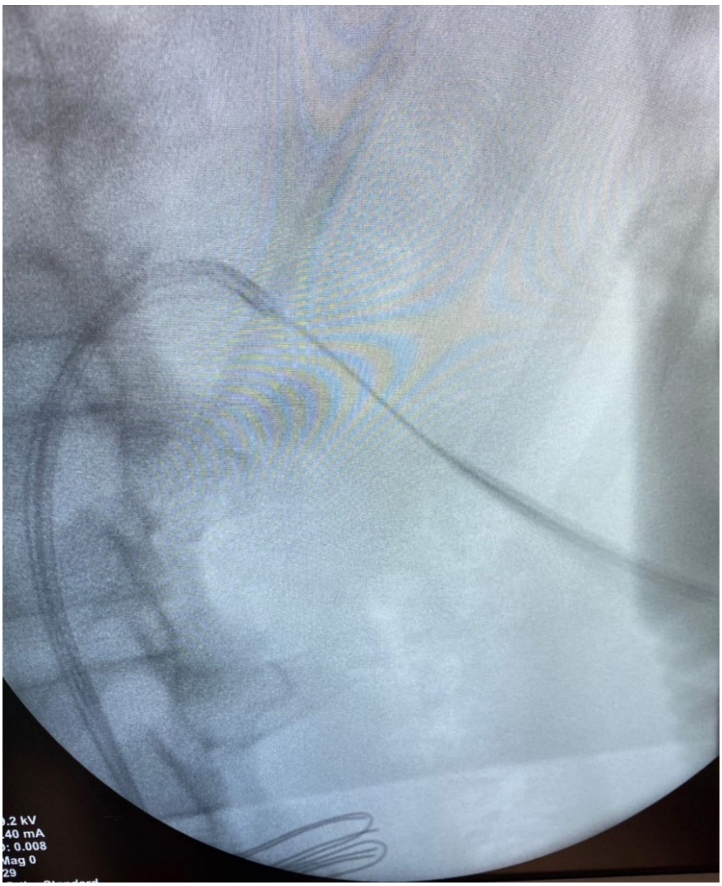

Figure 2. Through-through positioning of the guide wire

2.4. Lithotripsy:

Pneumatic or ultrasonic lithotripters can be used for lithotripsy, and the selection is based on the severity of the kidney stones and the diameter of the rigid nephroscope. Because of their small size and adaptability, lasers are essential for facilitating miniature access and wide-ranging inspection. The use of a rigid nephroscope for as much of the procedure as possible is central to the lithotripsy method, which alternates between more efficient disintegration and discharging the fragments with flushing, forceps, or baskets. As the ureteroscope is retracted into the ureter, it blocks the passage of fragments down the ureter and into the Amplatz sheath, protecting itself from injury while simultaneously facilitating irrigation of the collecting system. The flexible ureteroscope may be useful for in situ laser lithotripsy in calyces parallel to the Amplatz sheath or for transporting fragments in front of the percutaneous access.

A nephroscope and flexible ureterorenoscopy can view each other with a fingertip's touch in the intrarenal space. When placed side by side, two endoscopes have a finger-touch look. Finger-touch space refers to the intrarenal space where the procedure is carried out. Stones in the upper calyx and other areas that a nephroscope can't reach need to be checked out using a flexible ureterorenoscopy. The majority of stone is divided up using a nephroscope and Amplantz sheath. A miniature nephroscope with a Holmium laser for the extraction of stones can be used when necessary.

The stones are washed out of the kidney passively utilizing a washout mechanism while employing real-time ECIRS and removing the nephroscope from the Amplantz sheath. The intermediate-supine location is the primary driver of the downward orientation of the Amplantz sheath, which allows for passive retrievals. Furthermore, the irrigation fluid is continually injected toward the stone through the flexible ureterorenoscope, allowing the shattered stone to be expelled via the Amplantz sheath. The passive retrieval rate of real-time ECIRS may be increased by using a notion known as the washout process.

