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REVIEW ARTICLE

Small-caliber percutaneous nephrolithotomy (SC-PCNL). Therapeutic decision algorithm☆

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Abstract
Introduction: The progressive reduction in the caliber of the tract in percutaneous kidney surgery to the point of miniaturization has expanded its use to smaller stones that until now have been treated with extracorporeal shock wave lithotripsy (ESWL) and retrograde intrarenal surgery (RIRS).
Objective: To provide an update on the various techniques of small-caliber nephrolithotomy (SC-PCNL) analyze their efficacy, safety and indications and determine their degree of implantation at this time.
Material and methods: We performed a review in PubMed of Spanish and English medical literature on the various techniques of SC-PCNL.
Results: The use of SC-PCNL has reduced the morbidity associated with standard PCNL, particularly bleeding, and has enabled tubeless nephrolithotomy with greater safety. There are various techniques with blurred terminology (Miniperc, Microperc, Mini-microperc, Ultraminiperc), which differ in terms of gauge employed and in certain technical aspects that require their indications be specified. Currently, SC-PCNL competes with techniques that are less invasive than standard PCNL such as ESWL and the RIRS in treating small stones, but the role of SC-PCNL is still not sufficiently understood and continues to be the subject of debate.
Conclusions: The indications for PCNL are expanding to small stone sizes due to the miniaturization of the technique. PCNL competes in this field with ESWL and RIRS. Larder studies are needed to establish the specific indications for PCNL in treating nephrolithiasis.

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PALABRAS CLAVE
Nefrolitectomía percutánea;
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Nefrolitectomía percutánea de calibre reducido (NLP-CR). Algoritmo de decisión terapéutica

Resumen

Introducción: La progresiva reducción del calibre del tracto en cirugía percutánea renal, hasta alcanzar la miniaturización, ha expandido su utilización a litiasis de menor tamaño que hasta ahora se trataban mediante litotricia extracorpórea por ondas de choque (LEOCH) y cirugía retrógrada intrarrenal (CRIR).

Objetivo: Realizar una puesta al día de las diferentes técnicas de nefrolitectomía de calibre reducido (NLP-CR) analizando su eficacia, seguridad e indicaciones, así como su grado de implantación en la actualidad.

Material y métodos: Realizamos una revisión en PubMed de la literatura en castellano e inglés sobre las diferentes técnicas de NLP-CR.

Resultados: La NLP-CR ha disminuido la morbilidad asociada a la NLP estándar, particularmente el sangrado, y ha posibilitado la nefrolitectomía *tubeless* con mayor seguridad. Existen diferentes técnicas con confusa terminología (miniperc, microperc, mini-microperc, ultraminiperc) que se diferencian en el calibre que emplean y en determinados aspectos técnicos que hacen que sus indicaciones deban ser precisadas. Actualmente, la NLPCR compite con técnicas menos invasoras que la NLP estándar, como la LEOCH y la CRIR en el tratamiento de las litiasis de pequeño tamaño, pero todavía su papel no está suficientemente esclarecido y es aún motivo de debate.

Conclusiones: Las indicaciones de la NLP se están expandiendo a tamaños litiásicos más pequeños debido a la miniaturización de la técnica, compitiendo en este campo con LEOCH y CRIR. Precisamos mayores estudios para establecer sus indicaciones precisas en el tratamiento de la litiasis renal.

Introduction

Percutaneous nephrolithotomy (PCNL) is currently considered the standard treatment for renal calculi larger than 2 cm[1,2] but also for lithiases of 1–2 cm located in the renal lower pole with unfavorable factors for extracorporeal shock wave lithotripsy (ESWL), as recommended by the European guidelines on urolithiasis.[3] Since its initial description by Fernström,[4] PCNL has undergone significant changes in various aspects that have increased its efficacy and safety. Different patient positions have been described in the literature,[5–7] as well as new energies of fragmentation have emerged,[8] different ways of dilating the tract[9] and various calibers have been arisen. All those different approaches to treat PCNL have had a varying degree of acceptance among the urological community. The reduction of the caliber of the tract has had a great importance in percutaneous kidney surgery for the possibility of reducing complications inherent to dilatation. In addition to this, it is possible to reduce nephrostomy tube caliber or prevent it, and consequently improve the postoperative comfort of the patient.[8]

In 1998, Jackman[10] described a mini-percutaneous nephrolithotomy (m-PCNL) procedure in order to adapt the technique used in adults to the anatomy of the child. Subsequently, the m-PCNL technique was used successfully in adults.[11–13] Later on, advances in endoscopic technology and energy-based fragmentation have brought along substantial reductions in caliber, namely, 'microperc',[14] 'mini-microperc'[15] and 'ultra-miniperc',[16] which have miniaturized percutaneous nephrolithotomy and have expanded the role of PCNL in the treatment of lithiasis.

At present, m-PCNL competes with techniques that are less invasive than standard PCNL, such as ESWL and retrograde intrarenal surgery (RIRS) in treating small stones. However, the role of m-PCNL is still not sufficiently understood and continues to be a subject of debate.

Our objective is to evaluate the scientific evidence that would answer the following questions: 1) is the reduction of the tract beneficial? 2) what calibers are currently in use in PCNL?; and 3) in which cases are the use of calibers recommended?

Evidence acquisition

A literature review was performed using the PubMed database between 1975 and 2016 that included keywords from the Medical Subject Headings: percutaneous nephrolithotomy, minipercutaneous nephrolithotomy, ultraminipercutaneous nephrolithotomy and micropercutaneous nephrolithotomy. A total of 6199 articles were found, of which 250 were selected from studies of both experimental animals and humans, conducted in adults and pediatric, and published in English. Of these, 93 articles were selected that analyzed the different calibers used in the percutaneous renal surgery for the treatment of renal calculi. We examined the results and complications of those studies to determine the most optimal indications for percutaneous renal surgery depending on the factors that define successes and side effects reactions.

Evidence synthesis

We reviewed each of the selected studies to answer the questions set as objectives.

Arguments in favor of reducing the size of the caliber

Although PCNL represented a scientific progress on open surgery of calculi in terms of morbidity and postoperative reduction, with success rates ranging from 76% to 98%, it also entailed non-negligible rates of complications.[17] Bleeding, both intraoperatively and postoperatively, is the most common complication, with transfusion rates ranging from 2% to 23%.[17–19] It seems evident that performing dilation to create a conventional nephrostomy tract may damage vessels adjacent to it. Although experimental studies in animals demonstrate that alterations in renal structure and function are similar when comparing sequential dilation to balloon dilation,[20] we have sufficient evidence on the relevant role of the caliber of the tract as predisposing factor of bleeding.[18,21–24]

Traxer,[25] in his experimental study with pigs, demonstrated that the dilation of the tract will cause injury in the renal parenchyma that will be replaced by a scar, with the consequent area of ischemia and small loss of renal function. The author compares the damage produced by a mini percutaneous tract in the renal parenchyma versus a conventional tract, finding no volume differences in the parenchymal scar (0.63% for m-PCNL vs. 0.91% for standard PCNL). Thus, the study by Traxer demonstrated that the volume of damaged renal parenchyma does not exceed 1% of the total in both accesses.[25] However, these studies also report that the tissue adjacent to the tract suffers damage, recognizing areas of interstitial inflammation and ischemia in the tissue that can evolve to healing as well.

