Review paper

Videosurgery

Modern management of stone disease in patients with a solitary kidney

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Abstract

Analysing the data available in the literature, contemporary methods of treatment of nephrolithiasis are limited to the methods of minimally invasive percutaneous nephrolithotomy (PCNL) and ureterorenoscopic lithotripsy (URSL), not excluding their use in the presence of developmental abnormalities and kidney impairment only. Minimally invasive methods have become standard procedures. A complement to ineffective URSL and PCNL treatment is extracorporeal shock wave lithotripsy. This is confirmed by 30 years of observation in the only treatment of kidney calculi by Alken launched in 1981 and continued by Jones et al. Before the era of endoscopic procedures (PCNL and URSL) effectively removed the only deposits in the kidney in open operations. Minimally invasive treatments are recommended for patients with localized deposits in the pelvicalyceal system or solitary kidney ureter. They are recognized as safe and effective treatment in a solitary kidney in particular in patients who have already been operated on.

Key words: *solitary kidney, nephrolithiasis, mini-invasive treatment.*

Introduction

Patients with a functionally or anatomically solitary kidney require carefully planned surgery in order to optimize the chance for recovery after one effective surgical procedure and minimize the risk of complications. They lost the other kidney due to nephrolithiasis, hydronephrosis, a tumour or injury and are aware that the loss of the only kidney left incurs the risk of dialysis connected with the prolonged deterioration of the life quality or of the subsequent surgery connected with the possible transplantation. Those patients should be operated on with the classical technique and in their belief the procedure poses a high risk of organ loss.

That is why in the case of nephrolithiasis in the solitary kidney, an operator has to think of the safest method to remove concrements so that the risk of resurgery can be diminished and the patient can be protected from organ loss. Endoscopic surgical techniques are assumed to reduce a surgical injury, resulting in a lack of post-operational scars and faster psychophysical recovery.

The endoscopic procedures percutaneous nephrolithotomy (PCNL) and ureterorenoscopic lithotripsy (URSL), also known as mini-invasive procedures, are well accepted by the patient as they guarantee a smaller number of complications and high efficiency. The patient's stress rate connected with PCNL and URSL is lower than in the case of open surgery when compared on the grounds of the type of anaesthesia, small post-operational wound and short hospital stay. Nowadays practically any concre-

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ments located in the upper urinary tract (both or a solitary kidney) can be removed by means of endoscopic modalities. The effectiveness of treatment depends on an operator's skills and experience. In the case of a solitary kidney the pressure is put on performing PCNL or URSL successfully enough to avoid the next surgery.

Epidemiology

1.5% of the European population presents with nephrolithiasis. In Poland it is estimated at 1-2%. It is the third most frequent disease occurring after urinary system infection and prostatic adenoma. Men develop the condition 3 times more often than women. The peak incidence is from the 3rd to 5th decade of life. The risk of relapse within 5 years from the first diagnosis is 50% [1].

Pathogenesis

The pathogenesis of nephrolithiasis is difficult to clearly explain. Analysis of chemical composition of kidney stones shows their diversity. Approximately 40% of kidney stones are composed of calcium oxalate and calcium phosphate, 35% of calcium oxalate, 10% of ammonium magnesium phosphate (struvite) and carbonate apatite, 10% of uric acid and 2% of cystine and xanthine. At the base of the formation of kidney stones are primarily disorders of calcium-phosphate metabolism and oxalic acids. Urinary stones in 75% consist of calcium. In patients with renal stones hypercalciuria is recognized in 30-60% [2-4].