2.5. Transport Technique:

Stone fragments are moved to a different calyx in PCNL monotherapy. As the maximal angle is increased during PCNL monotherapy, the Amplantz sheath may be inserted into the nephroscope. When the renal parenchyma is damaged, internal bleeding might occur. When more stones were located in the upper pole and couldn't be reached by the lower pole approach, multi-tract PCNL might be an alternative solution. However, a flexible ureteroscope and stone basket may be employed to grab the stone in real-time simultaneous ECIRS if the top pole is difficult to reach after the lower pole has entered the Amplantz sheath. Using the Amplantz sheath and nephroscopic stone forceps, the stone is transferred from the basket to the nephroscope's finger-touch zone, where it may be felt and identified. Real-time simultaneous ECIRS transport is the technical term for this method of stone removal.

2.6. End of the Operation:

After the UAS is removed, antegrade pyelography is completed by attaching a double J stent with a thread under nephroscopic supervision, and then an 8F nephrostomy tube is placed. If the ureter is healthy the day after the surgery, the nephrostomy is removed and the next day the double J stent, thread, and catheter are removed. If the ureter is injured, it is recommended to leave a double J stent (without thread) in the ureter for 15-20 days after catheter removal.

3. Summary of Benefits of ECIRS

ECIRS provides a preliminary assessment of the lower urinary tract, early detection of urethral strictures, early detection of false urethral passages, as well as early detection of occluded or easily bleeding prostate adenomas. In addition, it has advantages such as early detection of calcified intravesical stents, detection of a possible narrow ureteral orifice, and passive ureteral dilatation due to the conical shape of the semi-rigid ureteroscope. Early detection of ureteral strictures is among its other advantages. Static anatomy information obtained from optical imaging inside the collecting system prior to PCNL guides upper urinary tract dynamics assessment and intraoperative decisions. For example, the presence of buried stones, collecting system anomaly, and calcium deposits evaluated as stones in the preoperative evaluation are clearly revealed before PCNL. The use of endoscopy to aid the development of the percutaneous canal using retrograde irrigation, a water channel can be created around the affected staghorn stones in a calyx, making it easier to implant the hydrophilic guidewire and providing more options for the dilation method and access route. Conical dilators such as balloon or silicone dilators cannot be used unless there is at least 1 cm of space in the calyx to insert their ends, while Alkene dilators can only be used with sufficient space to insert the ball-shaped end of the first. If the access calyx infundibulum is small, the surgeon will use inelastic instruments and accessories and choose a miniature inlet to avoid rupture of the collecting system and unnecessary bleeding. Treating/replacing calyceal stones that are difficult to reach anterogradely with both rigid and flexible nephroscopes seems ideal to eliminate the need for several percutaneous accesses. An ongoing antegrade lithotripsy procedure using a rigid or flexible nephroscope can be controlled retrogradely to prevent fragments from falling below the ureteral pelvic junction (UPJ). To achieve the best possible stone-free condition, it is important to perform a final integrated examination of all calyces with the flexible nephroscope to look for remaining fragments, as stones can be retrieved using a basket. Evaluation of the pelvicalyceal system, including evaluation of the descent of the contrast agent from the pyelocalyxal system to the sub-ureteropelvic junction into the ureter, is the final step in deciding whether treatment with or without a stent is necessary.

4. Conclusion

In conclusion, the available data shows that flexible nephroscopy and ureteroscopy may be useful for patients with large and/or complicated urolithiasis who have not responded to rigid PCNL alone. For example, retrograde flexible ureteroscopy has a dual function, both diagnostic and active, during PCNL by enabling the treatment to be adapted to the patient, urolithiasis, and collecting system architecture, hence increasing PCNL's effectiveness and decreasing its risks. A more modern, comprehensive, and adaptable form of PCNL is what we provide here at ECIRS.

