Flexible Ureteroscopy in Special Situations

Yazeed Barghouthy and Olivier Traxer

Abstract

In the last two decades, the share of flexible ureteroscopy (fURS) in the treatment of stone disease has increased dramatically, while the share of total treatments for percutaneous nephrolithotomy (PCNL) remained static and the share for extracorporeal shockwave lithotripsy and open surgery fell (Geraghty et al. J Endourol, 31(6):547–556, 2017). This is the result of substantial improvements in equipment, whether it be the endoscopes or laser technologies. Accordingly, the indications for the performance of fURS have increased considerably, and it has become the first-line modality in cases where it was previously impossible to perform, such as urinary diversions or anomalous kidneys.

Keywords

Flexible ureteroscopy · Diverticular stones Encrusted stents · Urinary diversions Pregnancy · Obesity · Ectopic · Horseshoe Transplanted · Kidney

Y. Barghouthy · O. Traxer (✉)
GRC n°20, Groupe de Recherche Clinique sur la Lithiase Urinaire, Sorbonne Université, Hôpital Tenon, Paris, France

Service d'Urologie, Sorbonne Université, AP-HP, Hôpital Tenon, Paris, France
e-mail: olivier.traxer@aphp.fr

In the last two decades, the share of flexible ureteroscopy (fURS) in the treatment of stone disease has increased dramatically, while the share of total treatments for percutaneous nephrolithotomy (PCNL) remained static and the share for extracorporeal shockwave lithotripsy and open surgery fell [1]. This is the result of substantial improvements in equipment, whether it be the endoscopes or laser technologies. Accordingly, the indications for the performance of fURS have increased considerably, and it has become the first-line modality in cases where it was previously impossible to perform, such as urinary diversions or anomalous kidneys.

In the next chapter, we will present the use of flexible ureteroscopy in special scenarios that need specific considerations, and the different approaches needed for a successful intervention will be highlighted.

1 Diverticular Stones

Calyceal diverticula of the kidney are non-secretory, urothelial-lined cavities, mostly found in the upper and mid-calyceal groups of the renal collecting system. These cavities are filled with urine that passively originates in the adjacent collecting system [2]. The prevalence of calyceal diverticula is approximately 4.5/1000 intravenous pyelograms. In one large review, calyceal diverticula were more common in female patients (63%) than in males (37%) and were equally

G. Zeng et al. (eds.), *Flexible Ureteroscopy*, https://doi.org/10.1007/978-981-19-2936-6_15

present in the left and right side. Average diverticulum size across the series was 1.72 cm and ranged from 0.5 to 7.5 cm [3].

Different types and classification systems of calyceal diverticula exist, the simpler of which differentiates between type I (communication with a minor calyx or infundibulum) and type II (communication with a major calyx or the renal pelvis) [4].

While many calyceal diverticula are asymptomatic, others may present complications requiring intervention. Persistent flank pain—present in approximately 50% of cases—accounts for the most common complaint. Other manifestations include diverticular stones, recurrent infections, and hematuria related to the diverticulum.

Diverticular stones, present in 10–50% of cases [5, 6], are primarily the result of urinary stasis due to a stenotic diverticular neck (see Fig. 1). Nonetheless, many patients with diverticular stones have underlying metabolic factors, promoting stone formation. Treatment of these factors is mandatory to prevent recurrence [7].

1.1 Management of Diverticular Stones

Management of diverticular stones with ESWL, although an attractive option due to its noninvasive nature, has low success rates [8], mainly due to the difficulty to evacuate fragments through a stenotic opening.

PCNL has been shown to achieve the best results for diverticular stone management [9, 10]. Nevertheless, PCNL in this scenario has certain limitations [11]. First, the puncture to achieve access to the diverticulum can pose a difficult challenge due to the upper pole position of many diverticula. Second, the ability to pass a guidewire through the opening of the diverticulum to the renal pelvis is usually impossible by the presence of a stone blocking the opening or the difficulty to negotiate the guidewire into the renal pelvis. Third, many diverticula have a small space not allowing the introduction of the nephroscope into the diverticular space for stone fragmentation.

With the remarkable advance in endoscopic equipment, facilitating access and manipulation even in small and difficult spaces, flexible ureteroscopy, allowing for retrograde intrarenal surgery (RIRS), has become a standard alternative for the management of diverticular stones, thus bypassing many of the limitations stated above for the standard treatments.

1.2 Endoscopic Management

Preoperative preparation, with the appropriate imaging and endoscopic tools, is a key to the success in managing these cases. Precise evaluation of the anatomy is made possible with CT urography, which shows the exact location of the diverticula, stone burden, and relation to other organs. A high index of suspicion is also important for identifying diverticular stones.

Before surgical treatment, it is important to bear in mind the different differential diagnoses to diverticular stones on preoperative imaging. These can include hydrocalyces or calyceal stones secondary to infundibular stenosis, submucosal stones caused by medullary sponge kidney, stones engulfed in a tissular matrix after previous procedures, and more rarely, renal milk of calcium cysts (a colloidal suspension of calcium salts occurring in calyceal cysts and diverticula) [12].

The presence of a sterile urine culture is mandatory, and antibiotic prophylaxis is required. Certain patients with recurrent positive cultures might need continuous, large spectrum antibiotic prophylaxis in the preoperative setting.

The cooperation of the anesthetic team is essential. Ventilation with low tidal volumes and respiratory rates facilitates the performance of the procedure by reducing renal mobility during respirations [13].

After positioning the patient in lithotomy and performance of a cystoscopy, a retrograde pyelography is performed (Fig. 1a), with the image acquired serving as a baseline for the rest of the procedure. A 0.038-in. safety guidewire is inserted into the renal pelvis. Access to the collecting system with a flexible ureteroscope along-

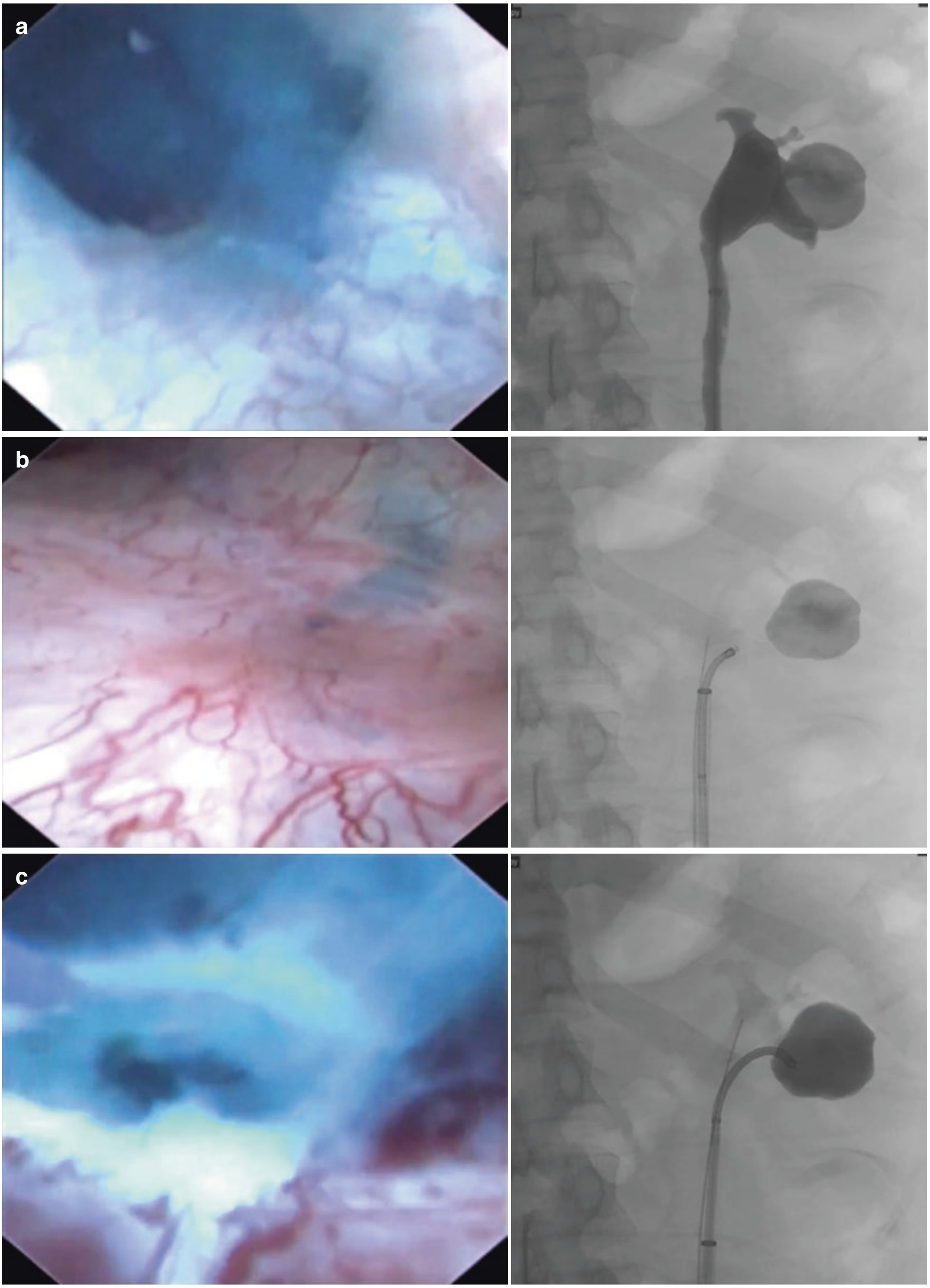

Fig. 1 Diverticular stone management: endoscopic and corresponding fluoroscopic views. From top to bottom: (**a**) blue dye contrast injection into the collecting system. (**b**) Identification of diverticular neck. (**c**) Neck incision by laser and access into diverticulum. (**d**) Fragmentation of diverticular stone. (*Courtesy of Dr Saeed bin Hamri-with permission- video available on Twitter/@ sbinhamrii*)