Clinical presentation

The clinical symptoms of solitary kidney nephrolithiasis vary depending on the size, location, how long the concrements remains in the urinary tract and possible coexistence of infection. Nephrolithiasis often proceeds asymptomatically and is diagnosed fortuitously. However, most frequently we deal with patients suffering from colic pain. A stone in the renal pelvis or ureter is the cause of such a situation. It may block urine flow, which results in a greater pressure in the pyelocalyceal system and local ischaemia of either the pelvic or ureter wall [5]. It manifests with pain in the lumbar region, which radiates to the abdomen, groin, testicle and medial thigh. Renal colic is accompanied by symptoms involving the digestive system such as nausea and vomiting. Haematuria and erythrocyturia are often observed when the concrement is passed from the body [6, 7]. In case of an anatomically or functionally solitary kidney, anuria is the first symptom besides pain due to occlusion of urine output from a solitary kidney. The clinical presentation should be supplemented by imaging examinations. In case of a patient with a solitary kidney or fever imaging examinations should be compulsory according to EAU (European Association of Urology) guidelines. Recently the European Association of Urology has been recommending non-enhanced computed tomography as a modality of choice in patients with renal colic symptoms since its sensitivity and specificity outperform classic X-ray image of the abdominal cavity [8-10].

The superiority of computed tomography (CT) over the conventional imaging methods is the detection possibility of uric acid concrements and xanthic stones, which are X-ray invisible [11]. However, if CT is unavailable it is indicated to perform an X-ray examination of the abdominal cavity, which detects 90% of concrements in the urinary tract. An X-ray image allows for an assessment of the location and the size of the concrement. The ultrasonography (USG) is supplementary to radiological examinations as a non-invasive and reproducible method of stone imaging. Urine culture and analysis are routinely performed in our centre. Leukocytosis, creatinine and urea concentrations in the serum are determined and glomerular filtration rate value is calculated to estimate the kidney function [12].

Operative treatment

Mini-invasive endoscopic techniques have dynamically developed in the recent years. They are applicable in the treatment of upper urinary tract nephrolithiasis in patients with a solitary kidney [13]. Previously, if a concrement had not been passed spontaneously by the body, the formations in the kidney or ureter were extracted surgically [14]. Endoscopic procedures were in the majority of cases limited to the removal of concrements from the distal ureter with a Zeiss loop [15] or Dormia Basket [16]. Currently, according to EAU guidelines the surgical treatment of a solitary kidney is reserved only for a large coral calculus [17], concrements in the transplanted kidney [18, 19], concrements in the ectopic kidney, scheduled resection of the renal pole, obese patients and anatomical anomalies [20]. In all the cases where mini-invasive procedures are either contraindicated or unsuccessful, surgical treatment is still advisable. Nowadays open surgery is most commonly performed due to iatrogenic perforation of the ureter or kidney during endoscopic procedures. Before embarking on invasive treatment of a stone, it is necessary to consider the possibility of spontaneous passage of a concrement. The location of a concrement in the urinary tract, anatomical conditions and its size are the most crucial factors. It is accepted that the spontaneous passage of a 4 mm concrement can be expected in 80% of patients. The EAU guidelines indicate the diameter of 7 mm above which surgical treatment is necessary [21]. Modern, mini-invasive techniques of solitary kidney upper urinary tract nephrolithiasis treatment include extracorporeal shock wave lithotripsy (ESWL), PCNL and URSL. The ESWL is performed by means of a lithotripter. The first devices were constructed in the 1980s in cooperation with Dornier. The first procedure was performed in 1980 with the lithotripter prototype HM1 (human model 1) and later on was put into clinical practice by Chaussy in 1982 [22, 23]. Concrements are broken in the kidney or ureter by a generated acoustic wave. There are three methods distinguished of generating a shock wave: electrohydraulic, piezoelectric and electromagnetic. The ESWL is believed to be a safe, reproducible method with a minimal number of complications, that can be performed ambulatorily, which is especially important for patients with a solitary kidney [24]. The efficiency of the procedure is dependent on the concrement's location, its chemical composition and anatomical conditions assuring free outflow of broken fragments. The bigger the concrement, the higher the number of ESWL sessions. According to EAU guidelines the number of sessions required per deposit should fluctuate between 3 and 5. Patients with concrements sized 0.5-20 mm, located in the renal pelvis, calyxes or in the ureter of one kidney above the crossing with the iliac artery qualify for ESWL [25]. In case of a concrement in the lower calyx it is crucial that the axis of the calyx was at a right angle with the pelvis axis. Also the neck of the calyx must be wide, which facilitates the outflow of the broken fragments [26]. For stones which failed ESWL, it can be combined with PCNL [27, 28]. In case of ESWL monotherapy the boundary size of a concrement is 40 mm × 30 mm [29].