The lack of information that we have about the actual damage that the tract produces in the papilla after healing has also been pointed out. It is estimated that the damage of the collecting ducts at that level may be undervalued and that the loss of global function may be greater than the one estimated so far, particularly when several tracts are used.[26]

On the other hand, the caliber of the tract should be adapted to the particular intrarenal anatomy of the patient. Unlike flexible ureteroscopy, where we manage parameters such as infundibular length and width to identify patients with 'unfavorable calyceal anatomy',[27] the priority when choosing the access calyx in PCNL has been the tuning of the axis of it with the lithiasis and the subcostal situation, without considering the conciliation between calyceal anatomy and caliber of the tract, since the latter was conditioned by the available technology.

Another argument in favor of reducing the caliber of the tract is the possibility of performing tubeless PCNL with greater safety. Several comparative studies had pointed out the possibility of reducing postoperative pain and hospital stay by replacing the 22–28 Fr caliber nephrostomy tube with a 9–10 Fr pigtail catheter, with no difference in bleeding.[28,29] That led to finishing PCNL without leaving nephrostomy. The concept of tubeless PCNL is almost as old as PCNL,[30] although early complications reported by few patients made the original idea of Wickham not to have a broad endorsement.[31]

In 1997, Bellman[32] demonstrated the safety and benefits of this clinical experiment on 50 patients in a case-control study, and although there are clear restrictions on tubeless PCNL,[33,34] according to a recent review, it is currently supported by more than 19 randomized comparative studies.[8] The use of sealant substances, that are necessary when standard caliber tracts are used,[35–37] raises controversy due to the risk of lithiasis formation.[38] Reducing the caliber of the m-PCNL tract could obviate the use of sealants when the tract is occluded spontaneously. Miniaturized calibers of PCNL, m-PCNL and ultra-mini PCNL are associated with tubeless intervention.[14–16]

Therefore, in order to reduce morbidity associated with calibers used by standard PCNL, and in the light of technological improvements, there have been changes in the instruments and in some aspects of this surgical technique.

Classification of percutaneous nephrolithotomy according to the caliber of the tract

PCNL has been performed since its origins with Amplazt from 26 Fr to 30 Fr. The caliber is appropriate to make way for the nefroscopes designed for this technique. Other authors have considered the 24 Fr caliber also as standard.[39]

When the PCNL was adapted to the pediatric population, the so called m-PCNL technique was first performed in a child using 15 Fr Hickman catheter sleeve and a 10 Fr[40] caliber infant cystoscope. Subsequently, Jackman[10] systematized the technique by operating on 11 children with an 11 Fr gauge provided by a catheter designed for such purpose. Then, the technique was applied in adults and the same author used a 13 Fr[11] caliber. In other initial studies, Monga and Lahme used 20 Fr and 15 Fr sheaths, respectively.[12,13] In 2007, the Storz team developed m-PCNL system with 18 Fr, 19.5 Fr, and 24 Fr sheaths that accommodate a 12 Fr nephroscope (Fig. 1), and shortly thereafter Wolf designed a similar equipment of sheaths of 15Fr and 18 Fr and nephroscope of 14 Fr.[41] There seemed to be consensus in defining m-PCNL as any PCNL employing a caliber equal to or lower than 20 Fr in a range that decreased to 11 Fr.[11,13,42,43] But with the description of the microperc[14] and later the ultra-mini PCNL[16] and mini-microperc,[15] the caliber was redefined for m-PCNL. Microperc employs a 4.8 Fr caliber with optics of 0. 9 mm.[14] Ultra-mini PCNL uses sheaths from 11 Fr to 13 Fr with miniature nephroscope 6 Fr,[16] and mini-microperc is a subsequent modification of microperc 8 Fr.[15]

A recent review concludes that a correct terminology would define m-PCNL as all PCNL using tract sized from 14 Fr to 20 Fr, ultra-mini PCNL from 11 Fr to 13 Fr, mini-microperc for 8 Fr gauge and microperc for 4.8 Fr gauge.[39]

PCNL with 22 Fr caliber would therefore be unclassified. One of the few references in the literature to this caliber is a retrospective study comparing the different sizes of Amplatz sheath from 22 Fr to 30 Fr. According to their findings, the fall in hemoglobin was significantly lower and the creatinine level significantly higher in patients treated with large Amplatz compared to the 22 Fr calibre.[44]

Figure 1 Nephroscope and sheaths for miniperc.

In view of the complexity of terms referring to the caliber, it has been proposed to simplify the nomenclature of PCNL-CR, referring to the strict size of the tract used as follows: PCNL^{+30}, PCNL^{+20}, PCNL^{+12}, etc.[45] or also establish an equivalence of the gauges with the nomenclature of the following sizes: XL, L, M, S, XS and XSS which would correspond to calibers greater than 25 Fr, 20 Fr to <25 Fr, 15 Fr to < 20 Fr, 10 Fr to < 15 Fr, 5 Fr to < 10 Fr and < 5 Fr, respectively.[46]

Mini-percutaneous nephrolithotomy/miniperc

The first reduction in caliber was reported by Helal in 1997, when treating a small-size lithiasis in a 2-year-old child, using a child cystoscope inserted through a 15 Fr tract provided by a peelable vascular sheath.[40] Then, as discussed above, it was Jackman who coined the term 'miniperc' or mini-PCNL to treat 11 children with lithiasis smaller than 2 cm using an 11 Fr tract, achieving a success rate of 85% without describing complications.[10] When the technique was transferred to the adult, preliminary studies showed success rates comparable to standard PCNL on lithiases smaller than 2 cm. Jackman applied it in 9 adults with lithiases smaller than or equal to 2 cm, achieving a success rate of 89% without mentioning complications.[11] Chan[42] reported a success rate of 94% in 17 patients, using a 13 Fr sheath. Monga,[12] using a 20 Fr sheath, reaches a success rate of 90% in 21 patients, reporting only complications in one case. Shortly after, Lahme[13] achieved similar results in 19 patients, referring only to a pyelonephritis as a complication. All the authors noted the lower morbidity of this technique over standard PCNL, although this consideration had no scientific support since none of those studies compared both techniques. A recent publication of more than 1300 patients undergoing m-PCNL-16 Fr reported a success rate of 82%, with a complication rate of 20.1%. Those results are apparently similar to the ones obtained in standard PCNL, although in this series of cases most were Clavien 1 and 2 and only 3.5% were Clavien 3.[47]

