

# All you need to know about percutaneous nephrolithotomy: supine versus prone and mini versus traditional

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## Introduction

Since the first percutaneous nephrolithotomy (PCNL), the technique has undergone many innovations, including modifications in positioning, miniaturisation of instruments and combination with retrograde intra-renal surgery (see Table 1 for an outline of the history of the technique).

Controversy has emerged as to which is the best position, and / or tract size, for PCNL and a number of variations in patient positioning have been proposed including prone, prone-flexed, lateral, prone split-leg position, total supine and several modified supine positions [9-11]. The recent Clinical research Office of the Endourological Society (CROES) PCNL Global Study data suggests that the majority of PCNL are still performed in the standard prone position and only 20% of all PCNLs are performed supine [12].

## Prone versus supine PCNL

The prone position results in a large surface area for kidney puncture (especially important where multiple tracts are required) and a wide space for instrument manipulation. It aids upper pole and anterior calyx access. However, it is associated with anaesthetic risks especially in

the morbidly obese or those with compromised cardiopulmonary status. Treatment of morbidly obese patients is becoming a more frequent challenge in urology, as the prevalence of obesity, and associated urolithiasis, is increasing. This highlights the potential benefit of increasing experience with supine PCNL with different anaesthetic risks, better access to the patient's airway and less repositioning. Supine PCNL also has the potential advantage of greater versatility of intra-renal stone manipulation and can be combined with simultaneous ureteroscopy, although the practicality of this latter point, requiring two competent endourologists and two stacks, is open to question in the NHS.

Theoretically, the angle of the tract may improve removal of stone fragments after lithotripsy and there may be less density overlap with the vertebrae whilst using fluoroscopy. Antero-medial displacement of the kidney during dilation of the tract has been reported in supine PCNL, resulting in a longer, more perpendicular tract [13]. A small but interesting study of 30 patients that underwent reduced dose CT in supine, prone and 30 degree prone-flex positions to identify differences in anatomical variations

when gaining percutaneous access revealed mean tract lengths and subcutaneous fat tissue lengths to be significantly longer in the supine position, which may be important in obese patients, resulting in the need to use longer access sheaths [14].

Many of the publications that compare supine and prone PCNL have small sample sizes and are retrospective comparisons. Liu et al. undertook a systematic review and meta-analysis in 2010 which includes two randomised controlled trials and two large prospective case controlled studies. The CROES PCNL Global Study Database report included 5803 patients from 96 international centres, and is the largest collated series found on literature search.

## Length of hospital stay

Shoma et al. (n=130) showed no significant difference between length of hospital stay (2.5 days supine vs. 2.7 days prone) [13]. The CROES report found no statistically significant difference in mean hospital stay [12]. Conversely, Mazzucchi et al. (n=56) compared prone versus supine in obese (BMI >30) patients and found that hospital stay was significantly shorter

**Table 1: History of PCNL.**

1941	Rupel and Down [1]	First open placed nephrostomy
1976	Fernström and Johansson [2]	First percutaneous stone extraction
1981	Alken et al. [3]	Series of percutaneous nephrolithotripsy
1988	Lehman and Bagley [4]	First PCNL and simultaneous ureteroscopy
1998	Valdivia Uria et al. [5]	First large series of supine PCNL
1998	Jackman et al. [6]	Miniaturised percutaneous nephrolitholapaxy (mini PCNL) to treat stones in paediatric patients
2011	Desai et al. [7]	Microperc using 'the all seeing needle'
2013	Desai et al. [8]	Ultra-mini PCNL

**Table 2: Tract size and primary stone-free rate.**

	Tract size	Primary stone free rate		Transfusion rate
		<2cm	>2cm	
Standard PCNL [27]	24-34Fr	-	20-30mm: 90% 31-40mm: 83.3% 41-60mm: 84.1%*	4.4% 4.4% 13.3%
Mini PCNL [34]	12-20Fr	90.8%	76.3%	1.2%
Ultra-mini PCNL (UMP) [35]	11-13Fr	88.9%	-	0%**
Microperc [35]	4.85-8Fr	84.8%	87.1%	0.70%

\* CROES data- large single renal stones; multiple or staghorn stones were excluded.  
\*\* small sample size (n=36)

in the supine group – 4.38 days (2-16) prone versus 2.68 days (2-5) supine [15].

#### Stone-free rates

Liu et al. reported no statistical difference in stone-free rates between prone and supine PCNL (83.5% supine vs. 81.5% prone). De Sio et al. (n=75) compared prone versus supine PCNL in patients with 'uncomplicated stones' and a BMI <30, finding no significant difference in stone-free rate (88.7% supine vs. 91.6% prone) [17]. Mazzucchi et al. looked at obese patients, also finding no significant difference between final stone-free rates (83.3% prone vs. 78.1% supine) [15]. However, the CROES data found the stone-free rate was significantly higher in prone PCNL (70.2% supine vs. 77% prone) and there were lower rates of failed procedures in prone patients [12]. This was also the case in patients with staghorn calculi (48.4% supine vs. 59.2% prone (P<.001)) [18]. These data are of course international and pooled and have generated much discussion at meetings.