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CHAPTER VIII

OPEN, LAPAROSCOPIC AND ROBOTIC SURGERIES IN THE TREATMENT OF KIDNEY STONES

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1. Introduction

In parallel with the groundbreaking technological developments in the 21st century, significant changes have also occurred in health services. Many old techniques have been replaced by newer techniques that are more minimally invasive. Many factors, such as the development of high-resolution optical and digital imaging systems, minimizing the size of the surgical instruments used, the ability of newly developed flexible devices to move between the folds of the urinary system with high maneuverability, and the introduction of high-tech lasers that easily fragment stones have revolutionized surgery. These new developments have shifted the direction of surgical treatment of kidney stone disease to minimally invasive endourological interventions such as ESWL (Extracorporeal Shock Wave Lithotripsy), PCNL (Percutaneous nephrolithotomy), and URS (Ureterorenoscopy). Another alternative to open surgery, which has been widely used in the surgical treatment of kidney stone disease for many years, is laparoscopic and robotic surgery options, which are also defined depending on technological developments. In this book chapter, the use of open, laparoscopic, and robotic surgery options in the surgical treatment of kidney stone disease is discussed.

2. Open Stone Surgeries

Since the 1970s, minimally invasive endourological intervention techniques have been used, and the devices used have been developed daily. For this reason, open surgery methods, which were the gold standard surgical treatment until recently, have begun to be abandoned.

1.1. Open Anatrophic Nephrolithotomy

Smith and Boyce first defined the Anatrophic Nephrolithotomy method in 1968 as removing the stones inside the kidney by performing a nephrotomy from the Brödel line, which is relatively avascular to the other parts of the kidney. (1) It is planned to open the kidney from this line between the ends of the end arteries feeding the anterior and posterior parts of the kidney to minimize the possible damage to the vascular structures and to prevent possible renal atrophy.

Following the routine preoperative preparations, after the patient is placed under general anesthesia, the foley catheter is inserted, and the patient is placed in a 90-degree flank position with the planned kidney on top. The patient is fixed on the table using materials to prevent pressure on the extremities and tissues. Following the covering of the surgical field, the kidney is reached from the retroperitoneal area with a flank incision, and the peritoneum is medialized while the pleura and diaphragm are pushed cranially. If the kidney is located high and difficult to access, the ribs that prevent access may need to be resected. By opening the Gerota fascia along the craniocaudal line, the perirenal fat tissues are dissected without entering the subcapsular plane, the kidney is accessed, and the kidney is fully mobilized. While dissection of the upper pole, the dissection should be done carefully to avoid damaging the adrenal gland. Dissection of both poles is necessary for easy control of the renal pedicle. The posterior branch of the renal artery is also dissected, while the dissection of the renal pedicle is done carefully to avoid damage to the vascular structures. This dissected branch is clamped with the help of a bulldog clamp, and 10-20 mL of intravenous (IV) methylene blue is injected into the artery to mark the area fed by the posterior branch of the kidney. Thus, the Brödel line located at the junction of the anterior and posterior branches of the renal artery is clearly revealed, and the location of the nephrotomy incision planned to be made from the avascular line is confirmed. After marking the Brödel line with cautery, the bulldog clamp on the posterior segmental artery should be removed. After the kidney is wrapped with a plastic cover, the patient is given IV mannitol and 10 minutes later; the renal pedicle is clamped with bulldog or Satinsky clamps. Following the clamping, the slush ice is placed around the kidney and waited for 10 minutes, and the temperature of the kidney parenchyma is tried to decrease to 15°C. During the clamped period, the slush ice around the kidney should be renewed at least every half hour. The marked Brödel line is cut down to the collecting system, the collecting system is opened with Pott scissors, the stones are reached, and the stones are collected using blunt triple Randall forceps. Each calyx should be carefully evaluated to see if any stones are left. After this stage, DJS (Double J Stent) is placed anterogradely, and the closure stage starts. Following the closure of the collecting system with continuous sutures, the renal parenchyma is closed with horizontally placed matrix sutures. After this stage, the slush ice around the kidney is cleared, and mannitol is given again to reduce renal perfusion damage. Following the bleeding control, Gerota's fascia is closed, and a drain is placed in the surgical site to monitor bleeding and extravasation.