The chemical composition of the stone influences the effectiveness of ESWL. Stones made of calcium oxalate dihydrate are the easiest to crush. Concrements resistant to lithotripsy consist of brushite. Stones made of uric acid are hard, but with higher energy used they break into small pieces. Cystine concrements are very resistant to breakage. Even if they break down, they break into big fragments, difficult to pass [30, 31]. Stones located in the ureter are more difficult to break than concrement formations in the renal pelvis. In case of a solitary kidney, ESWL treatment is seldom employed. Lack of free space, quite contrary to pelvic stones, is responsible for the situation. Concrements are the cause of ureter obstruction, which creates disadvantageous conditions for ESWL [32]. Concrements in the upper urinary tract have to be pushed to the kidney and then ESWL can be performed (push and bang). The ESWL is a procedure of choice in case of concrements in the middle ureter. Concrements in the distal ureter are removed with ESWL only when situated in the ureteral orifice [33]. The ESWL is the method of choice used at the beginning of "steinstrasse" [34]. In order to perform ESWL the following conditions must be met: no clinical presentation of urinary tract infection, no impediment to the urine outflow from the kidney and a concrement sized 15-20 mm. The presence of a concrement bigger than 15 mm may require the use of a double-curved selective catheter to decrease ureter obstruction and the following anuresis [35]. Pregnancy, blood coagulation disorder not responding to treatment and acute infection of the urinary tract are absolute contraindications to perform ESWL. Complications following ESWL may be divided into short and long-term. Short-term complications are connected with the direct result of the acoustic wave influence on the tissue and passage of broken fragments through the urinary tract. Long-term complications are connected with the lack of sufficient follow-up after ESWL [36]. Post-ESWL check-up is a standard procedure. We assess the calculus disintegration after 24-48 h and decide about purposefulness of the next procedure. It is indicated to check urine standstill and assess infection on the basis of urine analysis or culture. The results of solitary kidney nephrolithiasis ESWL treatment are promising. It is accepted that ESWL effectiveness is 92% for kidney concrements smaller than 10 mm. For concrements sized 10-20 mm it shows 59-89% effectiveness in eliminating stones, and for stones larger than 20 mm it is 39-70% [37].

Percutaneous nephrolithotomy is the removal of a kidney or upper ureter stone with a nephroscope. It is applied near the stone after the kidney is inflated via a percutaneous puncture. Firstly, on the side operated on, a rigid probe is inserted through the ureter to supply a contrast agent to the pyelocalyceal system of the kidney. Contrast medium allows for precise renal puncture under X-ray [38]. Alken or Amplatz dilators are employed to create a wide route to the kidney via which a nephroscope gets placed. A lithotripter, which is used to break stone fragments, is inserted through the nephroscope. Concrements can be broken with ultrasonic, electro-hydraulic or laser lithotripsy. Broken pieces are then removed with forceps [39]. Preoperative investigation should include USG, X-ray of the abdomen, urography or CT to learn about the anatomical structure of the kidney and surrounding organs. The USG allows for locating the surrounding organs and minimizing the risk of their damage. The concrement is located urographically and the access route is planned. The ideal place for an artificial fistula is the posterior, lower calyx. The approach reduces the risk of bleeding as the area is surrounded by the minimal number of blood vessels. It is medially limited by Brodel's line [40].

