Minimal-Invasive PCNL (Mini-PCNL)

16

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16.1 Introduction

Over a long period of about 20 years, the so-called conventional PCNL was the surgical procedure of choice for the treatment of larger stones of the upper urinary tract. The advantage of the conventional PCNL was the very high stonefree rate compared to extracorporeal shockwave lithotripsy. Percutaneous treatment of large stones was superior to all other treatment alternatives (retrograde endoscopic treatment, extracorporeal shockwave lithotripsy), especially in the lower calyx. However, conventional PCNL was associated with a significant morbidity, e.g. the transfusion rate was approximately 10%. In solitary cases serious complications were observed, such as loss of kidney. In addition, the large instruments of a conventional PCNL can only be used with restrictions in the treatment of pediatric stones of the upper urinary tract. The difficulty to perform percutaneous stone removal in children led to a miniaturization of the conventional PCNL. Jackman described a miniaturized PCNL in children using a 13 F Amplatz sheath and showed that PCNL with miniaturized instruments is feasible. He reached a stonefree rate of 89% in nine pediatric patients. Transfusions were not needed [1].

Based on the good results of the miniaturization of PCNL in children, a miniaturization of the conventional PCNL in adults was evaluated in 1999. The aim was to combine the low mobility of extracorporeal shockwave lithotripsy with the good efficacy of the conventional PCNL in adult patients. In 2001 the first specially designed miniaturized nephroscope was published for the application of Mini-PCNL in adult patients [2] (Fig. 16.1).

Meanwhile, the Mini-PCNL has become widely accepted as the new standard of percutaneous nephrolithotomy. Numerous international publications confirm the minimal invasiveness and the excellent stonefree rate of Mini-PCNL [3–5]. Since about 8 years various modifications of the 2001 published original version of the Mini-PCNL had been published. These include the Micro-PCNL, the Ultra-Mini-PCNL (UMP) [6] and the Super-Mini-PCNL (SMP) [7].

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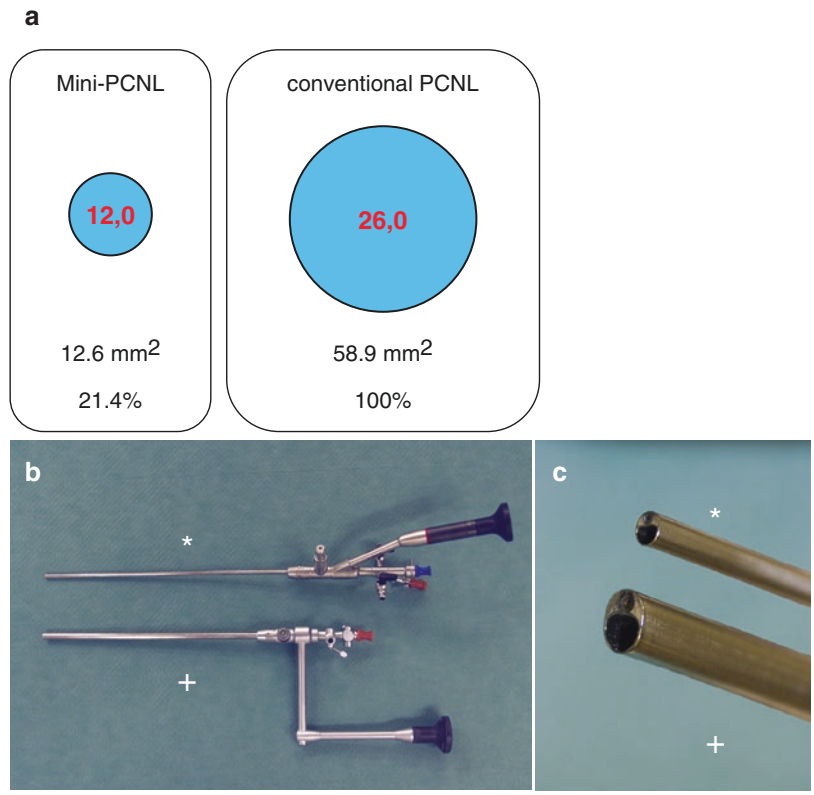

Fig. 16.1 Comparison of Mini-PCNL and conventional PCNL. (**a**) The Mini-nephroscope has only 21.4% of the cross section of the conventional nephroscope. (**b**) Comparison of Mini-nephroscope (∗) to conventional nephroscope (+). (**c**) Characteristics of the Mini-Perc procedure in comparison to a conventional PCNL