The results obtained in early comparative studies were not encouraging. The experimental study by Traxer discussed above, which compares the damage produced by an 11 Fr tract versus a 30 Fr tract in the renal parenchyma of the pig, did not justify the reduction of the caliber since the lesion was similar.[25] In a retrospective study, Giusti[48] compared m-PCNL, standard PCNL and tubeless PCNL, finding worse results in m-PCNL in terms of success rate and operating time, and although this technique had shorter hospital stay than standard PCNL, it did not exceed tubeless PCNL. In another prospective, non-randomized study of 50 consecutive patients comparing PCNL with 26 Fr Amplatz versus m-PCNL18 Fr, differences were found only in the minor hospitalization and postoperative pain of the m-PCNL. However, there was a bias in the results due to the difference in the lithiasic size of the treated patients.[22]

Subsequent comparative studies that are better designed have supported the statement that m-PCNL has lower morbidity. Cheng,[49] in a prospective randomized study with standard PCNL (24 Fr) versus m-PCNL (16 Fr) in three groups of patients (staghorn stones, renal pelvis and complex calyceal stones), showed a significantly lower bleeding rate that required transfusion for m-PCNL (10.4% for PCNL-24 Fr vs 1.4% for PCNL-16 Fr). The results showed similar success rates for the group of staghorn stones and renal pelvis, but better results for m-PCNL in the complex calyceal stones group (85.2% vs. 70% for m-PCNL and standard PCNL, respectively). According to the authors, that is due to the greater procedure of the m-PCNL sheath compared to the conventional one. In a prospective case-control study, Mishra[50] included 25 cases of m-PCNL (14 Fr-18 Fr) versus 28 cases of standard PCNL (24–28 Fr) of 1 to 2 cm sized renal stone. The author found no differences in success rate, and although the m-PCNL specified longer operative time than the standard, it was higher than the latter in the lower drop in hemoglobin, lower need for analgesia, and shorter hospital stay, noting the additional advantage of the higher rate of intraoperative conversion to tubeless m-PCNL. A recent meta-analysis involving 8 studies with 353 m-PCNL and 396 standard PCNL reveals similar stone-free rates in both techniques, showing significant differences in favor of m-PCNL in rates of bleeding, transfusion, pain, and postoperative stay. Standard PCNL was superior only in the operative time.[51]

But m-PCNL should not only be compared to its standard counterpart, but with less invasive techniques such as ESWL and RIRS, given the range of lithiasic size in which it has been used. Zeng[52] compares m-PCNL with ESWL in infants under 3 years of age with lithiasis ranging from 15 to 30 mm, finding similar success rates (96% vs 86% for m-PCNL and ESWL, respectively), but there were significant differences in complication rates and retreatment in favor of m-PCNL.

Kruck,[53] in a retrospective study of 482 patients comparing m-PCNL, RIRS and ESWL, points out a significantly worse

success rate for the latter, both in the lower pole and in any other location.

Several studies comparing m-PCNL with RIRS report a higher success rate, lower cost and no need for a double J stent in m-PCNL, although they show a greater fall in hemoglobin.[53–56]

Microperc

How much could the caliber be reduced in percutaneous surgery? This question was the basis for the development of micro-percutaneous nephrolithotomy. Bader et al.[57] used an optical needle of 0.9 mm diameter connected to a light source for ultrasound-guided needle aspiration in 15 patients undergoing PCNL. Shortly thereafter, Desai expanded the technique by performing the entire procedure through this 4.85 Fr needle.[14] The only working channel was transferring fiber optics, irrigation, and a 275 μm laser fiber. The miniature PCNL named microperc emerged in this way. The key was the quality of the micro-optics, which provided sufficient vision to perform the procedure safely and the main advantage is that there is no need for dilation of the tract; decreasing the possibility of bleeding. Microperc is manufactured by PolyDiagnost (Pfaffenhofen, Germany) with partially inventoried equipment[39] (Fig. 2).

Although from 2011 to the present several case series have been published on small calculi (10–20 mm) in both children and adults, with success rates around 90% and complication rates lower than 10%,[41,58–64] the number of treated patients is still small and restricted to a few centers to draw clear conclusions (Table 1). A retrospective study of 98 patients compared microperc to m-PCNL in 10–20 mm-sized stones in the lower calyx, showing a similar success rate, but a lower bleeding rate, shorter operative time, shorter hospital stay, and a higher tubeless rate for microperc.[65] Similar results were obtained by both techniques in pediatric patients with a lithiasic range of 10–20 mm.[66]

But microperc, given the constraints it has on stone size, must be confronted with RIRS and ESWL. Sabnis,[67] in a prospective randomized study, compared 35 patients undergoing microperc with 35 patients undergoing RIRS, for a renal stone size smaller than 15 mm. The success rate and operating time were similar; however, microperc caused greater drop in hemoglobin and greater pain, but had less need for double J stent.[67] Fata,[68] in a similar study but with fewer patients, found no significant differences between the two techniques. In contrast, in the lower calyx, microperc was superior to RIRS in a retrospective study of 127 patients with renal stones smaller than 20 mm.[69] Microperc obtained a higher stone-free rate, shorter operative time, and less need for a double J stent, although the fall in hemoglobin and postoperative duration were greater with this technique.[69]

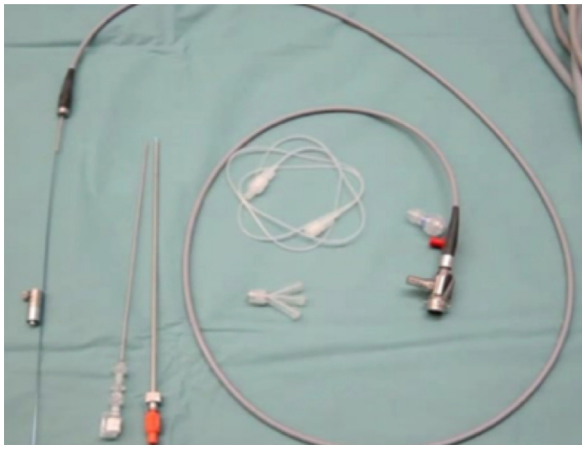

Figure 2 Equipment for microperc.

The literature shows a resolution rate for microperc equivalent to RIRS and m-PCNL in renal calculi smaller than 20 mm, and it seems to have a minimally invasive profile. However, this technique has significant limitations. Unlike m-PCNL, microperc does not allow the use of flexible ureterorenoscopes by anterograde.[8] The technique using 4.8 Fr needle, and even the 8 Fr sheath, due to its reduced size, is smaller than that achieved with the sheaths employing m-PCNL, which requires direct access to lithiasis because tangential trajectories to the stone may invalidate fragmentation.[70] If during this procedure a migration of fragments occurs, we are forced to reconvert the procedure to RIRS or m-PCNL in order to reach a complete resolution. In series with a large number of patients, such as Hatipoglu (*n*: 140) or Ganpule (*n*: 139), the rate of reconversion to m-PCNL due to migration of remains or poor vision was 8.57% and 6.47%,[41,62] respectively.