2.2. Open Pyelolithotomy

Open pyelolithotomy surgery can be easily performed in patients with an extrarenal pelvis but should not be performed in patients with an intrarenal pelvis. (1) In open pyelolithotomy, preparation is made just as in open anatrophic nephrolithotomy, and the patient is fixed by positioning. Gerota's fascia is opened, and the perinephric adipose tissue is dissected without entering the subcapsular plane. After locating and suspending the ureter, the ureter is dissected up to the renal pelvis to expose the renal pelvis. Access into the renal pelvis is achieved by making a "U" shaped incision on the renal pelvis without approaching the ureteropelvic junction. With the help of blunt-tipped Randall forceps, stones are collected and removed from the system. In the presence of accompanying small stones, a feeding catheter can be inserted into the ureter following the incision to prevent the stones from escaping into the ureter. After the stones are cleared, a flexible cystoscope can be used to evaluate the presence of residual stones. After it is understood that there is no residual stone, DJS is placed anterogradely into the collecting system, and the incision on the renal pelvis is sutured. After the drain is placed in the surgical site to monitor bleeding and urinary extravasation, the layers are closed by the procedure.

Open surgical methods can be performed with surgical materials found in almost every surgical clinic. They do not require high-technology products, and their costs are very low. However, recovery and hospital stay times are longer, morbidity and complication risks are higher than in minimally invasive surgical procedures. For this reason, open surgery should be considered as the last option in the surgical treatment planning of kidney stone diseases.

3. Laparoscopic Stone Surgery

Although laparoscopic surgery performs similar procedures to open surgery, because laparoscopy is a more minimally invasive method, lower morbidity and faster recovery times are achieved compared to open surgery, and a higher quality of patient life can be achieved. However, laparoscopic surgeries have been widely accepted in treating many benign and malignant processes in urology, but their use in treating kidney stone diseases is limited.

3.1. Laparoscopic Pyelolithotomy

Laparoscopic pyelolithotomy (LP) surgery was first described in 2009 by Salvado et al. (2) Although LP is not a commonly used procedure, it is a method that can be used in patients with renal stones whose stone is desired to be completed in a single session, in patients with ectopic kidney stones and patients with stones accompanying ureteropelvic junction stenosis (UPJS). The LP procedure can be performed simultaneously with pyeloplasty or alone. Images of laparoscopic pyelolithotomy performed in a patient who underwent laparoscopic pyeloplasty for UPJS are shown in figure 1 **(Figure 1)**.

Figure 1. *Images of laparoscopic pyelolithotomy during laparoscopic pyeloplasty. (From Dr Ezer's archive)*

a. *Separation of the UP junction from the renal pelvis*

b. *Stones in the renal pelvis*

c. *Collecting stones in the renal pelvis with a grasper*

d. *Placing the removed stones in the endobag*

e. *Checking the residual stones with a flexible cystoscope*

f. *Kidney stones collected in endobag*

However, it should be remembered that removing all stones from a single incision in patients with complex renal stones may not be possible. While it can be performed more easily in patients with an extrarenal pelvis, it is more challenging to perform the procedure in patients with an intrarenal pelvis. In the studies, it was recommended that it should not be preferred in orthotopically located kidneys, and it was stated that it required longer operation time and longer hospitalization compared to the PCNL procedure and that cosmetic results were worse. (3,4) LP may be a promising treatment option in patients with renal anomalies in whom classical endourological interventions are unsuccessful. Figure 2 shows images of LP surgery performed on a patient with a horseshoe kidney anomaly **(Figure 2)**.