16.2 Indications for Mini-Perc

The European Association of Urology (EAU) recommends percutaneous treatment of stones from the upper urinary tract if the diameter of the urinary stone is more than 2 cm. For urinary stones with a diameter between 1 and 2 cm, percutaneous stone treatment is only a second-choice therapy. If the renal stone is less than 1 cm in diameter, percutaneous nephrolithotomy is only recommended as a third-line treatment [8]. In this context, it must be kept in mind, that these recommendations of the scientific societies are based on publications that are only dealing with conventional PCNL. In other words, this means that the indications for Mini-PCNL may differ from the general recommendations for performing conventional PCNL. At present there is still the difficulty that only a limited number of publications are available for the indication of Mini-PCNL and, therefore, so far no consideration was given in the guidelines. Based on the publications available so far, it can be assumed that Mini-PCNL can be recommended as a primary treatment option in urinary calculi of the upper urinary tract if the diameter is at least 1 cm [9]. However, it must again be emphasized that these indications cannot yet be based on the recommendations of the scientific societies. At present, this means that in the case of a Mini-PCNL of urinary stones with a diameter of less than 2 cm, appropriate information must be provided for the patient. The patient must always be informed about the treatment alternatives (extracorporeal shockwave lithotripsy and flexible ureterorenoscopy). Nevertheless the Mini PCNL is currently a minimally invasive procedure with low morbidity. However, so far it cannot be used on the basis of the current guidelines of the scientific societies [10].

16.3 Treatment Alternatives to Mini-PCNL

Depending on the size of the stone and the location of the stone, there are different treatment alternatives to the Mini-PCNL. In the case of stones of the upper urinary tract, the principal alternative treatment options are extracorporeal shockwave lithotripsy and flexible ureterorenoscopy. Shock wave lithotripsy offers a low morbidity; however, the stonefree is very low and the retreatment rate high. In addition, the treatment time of shockwave lithotripsy is very long.

In the case of retrograde flexible ureterorenoscopy as a minimally invasive treatment alternative, the stonefree rate is high and the morbidity of the procedure is also low. However, in the case of urinary stones larger than 1 cm in diameter, the operation time is significantly longer. For urinary calculi larger than 2–3 cm, retrograde flexible ureterorenoscopy cannot be recommended as the first-choice treatment [11, 12]. In contrast to Mini-PCNL, flexible ureterorenoscopy allows easier access to the ureter by using a ureteral access sheath. In addition, the instruments for flexible ureterorenoscopy are very expensive and fragile. In case of damage, high repair costs have to be expected (Fig. 16.2).

16.4 Equipment

The successful implementation of Mini-PCNL depends above all on the availability of appropriate instruments and suitable disposables.

In the first part of Mini-PCNL, a retrograde pyelography is performed using a special ureteral catheter (5 F). The use of contrast dye and methylene blue is required for dilatation, as well as for the radiographic and endoscopic identification of the renal calyceal system.

To perform a Mini-PCNL a 12 F nephroscope is needed. Furthermore, a so-called one-step dilator (15 F) and a reusable stainless steel Amplatz sheath are used. For lithotripsy, a holmium laser should be used. As a postoperative urinary diversion the insertion of a nephrostomy tube is advisable. As a treatment option, the antegrade use of a flexible endoscope through percutaneous access or the use of forceps and stone graspers may be necessary in solitary cases.

	Mini-PCNL	flexible URS
access	experience required	easy
stonefree rate	+++	++
hemostatic disorders	absolute contraindication	relative contraindication
prefered stone localization	lower pole	upper pole mid calix
cost effectiveness	+++	–
lithotripsy	Holmiumlaser	Holmiumlaser
transfusion rate	≈ 1%	< 1%

Fig. 16.2 Comparison of Mini-PCNL to flexible ureterorenoscopy

16.5 Surgical Procedure

The procedure of a Mini-PCNL consists of two steps [13]. The first step of the procedure is a retrograde pyelography. Preferably, a ureteral balloon catheter is used. The retrograde pyelography allows getting all information about the morphology of the ureter, such as strictures, kinkings or additional ureteral stones. The ureteral catheter is placed above the ureteropelvic junction and the balloon is inflated.

The next step is to reposition the patient. Mini-PCNL can be performed in the prone or supine position. Most Mini-PCNL procedures are done in the prone position. A percutaneous access to the renal calyceal system is established, the urinary stone disintegration is performed and the stone fragments are removed by means of the irrigation flow (Fig. 16.3a–f).

16.5.1 Retrograde Pyelography

First, a diagnostic endoscopy of the bladder is performed to exclude additional pathological findings of the lower urinary tract. Subsequently, a 5 F ureteral catheter is inserted through the ureteral orifice. The retrograde pyelography then shows any additional abnormalities of the ureter. In the case of a balloon ureteral catheter, it is blocked above the ureteral pelvic junction with approximately 0.5–1.0 mL of sterile saline. This is done under fluoroscopic control. In individual cases, the blockage of the ureteral balloon catheter can also be done in the proximal ureter under radiological guidance. This is always to be preferred if the urinary stone mass in the renal pelvis does not permit the position of the ureteral catheter in the renal pelvis due to limited space of the renal pelvis. Finally, after retrograde pyelography and the insertion of the ureteral catheter, the insertion of a transurethral catheter is performed (Fig. 16.3b).