After the procedure drainage is left in the renal fistula. It prevents possible bleeding from renal parenchyma and allows urine outflow from the kidney. Patients with solitary kidney nephrolithiasis are selected for PCNL when EWSL is contraindicated or ineffective. A stone sized below 20 mm located in a slightly widened, renal pelvis is an ideal concrement formation for PCNL. The procedure can be successfully employed in case of calyx concrements [41]. The effectiveness of the procedure, meaning the smallest number of remaining concrements, depends mostly on the skill and experience of the operator. Nephrolithiasis in the solitary kidney with concurrent ureteropelvic junction obstruction is the next indication for PCNL. After performing PCNL, internal optical urethrotomy, so-called percutaneous endopyelotomy is done [42]. Hard stones (made of cystine, uric acid or calcium oxalate monohydrate) in which EWSL would provide poor results, are the last indication for PCNL in patients with a solitary kidney [43]. Contraindications to PCNL are blood coagulation disorder not responding to treatment, pregnancy, tuberculosis of the urinary tract and urosepsis connected with the infected urine standstill. Anaesthesia depends on the length of the procedure. In case of short local procedures, lasting up to 2 h, it is advisable to use conduction anaesthesia. If it lasts more than 2 h general anaesthesia is recommended [44].

The PCNL is a mini-invasive procedure. It is safe due to the small number of complications and patient-friendly as the patient does not spend much time in hospital. The PCNL is not free of complications. Injury to adjacent organs may occur during kidney puncture. Another common complication associated with PCNL is intraoperative bleeding, the source of which can be renal parenchymal injury induced during channel dilatation or severe trauma to the pyelocalyceal system when coral calculus is removed. If the bleeding makes it impossible to continue with the procedure, it must be terminated and performed in the so-called stage II. Persistent bleeding may be connected with arteriovenous fistula which is treated by selective embolization. The bleeding may also result in haemorrhage in the perirenal space, which should be absorbed spontaneously [45]. The renal pelvis may be injured during insertion of dilators. If the mucosa is not severely injured, PCNL can be proceeded with. However, if an opening in the renal pelvis is made, the procedure must be discontinued in order to avoid hypotonic fluid loss and water poisoning [46]. Urinary tract infection after PCNL appears in 25% of patients with positive urine culture performed before the procedure. A short-term fever up to 38.5°C is observed. It recedes after antibiotic therapy. The infection occurs most commonly after PCNL performed on coral calculi, which are always infected [47, 48]. It is assessed that pelvic stones up to 20 mm are entirely removed in 98% of cases. In case of coral calculi, remaining deposits are observed in 40% of patients. Concrements up to 4 mm are treated as fragments prone to spontaneous passage. If they are above 7 mm, we plan supplementary ESWL treatment. Treatment of coral nephrolithiasis in a solitary kidney is always planned as a combination of different methods. The PCNL, which is used to remove stones from the renal pelvis, is combined with ESWL for calyceal concrements and possible URSL when the remaining concrement gets stuck during passage in the ureter of a solitary kidney [49].

Stone removal through URSL is performed under direct vision by means of a ureterorenoscope in the operating room. Conduction anaesthesia is employed. A ureterorenoscope is a device which is introduced into the bladder via the urethra and then it is advanced into the ureter. If the ureteral orifice is narrow, special dilators must be used, which allow for non-harmful orifice widening and unconstrained access via the intramural ureter. After reaching a formation, the lithotripter is introduced to crush the stone. Broken fragments are removed with forceps. After the procedure a rigid ureteral catheter D-J ureteral stent may be left in the ureter depending on the concrement's location, its size and the condition of the urethral mucosa [50]. The indication for URSL surgery is a stone situated in the ureter, which is not subjected to destruction of ESWL or is located in a place where the performance of ESWL treatment is impossible. The URSL in case of a solitary kidney may be performed on every segment of the ureter. Modern techniques of laser lithotripsy considerably facilitate the procedure [51]. Absolute contraindications to PCNL are blood coagulation disorder, acute infection of the urinary tract and tuberculosis. Urinary tract infection with impeded urine outflow from the solitary kidney requires creation of a renal fistula and postponing the procedure until full recovery [52]. Rigid, semi-rigid and flexible ureterorenoscopes are used for URSL.