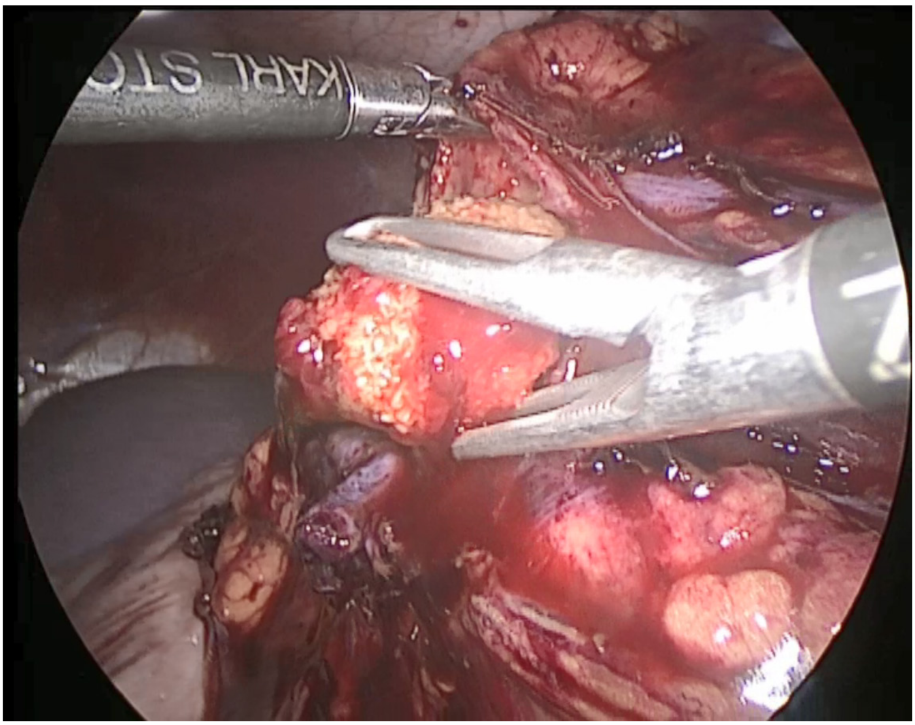

Figure 2. A kidney stone removed from a pyelotomy incision over the renal pelvis in a patient with a horseshoe kidney anomaly. (From Dr Ezer's archive)

Like many laparoscopic surgical procedures, it can be performed transperitoneally or retroperitoneally using 3 or 4 ports. While the stone can be removed from the pyelotomy incision with the help of forceps, the stones located in the calyceal can also be removed with the help of a flexible cystoscope and basket delivered through the port. At the end of the procedure, DJS is usually placed, the pyelotomy incision is sutured, and the DJS is planned to remain for 4-6 weeks in the postoperative period. It should be considered that irrigation fluids flowing into the peritoneum may cause postoperative ileus, especially when using the nephroscope in the transperitoneal method. For this reason, there are also studies in the literature suggesting that CO_2 can be used instead of irrigation fluid. (5) One of the conditions that should be considered, especially during transperitoneal LP, is the risk of losing the stones by dropping them into the peritoneum in cases with more than one stone. The time spent to find the stone again will prolong the surgical time, and stones that cannot be seen by being lost in the abdomen may cause recurrent infections, adhesions and fistulas. The risk of developing an intra-abdominal infection of the fluids that will flow into the abdomen while removing the infection stones is also a cause for concern. Figure 3 shows the collection of stones in the kidney with a flexible cystoscope during laparoscopic pyelolithotomy (Figure 3).

Figure 3. The collection of stones in the kidney with a flexible cystoscope during laparoscopic pyelolithotomy. Please note that two separate screens are used for the laparoscopic camera and the flexible cystoscope to prevent stone loss in the abdomen during stone collection, and CO_2 is used instead of irrigation fluid in the flexible cystoscope to avoid giving irrigation fluid to the abdomen. (From Dr Ezer's archive)

3.2. Laparoscopic Surgery of Calicial Diverticulum Stones

Calicial diverticulum stones are usually asymptomatic and become symptomatic in the presence of infection. The main treatment principles are eliminating the stone in the diverticulum and eliminating obstruction of the diverticulum entrance. Although many calyceal diverticulum stones can be treated with endourological interventions, large diverticulum stones located in a thin renal parenchyma are suitable candidates for laparoscopic surgery. Because in this patient group, it will be difficult to fix the guide wire in the cavity while performing PCNL, and manipulation of the nephroscope will be more difficult due to the large stone and narrow range of motion. In addition, having a thin renal parenchyma causes less bleeding during laparoscopic surgery. Since it is technically challenging to intervene in anterior calyceal stones using the PCNL method, laparoscopic surgery may be preferred in this patient group.