16.5.2 Repositioning of the Patient

Upon completion of the ureteral catheter insertion, the patient is repositioned to perform the Mini-PCNL. This can be done either in the prone or supine position. The decision on the type of positioning primarily depends on the experience of the surgeon. In case of prone positioning, the kidney may be fixed by a cushion positioned under the abdomen. Alternatively, the pelvis and the thorax can be elevated by means of a cushion to have a mobile kidney to perform Mini-PCNL. Through the ureteral catheter a mixture of contrast dye and methylene blue is applied. This leads to a dilatation of the renal pelvis and facilitates the puncture of the renal calyceal system. In addition, the successful puncture of the renal calyceal system is easier to monitor after applying methylene blue through the ureteral catheter.

16.5.3 Puncture of the Calyceal System

The puncture of the renal pelvis can be done either under ultrasound control, under radiographic control or by a combination of both methods. After application of a mixture of contrast dye and methylene blue, the successful puncture of the renal calyceal system can be easily detected fluoroscopically and clinically. If the calyceal system had been punctured successfully, the next step is to insert a guidewire (Fig. 16.3c). Then the puncture needle is removed and a so-called single step dilator is inserted under radiological guidance. The next step is to insert a stainless steel Amplatz sheath, which exactly fits to the stainless steel dilator. Finally, the stainless steel dilator is removed (Fig. 16.3d). By means of the mini-nephroscope, an endoscopic evaluation of the renal calyceal system is performed. If the Amplatz sheath is placed properly and no further difficulties are detected by mini-nephroscopy, the guidewire can be removed. The removal of the guidewire in Mini-PCNL is always recommended as without the guidewire the so-called vacuum-cleaner effect is facilitated (see below).

16.5.4 Nephroscopy

The nephroscopy is performed with the mini-nephroscope, which has a diameter of 12 F. It can be inserted through the stainless steel Amplatz