Another drawback to be noted is the absence of the 'venturi' effect produced by m-PCNL, which enables spontaneous extraction of the lithiasic fragments through the sheath, and this forces the lithiasis to vaporize to avoid significant debris.[41]

Finally, a controversial aspect in this field is the high pressures reached in the renal pelvis during some phases of the intervention due to the absence of drainage through the micropercutaneous sheath. This technique has proved to have pressures significantly higher than those achieved with standard PCNL during the different phases of the intervention.[71] The highest pressure reached with microperc was 30.3 mm Hg compared to 20.1 mm Hg with standard PCNL, which is the threshold pressure for pyelovenous reflux.[72] However, the complication rate was similar in both groups. The question is whether this hyperpresence has or does not have clinical consequences.[71]

Ultra-mini PCNL

Ultra-mini percutaneous nephrolithotomy (UMP) corresponds to the miniaturized PCNL using 11 Fr to 13 Fr calibers manufactured by LUT (Leben und Technologie). Once the 18 gauge needle is punched and the guide is passed, the 11 Fr or 13 Fr sheath with its obturator is slid through the guide without dilation (Figs. 3 and 4). UMP employs a 6 Fr nephroscope and holmium laser as the only feasible source of energy for fragmentation.[39] UMP offers some advantages over microperc in relation to its greater caliber, such as the possibility of extracting small fragments with baskets and maintaining the 'venturi effect' offered by m-PCNL. The first experience with this technique[16] comprised 36 patients with renal calculi smaller than 2 cm in which a success rate of

Table 1 Descriptive series of microperc, in pediatric and adult population.

Author	Year	*N*	Size (mm)	Stone-free	Complic.	Type
Desai[14]	2011	10	14.3	88.9%	10%	Adult
Piskin[58]	2012	11	12.8	85%	8.5%	Pediatric
Armagan[59]	2013	30	17.9	93%	10%	Adult
Tepeler[60]	2013	21	17.5	85.7%	9%	Adult
Silay[61]	2013	19	14.8	89.5%	5.3%	Pediatric
Hatipoglu[62]	2014	140	15	82.1%	8%	Adult
Ganpule[41]	2015	139	13	91.5%	10%	Adult
Daggülli[63]	2015	40	16.5	80%	2.5%	Pediatric
Karatab[64]	2015	70	11	95.7%	5.7%	Adult

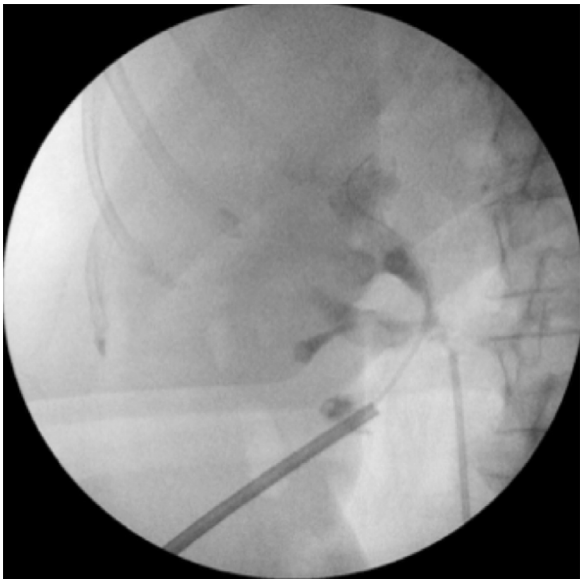

Figure 3 Ultraminiperc in lower calyx with 13 Fr. sheath.

Figure 4 Nephroscope and UMP sheaths.

97.2% was achieved per month, with a complication rate of 16.7%. No patient required transfusion, but there were two cases of sepsis.[16]

Subsequently, UMP has been performed in renal stones ranging from 2 to 3 cm, with success rates of 81.8% in monotherapy and 90.9% when associated with RIRS.[73] In children, UMP achieved better results compared to microperc in that it will not generate overpressure in the urinary tract.[74] A recent randomized comparative study with standard PCNL in renal stones smaller than 2.5 cm showed equal success rate for both techniques, but UMP had fewer complications and required less radiation exposure and shorter operative time.[75]

Indications of the different calibers

Despite the appearance of this treatment nearly two decades ago, the indications of the PCNL with reduced calibers are not well defined and the EUA and AUA guidelines on urolithiasis make few references on their use. A comparative meta-analysis of ESWL, RIRS and reduced caliber PCNL from 2014 concludes that RIRS should be the first choice of treatment, given its greater efficacy and lesser morbidity, until we have more randomized studies.[76] De[77] exhibits the same conclusions in his more recent meta-analysis when comparing PCNL versus RIRS. In the minimally invasive PCNL subgroup, the results in both success rate and complications were favorable for RIRS. Thus, the authors consider that this technique should be the standard treatment for renal stones smaller than 2 cm.[77] But other studies show favorable results for m-PCNL except for bleeding.[53–56] A recent randomized comparative study for renal stones larger than 1 cm between m-PCNL and RIRS showed similar success rates, surgical time, hemoglobin fall and hospital stay, but the postoperative pain and the need for analgesia was greater for RIRS.[78]

Obviously, the standard treatment of renal stones larger than 2 cm in children is m-PCNL,[3] but the indications in the adult are not yet well clarified and it has been used in renal stones larger than 2 cm, as well as in renal stones smaller than 2 cm where ESWL or RIRS[42] had previously failed, or were located in the lower pole.[35,54]

Initially, Chan[42] proposed some accurate recommendations: lithiasic volume between 1 and 2 cm^2, failure or unfavorable lower pole anatomy for ESWL or ureterorenoscopy (URS), or presence of anatomical abnormality that compromises them, cystine stones smaller than 2 cm^2 and as secondary access to residual calculi in standard PCNL.[42] Subsequently, other authors have expanded their indications. Thus, obstructive uropathy has been used in the treatment of large proximal ureteral calculi, achieving a higher success