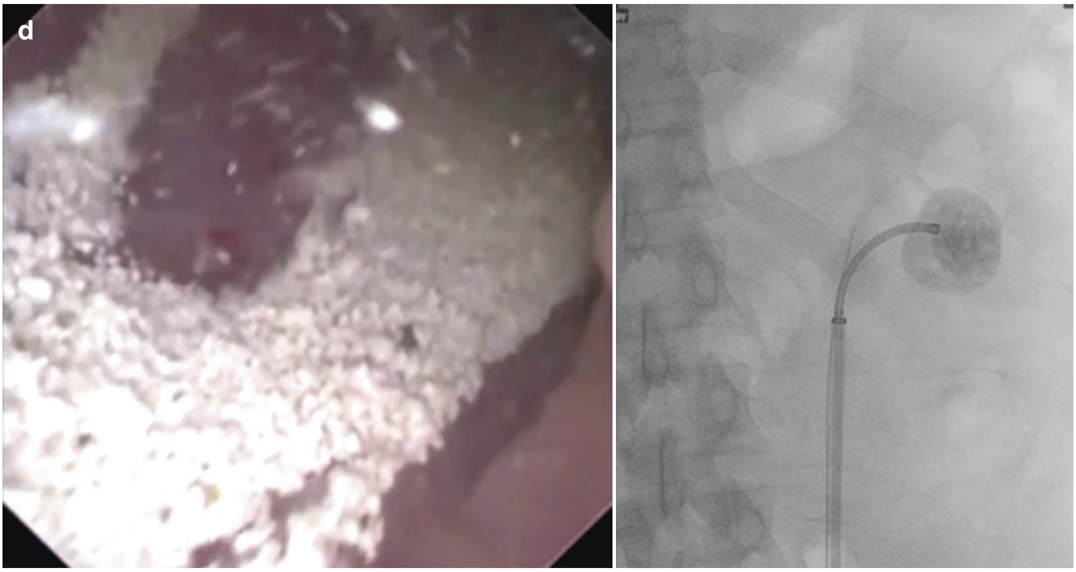

Fig. 1 (continued)

side the safety wire can be attempted, especially if a stent was placed previously and the ureter seems accommodating. If that is not possible, the ureteroscope can be railroaded up into the renal pelvis, over a second 0.038-in. working wire, under fluoroscopic guidance. In cases where resistance is encountered, and the ureteroscope cannot be advanced up into the ureter, a double-J stent is left in place, allowing the narrow ureter to passively dilate for 1–2 weeks, before another attempt is undertaken.

In our institution, we prefer the use of digital endoscopes for these procedures, which gives an optimal image quality while maintaining excellent maneuverability of the ureteroscope, both valuable assets for accurate and effective performance of the procedure. The two leading digital endoscopes available today are the Flex-X^{c} (Karl Storz) and the URF-V3 (Olympus). New-generation disposable endoscopes, with better quality imaging, offer a good alternative in difficult cases, especially where risk of breakage of the endoscope might be high.

The endoscopic image quality can play a crucial role in localization of the diverticular opening, usually pinhole-sized and barely visible, located anywhere from the fornix of the calyx to the infundibulum (Fig. 1b). Intra-operative fluoroscopy, enhanced by the injection of diluted contrast, can aid in directing the tip of the endoscope toward the location of the diverticular stone, while the surgeon inspects endoscopically any mucosal site, suggesting the presence of the diverticular opening.

In cases in which the diverticular opening is not easily localized, the "blue spritz" technique can be easily utilized. This technique entails the injection of a readily available colored dye solution, in the presumed location of diverticular opening. After irrigating the system, droplets of blue dye solution, trapped in the diverticulum, start dripping out through the narrow opening, thus helping to identify the site of the diverticulum. A minor modification involves injection of a 50:50 mixture of methylene blue and iodine contrast. This allows for fluoroscopic guidance of the previous steps and further helps to localize the diverticular opening [14].

Once the opening is identified, a working 0.038-in. guidewire is introduced through the working channel and coiled in the diverticulum to guard the access. The endoscope is pulled out and re-introduced alongside the working wire. Two options exist to access the cavity of the diverticulum and treat the stones. If the opening neck is short, then laser incision is performed, and the ureteroscope is introduced into the cavity (Fig. 1c). Use of a small laser fiber (e.g., 200 μm) is advised to limit the effect on endoscope deflection. An alternative option is balloon dilation, preferred in cases where the neck is long, preferred over a laser incision, which would raise the risk of bleeding or extravasation [15]. Upon entry into the diverticular cavity, the stones can be treated as in normal cases, with laser dusting, fragmentation, and basketing, preferably with a zero-tip basket to reduce trauma to the mucosa and inadvertent hematuria affecting visibility (Fig. 1d). Careful inspection of the mucosa for suspicious lesions is mandatory, and the decision to fulgurate the mucosa is usually taken for recurrent cases rather than in the primary intervention.

At the end of the procedure, an indwelling double-J stent is left in place, preferably with the upper loop inside the diverticular space, to facilitate the evacuation of stone fragments or other debris and prevent the early restenosis of the diverticular opening. A urinary catheter is usually left in place for 1 day, depending on the complexity of the procedure. Postoperative imaging is mandatory to decide on the need for re-treatment.

Potential adverse effects include urinary infection, bleeding from the infundibular vessels during laser incision of the diverticular neck, and urinary extravasation due to perforation of the thin layer of cortex above the diverticulum. This is usually identified intra-operatively by fluoroscopy showing contrast perirenal extravasation. In this case, the safest option would be to abort the procedure, drain the collecting system with an indwelling stent, and performing a second look in 2 weeks. If the surgeon chooses to complete the procedure, the use of low irrigation pressure is highly recommended.

1.3 Treatment Selection

Different factors are considered when choosing the best management option for diverticular stones [16]. These include the location of the diverticula, its anterior or posterior aspect, stone burden, the presence of associated symptoms, concomitant anomalies, and finally, surgeon's experience and available equipment.

In large stones, specifically >12 mm in size, we suggest the following algorithm for treatment selection (Fig. 2):

The results for flexible ureteroscopy in the management of diverticular stones are generally satisfactory, with previous reviews reporting a high stone-free rates of 73–90% [15].

Despite the fact that these numbers are lower than the results of the percutaneous approach in the treatment of diverticular stones, fURS has the advantage of being less invasive with lower complication rates than PCNL, presenting a fair compromise for many surgeons and patients alike. The patient should be nonetheless aware of the possibility of repeat procedures to achieve a stone-free status.

Endoscopic combined intra-renal surgery (ECIRS) is the preferred option in cases of large stone burden, lower pole stones, or large diverticula requiring ablation of the cavitary urothelial lining. A combination of flexible ureteroscopy with ESWL is also an option in certain centers.

Laparoscopic surgery has also been utilized for large diverticula difficult to manage endoscopically, or simultaneous with other anomalies requiring surgical repair [17].

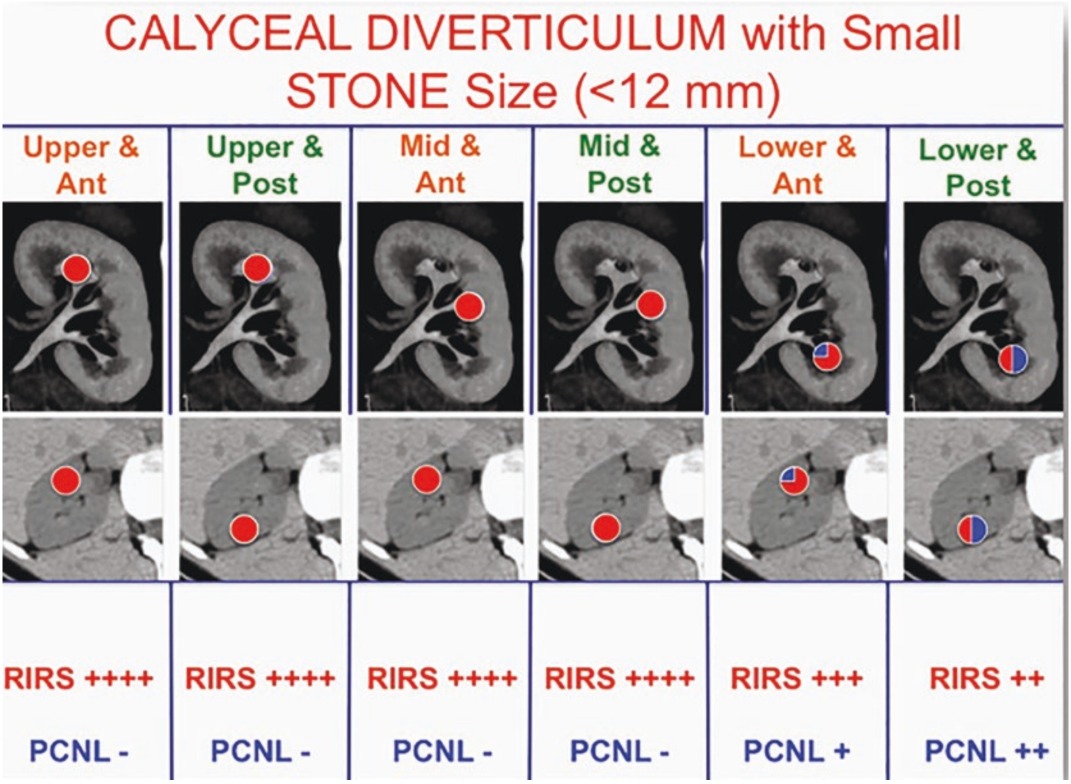

Fig. 2 Guide to treatment choice for renal diverticular stones larger than 12 mm. (*Image from O. Traxer on Twitter*)

2 Horseshoe, Pelvic, and Transplanted Kidneys

2.1 Horseshoe Kidneys

Horseshoe kidneys present multiple challenges for the performance of flexible ureteroscopy, owing to their unique location and orientation. The most common renal fusion abnormality, with an estimated prevalence of 0.25%, horseshoe kidneys are the result of incomplete cephalad migration and malrotation of the two fused kidneys, due to the entrapment of the isthmus under the inferior mesenteric artery [18].