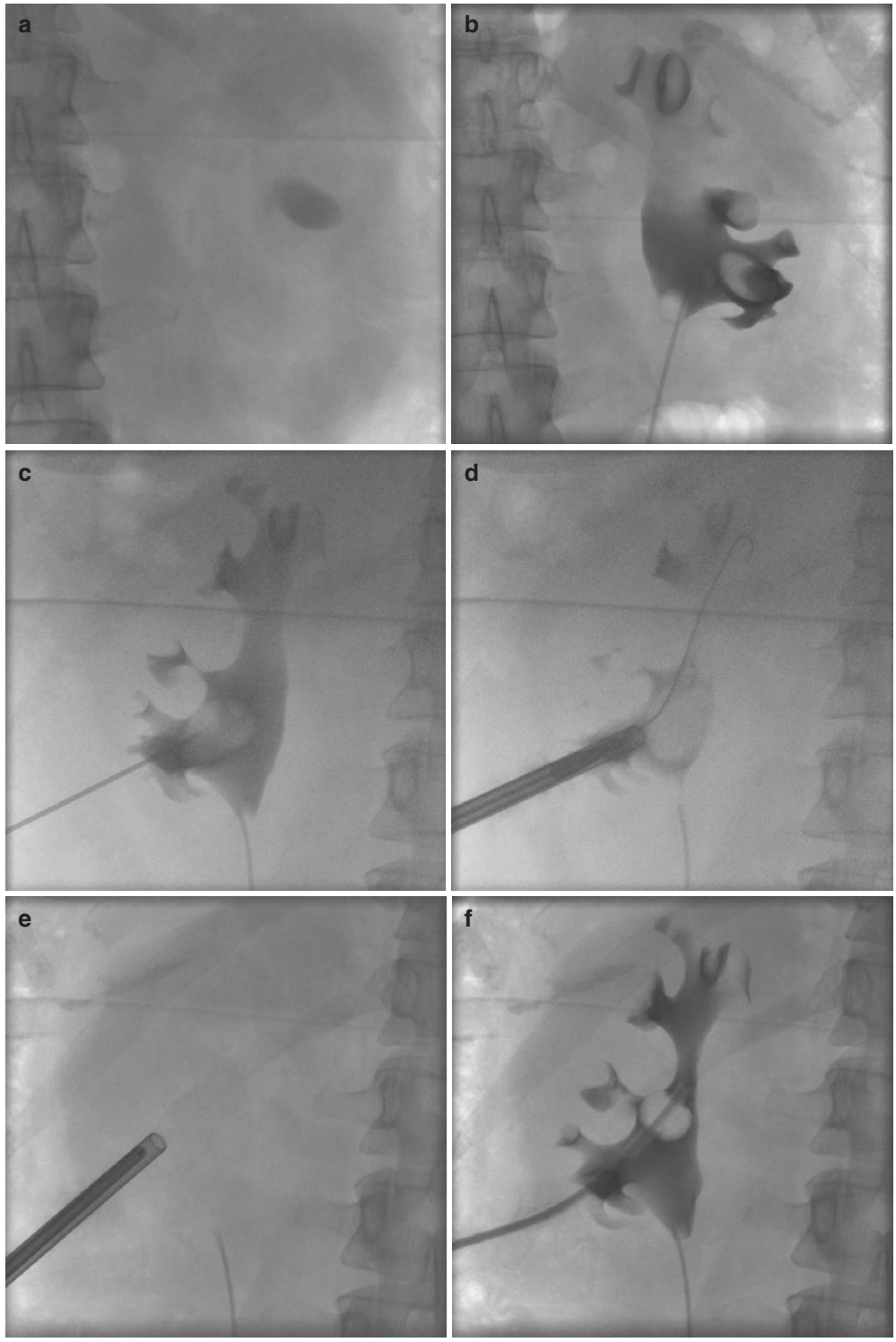

Fig. 16.3 Mini-Perc procedure. (**a**) 2 cm renal pelvic stone. (**b**) Retrograde pyelography and insertion of ureteral balloon catheter. (**c**) Puncture of the renal calyceal system. (**d**) Dilation of the tract and insertion of an Amplatz sheath. (**e**) Stonefree-status at the end of the procedure. (**f**) Insertion of nephrostomy tube

sheath. Once the correct position of the Amplatz sheath has been verified under nephroscopic vision, the still inserted guide wire can be removed. The aim of the removal of the guidewire is that the fragments later produced by holmium-laser lithotripsy can be more easily rinsed through the Amplatz sheath and the guidewire is not an obstruction, which stops the migration of stone fragments. For inspection of the renal calyceal system flexible endoscopes can also be used. Here, the indication is based on the morphology of the renal calyceal system. The orientation during nephroscopy is mainly done under endoscopic view. But it can be additionally facilitated by fluoroscopy and contrast dye application.

16.5.5 Stone Disintegration

The stone disintegration in Mini-PCNL should preferably be done by means of a holmium laser. The reason for this recommendation is that the cross-section of the holmium-laser fiber is very small and thus no decrease of the irrigation flow takes place. In addition, due to the different settings of a holmium laser, various different types of stone disintegration can be applied. According to the particular stone situation, disintegration into fragments, and disintegration into dust or a popcorn-effect can be performed. The goal in any Mini-PCNL case is to achieve such small stone fragments, which automatically can leave the renal calyceal system through the space between the mini-nephroscope and the Amplatz sheath. In holmium-laser lithotripsy, the laser fiber is brought close to the surface of the urinary stone. When applying the laser, the fragment size can be varied depending on the frequency and energy used. In the case of a Mini-PCNL, it is recommended to generate as small as possible fragments of the stone and to prevent the simultaneous formation of several larger fragments of the initial stone. If an ultrasound device is used for stone disintegration, it should be noted on the one hand that a reduction of the irrigation flow occurs due to the cross section of the ultrasound probe and, on the other hand, a collapse of the renal pelvis can occur due to the suction effect of the ultrasound probe. Therefore in Mini-PCNL a holmium-laser lithotripsy is most suitable.

16.5.6 Stone Extraction

In Mini-PCNL, the removal of disintegrated urinary stone fragments occurs only through the flushing stream of the irritation. In this respect, the use of forceps or baskets is not required. Due to the special ratio of the diameter and length of the Amplatz sheath a special suction effect occurs, which is known as the so-called vacuum-cleaner effect. This effect does not occur in the conventional PCNL and is considered to be the main difference of the Mini-PCNL to the conventional PCNL. If peripheral renal calculi are present in the renal calyceal system, the use of flexible endoscopes via the Mini-PCNL Amplatz sheath may be useful. The aim of the Mini-PCNL is in any case to treat the patient endoscopically and radiologically confirmed stonefree.

16.5.7 Postoperative Drainage of the Calyceal System

For the postoperative drainage of the renal calyceal system, the insertion of a 12 or 14 F nephrostomy tube is recommended. The insertion of a percutaneous nephrostomy tube reduces the risk of postoperative fever. In addition, the percutaneous access to the kidney is preserved so that, if necessary, a second procedure can be performed without a new puncture of the renal calyceal system. If one refrains from inserting a percutaneous nephrostomy and inserts a DJ stent instead, one speaks of a tubeless PCNL. If neither a percutaneous nephrostomy nor a DJ stent is inserted, this is called a totally tubeless PCNL (Fig. 16.3e, f) [14].