This surgery can be performed using 3 or 4 ports with a transperitoneal and retroperitoneal approach. Ureteral access should be provided retrogradely during the procedure, and if possible, intraoperative laparoscopic USG should be available. If the diverticulum cannot be detected with retrograde methylene blue, it is localized using USG. Following recognizing the diverticulum, it is incised using laparoscopic scissors or laparoscopic cautery, and the stone is removed and placed in the endobag. Following the stone's removal, the diverticulum's neck is fulgurated and repaired by laparoscopic suturing6. The stone-free rates of this method in the literature have been reported between 92% and 100% in different studies. It constitutes a satisfactory treatment alternative with low complications and high success rates in the appropriately selected patient group. (6)

3.3. Laparoscopic Anatrophic Nephrolithotomy (LANL)

LANL can be applied in patients with complex staghorn stones to achieve stone-free status in a single session. It is a more minimally invasive procedure compared to open anatrophic nephrolithotomy. In the classical LANL technique, the kidney is dissected from the surrounding tissues after the placement of the laparoscopic ports is completed. The renal pedicle is exposed and clamped with laparoscopic bulldog or Satinsky clamps en bloc. (7) After the kidney is opened longitudinally from the Brödel line, the stones in the collecting system are collected into the endobag. A nephrostomy tube is placed in this opening by making an opening extending from the nephrotomy line to the collecting system. Then the collecting system, renal parenchyma and renal capsule are closed, and the procedure is terminated. Placing a drain in the surgical site is recommended to monitor possible bleeding and collect system leaks.

Trying to collect the stones individually may create technical difficulties in patients with many small stones. It should not be preferred in patients with anatomical calyceal anomalies planning to undergo simultaneous anatomical correction. It may lead to renal atrophy due to a prolonged warm ischemia period. One of the most critical problems of the method is that a standard renal hypothermia method, which is effective in preserving kidney functions during laparoscopy, has yet to be demonstrated.

3.4. Laparoscopic Simple Nephrectomy and Laparoscopic Partial Nephrectomy

While laparoscopic partial nephrectomy can be performed in kidneys with hydrocalyx developed due to obstructed stones and with partial loss of function, laparoscopic simple nephrectomy can be performed in patients who have lost their function due to stones.

Laparoscopic surgical methods are a valuable surgical treatment option for patients who want to be stone-free in a single session, in cases where endourological interventions are unsuccessful, and in patients with large renal stones and accompanying urinary system anomalies.

4. Robotic Kidney Stone Surgeries

Following the development of *da Vinci Robotic Surgery Systems®* (Sunnyvale, CA, USA) just before the 2000s, robotic surgery technology quickly entered many surgical fields. (8) The *da Vinci Robotic Surgery System®* is a robotic system with a master-slave system. The surgery is not performed automatically by the robot itself, as is commonly thought, but by a surgeon sitting on the robot console by controlling all the robot's movements.

Indications for robotic surgery are similar to those for laparoscopic surgery. In addition to the advantages of laparoscopic surgery over open surgery, it offers high image quality, tremor elimination and high maneuverability for the surgeon. With these advantages, it can provide serious technical convenience for the surgeon if reconstruction is planned for the urinary system anomalies accompanying the stone in the patient. Robot-assisted laparoscopic ureterolithotomy, robot-assisted laparoscopic pyelolithotomy, and robot-assisted laparoscopic anatrophic nephrolithotomy methods have been described in the literature. (9,10)

Although robotic surgery has found widespread applications in many areas of urology, its use in treating stone disease is still controversial. However, it has advantages such as higher quality of life and shorter hospital stay compared to open surgical techniques, higher costs for patients and social security institutions and less accessibility are important disadvantages of the method.

5. Conclusion

With the endourological developments, open surgeries and major surgical interventions have been replaced by more minimally invasive procedures such as ESWL, URS, and PCNL. In the treatment of stone disease, Laparoscopic and Robotic interventions can be used with limited indications in patients with renal stones who want to achieve a high stone-free rate in a single session or in the presence of a condition that requires surgical intervention, such as UPJS, where anatomical correction is planned simultaneously with the stone treatment. On the other hand, open surgeries should be used in planning as a last salvage option after evaluating all other minimally invasive treatment methods for kidney stone disease.

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