Rigid ureterorenoscopes are 40 cm long with a 10.5-13 F sheath. The optics used in those ureterorenoscopes ranges from 0 to 70°. Ultrasonic, electrohydraulic and laser lithotripters can be used in rigid ureterorenoscopes [53].

Semi-rigid ureterorenoscopes are called miniscopes due to their smaller calibre (6.0-7.2 F). They are fibre-optic based, which does not distort the visual field when bending during the procedure. Laser lithotripsy is used in semi-rigid ureterorenoscopes [54].

Flexible ureterorenoscopes are divided into passive and active. In a passive device the tip cannot be deflected, which is possible in case of an active device. The tip deflection allows one to reach the calyceal stones, including the lower calyx, and to remove them through the ureter. Flexible ureterorenoscopes' calibre ranges from 7.5 F to 9.8 F [55]. The use of a smaller diameter device facilitates introduction to the ureteral orifice without additional dilatation, which reduces damage to the ureteral wall and the number of complications.

The employment of lasers to crush stones was the next stage of ureterorenoscopic lithotripsy development. The first attempts were based on pulse alexandrite or Nd:YAG laser usage. Currently, a holmium laser is a gold standard in URSL [56]. It was introduced in 1995 for lithotripsy of ureteral and renal concrements. A holmium laser utilizes a wavelength in the infrared zone (2100 microns), which is entirely absorbed by water. Since the holmium laser penetrates 0.5 mm in the surrounding tissues, it is safe during breakage of stones in a solitary kidney. Concrements broken with the laser's energy are completely disintegrated. If small fragments are left, they are easily removed from the ureter with forceps. When the laser is used, no concrements are pushed up the ureter, which takes place in case of lithotripters [57]. The URSL is a highly effective treatment for the removal of stones from the ureter. The success depends on the concrement's location in the ureter, its size and the lithotripter used. In the lower segment it amounts to 96% and with the holmium laser it reaches even 100%. In the middle part it is 81%. Concrements sized up to 5 mm are removable in 95% of cases. Bigger stones are crushed with 90% effectiveness. The poorest results are achieved with concrements sized more than 10 mm and the success rate is around 85% [58]. Mucosa damage occurs quite often during dilatation or introduction of the ureterorenoscope. Small damage is spontaneously healed without cicatrization of the ureter. Perforation of the ureter is a complication endangering the life of a patient with a solitary kidney. If urine can be transferred via renal fistula ureteral splinting is possible, it can be managed conservatively. If urine transfer or splinting is impossible, the surgery is performed on the spot. Classic surgery is also performed in case of complete ureteral severance. Such severance may result from too intense ureterorenoscope movement in the narrow ureter or when a Dormia basket or forceps are used to remove the stone. In the early postoperative period retrograde urine flow may occur in 20-30% of cases. It recedes spontaneously after 3 weeks. Ureteral narrowing resulting from mechanical damage or thermal energy used in a lithotripter is a late post-operational complication. The incidence is between 2% and 5%. Ureteral narrowing is diagnosed when the urine standstill is visible in imaging examinations and persists 6-12 weeks after the procedure. Such narrowing is operated on endoscopically. The ureter is incised under direct vision [59]. The way of performing URSL in patients with a solitary kidney does not differ from the procedure in patients with both kidneys.

Mini-invasive procedures are recommended in patients with concrements located in the pyelocalyceal system or ureter of a solitary kidney. They are believed to be a safe and successful method of treatment in patients who were previously operated on. It is necessary to remember, however, that it is the doctor performing the surgery who is responsible for the effectiveness and safety of the method. That is why PCNL and URSL in case of a solitary kidney is safe and effective when performed by an experienced urologist.

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