16.5.8 Particular Situations

In the case of very large masses of stone, it may be necessary to create multiple accesses to the

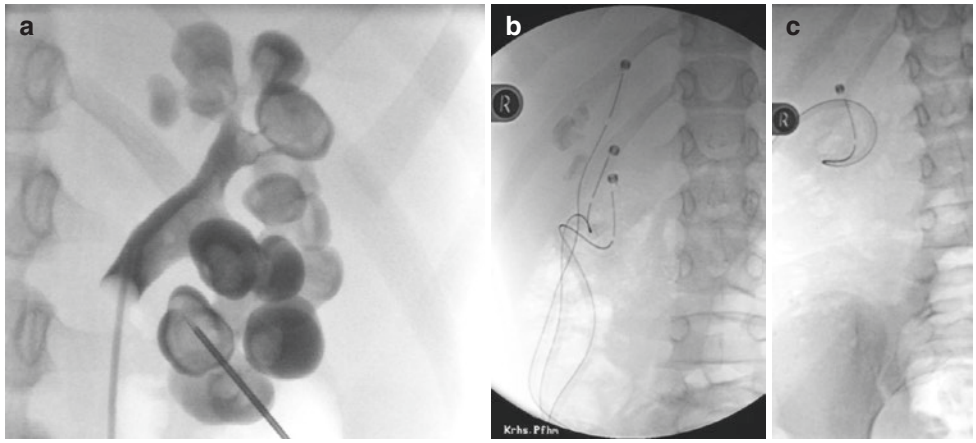

Fig. 16.4 In staghorn calculi, Mini-PCNL can be performed by multiple accesses. (**a**) Primary puncture of the lower calyx. (**b**) Multiple punctures due to peripheral stone mass. (**c**) Complete removal of all stones after seven sessions with no complications

kidney. In this case we are talking about a multitract Mini-PCNL (Fig. 16.4). If it is not possible to completely remove the stones in a Mini-PCNL, it is advisable to perform a second puncture [15].

In some cases a multiple tract PCNL can be expected before the procedure starts. In these cases it is recommended first to perform multiple punctures but not to perform any dilation. After multiple punctures had been done and guidewires in each access had been placed, the dilation of one tract can be started. Later one of the additional guidewires can be used for dilation and introducing an additional Amplatz sheath. According to the success of the procedure in some cases not all punctures are needed to insert an Amplatz sheath. At the end of the procedure any remaining guidewires can be removed without any difficulties.

In obese patients, using a longer Amplatz sheath may be helpful. However, in this case, the effect of the "vacuum-cleaner effect" is reduced.

16.6 Effectiveness of Mini-Perc

In experienced hands, the Mini PCNL is an effective and safe treatment modality for mid-sized stones of the renal calyceal system. The overall stonefree rate of the Mini PCNL is approximately 94%. The average operation time is approximately 65 min. If large urinary stones are treated, the operation time can be significantly longer. Interestingly the results of large upper urinary tract stones are comparable to the overall results. If an increase of the retreatment rate and a slight increase of the operating time are accepted, large stones can also be successfully treated by Mini-PCNL (Fig. 16.5) [16].

16.7 Complications

Basically complications of Mini-PCNL do not vary from complications of conventional PCNL—but frequency differs significantly. The main complications of Mini-PCNL are febrile urinary tract infections, perforation of the calyceal system, bleeding, strictures of the calyceal neck, fistulas and alterations of inner organs. Almost all perforations are treated with a prolonged insertion of a DJ-stent. No further difficulties remain in these cases. Major complications in Mini-PCNL are very rare. The transfusion rate is approximately 1% (Fig. 16.5) [17].

Fig. 16.5 Results of Mini-Perc in $n = 1048$ cases

		overall	> 5cm²
stone burden [cm²]		4.1	9.6
localisation [n]	calix	425	
	diverticulum	79	
	renal pelvis	353	
	part. staghorn	168	
	prox. ureter	18	
	horse shoe kidney	5	
operative time [min]		63.1	76.5
stonefree rate [%]		91.6	93.2
retreatment rate [%]		23.1	33.2
transfusion rate [%]		1.3	1.1
pyelonephritis [%]		7.0	7.7

16.8 Mini-PCNL in Particular Situations

Mini-PCNL is not only suitable in adult patients suffering from upper urinary tract calculi. Mini-PCNL can also be applied in particular situations which are challenging for endourological stone treatment.

16.8.1 Calyceal Diverticulum Stones

In calyceal diverticulum stones, the stones and the underlying morphological obstruction have to be treated simultaneously. There is almost no localization of calyceal diverticulum stones which cannot be reached by means of Mini-PCNL. This is a significant advantage in comparison to flexible ureterorenoscopy as in flexible ureterorenoscopy sometimes calyceal diverticula cannot be reached. In the case of Mini-PCNL, first the puncture is done. Then the calyceal diverticulum stone is disintegrated and removed. As the diverticulum is usually very narrow and there is only a limited space to place the nephroscope, Mini-PCNL is superior to conventional PCNL in this situation. Subsequently the diverticulum neck is passed by a guidewire by an antegrade way. Along the guidewire a holmium-laser incision of the diverticulum neck is done. Finally a nephrostomy tube is inserted and left in place for some days. There is scientific evidence that the percutaneous treatment of calyceal diverticulum stones is more effective than by means of flexible ureterorenoscopy (Fig. 16.6a–e).