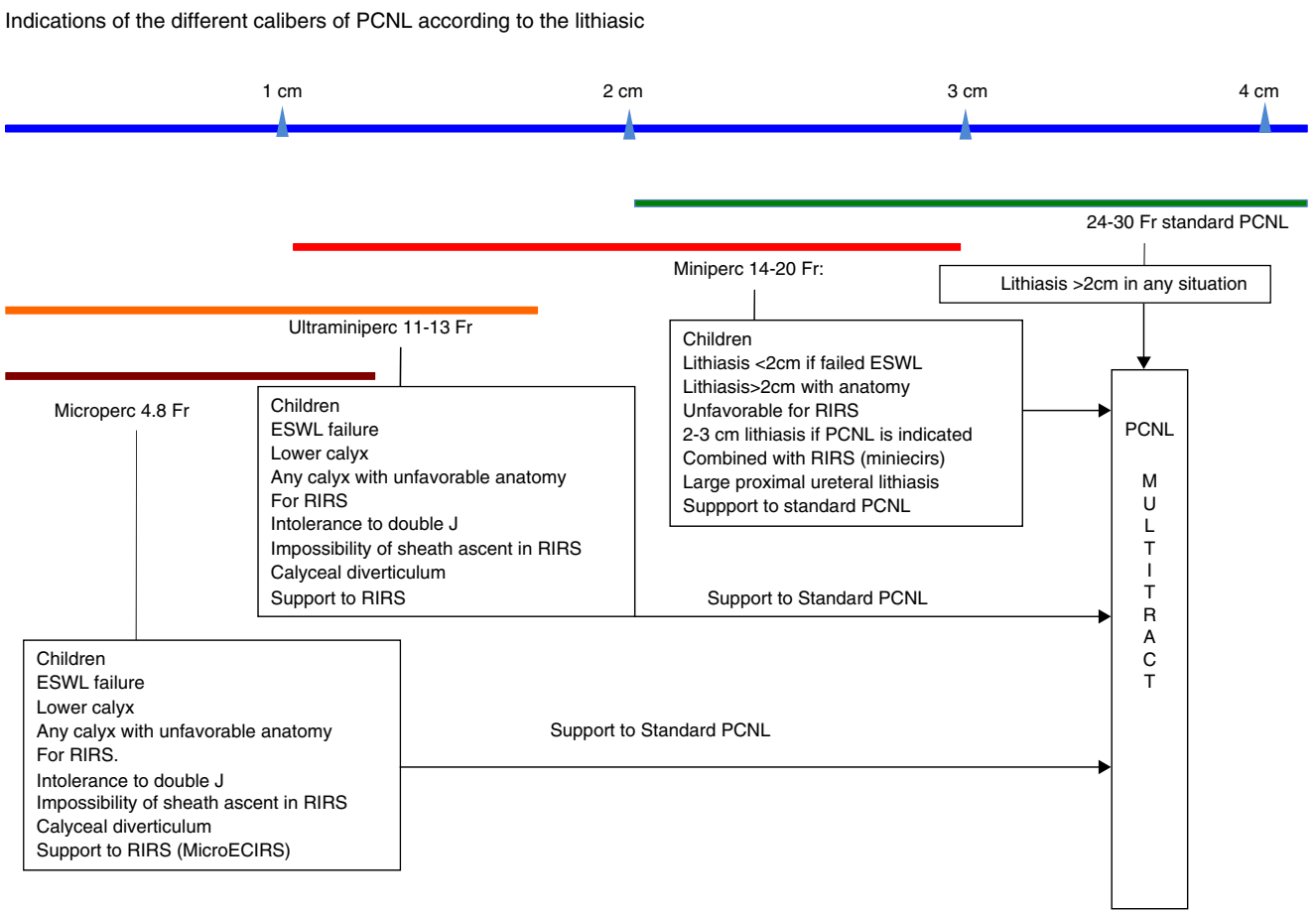

Figure 5 Indications of the different calibers of PCNL according to the lithiasic size.

rate, with shorter operative time and less need for retreatment than retrograde ureterorenoscopy.[79,80] A randomized comparative study exposes better results than URS in proximal ureteral stones.[81] Even large series of Asian authors report the use of obstructive uropathy in the treatment of staghorn stones with multiple tracts.[49,82–84] Cheng found no difference in the success rate between standard PCNL versus m-PCNL in staghorn stones (75.9% vs 72.2%, respectively; $p > 0.05$).[49] But it seems clear that one of the limitations of m-PCNL is the time it takes for extracting fragments.[22,50] Therefore, its role in large volumes of lithiasis would support the standard PCNL[23] in inaccessible or residual lithiasis,[42] or in surgery combined with RIRS.[85,86]

In renal stones smaller than 2 cm, m-PCNL is comparable to standard PCNL in success rate, with lower rate of complications[22,84] and is clearly superior to ESWL in both adults and children, despite its greater invasiveness.[52,53,87–89] M-PCNL provides an interesting fact that is impeded in microperc and ultra-mini PCNL, such as the possibility of using flexible ones.[8]

Microperc seems to have a clear application in pediatric patients requiring percutaneous surgery to treat small or moderate size stones.[58,61,63,90] The lack of need to insert a double J stent at the end of the intervention makes this technique preferable to RIRS in infants.[91]

But Cheng's indications are not yet established in adults. Do microperc and ultra-mini PCNL have a role in the treatment of adult renal stones? Although neither EAU nor AUA clinical guidelines mention those techniques due to the lack of scientific evidence, the current sparse literature outlines some possible indications for microperc: renal stone <15 mm with unfavorable anatomy for ESWL or RIRS, auxiliary accesses in the context of multitract PCNL[8,39,92] and its employability in the small diverticulum and horseshoe kidney.[14]

Although we do not yet have enough data to identify possible indications of ultra-mini PCNL due to the limited experience with this technique, the small caliber used would offer indications superimposable to microperc, including in the pediatric population.[93] Nonetheless, intrarenal pressure control and the possibility to perform the venturi effect and use nitinol baskets to evacuate small fragments could expand its scope beyond the 15 mm microperc. Fig. 5 summarizes the indications of the different PCNL calibers in reference to the renal stone size according to the existing literature.

Conclusions

PCNL developments related to the narrowing of the tract caliber has changed the indications of this technique, expanding its scope to smaller sizes that were restricted to less invasive techniques such as ESWL and RIRS. While

m-PCNL has an increasingly defined role as a less invasive percutaneous technique, miniaturized caliber PCNL requires further study to establish accurate indications in the treatment of renal stones.

Conflict of interest

None.