While the lower urinary system and lower ureter are usually normal, the course of the upper ureter is aberrant in horseshoe kidneys. Below the insertion of the ureter into the UPJ, it passes over the fused lower poles, where it is susceptible to compression by the vessels supplying the isthmus and the lower poles. This might give rise to ureteral obstruction leading to urinary stasis, hydronephrosis, and stone formation, the incidence of which is evaluated between 20% and as high as 60% [19]. Most stones are composed of calcium oxalate, with the medially situated, posterior lower pole calyx the most common site for stone formation, followed by the renal pelvis [9].

2.2 Flexible Ureteroscopy in Horseshoe Kidney

Preoperative planning with CT urography and, if possible, 3D reconstruction images is indispensable. Careful mapping of all calyces and stones should be prepared before the procedure starts, and all images and diagrams must be available to the surgeon in the operative room. Antibiotic prophylaxis is the rule as in usual practice.

The procedure should begin with insertion of a 0.038-in guidewire through the ureter and performance of a retrograde uretero-pyelogram. The images obtained should be compared with the preoperative imagery and kept for further reference.

Access of the ureteroscope through the ureterovesical junction is usually straightforward, and the ureter is usually shorter due to the lower position of the kidneys. In case of a tortuous ureter, the use of a hydrophilic stiff guidewire and UAS can straighten the ureter, facilitate the access with the ureteroscope, and improve its deflection in the kidney.

Next, the ureter classically has a high insertion into an elongated ureteropelvic junction (UPJ). Thus, access to the lower poles—where stones are often found—can be challenging, and the urologist needs to work with an almost constant deflection. The use of nitinol baskets can help place lower pole stones in an easier-to-reach site, such as the renal pelvis or the upper pole calyces.

The axis of the horseshoe kidney is more horizontal than usual, the renal pelvis is more anterior, and the calyces point either dorso-medially or dorso-laterally. For these reasons, the orientation in the collecting system and the calyceal spaces is not intuitive, and it can be a challenging task even for experienced endourologists, especially if hydronephrosis is also present. The position of the bubble on the endoscopic field will point to the 12 o'clock position, and this is always a helpful tool for orientation.

Moreover, stone fragmentation in a horseshoe kidney can result in accumulation of fragments in the dependent portions of the kidney, the removal of which is necessary to reduce recurrence rates.

To avoid the strain and the possible breakage on the endoscope, a single-use ureteroscope should be considered, if a challenging case is anticipated. A ureteral stent should always be left in place to help evacuate residual fragments, and to improve drainage in these kidneys.

The use of fURS for these cases is becoming more popular with the evolution of new basketing equipment and endoscopes with better secondary deflection. In addition, new laser technology, allowing more efficient dusting techniques, with smaller fibers allowing for better endoscope deflection, also helps in rendering even difficult cases stone-free.

Few studies with small cohorts have been published regarding the performance of fURS in horseshoe kidneys. Molimard et al. (2010) published their results in 17 patients, with an average stone burden of 16 mm, treated consecutively with fURS. The mean number of procedures was 1.5 per patient and the mean operative time was 92 min. About 88.2% of patients were successfully treated using only flexible ureteroscopy [20].

Despite the promising improvements with fURS, horseshoe kidneys are considered challenging cases due to the anatomic reasons stated above, and many surgeons still regard PCNL as the classical treatment option in horseshoe kidneys, especially for a large stone burden. Indeed, the lower position of the kidney, the anterior rotation of the renal pelvis, and the horizontal axis of the kidney, all make access through the upper pole calyces a relatively safe option. However, even with these conditions favoring the percutaneous approach, the length of the puncture tract often exceeds the length of the rigid nephroscope. Thus, if PCNL is performed in horseshoe kidneys, flexible ureteroscopy can play an essential complementary role, as part of an endoscopic combined intra-renal surgery (ECIRS).

Therefore, the patient should always be informed regarding this option before surgery even if fURS is planned, and the surgeon should also be prepared to conversion to PCNL with the appropriate technical setup available in the operation room.

Last but certainly not least, prevention of stone recurrence with a full metabolic evaluation is indispensable in these patients due to underlying metabolic abnormalities in many patients, responsible for stone formation in the first place [21].

2.3 Ectopic Kidneys

The most common site of ectopic kidneys is the pelvis, reported in approximately 1/1000 births [22]. Other rare sites are the abdomen and the thorax. The pelvic kidney, more common on the left than on the right side, is retroperitoneal, with posterior access usually blocked by the bony pelvis, and interposing intestinal loops precluding percutaneous access through the anterior abdominal wall.

Flexible ureteroscopy is the least invasive and thus the preferable first treatment option. Access through the UVJ might be challenging due to an ectopic orifice. This obstacle can be overcome by searching the jet of blue dye in the bladder mucosa after IV injection of methylene blue, in the absence of allergy or contra-indication (e.g., G6PD deficiency).

The ureter might have a tortuous course that might complicate the insertion of the endoscope. This is usually overcome by using a hydrophilic stiff guidewire or a UAS that can help straighten the ureter, thus facilitating the passage of the ureteroscope. Flexible ureteroscopy with holmium laser and basketing can then be performed with reported good results [23].

An alternative to flexible ureteroscopy is PCNL, with percutaneous access acquired through US or CT guidance. If this is not possible, laparoscopic-assisted PCNL procedures can be performed. In these procedures, laparoscopy can guide the percutaneous puncture of the kidney and mobilize intervening organs or bowel loops away from the puncture needle's tract.

2.4 Transplantation Kidneys

Urolithiasis in transplanted kidneys is relatively rare with an incidence between 0.2 and 4.4% [24]. Due to the substantial risks involved, management in these cases should preferably take place in experienced centers.

Risk factors for stone formation in transplanted kidneys are metabolic abnormalities, presence of foreign bodies (nonabsorbable suture material, forgotten stents), papillary necrosis, and recurrent infection.

The most common anatomical position for transplanted kidneys entails having the donor's left kidney placed into the recipient's right iliac fossa, with the kidney rotated 180° on its axis. Thus, the renal pelvis is oriented medially, the posterior calyces point anteriorly, and, vice versa, the anterior calyces point posteriorly.

These are important points to remember during flexible ureteroscopy, or during PCNL, where an anterior percutaneous approach through the abdominal wall is similar to the posterior approach in native kidneys.

ESWL is a possible primary treatment option for stones less than 15 mm in transplanted kidneys [25]. However, the serious consequences of potential complications such as steinstrasse and the good results of flexible ureteroscopy, make the latter the preferred option in many centers.

2.5 Technique

During cystoscopy, identification of the ureteral orifice can be challenging and is achieved by careful inspection of the mucosa in the presumed area of ureteral insertion. If the ureteral insertion was done by an extra-vesical approach (i.e., Lich Gregoir) as is in the majority of cases, the orifice will usually be located supero-laterally, in the right upper bladder wall. Use of a 70° cystoscope can be helpful.

Blind repeated attempts to introduce the guidewire into a presumed orifice in the mucosal wall should be discouraged, since the resulting hematuria can obscure vision and delay the procedure. In certain cases, IV injection of methylene blue can help in identifying the ureteral orifice.

Once the orifice is identified, a guidewire is introduced gently under fluoroscopic guidance, and a pyelogram is performed, with care to avoid high instillation pressure of contrast to reduce the risk for infection. In case of difficult insertion of the guidewire, angled tip guidewires, or angled catheters, such as a Kumpe or cobra catheter, can prove extremely helpful [26].

Ureteral obstruction, whether intrinsic or extrinsic, occurs in up to 10% of renal transplant recipients, and blind instrumentation can thus risk perforation or even avulsion, hence the importance of identifying these cases early with a uretero-pyelogram.

As mentioned before for pelvic kidneys, insertion of the ureteroscope through the tortuous and redundant ureter can be facilitated through the insertion of a hydrophilic stiff guidewire. Certain endourologists advocate exchanging the hydrophilic safety wire for an Amplatz extra-stiff wire to reduce the risk of inadvertent wire withdrawal and loss of access to the ureter, in addition to support the allograft ureter. The use of a UAS can also straighten the ureter, reduce the fluid pressure in the collecting system, and facilitate repeated passage of the flexible ureteroscope; however, attention must be given to the length of the UAS used, and its insertion must be done with great care, due to the risk of traumatic injury to the ureteral wall or orifice [27, 28].

Once access to the collecting system is achieved, flexible ureteroscopy can then be performed as for a normal kidney, with keeping in mind the mirror image of the calyceal system in the transplanted kidney from that of the normal kidney.

In a comprehensive review including 101 cases from 11 studies, an SFR of 100% in five studies and 60–91% in four studies with an overall complication rate of 12.9%, of which 10 were Clavien 1 and three Clavien ≥ 3. The authors concluded that posttransplant urolithiasis a safe and effective procedure for posttransplant urolithiasis [29].

If access of the endoscope and completion of the procedure is not possible, the retrograde access can guide a percutaneous approach, which is usually facilitated by the superficial position of the transplanted kidneys. Antegrade access in this case is usually safely established into the lower pole, with the skin puncture performed as caudal as possible to avoid intraperitoneal content.

The surgeon must remember that entrance is through the anterior calyces of the transplanted kidney, thus puncturing through the papilla might be harder, and instead puncturing of the infundibulum may occur, increasing the risk of hemorrhagic complications (e.g., pseudoaneurysm and AV fistula). In addition, puncture and subsequently dilation of the access tract might be more difficult due to the scar tissue around the graft.

3 Management of Encrusted Stents

Ureteral stents are routinely used in endoscopic surgery for the drainage of the urinary system. In lithotripsy, ureteral double-J stents or urinary catheters are inserted to prevent postoperative obstruction by edema or residual fragments. In urinary system reconstructive surgery and diversion procedures, they are used to maintain the patency of the ureter and minimize urinary leaks.