16.8.2 Stone Removal in Transplanted Kidneys

Stones in transplanted kidneys can easily be reached by means of a Mini-PCNL. In contrast to pelvic kidneys, transplanted kidneys are located next to the abdominal wall with no interposition of the bowel. The ultrasound-guided puncture of the calyx of a transplanted kidney is often easy. Mini-PCNL also avoids any passage of the fragile ureteral anastomosis of the transplanted kidney. This means that Mini-PCNL in transplanted kidneys preserves the fragile anatomy of the transplanted ureter.

16.8.3 Pediatric Upper Urinary Tract Stones

The anatomy of the renal calyceal system in children is characterized by a limited space and a small diameter of the calyceal necks. Mini-PCNL with its limited diameter of the Amplatz sheath avoids any damage of the fragile infant calyceal system. Mini-PCNL is an ideal treatment option in upper urinary tract stones in childhood [1, 18]. Even in early born infants, Mini-PCNL can be applied. Remember that Mini-PCNL initially was designed for the treatment of upper urinary tract stones in children. A special chapter in this book deals with this topic (refer Chap. 19 by Dr. Kemal Sarica).

16.9 Recent Modifications of the Original Version of Mini-PCNL

From 2001 to 2011 Mini-PCNL has only been performed in its original version. Starting in 2011 several modifications of Mini-PCNL were presented. The main aim was to further minimize the risk of complications and to receive a comparable stonefree rate.

16.9.1 Micro-PCNL

Bader et al. published the Micro-PCNL technique in 2011. They developed a further minia-

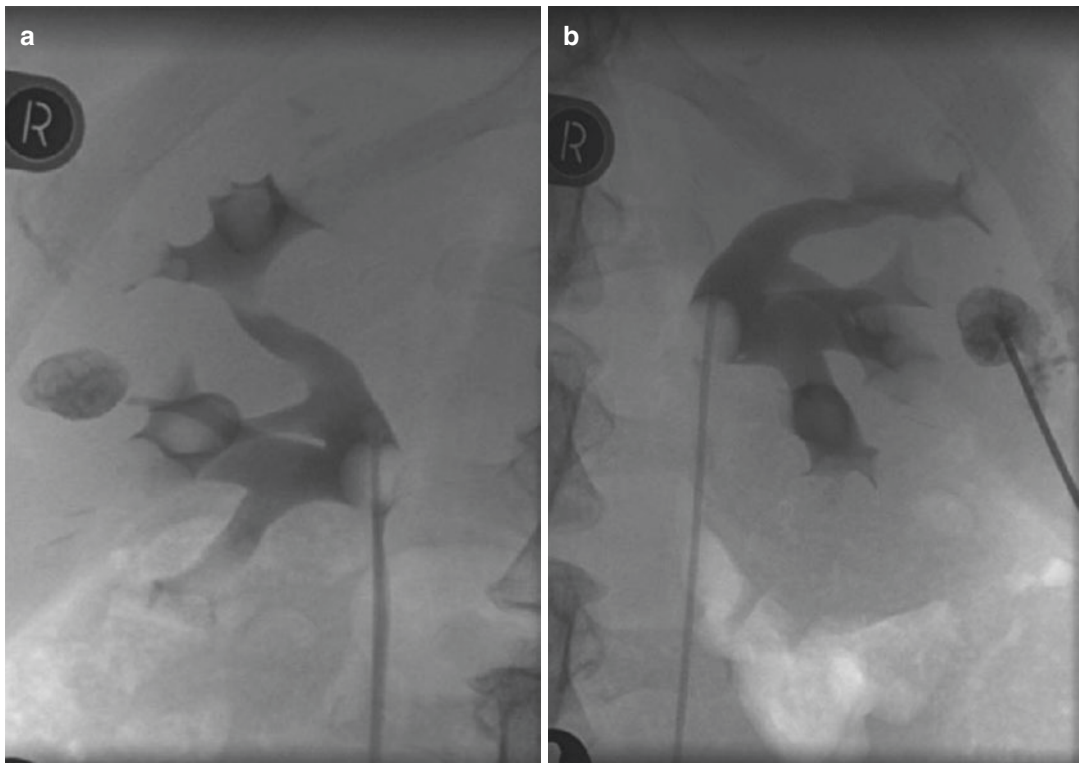

Fig. 16.6 (**a**) Calyceal diverticulum stone. (**b**) Retrograde pyelography in prone position. (**c**) Percutaneous puncture and removal of stone by Mini-PCNL. (**d**) Antegrade insertion of guidewire and holmium laser incision of the calyceal neck. (**e**) Insertion of nephrostomy tube