References

1. Skolarikos A1, Alivizatos G, de la Rosette JJ. Percutaneous nephrolithotomy and its legacy. Eur Urol. 2005;47:22–8.
2. Wolf JS Jr, Clayman RV. Percutaneous nephrostolithotomy. What is its role in 1997? Urol Clin North Am. 1997;24:43–58.
3. Turk C, Petrik A, Sarica K, Skolarikos A, Straub M, Knoll T, et al. EAU Guidelines on interventional treatmentfor urolithiasis. Eur Urol. 2016;69:475–82.
4. Fernström I, Johansson B. Percutaneous pyelolithotomy. A new extraction technique. Scand J Urol Nephrol. 1976;10:257–9.
5. Valdivia Uria JG, Valle Gerhold J, Lopez Lopez JA, Villarroya Rodríguez S, Ambroj Navarro C, Ramirez Fabián M, et al. Technique and complications of percutaneous nephroscopy: experience with 557 patients in the supine position. J Urol. 1998;160:1975–8.
6. Ibarluzea G, Scoffone CM, Cracco CM, Poggio M, Porpiglia F, Terrone C, et al. Supine Valdivia and modified lithotomy position for simultaneous anterograde and retrograde endourological access. BJU Int. 2007;100:233–6.
7. Ray AA, Chung DG, Honey RJ. Percutaneous nephrolithotomy in the prone and prone-flexed positions: anatomic considerations. J Endourol. 2009;23:1607–14.
8. Ghani KR, Andonian S, Bultitude M, Desai M, Giusti G, Okhunov Z, et al. Percutaneous nephrolithotomy: update, trends, and future directions. Eur Urol. 2016;70:382–96.
9. Dehong C, Liangren L, Huawei L, Qiang W. A comparison among four tract dilation methods of percutaneous nephrolithotomy: a systematic review and meta-analysis. Urolithiasis. 2013;41:523–30.
10. Jackman SV, Hedican SP, Peters CA, Docimo SG. Percutaneous nephrolithotomy in infants and preschool age children: experience with a new technique. Urology. 1998;52:697–701.
11. Jackman SV, Docimo SG, Cadeddu JA, Bishoff JT, Kavoussi LR, Jarrett TW. The mini-perc technique: a less invasive alternative to percutaneous nephrolithotomy. World J Urol. 1998;16:371–4.
12. Monga M, Oglevie S. Minipercutaneous nephrolithotomy. J Endourol. 2000;14:419–21.
13. Lahme S, Bichler KH, Strohmaier WL, Götz T. Minimally invasive PCNL in patients with renal pelvic and calyceal stones. Eur Urol. 2001;40:619–24.
14. Desai MR, Sharma R, Mishra S, Sabnis RB, Stief C, Bader M. Single-step percutaneous nephrolithotomy (microperc): the initial clinical report. J Urol. 2011;186:140–5.
15. Sabnis R, Ganesamoni R, Ganpule A, Mishra S, Vyas J, Jagtap J. Current role of microperc in the management of small renal calculi. Indian J Urol. 2013;29:214–8.
16. Desai J, Zeng G, Zhao Z, Zhong W, Chen W, Wu W. A novel technique of ultra-mini-percutaneous nephrolithotomy: introduction and an initial experience for treatment of upper urinary calculi less than 2 cm. Biomed Res Int. 2013;2013:490793.
17. Michel MS, Trojan L, Rassweiler JJ. Complications in percutaneous nephrolithotomy. Eur Urol. 2007;51:899–906.
18. Yamaguchi A, Skolarikos A, Buchholz NP, Chomón GB, Grasso M, Saba P, et al. Operating times and bleeding complications in percutaneous nephrolithotomy: a comparison of tract dilation methods in 5,537 patients in the Clinical Research Office of the Endourological Society Percutaneous Nephrolithotomy Global Study. Clinical Research Office of The Endourological Society Percutaneous Nephrolithotomy Study Group. J Endourol. 2011;25:933–9.
19. Stoller ML, Wolf JS Jr, St. Lezin MA. Estimated blood loss and transfusion rates associated with percutaneous nephrolithotomy. J Urol. 1994;152 Pt 1:1977–81.
20. Handa RK, Matlaga BR, Connors BA, Ying J, Paterson RF, Kuo RL, et al. Acute effects of percutaneous tract dilation on renal function and structure. J Endourol. 2006;20:1030–40.
21. Davidoff R, Bellman GC. Influence of technique of percutaneous tract creation on incidence of renal hemorrhage. J Urol. 1997;157:1229–31.
22. Knoll T, Wezel F, Michel MS, Honeck P, Wendt-Nordahl G. Do patients benefit from miniaturized tubeless percutaneous nephro- lithotomy? A comparative prospective study. J Endourol. 2010;24:1075–9.
23. Akman T, Binbay M, Sari E, Yuruk E, Tepeler A, Akcay M, et al. Factors affecting bleeding during percutaneous nephrolithotomy: single surgeon experience. J Endourol. 2011;25:327–33.
24. Kukreja R, Desai M, Patel S, Bapat S, Desai M. Factors affecting blood loss during percutaneous nephrolithotomy: prospective study. J Endourol. 2004;18:715–22.
25. Traxer O, Smith TG 3rd, Pearle MS, Corwin TS, Saboorian H, Cadeddu JA, et al. Renal parenchymal injury after standard and mini percutaneous nephrostolithotomy. J Urol. 2001;165:1693–5.
26. Williams SK, Leveillee RJ. Management of staghorn calculus: single puncture with judicious use of the flexible nephroscope. Curr Opin Urol. 2008;18:224–8.
27. Grasso M, Ficazzola M. Retrograde ureteropyeloscopy for lower pole caliceal calculi. J Urol. 1999;162:1904–8.
28. Maheshwari PN, Andankar MG, Bansal M. Nephrostomy tube after percutaneous nephrolithotomy: large-bore or pigtail catheter? J Endourol. 2000;14:735–7.
29. Pietrow PK, Auge BK, Lallas CD, Santa-Cruz RW, Newman GE, Albala DM, et al. Pain after percutaneous nephrolithotomy: impact of nephrostomy tube size. J Endourol. 2003;17:411–4.
30. Wickham JE, Miller RA, Kellett MJ, Payne SR. Percutaneous nephrolithotomy: one stage or two? Br J Urol. 1984;56:582–5.
31. Winfield HN, Weyman P, Clayman RV. Percutaneous nephrostolithotomy: complications of premature nephrostomy tube removal. J Urol. 1986;136:77–9.
32. Bellman GC, Davidoff R, Candela J, Gerspach J, Kurtz S, Stout L. Tubeless percutaneous renal surgery. J Urol. 1997;157:1578–82.
33. Cracco CM, Scoffone CM, Scarpa RM. New developments in percutaneous techniques for simple and complex branched renal stones. Curr Opin Urol. 2011;21:154–60.
34. Antonelli JA, Pearle MS. Advances in percutaneous nephrolithotomy. Urol Clin North Am. 2013;40:99–113.
35. Nagele U, Schilling D, Anastasiadis AG, Corvin S, Seibold J, Kuczyk M, et al. Closing the tract of minipercutaneous nephrolithotomy with gelatine matrix hemostatic sealant can replace nephrostomy tube placement. Urology. 2006;68:489–93.
36. Shah HN, Hegde S, Shah JN, Mohile PD, Yuvaraja TB, Bansal MB. A prospective, randomized trial evaluating the safety and efficacy of fibrin sealant in tubeless percutaneous nephrolithotomy. J Urol. 2006;176 Pt 1:2488–92.
37. Cormio L, Perrone A, Di Fino G, Ruocco N, de Siati M, de La Rosette J, et al. TachoSil sealed tubeless percutaneous nephrolithotomy to reduce urine leakage and bleeding: outcome of a randomized controlled study. J Urol. 2012;188:145–50.
38. Kim IY, Eichel L, Edwards R, Uribe C, Chou DS, Abdelshehid C, et al. Effects of commonly used hemostatic agents on the porcine collecting system. J Endourol. 2007;21:652–4.