Since their introduction, urinary stents have gone through significant development in material composition, coating materials, and designs, resulting in a wide range of different stents responding to various clinical indications and with different biocompatibility and tolerability profiles [30].

Despite the central role stents play in endourological surgery, their use is not devoid of side effects and potential complications, such as irritative urinary symptoms, hematuria, and pain.

Moreover, previous studies have shown that in contact with urine, ureteral stents are rapidly covered by a bacterial film (biofilm) and by mineral and/or organic encrustations [31].

Stent encrustation can potentially give rise to new stones and even lead to obstruction of the urine drainage. In one study, the main composition of the encrustations was calcium oxalate monohydrate and dihydrate, carbapatite, and protein matrix [32]. The FeCal classification proposed by Acosta-Miranda et al. is used to describe the location and the degree of encrustation of each calcified stent [33].

The rate of stent encrustation is primarily dependent on the duration of contact with urine, which can be prolonged in cases of forgotten stents. This situation is usually caused by patients' poor compliance or misinformation regarding the need and timing for stent retrieval after an intervention, leading to their belated presentation with significantly incrusted stents. Some patients are also left with retained stents due to comorbidities outweighing the importance of stent retrieval. In addition, encrustation is also affected by patient factors such as a history of stone formation or pregnancy for example.

Stent material composition also plays a role, with several studies suggesting that silicone stents might have significantly fewer mineral encrustations and biofilm development in kidney stone formers, compared to other materials including polyurethane stents [34].

Surgical intervention in these cases is essential due to the serious consequences to the urinary system, including recurrent infections, loss of renal function, and in extreme cases, urothelial dysplasia and even development of squamous cell carcinoma due to the constant irritation of the mucosa.

Management has traditionally involved multi-staged procedures and combined retrograde and antegrade approaches, with PCNL playing a central role in cases with large encrustation or stone burden in the renal pelvis. More recently, endoscopic combined intra-renal surgery (ECIRS) has gained popularity for more complex cases. However, with the advance of endoscopic and laser equipment, multiple publications highlighted the role of flexible ureteroscopy in the treatment of encrusted stents, even in complex cases.

In the next segment, we will present the technique of managing encrusted stents in a stepwise approach, using only flexible ureteroscopy.

3.1 Preoperative Considerations

Preoperative CT urography must be obtained before surgery to evaluate the anatomy and the stone burden in the collecting system (Fig. 3b). If doubt exists, renal scan must be performed to evaluate the basal function of the ipsilateral renal parenchyma. This examination is also important for its medicolegal value. Urinary culture results must be verified, and antibiotic prophylaxis must be noted, if needed starting 48 h before surgery. This is especially critical in these cases due to the high rate of contaminated urine and the risk for serious infections postoperatively.

General anesthesia is preferred in all cases. The surgeon must be prepared on a technical and organizational level, to the potential need of a combined retrograde and antegrade approach if the procedure cannot be completed solely retrogradely. The patient must also be informed regarding this scenario.

3.2 Procedure Technique

After appropriate antibiotic prophylaxis and installation of the patient in a lithotomy position, cystoscopy is performed to evaluate the inferior

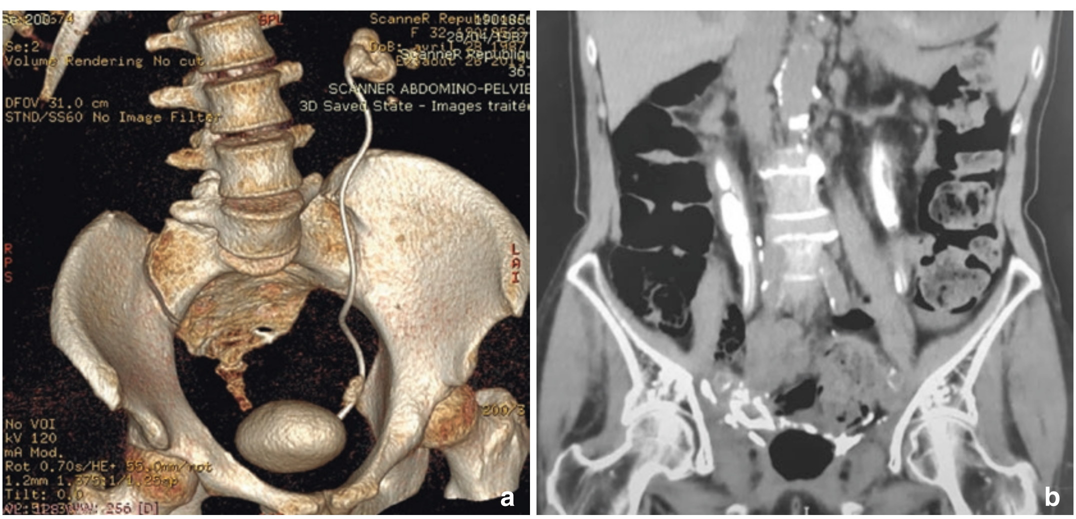

Fig. 3 (**a**) 3D reconstruction image of an incrusted stent in the left kidney, lower ureter, and bladder. (**b**) CT image in coronal view demonstrating bilateral encrusted stents

loop of the stent. The first step is insertion of a 0.038-in. safety guidewire into the collecting system, under fluoroscopic guidance, alongside the encrusted stent. Fragmentation of the encrustations or stone engulfing the inferior stent loop is performed cystoscopically with laser energy (e.g., Ho:YAG laser). To reduce the oscillations of the laser fiber, it is introduced through a 35-cm segment of 5 F ureteral catheter, cut with simple scissors. In certain situations, the stone burden in the bladder is so large, it necessitates fragmentation with an ultrasonic or mechanical lithotripter, inserted into the bladder by a nephroscope through the urethra in females or percutaneously through a working channel in the supra pubic area in males.

After the inferior loop is freed from encrustations, the next step involves liberating the intra ureteral portion of the stent. This segment is usually less prone to encrustation than the bladder or renal pelvis, due to the function of the ureter as a conduit of urine and thus the shorter contact duration between the stent and the urine. The presence of the indwelling ureteral stent allows for sufficient ureteral distension, and subsequently enough space to accommodate a flexible ureteroscope, introduced into the ureter alongside the stent under direct vision. To facilitate this step, the distal loop of the stent is exteriorized through the urethral orifice and fixed by a stitch to the skin, to maintain a gentle traction on the stent. This is achievable usually only in female patients due to the length of the urethra in males. If insertion of a flexible ureteroscope is not successful, the use of a semirigid ureteroscope can be a good alternative. The ureteroscope is introduced as proximal as possible alongside the encrusted stent.

If the renal pelvis is reached, the procedure is continued as usual for retrograde intra-renal surgery, and the encrustations engulfing the proximal loop are fragmented, thus uncoiling the loop and removing the stent entirely. In most cases, however, it is impossible to advance the ureteroscope all the way up to the renal pelvis, due to encrustations in the ureteral portion. In these cases, the encrustations are fragmented and the double-J stent is cut using the Ho:YAG laser cutting setting (10 Hz–1.0 J). The free, cut portion of the stent can be removed with a forceps to create space and allow further progression of the ureteroscope, until the arrival to the renal segment of the encrusted stent. This step is usually repeated twice, depending on the length of the ureter and burden of encrustations around the stent.

When the ureter is emptied from encrustations and stent segments, the mucosa needs to be inspected carefully, and if found intact, a ureteral access sheath (UAS) can be inserted, thus allowing the continuation of the procedure in the upper portion of the collecting system with low intrapelvic pressure. In addition, the UAS protects the ureteral wall from injury during removal of the proximal loop.

When the renal pelvis is reached, the encrustations and any concomitant stones can be fragmented, and the final upper portion of the stent can be removed with a basket or endoscopic forceps (Fig. 4).

The surgeon must avoid working with elevated intrapelvic pressures, to reduce fluid extravasation, which is extremely important given the high risk of contaminated urine due to the presence of biofilm on the encrusted stents.

Fig. 4 Cut segments after procedure to extract encrusted stents

Due to the complexity and length of these procedures, they can be performed in a multi-stage approach. A new double-J ureteral stent can be placed until the next session in tandem with the encrusted stent, to prevent obstruction by edema or residual fragments.

Thomas et al. reported their results with this technique. In their study including 51 patients with a mean indwelling time of 10.4 months and grade 5 encrustations according to the FeCa classification in 80% of patients, removal of the encrusted stent was possible in 98% of patients through flexible ureteroscopy, with a mean operative time of 110 min and mean hospital stay was 2.33 days [35].

The principal complication to this procedure is pyelonephritis, and in some cases bacteremia and sepsis. This is especially relevant in the treatment of encrusted stents since biofilm is present in virtually all retained stents. The use of UAS and working in the minimal possible irrigation pressure can lower the risk for infection. Postoperative antibiotic therapy should be considered for all patients, especially in patients with struvite stones, and monitoring is essential for early management in case of sepsis. Another possible important complication is injury to the ureteral wall due to the extensive use of laser energy in a limited luminal working space.

Flexible ureteroscopy thus is an important tool in the management of retained encrusted stents, offering a less-invasive option than PCNL. Nonetheless, cases with a large stone burden might require a combined endoscopic approach (ECIRS) with PCNL to avoid multiple procedures.

4 Obese Patients

Obesity is a major healthcare problem with increasing prevalence worldwide [36], aggravated by accompanying conditions such as hypertension, hyperlipidemia, diabetes mellitus, cardiovascular disease, in addition to gout and obstructive sleep apnea. The relative risk of these comorbidities increases significantly with the BMI of the patient, and thus presents significant anesthetic and operative challenges in this patient population [37].

Moreover, obese patients present multiple lithogenic factors increasing the risk of kidney stone disease [38]. These include insulin resistance accompanied by a low urinary pH, lower urinary citrate levels, in addition to a high caloric intake, and metabolic sequels of previous bariatric surgeries. These factors among others increase the risk of urinary stones, principally calcium oxalate (both mono- and di-hydrate) and uric acid stones [39].