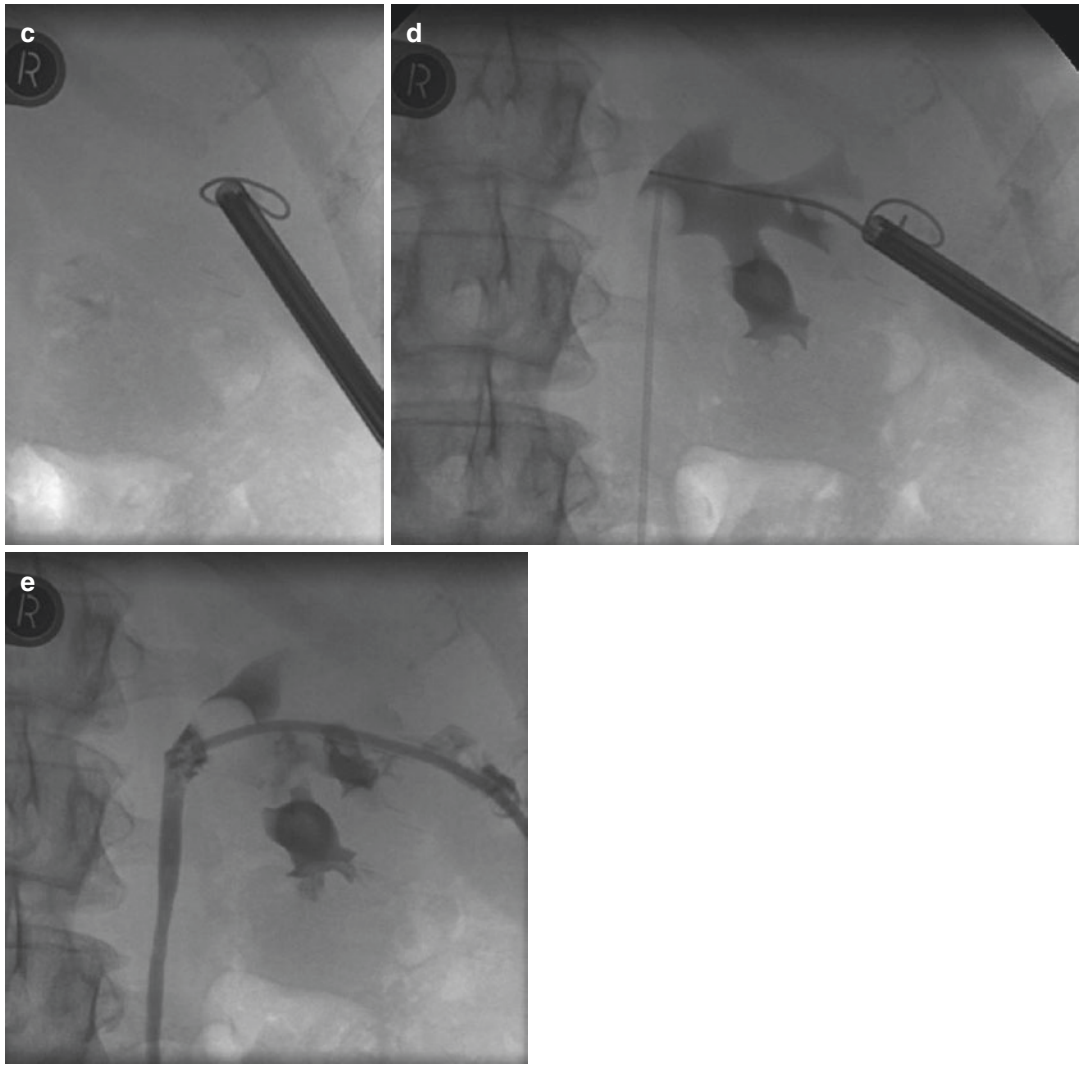

Fig. 16.6 (continued)

turized nephroscope which was inserted in a special puncture needle. As the nephroscope was used during the puncture, this particular needle was called the "all-seeing needle." The diameter of the needle is 5 F, and the puncture of the renal calyceal system is done under direct endoscopic vision and ultrasound and/or fluoroscopic guidance. No dilation of the tract is needed. The only type of stone disintegration that works with Micro-PCNL is the holmium-laser lithotripsy. Due to the limited diameter of the Micro-PCNL Amplatz sheath, no stone removal is possible. The aim is to produce stone dust. These very small dust particles have to pass the ureter. The Micro-PCNL technique leads to a disintegration of the renal stones but does not provide any immediate stonefree status after the procedure. Furthermore there is no low pressure in the renal calyceal system as the irrigation flow is applied through the scope, but no space is available to allow the irrigation water to come out of the calyceal system. This is the reason why most urologists performing Micro-PCNL prefer to insert a large ureteral catheter.