39. Wright A, Rukin N, Smith D, de la Rosette J, Somani BK. 'Mini, ultra, micro' – nomenclature and cost of these new minimally invasive percutaneous nephrolithotomy (PCNL) techniques. Ther Adv Urol. 2016;8:142–6.
40. Helal M, Black T, Lockhart J, Figueroa TE. The Hickman peel-away sheath: alternative for pediatric percutaneous nephrolithotomy. J Endourol. 1997;11:171–2.
41. Ganpule AP, Bhattu AS, Desai M. PCNL in the twenty-first century: role of microperc, miniperc, and ultraminiperc. World J Urol. 2015;33:235–40.
42. Chan DY, Jarrett TW. Mini-percutaneous nephrolithotomy. J Endourol. 2000;14:269–72.
43. Nagele U, Schilling D, Sievert KD, Stenzl A, Kuczyk M. Management of lower-pole stones of 0.8 to 1.5 cm maximal diameter by the minimally invasive percutaneous approach. J Endourol. 2008;22:1851–3.
44. Karaköse A, Aydogdu Ö, Yusuf Z. The use of the amplatz sheath in percutaneous nephrolithotomy: does amplatz sheath size matter? Curr Urol. 2014;7:127–31, 43.
45. Tepeler A, Sarica K. Standard, mini, ultra-mini, and micro percutaneous nephrolithotomy: what is next? A novel labeling system for percutaneous nephrolithotomy according to the size of the access sheath used during procedure. Urolithiasis. 2013;41:367–8.
46. Schilling D, Husch T, Bader M, Herrmann TR, Nagele U. Nomenclature in PCNL or the Tower of Babel: a proposal for a uniform terminology. World J Urol. 2015;33:1905–7.
47. Hu G, Guo Z, Liu H, Luo M, Liu M, Lai P, et al. A novel minimally invasive percutaneous nephrolithotomy technique: safety and efficacy report. Scand J Urol. 2015;49:174–80.
48. Giusti G, Piccinelli A, Taverna G, Benetti A, Pasini L, Corinti M, et al. Miniperc? No, thank you! Eur Urol. 2007;51:810–4.
49. Cheng F, Yu W, Zhang X, Yang S, Xia Y, Ruan Y. Minimally invasive tract in percutaneous nephrolithotomy for renal stones. J Endour. 2010;24:1579–82.
50. Mishra S, Sharma R, Garg C, Kurien A, Sabnis R, Desai M. Prospective comparative study of miniperc and standard PNL for treatment of 1 to 2 cm size renal stone. BJU Int. 2011;108:896–9.
51. Zhu W, Liu Y, Liu L, Lei M, Yuan J, Wan SP. Minimally invasive versus standard percutaneous nephrolithotomy: a meta-analysis. Urolithiasis. 2015;43:563–70.
52. Zeng G, Jia J, Zhao Z, Wu W, Zhao Z, Zhong W. Treatment of renal stones in infants: comparing extracorporeal shock wave lithotripsy and mini-percutaneous nephrolithotomy. Urol Res. 2012;40:599–603.
53. Kruck S, Anastasiadis AG, Herrmann TR, Walcher U, Abdelhafez MF, Nicklas AP, et al. Minimally invasive percutaneous nephrolithotomy: an alternative to retrograde intrarenal surgery and shockwave lithotripsy. World J Urol. 2013;31:1555–61.
54. Kirac M, Bozkurt OF, Tunc L, Guneri C, Unsal A, Biri H. Comparison of retrograde intrarenal surgery and mini-percutaneous nephrolithotomy in management of lower-pole renal stones with a diameter of smaller than 15 mm. Urolithiasis. 2013;41:241–6.
55. Pan J, Chen Q, Xue W, Chen Y, Xia L, Chen H, et al. RIRS versus mPCNL for single renal stone of 2–3 cm: clinical outcome and cost-effective analysis in Chinese medical setting. Urolithiasis. 2013;41:73–8.
56. Zeng G, Zhu W, Li J, Zhao Z, Zeng T, Liu C, et al. The comparison of minimally invasive percutaneous nephrolithotomy and retrograde intrarenal surgery for stones larger than 2 cm in patients with a solitary kidney: a matched-pair analysis. World J Urol. 2015;33:1159–64.
57. Bader MJ, Gratzke C, Seitz M, Sharma R, Stief CG, Desai M. The ''allseeing needle'': initial results of an optical puncture system confirming access in percutaneous nephrolithotomy. Eur Urol. 2011;59:1054–9.
58. Piskin MM, Guven S, Kilinc M, Arslan M, Goger E, Ozturk A. Preliminary, favorable experience with microperc in kidney and bladder stones. J Endourol. 2012;26:1443–7.
59. Armagan A, Tepeler A, Silay MS, Ersoz C, Akcay M, Akman T, et al. Micropercutaneous nephrolithotomy in the treatment of moderate-size renal calculi. J Endourol. 2013;27:177–81.
60. Tepeler A, Armagan A, Sancaktutar AA, Silay MS, Penbegul N, Akman T, et al. The role of microperc in the treatment of symptomatic lower pole renal calculi. J Endourol. 2013;27:13–8.
61. Silay MS, Tepeler A, Atis G, Sancaktutar AA, Piskin M, Gurbuz C, et al. Initial report of microperc in the treatment of pediatric nephrolithiasis. J Pediatr Surg. 2013;48:1578–83.
62. Hatipoglu NK, Tepeler A, Buldu I, Atis G, Bodakci MN, Sancaktutar AA, et al. Initial experience of micro-percutaneous nephrolithotomy in the treatment of renal calculi in 140 renal units. Urolithiasis. 2014;42:159–64.
63. Dağgülli M, Utanğaç MM, Dede O, Bodakçi MN, Penbegül N, Hatipoğlu NK, et al. Micro-percutaneous nephrolithotomy in the treatment of pediatric nephrolithiasis: a single-center experience. J Pediatr Surg. 2016;51:626–9.
64. Karatag T, Buldu I, Inan R, Istanbulluoglu MO. Is micropercutaneous nephrolithotomy technique really efficacicous for the treatment of moderate size renal calculi? Yes. Urol Int. 2015;95:9–14.
65. Tok A, Akbulut F, Buldu I, Karatag T, Kucuktopcu O, Gurbuz G, et al. Comparison of microperc and mini-percutaneous nephrolithotomy for medium-sized lower calyx stones. Urolithiasis. 2016;44:155–9.
66. Karatag T, Tepeler A, Silay MS, Bodakci MN, Buldu I, Daggulli M, et al. A comparison of 2 percutaneous nephrolithotomy techniques for the treatment of pediatric kidney stones of sizes 10–20 mm: microperc vs miniperc. Urology. 2015;85:1015–8.
67. Sabnis RB, Ganesamoni R, Doshi A, Ganpule AP, Jagtap J, Desai MR. Micropercutaneous nephrolithotomy (microperc) vs retrograde intrarrenal surgery for the management of small renal calculi: a randomized controlled trial. BJU Int. 2013;112:355–61.
68. Ramón de Fata F, García-Tello A, Andrés G, Redondo C, Meilán E, Gimbernat H, et al. Comparative study of retrograde intrarenal surgery and micropercutaneous nephrolithotomy in the treatment of intermediate-sized kidney stones. Actas Urol Esp. 2014;38:576–83.
69. Armagan A, Karatag T, Buldu I, Tosun M, Basibuyuk I, Istanbulluoglu MO, et al. Comparison of flexible ureterorenoscopy and micropercutaneous nephrolithotomy in the treatment for moderately size lower-pole stones. World J Urol. 2015;33:1827–31.
70. Ganpule A, Chabra JS, Kore V, Mishra S, Sabnis R, Desai M. Factors predicting outcomes of micropercutaneous nephrolithotomy: results from a large single-centre experience. BJU Int. 2016;117:478–83.
71. Tepeler A, Akman T, Silay MS, Akcay M, Ersoz C, Kalkan S, et al. Comparison of intrarenal pelvic pressure during micropercutaneous nephrolithotomy and conventional percutaneous nephrolithotomy. Urolithiasis. 2014;42:275–9.
72. Thomsen HS, Talner LB, Higgins CB. Intrarenal backflow during retrograde pyelography with graded intrapelvic pressure. A radiologic study. Invest Radiol. 1982;17:593–603.
73. Shah AK, Xu K, Liu H, Huang H, Lin T, Bi L, et al. Implementation of ultramini percutaneous nephrolithotomy for treatment of 2–3 cm kidney stones: a preliminary report. J Endourol. 2015;29:1231–6.
74. Dede O, Sancaktutar AA, Dağguli M, Utangaç M, Baş O, Penbegul N. Ultra-mini-percutaneous nephrolithotomy in pediatric