Diagnosis of stones might be affected by the lower yield of sonography in obese patients, making CT a better diagnostic tool in these patients. The management of stones in obese patients presents certain limitations of the standard treatment options.

ESWL might be less effective in obese patients, and increasing abdominal circumference and visceral fat is related to decreasing stone-free rates after SWL [40, 41]. Moreover, targeting of the stone might be harder due to the increased skin to stone distance and higher prevalence of uric acid in obese patients [42].

PCNL might pose an anesthetic difficulty due to the need to ventilate a patient with smaller functional residual capacity of the lungs, in a flank or prone position. In addition, patient positioning on the table is more challenging and requires more time and personnel. PCNL in an obese patient can also necessitate extra-long puncturing needles and access sheaths to reach the collecting system (Fig. 5), while this equipment might not be readily available in every center.

With the improvement of ureteroscopy in recent decades, flexible ureteroscopy has become a preferred option in obese patients, presenting multiple advantages in comparison with ESWL and PCNL. These include a higher success rate than ESWL, easier positioning in lithotomy than flank or prone positions in PCNL and absence of a kidney puncture.

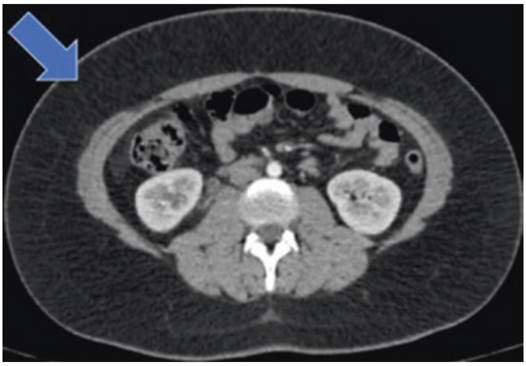

Fig. 5 CT image in an obese patient, arrow showing abdominal wall fat content. (*From O. Traxer twitter account*)

4.1 Preoperative Considerations

Multidisciplinary evaluation is essential in this patient population, due to the possible presence of associated comorbidities, especially cardio-pulmonary diseases, and obstructive sleep apnea. These conditions carry potential anesthetic risks, and any concern regarding intubation (e.g., LMA vs. intubation) or ventilation of a patient in the lithotomy position must be discussed with the anesthetist preoperatively, with higher ventilation pressures sometimes needed to compensate for a restricted respiratory capacity.

Blood pressure and glycemic control must be maintained to avoid perioperative complications. Prophylaxis to deep vein thrombosis with compression stockings and possibly subcutaneous heparin is also essential. Postoperative monitoring is also important and must be discussed with the anesthetist and the patient beforehand.

4.2 Technical Considerations

The presence of a fluoroscopy table in the operation room, able to withstand the overweight patient, must be verified before the patient arrives to the surgery room. In rare cases, the use of two tables might be necessary to accommodate a patient with severe morbid obesity (BMI > 40 kg/m^2).

Special attention should be drawn to the appropriate positioning and padding of the patient, to avoid the risk of nerve compression and crush injuries, which may even lead to rhabdomyolysis in extreme conditions. Access to the urethral meatus might not be straightforward as in normal conditions, and the pannus or adjacent skin folds might require special positioning.

While the different steps of flexible ureteroscopy are performed in a similar fashion to non-obese patients, the use of fluoroscopy during the procedure deserves special attention. The operator must be aware of the larger scatter of radiation, due to the larger body mass of the patient [43]. Thus, despite the lower quality of the image due to the patient's habitus, overuse of fluoroscopic imaging must be avoided to limit radiation exposure of the operating team.

Given the limitations and risks of the other treatment modalities as stated above, several studies have shown that fURS is an excellent option for the treatment of *most* stones in obese patients, with operative times, an important indicator of surgical complexity, reported to be comparable among the obese and nonobese patients [44, 45]. As for large stones (>2 cm), fURS might also be an alternative, to avoid the risks of PCNL, even at the cost of a multi-staged approach. In complex cases with a large stone burden, endoscopic combined intra-renal surgery (ECIRS) is an excellent option, in which flexible URS guides the percutaneous calyceal puncture and contributes to the fragmentation of the stones.

5 Flexible Ureteroscopy in Urinary Diversions

Urinary diversions, whether for oncological or reconstructive functional reasons, constitute another subset of challenging cases in endoscopic surgery. They are usually divided into continent (orthotopic or non-orthotopic neobladder) or non-continent diversions (e.g., Bricker, Wallace) [46]. Regardless of the type of diversion, retrograde ureteroscopy may be indicated for the treatment of nephrolithiasis, surveillance, and diagnosis of suspected malignancies or the treatment of ureteric strictures. For these reasons, acquaintance with the endoscopic approach to the diverted urinary system is mandatory.

Stone formation in patients with urinary diversion is a multifactorial process and includes dehydration, metabolic disturbances like chronic metabolic acidosis, hypocitraturia, hypercalciuria, and enteric hyperoxaluria [47, 48]. In addition, chronic bacterial colonization with urease-producing bacteria can lead to the formation of struvite stones. The presence of foreign bodies like sutures, exposed staples, in addition to the urinary stasis within a chronically refluxing dilated system, also constitutes a risk factor for stone formation.

PCNL was long considered the most straightforward approach to treat stones or obstructions in the diverted upper urinary system. This is especially true for neobladder cases and non-orthotopic diversions (e.g., Indiana pouch), due to the extremely difficult retrograde access. However, with the improvements in ureteroscopes, allowing better maneuvering and deflection of the endoscope, and better endoscopic imaging, more experience is being gained with flexible ureteroscopy, offering a less-invasive alternative to PCNL.

5.1 Technical Aspects

Preoperative evaluation of the anatomy with CT urography and 3D reconstruction images is imperative, assuming no allergies to contrast exist and renal function allows for the injection of IV contrast material. In any doubt regarding the surgical anatomy, previous medical records must be inspected. Antibiotic prophylaxis is also mandatory due to the high risk of infectious complications.

The patient should be informed regarding the different approaches for treatment and the possibility of combined antegrade and retrograde endoscopic surgery. The surgeon must also be prepared with the equipment for both approaches available in the operation theater.

In patients with *ileal conduit*, the procedure begins with a flexible cystoscope through the conduit (conduitoscopy). Use of the flexible cystoscope also allows for simultaneous suction of mucus which might obscure vision. Injection of contrast material and fluoroscopy helps to find the right orientation, which can be difficult to achieve in elongated redundant conduits. Injection of contrast can suggest the site of the ureteral orifice through passive reflux into the ureter. Patients with Bricker's anastomosis will have two independent ureteral orifices, toward the proximal end of the conduit. Patients with the less common Wallace anastomosis will classically have a single-joint orifice for the two ureters at the proximal end of the ileal loop. If identification of the orifices is impossible, IV administration of methylene blue or indigo carmine (with furosemide) may help localize the site of the orifice upon dye excretion with the urine, usually within 10 min of injection.

Once identified, the ureteral orifice is intubated with a hydrophilic stiff guidewire. Certain surgeons advocate replacement of this wire with an Amplatz super stiff guide, to reduce the risk of unintentional withdrawal of the guide. A double-lumen catheter is inserted on the guidewire, and a retrograde uretero-pyelogram is performed, with the images kept for subsequent reference during the procedure. Identifying a uretero-enteric stenosis or any obstruction at this stage is essential, to avoid traumatic injury with the endoscopic instruments. After securing the safety guidewire, a flexible ureteroscope is inserted through either direct vision if possible or, alternatively, railroaded on a working guidewire placed in tandem with the security guidewire. Insertion of a UAS can be dangerous and traumatic for the uretero-enteric anastomosis and is thus not advisable. A Foley catheter can be kept in the conduit to drain the irrigation fluid and avoid an overdistended collecting system.

In *neobladders*, injection of contrast material through a flexible cystoscope and fluoroscopy are used to outline the neobladder and afferent limb anatomy. Reflux of contrast material can usually outline the presence of the ureteral orifices [49]. In continent non-orthotopic diversions (e.g., Indiana pouch), insertion of instruments must be done with extreme caution to avoid trauma to the catheterized stoma and inadvertent damage to the delicate sphincteric mechanism.

Once access to the collecting system is achieved, RIRS with the flexible ureteroscope is then completed, with care taken to use the lowest possible irrigation pressure [50], in a urinary system already colonized with bacteria. Dusting of stones is preferred if possible, due to the difficulty and time consumption of multiple withdrawals and insertions of the endoscope, without a UAS.

Hyams et al. reported their experience with retrograde access in patients with urinary diversions. Out of 28 retrograde access attempts, 21 (75%) were successful. The success rate for each type of urinary diversion was 90% for orthotopic neobladders, 73% for ileal conduits, and 33% for Indiana pouches. Patients with ureteral anastomotic stricture has a lower success rate. No complications were reported [51].

Potential complications are pyelonephritis, the risk of which is increased due to the preexisting bacterial colonization. Other possible risks are iatrogenic trauma to the delicate continence mechanisms of the urinary diversion or to the uretero-enteric anastomosis.

Drainage of the collecting system is done with a ureteral single-J stent, and a repeat UPG is performed before retrieval of the stent if there is any doubt regarding the integrity of the anastomosis and urinary system.

6 Flexible Ureteroscopy in Pregnancy

Ureteroscopy for stone management in pregnant patients came a long way in the last two decades since it was contraindicated in the past, due to fears of possible fetal and maternal consequences. Furthermore, the medico-legal aspects and unfamiliarity with obstetrical considerations discouraged many urologists from taking an active treatment approach for stone management in pregnant patients.

However, multiple studies have been published in recent years, shedding light on this subject and helping to change the management paradigm in this patient group.