The missing percutaneous outflow of the irrigation flow also leads to an increase of the pressure of the renal calyceal system, which is also a significant disadvantage. The stonefree rate of Micro-PCNL is significant lower than in original Mini-PCNL, and the probability to convert to Mini-PCNL is up to 15% [19].

16.9.2 Ultra-Mini-PCNL (UMP)

An UMP is performed by means of a 6 F nephroscope and an 11 F Amplatz sheath. The underlying principle of UMP is the same as in the original Mini-PCNL. After puncturing the renal calyceal system, a dilation of the tract is performed. Lithotripsy is performed by means of a holmium laser. Small fragments can be washed out of the calyceal system by means of the irrigation flow. This means that the so-called vacuum-cleaner effect also occurs in UMP. Unfortunately the stone fragments have to be very small. Otherwise it is impossible to wash out the stone fragments. UMP provides a low morbidity and an acceptable stonefree rate. But the operative time is longer and UMP is not recommended in large stone burden. UMP usually is performed as a tubeless procedure, which means, that no nephrostomy tube is inserted after the procedure [6, 20].

16.9.3 Super Mini-PCNL (SMP)

SMP had been evaluated by Zeng et al. The puncture and the dilation are similar to the original Mini-PCNL. In contrast to the original Mini-PCNL in SMP, active irrigation and active suction are used. The SMP Amplatz sheath consists of a particular connection to apply suction. The result is that with active irrigation and active suction the stone fragments can be washed out quicker. Particular in larger stone burden, the SMP is an advantage. The disadvantage is that the equipment is more complex to install and more expensive.

16.9.4 Minimal Invasive PNL (MIP XS, S, M, L)

The MIP technique works similar to the original Mini-PCNL. After puncturing the calyceal system, a single-step dilation is performed. The particular instrument used is chosen according to the stone burden, e.g. MIP S in small stones, MIP L in staghorn stones. The size of the nephroscope corresponds to each size of the Amplatz sheath, which means that different Amplatz sheaths have different nephroscopes.

16.9.5 Perfect Perc (PP)

The PP was introduced in 2014. This technique is based on a variety of different Amplatz sheaths, which can be combined with the same further miniaturized nephroscope with a diameter of 4.5 F. The idea is to adjust the size of the Amplatz sheath to the size of the stone but always to use the same mini-nephroscope. Amplatz sheaths are available from 10 to 16 F. As the nephroscope is only used to have an endoscopic view of the stone and to apply the laser, a very small mini-nephroscope is suitable for all sizes of Amplatz sheaths. As the same mini-nephroscope fits to all sizes of Amplatz sheaths, the PP is a very cost-effective procedure. In addition not only the diameter of the Amplatz sheaths can be adjusted to the size of the stone but also the length of the Amplatz sheath. All different sizes of the Amplatz sheaths are available in different lengths from 120 to 180 mm according to the obesity of the patient. As the "vacuum-cleaner effect" depends on the diameter and length of the Amplatz sheath, the PP can provide the optimum combination of Amplatz sheath diameter and length at any time.

16.10 When to Choose Mini-PCNL

As already discussed numerous modifications of the original Mini-PCNL are available. Figure 16.7 gives an overview of which type of Mini-PCNL

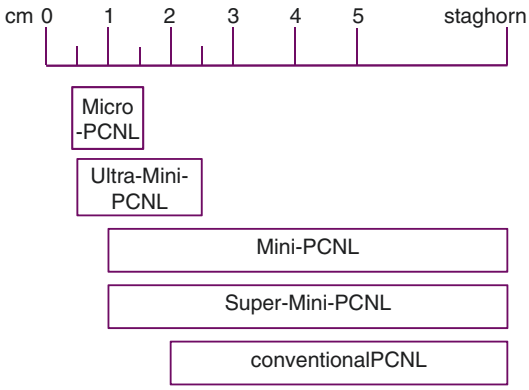

Fig. 16.7 Differential indications for PCNL according to stone sizes

to choose for which type of stones. Mini-PCNL can be recommended for stones exceeding a diameter of 1 cm. There is no limitation according to the stone size. The surgeon should always take into consideration that Mini-PCNL in stones from 1 to 2 cm is not yet covered by the guidelines. The type of PCNL used depends on the stone burden. According to the stone size, different types of PCNL can be recommended (Fig. 16.7) [21].

16.11 Conclusions

Mini-PCNL is a minimal-invasive modification of conventional PCNL. By means of a miniaturized instrument, a minimally invasive percutaneous procedure can be performed. Depending on stone size, location and composition, stonefree rate of 90% or more can be reached. As the puncture of the calyceal system is the most important step of the procedure, Mini-PCNL requires a lot of experience of the surgeon. Stone extraction, like in conventional PCNL, is not needed due to the effect by irrigation flow. It is expected that Mini-PCNL will be the percutaneous approach of choice and will be considered in the guidelines as soon as prospective trials are available to determine the effectiveness of Mini-PCNL even in smaller stone masses.

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