nephrolithiasis: both low pressure and high efficiency. J Pediatr Urol. 2015;11:253.
75. Karakan T, Kilinc MF, Doluoglu OG, Yildiz Y, Yuceturk CN, Bagcioglu M, et al. The modified ultra-mini percutaneous nephrolithotomy technique and comparison with standard nephrolithotomy: a randomized prospective study. Urolithiasis. 2017;45:209–13.
76. Srisubat A 1, Potisat S, Lojanapiwat B, Setthawong V, Laopaiboon M. Extracorporeal shock wave lithotripsy (ESWL) versus percutaneous nephrolithotomy (PCNL) or retrograde intrarenal surgery (RIRS) for kidney stones. Cochrane Database Syst Rev. 2014;11:CD007044.
77. De S, Autorino R, Kim FJ, Zargar H, Laydner H, Balsamo R, et al. Percutaneous nephrolithotomy versus retrograde intrarenal surgery: a systematic review and meta-analysis. Eur Urol. 2015;67:125–37.
78. Lee JW, Park J, Lee SB, Son H, Cho SY, Jeong H. Mini-percutaneous nephrolithotomy vs retrograde intrarenal surgery for renal stones larger than 10 mm: a prospective randomized controlled trial. Urology. 2015;86:873–7.
79. Long Q, Guo J, Xu Z, Yang Y, Wang H, Zhu Y, et al. Experience of mini-percutaneous nephrolithotomy in the treatment of large impacted proximal ureteral stones. Urol Int. 2013;90:384–8.
80. Yang Z, Song L, Xie D, Hu M, Peng Z, Liu T, et al. Comparative study of outcome in treating upper ureteral impacted stones using minimally invasive percutaneous nephrolithotomy with aid of patented system or transurethral ureteroscopy. Urology. 2012;80:1192–7.
81. Gu XJ, Lu JL, Xu Y. Treatment of large impacted proximal ureteral stones: randomized comparison of minimally invasive percutaneous antegrade ureterolithotripsy versus retrograde ureterolithotripsy. World J Urol. 2013;31:1605–10.
82. Zeng G, Mai Z, Zhao Z, Li X, Zhong W, Yuan J, et al. Treatment of upper urinary calculi with Chinese minimally invasive percutaneous nephrolithotomy: a single-center experience with 12,482 consecutive patients over 20 years. Urolithiasis. 2013;41:225–9.
83. Zhong W, Zeng G, Wu W, Chen W, Wu K. Minimally invasive percutaneous nephrolithotomy with multiple mini tracts in a single session in treating staghorn calculi. Urol Res. 2011;39:117–22.
84. Liu C, Cui Z, Zeng G, Wan SP, Li J, Zhu W, et al. The optimal minimally invasive percutaneous nephrolithotomy strategy for the treatment of staghorn stones in a solitary kidney. Urolithiasis. 2016;44:149–54.
85. Amón JH, Cepeda M, Conde C, Alonso D, González V, Martínez-Sagarra JM. Retrograde intrarenal surgery (RIRS). Technical complement for cases of acute lithiasis. Actas Urol. 2011;35:108–14.
86. Hamamoto S, Yasui T, Okada A, Taguchi K, Kawai N, Ando R, et al. Endoscopic combined intrarenal surgery for large calculi: simultaneous use of flexible ureteroscopy and mini-percutaneous nephrolithotomy overcomes the disadvantageous of percutaneous nephrolithotomy monotherapy. J Endourol. 2014;28:28–33.
87. Ferakis N. Stavropoulos mini percutaneous nephrolithotomy in the treatment of renal and upper ureteral stones: lessons learned from a review of the literature. Urol Ann. 2015;7:141–8.
88. Kiremit MC, Guven S, Sarica K, Ozturk A, Buldu I, Kafkasli A, et al. Contemporary management of medium-sized (10–20 mm) renal stones: a retrospective multicenter observational study. J Endourol. 2015;29:838–43.
89. Kumar A, Kumar N, Vasudeva P, Kumar Jha S, Kumar R, Singh H. A prospective, randomize comparison of shock wave lithotripsy, retrograde intrarenal surgery and miniperc for treatment of 1 to 2 cm radiolucent lower calyceal renal calculi: a single center experience. J Urol. 2015;193:160–4.
90. Pérez-Fentes D, Blanco-Gómez B, García-Freire C. Micropercutaneous nephrolithotomy. A new therapeutic option for pediatric renal lithiasis. Actas Urol Esp. 2014;38:483–7.
91. Baş O, Dede O, Aydogmus Y, Utangaç M, Yikilmaz TN, Damar E, et al. Comparison of retrograde intrarenal surgery and micropercutaneous nephrolithotomy in moderately sized pediatric kidney stones. J Endourol. 2016;30:765–70.
92. Druskin SC, Ziemba JB. Minimally invasive (mini) percutaneous nephrolithotomy: classification, indications, and outcomes. Curr Urol Rep. 2016;17:30.
93. Simal I, Parente A, Burgos L, Ortiz R, Martínez AB, Rojo R, et al. Therapeutic possibilities for urolithiasis in childhood. Actas Urol Esp. 2016;40:577–84.