6.1 Stones in Pregnant Patients

The incidence of stones in pregnancy varies widely between 0.07 and 0.5% of pregnancies in different publications. However, a recent Canadian comprehensive population study estimated the incidence of pregnancies with stones to be 0.2%, with almost 80–90% in the second and third trimesters, and the majority being first-time stone formers [52, 53]. Stone presentation seems to be equal on the left and the right side, although the right side is usually more dilated, owing to the mechanical obstruction of the ureter at the pelvic brim by the enlarging uterus.

Calcium phosphate stones are the most common stone type according to certain studies [54], while others suggest the types of stones in pregnancy do not differ from those in nonpregnant women [55]. Regardless, multiple biochemical risk factors for stone formation exist in pregnant women, including elevated urinary calcium, which likely promotes the frequent encrustations seen in urinary drainage stents in pregnancy. In addition, elevated urine pH and uric acid levels have also been observed during pregnancy.

Despite the above factors, pregnancy itself does not seem to increase the incidence of urolithiasis, even among identified stone formers [56]. This is probably the result of the concomitant increase of urinary inhibitors of stone formation, such as citrate and magnesium, in addition to the higher GFR, contributing to urine dilution.

6.2 Presentation

Stones in pregnancy are frequently symptomatic, due to the physiologic dilatation of the urinary tract, facilitating stone migration into the ureters, with the resultant obstruction and renal colic [57]. Indeed, stones are found in the ureter twice as often as in the renal pelvis during pregnancy [58].

When compared with matched pregnancies without stones, pregnancies with stones had an increased risk (OR 1.62) for adverse birth outcomes, including increased risk of low birth weight, premature birth, preeclampsia, and caesarian section [52].

6.3 Diagnosis and Natural History of Pregnancy Stones

When a pregnant woman presents with flank pain, the differential diagnosis is wide, and a high index of suspicion is required for early diagnosis and management.

US is the most widely recommended diagnostic method [59]. Its two main disadvantages, however, are the operator dependence and the inability to differentiate between the physiologic dilatation and an acute obstruction. Documenting ureteral jets, measuring resistive index [60], and using three-dimensional extended imaging US can help improving the performance of US.

The American Urological Association (AUA) introduced imaging recommendations in 2013, which suggested the use of low-dose CT as a second-line imaging modality in the second and third trimester of pregnancy when ultrasound studies failed to secure a diagnosis [61]. This has also been supported by the American College of Obstetricians and Gynecologists (ACOG) [62]. However, concern still exists regarding the potential carcinogenic effects of radiation to the fetus [63]. Consequently, the decision to use this modality must be justified and discussed with the radiologist, after explaining the pros and cons to the patient [64].

The natural history of stones in pregnant patients is also variable according to different publications. Previous studies have suggested high percentages of stone expulsion in pregnant patients, previously estimated around 65% and as high as 84% in one study [65, 66]. This number has recently been reevaluated and found to be around 48% in one study [67].

In a recent large study, including 2863 pregnancies with stones, 26% of pregnant patients eventually had an intervention, most commonly a stent or ureteroscopy [52].

Obstruction by urinary stones in pregnant patients can be complicated by pyelonephritis and, in some cases, premature rupture of membranes, risking fetal loss in extreme cases. Thus, in any case of suspected stone associated with an infection, urgent decompression, with a nephrostomy tube or a ureteral stent, is the rule.

6.4 Definitive Treatment

Drainage procedures with ureteral stents or nephrostomy tubes are only *temporizing measures*, and these tubes are prone to frequent and recurrent encrustations, necessitating periodic replacement every 4–6 weeks, in addition to infectious complications and bothersome urinary symptoms. Due to the need for recurrent procedures to replace the drainage tubes, there is a need for early definitive treatment in cases where multiple such replacements are predicted.

ESWL and PCNL in pregnancy are formally contraindicated due to the serious adverse effects and dangers, both to the fetus and to the mother.

6.5 The Evolution of fURS in Pregnancy

The concerns precluding the routine use of fURS in pregnancy involve primarily the utilization of imaging, whether preoperative evaluation of stone site and volume, or intraoperative fluoroscopy, and the potential consequences for the fetus. Second, the anesthetic risks for both the fetus and the mother were long considered an obstacle to performing any procedure more elaborate than the insertion of a nephrostomy tube or ureteral stent. Third, retrograde access to the upper ureter and collecting system were difficult to achieve with older rigid endoscopes. As a result of these concerns, management of cases presenting with an obstructive stone mainly consisted of drainage with a nephrostomy tube or a ureteral stent alone.

Imagery and radiation are two of the thorniest issues in pregnancy and urolithiasis, due to the potential dangers of radiation to the fetus. Despite the difficulty in accurately evaluating the radiation exposure and its effects on the fetus, recent studies have shown that the teratogenic risk is minimal with radiation doses <50 mGy. This is especially relevant for the period before the eighth week or after the 23rd week of gestation. Stochastic effects (e.g., carcinogenesis) on the other hand are independent of the dose and can occur without a threshold level, thus presenting the main reason for concern.

Regarding the anesthetic angle, the American College of Obstetricians and Gynecologists' Committee on Obstetric Practice and the American Society of Anesthesiologists published in a joint statement in 2017 that a pregnant woman should never be denied medically necessary surgery or have that surgery delayed regardless of trimester because this can adversely affect the pregnant woman and her fetus [68]. In addition, no currently used anesthetic agents have been shown to have any teratogenic effects in humans when using standard concentrations at any gestational age.

The improvement in flexible endoscopes has made it possible to use miniaturized equipment with excellent deflection capacity, able to negotiate tortuous ureters and explore the entirety of the collecting system.

These factors combined, encouraged urologists to take a more proactive approach for stone management during pregnancy, leading to a growing number of ureteroscopic procedures in the pregnant patient.

6.6 Procedure

Preoperative planning is mandatory. The considerations for performing the procedure and the potential risks must be explained to the patient, and a shared decision is always encouraged.

Every decision to perform a URS procedure must be taken in a multidisciplinary team, involving a urologist, obstetrician, neonatologist. Anesthetist, and possibly the radiologist as well.

In case the diagnosis was made with US imaging only, the possibility of "white" (negative) URS must also be discussed. White et al. published in their study that the rate of negative ureteroscopy among patients who underwent renal ultrasound alone, renal ultrasound and low dose computerized tomography, and renal ultrasound and magnetic resonance urography, was 23%, 4.2%, and 20%, respectively [69].

Antibiotic prophylaxis must be given and adapted to the urinary cultures, due to the elevated risk for urinary colonization in pregnant women.

DVT prophylaxis is also mandatory and must be discussed preoperatively. Formal obstetric consultation including fetal monitoring during the procedure are mandatory.

During the procedure itself, the patient is installed in the lithotomy position with the right side elevated, to reduce the pressure of the gravid uterus on the IVC, decreasing the venous return.

The procedure is begun with a cystoscopy, identification of the ureteral orifice, and insertion of a safety guidewire retrogradely. Insertion of the wire must be performed with the greatest attention to any resistance that might signify a stone or other obstruction. Usually, a hydrophilic coated 0.038-in guidewire is used. If the surgeon prefers, this wire can be exchanged for a non-hydrophilic guide wire, less prone to withdrawal, through a ureteral catheter. Regardless, working with a safety guidewire is imperative in these cases, where any change in fetal monitoring or maternal status might necessitate and immediate abortion of the procedure, with time only to insert a ureteral stent or catheter for drainage.

In our institution, we introduce the safety guidewire through the ureteral orifice, followed by a flexible ureteroscope alongside the safety wire that is advanced gradually and under direct endoscopic vision. An alternative is the "follow the wire" approach, reported in 26 pregnant patients in 2009 [70]. In this approach, a semi-rigid ureteroscope is introduced by advancing the guidewire through the ureteroscope into the ureteric orifice and following it stepwise up to the site of obstruction; then the GW was advanced past the obstruction under vision to the kidney, and the ureteroscope was removed and re-introduced.

Regardless of the technique used, this step, in a normal case, would be performed with fluoroscopic guidance. In pregnancy, however, radiation use must be reduced to the minimum and avoided wherever possible.

Although the radiation limit in the previously mentioned ACOG recommendations was 50 mGy, and fluoroscopic imaging produces much less radiation than this limit, the dose-independent carcinogenic risk still exists and needs to be taken into consideration.

The recommendation to the use of fluoroscopy includes using pulsed and not continuous fluoroscopy, with the lowest possible dose settings, and with coning of the image to include only the kidney. The C-arm X-ray *source* must be placed under the patient the farthest possible from the patient, by either lowering the source or elevating the table. To shield the pelvis from radiation, a lead apron may be placed *beneath* the patient's pelvis. Another alternative, allowing for manipulation of the shielded field, is inversion of the C-arm with the X-ray source above the patient, and the apron on the abdomen, shielding the fetus.

Optimally, a simultaneous renal US can guide the insertion of the guidewire or endoscope and the placement of a ureteral stent at the end of the procedure.

After passage of a safety guidewire, the ureter can then be inspected by a flexible or a semirigid ureteroscope, alongside the safety wire. The ureter is generally dilated and accommodating to the insertion of the endoscope, and the gravid uterus does not prevent the retrograde passage. The flexible ureteroscope allows inspection of the collecting system. During the inspection, stones are either extracted, if possible, or fragmented.

If lithotripsy is to be performed, Ho:YAG laser is the ideal method due to its ability to fragment every stone type, small size of new laser fibers allowing better endoscope manipulation, and the inexistent side effects for the fetus. Ho:YAG is safe to use due to the little tissue penetration depth.

The alternative for lithotripsy besides the use of laser is pneumatic lithotripsy. The drawbacks with its use, however, is the potential retropulsion of the stones into the collecting system and that it must be used with a semirigid ureteroscope. Ultrasonic lithotripters's use is limited due to potential risk for auditory damage to the fetus, and electrohydraulic lithotripsy is also avoided due to safety concerns, mainly effects on fetal hearing and uterine contractions [71].

A ureteral stent is preferably left in place for 5–7 days, with specific instructions for removal of the stent, to avoid unintentional prolonged dwelling time (i.e., forgotten stent) and stent encrustation. The strings of the double-J stent can be left in place and attached to the pubis for easier withdrawal. They also would serve as a reminder for the presence of the stent and need for its withdrawal.

6.7 Results

In a review by Laing et al. of 15 studies with a total of 116 procedures, SFR was achieved in 86% of cases, and only two major complications were identified: one ureteral perforation and one case of premature uterine contraction. In another review by Guisti et al., including 8 studies and 198 cases, SFR ranged from 73 to 100% [72].

Semins et al. performed a systematic review of the literature concerning the safety of ureteroscopy in pregnancy. The overall complication rate was 8.3% with two Clavien 1, six Clavien 2, and one Clavien 3 complications being noted. When compared with the complication rates derived from the AUA/EAU ureteral stone guidelines, no statistical difference in the rate of ureteral injury or UTI was shown [73].

Another study focusing on obstetric complications in 46 patients undergoing ureteroscopic stone removal during pregnancy found two (4.3%) obstetric complications, both premature contractions in the third trimester. One was managed with tocolytics and the other required cesarean section [74].

Today, many of the concerns that precluded the use of fURS in pregnant patients are now deconstructed and better understood with recent experience and evidence-based medicine [75–78]. Thus, primary fURS is certainly an option to be considered in a multidisciplinary fashion for the management of stones in pregnant patients. These procedures should preferably be performed by an experienced endourologist in a high-volume center, with available supporting obstetrics and neonatology units.

References

1. Geraghty RM, Jones P, Somani BK. Worldwide trends of urinary stone disease treatment over the last two decades: a systematic review. J Endourol.

2017;31(6):547–56. https://doi.org/10.1089/end.2016.0895.
2. Timmons JW, Malek RS, Hattery RR, Deweerd JH. Caliceal diverticulum. J Urol. 1975;114(1):6–9. https://doi.org/10.1016/s0022-5347(17)66930-1.
3. Waingankar N, Hayek S, Smith AD, Okeke Z. Calyceal diverticula: a comprehensive review. Rev Urol. 2014;16(1):29–43.
4. Wulfsohn MA. Pyelocaliceal diverticula. J Urol. 1980;123(1):1–8. https://doi.org/10.1016/s0022-5347(17)55748-133.
5. Jones JA, Lingeman JE, Steidle CP. The roles of extracorporeal shock wave lithotripsy and percutaneous nephrostolithotomy in the management of pyelocaliceal diverticula. J Urol. 1991;146(3):724–7. https://doi.org/10.1016/s0022-5347(17)37906-5.
6. Canales B, Monga M. Surgical management of the calyceal diverticulum. Curr Opin Urol. 2003;13(3):255–60. https://doi.org/10.1097/00042307-200305000-00015.
7. Liatsikos EN, Bernardo NO, Dinlenc CZ, Kapoor R, Smith AD. Caliceal diverticular calculi: is there a role for metabolic evaluation? J Urol. 2000;164(1):18–20. https://doi.org/10.1016/s0022-5347(05)67439-3.
8. Lechevallier E, Saussine C, Traxer O. Prise en charge des calculs des diverticules caliciels rénaux. Prog Urol. 2008;18(12):989–91. https://doi.org/10.1016/j.purol.2008.09.019.
9. Tan YK, Cha DY, Gupta M. Management of stones in abnormal situations. Urol Clin N Am. 2013;40(1):79–97. https://doi.org/10.1016/j.ucl.2012.10.001.
10. Shalhav AL, Soble JJ, Nakada SY, Wolf JS, McClennan BL, Clayman, R. V. Long-term outcome of caliceal diverticula following percutaneous endosurgical management. J Urol. 1998;160(5):1635–9. https://doi.org/10.1016/s0022-5347(01)62366-8.
11. Grasso M, Lang G, Loisides P, Bagley D, Taylor F. Endoscopic management of the symptomatic caliceal diverticular calculus. J Urol. 1995;153(6):1878–81. https://doi.org/10.1016/s0022-5347(01)67337-3.
12. Khan SA, Khan FR, Fletcher MS, Richenberg JL. Milk of calcium (MOC) cysts masquerading as renal calculi—a trap for the unwary. Cent Eur J Urol. 2012;65(3):170–3. https://doi.org/10.5173/ceju.2012.03.art16.
13. Kourmpetis V, Sofer M. Toward respiratory-gated retrograde intrarenal surgery: a prospective controlled randomized study. J Endourol. 2018;32(9):812–7. https://doi.org/10.1089/end.2018.0231.
14. Soni SD. Modified “Blue Spritz” technique for ureteroscopic localization and management of caliceal diverticula. Videourology. 2018;32(3):2018.
15. Chong TW, Bui MHT, Fuchs GJ. Calyceal diverticula. Urol Clin N Am. 2000;27(4):647–54. https://doi.org/10.1016/s0094-0143(05)70114-2.
16. Smyth N, Somani B, Rai B, Aboumarzouk OM. Treatment options for calyceal diverticula. Curr Urol Rep. 2019;20(7):1–4. https://doi.org/10.1007/s11934-019-0900-x.
17. Hoznek A, Chopin DK, Abbou C-C. Symptomatic caliceal diverticula treated with extraperitoneal laparoscopic marsupialization fulguration and gelatin resorcinol formaldehyde glue obliteration. J Urol. 1998;160(2):352–5. https://doi.org/10.1016/s0022-5347(01)62893-3.
18. Gupta M, Lee MW. Treatment of stones associated with complex or anomalous renal anatomy. Urol Clin N Am. 2007;34(3):431–41. https://doi.org/10.1016/j.ucl.2007.04.004.
19. Yohannes P, Smith AD. The endourological management of complications associated with horseshoe kidney. J Urol. 2002;168(1):5–8. https://doi.org/10.1016/s0022-5347(05)64819-7.
20. Molimard B, Al-Qahtani S, Traxer O. Flexible ureterorenoscopy with holmium laser in horseshoe kidneys. Urology. 2010;76(6):1334–7. https://doi.org/10.1016/j.urology.2010.02.072.
21. Raj GV, Auge BK, Assimos D, Preminger GM. Metabolic abnormalities associated with renal calculi in patients with horseshoe kidneys. J Endourol. 2004;18(2):157–61. https://doi.org/10.1089/089277904322959798.
22. Bingham G, Leslie SW. Pelvic kidney. Treasure Island: StatPearls; 2020.
23. Weizer AZ, Assimos DG, Preminger GM. Ureteroscopic management of renal calculi in anomalous kidneys. Urology. 2005;65(2):265–9. https://doi.org/10.1016/j.urology.2004.09.055.
24. Harraz AM, Kamal AI, Shokeir AA. Urolithiasis in renal transplant donors and recipients: an update. Int J Surg. 2016;36:693–7. https://doi.org/10.1016/j.ijsu.2016.11.032.
25. Challacombe B, Dasgupta P, Tiptaft R, Glass J, Koffman G, Goldsmith D, Khan MS. Multimodal management of urolithiasis in renal transplantation. BJU Int. 2005;96(3):385–9. https://doi.org/10.1111/j.1464-410X.2005.05636.x.
26. Hyams E, Marien T, Bruhn A, Quirouet A, Andonian S, Shah O, Matlaga B. Ureteroscopy for transplant lithiasis. J Endourol. 2012;26(7):819–22. https://doi.org/10.1089/end.2011.0495.
27. Del Pizzo JJ, Jacobs SC, Sklar GN. Ureteroscopic evaluation in renal transplant recipients. J Endourol. 1998;12(2):135–8. https://doi.org/10.1089/end.1998.12.135.
28. Sevinc C, Balaban M, Ozkaptan O, Karadeniz T. Flexible ureterorenoscopy and laser lithotripsy for the treatment of allograft kidney lithiasis. Transplant Proc. 2015;47(6):1766–71. https://doi.org/10.1016/j.transproceed.2015.06.020.
29. Reeves T, Agarwal V, Somani BK. Donor and post-transplant ureteroscopy for stone disease in patients with renal transplant: evidence from a systematic review. Curr Opin Urol. 2019;29(5):548–55. https://doi.org/10.1097/MOU.0000000000000618.
30. Mosayyebi A, Manes C, Carugo D, Somani BK. Advances in ureteral stent design and materials. Curr Urol Rep. 2018;19(5):1–9. https://doi.org/10.1007/s11934-018-0779-y.
31. Bouzidi H, Traxer O, Doré B, Amiel J, Hadjadj H, Conort P, Daudon M. Caractéristiques des incrusta-

tions des endoprothèses urétérales chez les patients lithiasiques. Prog Urol. 2008;18(4):230–7. https://doi.org/10.1016/j.purol.2008.02.004.
32. Rouprêt M, Daudon M, Hupertan V, Gattegno B, Thibault P, Traxer O. Can ureteral stent encrustation analysis predict urinary stone composition? Urology. 2005;66(2):246–51. https://doi.org/10.1016/j.urology.2005.03.054.
33. Acosta-Miranda AM, Milner J, Turk TMT. The FECal double-J: a simplified approach in the management of encrusted and retained ureteral stents. J Endourol. 2009;23(3):409–15. https://doi.org/10.1089/end.2008.0214.
34. Tunney M, Gorman S. Evaluation of a poly(vinyl pyrollidone)-coated biomaterial for urological use. Biomaterials. 2002;23(23):4601–8. https://doi.org/10.1016/s0142-9612(02)00206-5.
35. Thomas A, Cloutier J, Villa L, Letendre J, Ploumidis A, Traxer O. Prospective analysis of a complete retrograde ureteroscopic technique with holmium laser stent cutting for management of encrusted ureteral stents. J Endourol. 2017;31(5):476–81. https://doi.org/10.1089/end.2016.0816.
36. Ishii H, Couzins M, Aboumarzouk O, Somani BK. Outcomes of systematic review of ureteroscopy for stone disease in the obese and morbidly obese population. J Endourol. 2016;30(2):135–45. https://doi.org/10.1089/end.2015.0547.
37. Stevens J, Cai J, Pamuk W, J. L. The effect of age on the association between body-mass index and mortality. N Engl J Med. 1998;338(1):1–7. https://doi.org/10.1056/nejm199801013380101.
38. Duffey BG, Pedro RN, Monga M. Lithogenic risk factors in the morbidly obese population. J Urol. 2008;179(4):1401–6. https://doi.org/10.1016/j.juro.2007.11.072.
39. Spatola L, Ferraro PM, Gambaro G, Badalamenti S, Dauriz M. Metabolic syndrome and uric acid nephrolithiasis: insulin resistance in focus. Metabolism. 2018;83:225–33. https://doi.org/10.1016/j.metabol.2018.02.008.
40. Juan HC, Lin HY, Juan YS. Abdominal fat distribution on computed tomography predicts ureteric calculus fragmentation by shock wave lithotripsy. Eur Radiol. 2012;22(8):1624–30. https://doi.org/10.1007/s00330-012-2413-6.
41. Cloutier J, Villa L, Traxer O, Daudon M. Kidney stone analysis: "Give me your stone, I will tell you who you are!". World J Urol. 2015;33(2):157–69. https://doi.org/10.1007/s00345-014-1444-9.
42. Calvert RC, Burgess NA. Urolithiasis and obesity: metabolic and technical considerations. Curr Opin Urol. 2005;15(2):113–7. https://doi.org/10.1097/01.mou.0000160626.36236.22.
43. Mancini JG, Raymundo EM, Ferrandino MN. Factors affecting patient radiation exposure during percutaneous nephrolithotomy. J Urol. 2010;184(6):2373–7. https://doi.org/10.1016/j.juro.2010.08.033.
44. Chew BH, Zavaglia B, Miller NL. A multicenter comparison of the safety and effectiveness of ureteroscopic laser lithotripsy in obese and normal weight patients. J Endourol. 2013;27(6):710–4. https://doi.org/10.1089/end.2012.0605.
45. Andreoni C, Afane J, Olweny E, Clayman RV. Flexible ureteroscopic lithotripsy: first-line therapy for proximal ureteral and renal calculi in the morbidly obese and superobese patient. J Endourol. 2001;15(5):493–8. https://doi.org/10.1089/089277901750299285.
46. Davis NF, Burke JP, McDermott T, Flynn R, Manecksha RP, Thornhill JA. Bricker versus Wallace anastomosis: a meta-analysis of ureteroenteric stricture rates after ileal conduit urinary diversion. Can Urol Assoc J. 2015;9(5–6):284. https://doi.org/10.5489/cuaj.2692.
47. Okhunov Z, Duty B, Smith AD, Okeke Z. Management of urolithiasis in patients after urinary diversions. BJU Int. 2011;108(3):330–6. https://doi.org/10.1111/j.1464-410x.2011.10194.x.
48. Ramachandra MN, Somani BK. Challenges of retrograde ureteroscopy in patients with urinary diversion: outcomes and lessons learnt from a systematic review of literature. Urol Int. 2018;101(3):249–55. https://doi.org/10.1159/000488325.
49. Nelson CP, Wolf JS, Montie JE, Faerber GJ. Retrograde ureteroscopy in patients with orthotopic ileal neobladder urinary diversion. J Urol. 2003;170(1):107–10. https://doi.org/10.1097/01.ju.0000070962.91546.bd.
50. Doizi S, Traxer O. Flexible ureteroscopy: technique, tips and tricks. Urolithiasis. 2017;46(1):47–58. https://doi.org/10.1007/s00240-017-1030-x.
51. Hyams ES, Winer AG, Shah O. Retrograde ureteral and renal access in patients with urinary diversion. Urology. 2009;74(1):47–50. https://doi.org/10.1016/j.urology.2009.02.050.
52. Ordon M, Dirk J, Slater J, Kroft J, Dixon S, Welk B. Incidence, treatment and implications of kidney stones during pregnancy: a matched population-based cohort study. J Endourol. 2019;34(2):215–21. https://doi.org/10.1089/end.2019.0557.
53. Swartz MA, Lydon-Rochelle MT, Porter MP. Admission for nephrolithiasis in pregnancy and risk of adverse birth outcomes. Obstet Gynecol. 2007;109(5):1099–104. https://doi.org/10.1097/01.AOG.0000259941.90919.c0.
54. Ross AE, Handa S, Lingeman JE, Matlaga BR. Kidney stones during pregnancy: an investigation into stone composition. Urol Res. 2008;36(2):99–102. https://doi.org/10.1007/s00240-008-0138-4.
55. Coe FL, Parks JH, Lindheimer MD. Nephrolithiasis during pregnancy. N Engl J Med. 1978;298(6):324–6. https://doi.org/10.1056/nejm197802092980608.
56. Maikranz P, Lindheimer M, Coe F. 8 Nephrolithiasis in pregnancy. Baillieres Clin Obstet Gynaecol. 1994;8(2):375–86. https://doi.org/10.1016/s0950-3552(05)80326-8.
57. Kroovant RL. Stones in pregnancy. In: Coe FLFM, Pak CYC, Parks JH, Preminger GM, editors. Kidney stones: medical and surgical management. Philadelphia: Lippincott-Raven; 1996. p. 1059–64.

58. White J, Ory J, Lantz Powers AG, Ordon M, Kroft J, Cox A. Urological issues in pregnancy: a review for urologists. Can Urol Assoc J. 2020;14(10):352. https://doi.org/10.5489/cuaj.6526.
59. Moş C, Holt G, Hălbac M. The sensitivity of transabdominal ultrasound in the diagnosis of ureterolithiasis. Med Ultrason. 2010;12(3):188–97.
60. Shokeir AA, Mahran MR, Abdulmaaboud M. Renal colic in pregnant women: role of renal resistive index. Urology. 2000;55(3):344–7. https://doi.org/10.1016/s0090-4295(99)00475-6.
61. Fulgham PF, Assimos DG, Pearle MS, Preminger GM. Clinical effectiveness protocols for imaging in the management of ureteral calculous disease: AUA technology assessment. J Urol. 2013;189(4):1203–13. https://doi.org/10.1016/j.juro.2012.10.031.
62. Committee Opinion No. 723. Committee Opinion No. 723: Guidelines for diagnostic imaging during pregnancy and lactation. Obstet Gynecol. 2017;130(4):e210–6. https://doi.org/10.1097/aog.0000000000002355.
63. Pearce MS, Salotti JA, Berrington de González A. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 2012;380(9840):499–505. https://doi.org/10.1016/s0140-6736(12)60815-0.
64. White WM, Zite NB, Gash J, Waters WB, Thompson W, Klein FA. Low-dose computed tomography for the evaluation of flank pain in the pregnant population. J Endourol. 2007;21(11):1255–60. https://doi.org/10.1089/end.2007.0017.
65. Parulkar BG, Hopkins TB, Wollin MR, Howard PJ, Lal A. Renal colic during pregnancy: a CASE for conservative treatment. J Urol. 1998;159(2):365–8. https://doi.org/10.1016/s0022-5347(01)63918-1.
66. Stothers L, Lee LM. Renal colic in pregnancy. J Urol. 1992;148(5):1383–7. https://doi.org/10.1016/s0022-5347(17)36917-3.
67. Burgess KL, Gettman MT, Rangel LJ, Krambeck AE. Diagnosis of urolithiasis and rate of spontaneous passage during pregnancy. J Urol. 2011;186(6):2280–4. https://doi.org/10.1016/j.juro.2011.07.103.
68. American College of Obstetricians and Gynecologists. Nonobstetric surgery during pregnancy. ACOG Committee Opinion No. 775. Obstet Gynecol. 2019;133:e285–6.
69. White WM, Johnson EB, Zite NB, Beddies J, Krambeck AE, Hyams E, Marien T, Shah O, Matlaga B, Pais VM Jr. Predictive value of current imaging modalities for the detection of urolithiasis during pregnancy: a multicenter, longitudinal study. J Urol. 2013;189(3):931–4. https://doi.org/10.1016/j.juro.2012.09.076.
70. Tawfiek ER. Ureteroscopy during pregnancy with follow-the-wire technique. Afr J Urol. 2009;15(4):245–9. https://doi.org/10.1007/s12301-009-0044-1.
71. Watterson JD, Girvan AR, Beiko DT, et al. Ureteroscopy and holmium: YAG laser lithotripsy: an emerging definitive management strategy for symptomatic ureteral calculi in pregnancy. Urology. 2002;60:383–7.
72. Giusti G, Proietti S, Graziotti P. Sky is no limit for ureteroscopy: extending the indications and special circumstances. World J Urol. 2014;33(2):257–73. https://doi.org/10.1007/s00345-014-1345-y.
73. Semins MJ, Matlaga BR. Kidney stones during pregnancy. Nat Rev Urol. 2014;11(3):163–8. https://doi.org/10.1038/nrurol.2014.17.
74. Johnson EB, Krambeck AE, White WM, Hyams E, Beddies J, Marien T, Shah O, Matlaga B, Pais VM Jr. Obstetric complications of ureteroscopy during pregnancy. J Urol. 2012;188:151–4.
75. Bjazevic J, Razvi H. Stones in pregnancy and pediatrics. Asian J Urol. 2018;5(4):223–34. https://doi.org/10.1016/j.ajur.2018.05.006.
76. Laing KA, Lam TBL, McClinton S, Cohen NP, Traxer O, Somani BK. Outcomes of ureteroscopy for stone disease in pregnancy: results from a systematic review of the literature. Urol Int. 2012;89(4):380–6. https://doi.org/10.1159/000343732.
77. Ishii H, Aboumarzouk OM, Somani BK. Current status of ureteroscopy for stone disease in pregnancy. Urolithiasis. 2013;42(1):1–7. https://doi.org/10.1007/s00240-013-0635-y.
78. Duvdevani M, Sfoungaristos S, Razvi H. Stones in special situations. World J Urol. 2017;35(9):1381–93. https://doi.org/10.1007/s00345-017-2011-y.