#### Mean operative time

Liu et al. reported supine PCNL had shorter operative time than prone [16]. Included in that review, De Sio et al. reported a significant difference in mean operative time of 68 minutes prone versus 43 minutes supine, in patients with uncomplicated stones and BMI<30 [17]. Manohar et al. (n=62) reported a mean operative time of 73.66 minutes (range 20-250) in supine PCNL with ultrasound guided access [19]. Mazzucchi et al. reported no significant difference in mean operative time – 120.3 minutes (range 40-300 minutes) prone versus 120.2 minutes (range 30-360 minutes) supine – in obese patients with BMI>30 [15]. Once again varying

data from the CROES study found that the mean operative time was lower for prone as compared to supine (82.7 minutes vs. 90.1 minutes), although this is unlikely to be clinically significant [12]. The difference was greater in staghorn calculi (103.2 minutes prone vs. 123.1 minutes supine) [18]. Wang et al. (n=122) also reported a lower mean operative time with prone procedures (78 minutes prone vs. 88 minutes supine (P<0.05)) but felt this might have been affected by the authors' shorter experience with supine PCNL [20].

#### Anaesthetic considerations

Prone positioning presents a number of challenges to the anaesthetist. Firstly those related to repositioning, and secondly those related to physiological changes in the prone position. Even safely secured endotracheal tubes can pass into the right main bronchus, secondary to increased neck flexion in prone patients, resulting in lobar collapse. Accidental extubation can occur, especially during repositioning which can be disastrous. Being in the prone position may be more stimulating for the patient, thus requiring a greater depth of anaesthesia, which in combination with decreased cardiac output due to decreased venous return (higher thoracic pressure and / or abdominal compression), can result in the need for more invasive monitoring and potentially cardiovascular support [21]. Should unforeseen complications occur then the insertion of invasive monitoring lines is much more difficult in the prone position [22]. Multiple pressure related injuries have been described secondary to prone positioning including peripheral nerve injuries (brachial plexus, ulnar, radial, lateral cutaneous nerve of the thigh and supraorbital nerve injuries) [23], although these are very rare and tend

to happen in patients with specific risk factors (diabetes, peripheral vascular disease, alcohol dependency, pre-existing neuropathy and anatomical variants) [24]. Ocular injuries can include corneal abrasions and globe injury or ischaemia. There are also case reports of hepatic ischaemia after prolonged prone positioning.

#### Complications

Published transfusion rates after standard PCNL have varied enormously. Keoghane et al. (n=547) reported a transfusion rate of 3.8% in prone PCNL, with one nephrectomy (0.2%) and five selective embolisations (0.9%) [25]. In the first large series of supine PCNLs, Valdivia et al. (n=557) showed a transfusion rate of 1.4%, with one nephrectomy (0.18%) and one selective embolisation (0.18%) [5]. Other reported rates of transfusion in supine PCNL range from 0-9.4% [12,13,15,19,26]. As stone size increases, the transfusion rate increases; CROES data reported transfusion rate of 4.4% in PCNL (all methods) done for single stones 20-40mm, which increased to 13.3% in stones 41-60mm [27]. Liu et al. reported no statistically significant difference in complications, blood transfusion rate or fever, in their systematic review and meta-analysis [16]. The CROES study reported prone patients exhibited higher rates of blood transfusions (6.1% vs. 4.3%) and fever (11.1% vs. 7.6%) [12]. Conversely, Manohar et al. reported 18% postoperative infection in supine PCNL [19]. In one of the few randomised controlled trials, De Sio et al. found no difference in complication rates between the two approaches [17]. One concern urologists have had about supine PCNL is the perceived risk of colonic injury. In fact, in a study of 500 patients who underwent CT scanning prone or supine 2% of patients had

a retrorenal colon when supine and increased to 10% when turned prone, therefore the possibility of colonic injury may in fact be lower when supine [28]. Colonic perforation has been reported at 0.2-0.3% in prone PCNL [25-29]. In a review of nine studies for supine PCNL, de la Rosette found 0% reported visceral injuries [30]. CROES suggested overall higher rates of perforation (3.4% supine vs. 3.3% prone) but no difference between the two groups [12].

### Learning curve

There are no specific data about the learning curve to achieve surgical competence in supine PCNL but it has been suggested that figures compare to the learning curve for prone PCNL which Tanriverdi et al. suggested was 60 cases (operative time and fluoroscopy screening times drop to steady state after performing 60 procedures) [31] and Ziaee et al. suggested that competence is obtained at 45 cases and excellence after 105 cases [32].

### Conclusion

Both prone and modified supine positions appear to be effective and similarly safe, although there may be variations in operative time and stone-free rates dependent on surgeon experience. Supine PCNL should be considered in higher risk anaesthetics, or where there are pre-existing risk factors for pressure-related injuries whereas prone PCNL may be preferable for staghorn calculi.

### Miniaturised tracts vs. standard PCNL

In 1998 Jackman et al. developed miniaturised percutaneous nephrolitholapaxy (mini PCNL) to treat stones in paediatric patients [6]. Since then mini PCNL has been utilised to manage adult stones and further innovations have led to the development of the ultra-mini PCNL (UMP) and microperc. The benefits of miniaturised tracts remain controversial; the perceived benefit is that the area of renal parenchyma damaged by a miniaturised tract is decreased compared to standard PCNL, thereby reducing complications. However, the size of the tract also limits flow and fragment extraction methods. Current European Association of Urology (EAU) guidance

suggests that stones <2cm in the renal pelvis, middle and upper poles should be approached using extracorporeal shock wave lithotripsy (ESWL), and larger stones should be approached with PCNL [33]. There is an extended indication for PCNL in 1-2cm lower pole stones where there are unfavourable factors for ESWL success, or ESWL has already failed. Although mini PCNL, UMP and microperc are mentioned as a modality to treat renal calculi, it is stated that the benefits remain controversial.

### Mini-PCNL

Mini-PCNL is generally reserved for stones <2cm, however some departments have moved solely to mini-PCNL in place of standard PCNL independent of stone size. The role of mini-PCNL in treating a large stone burden remains unclear. The primary stone-free rates using mini-PCNL are higher when operating on smaller stones (<2cm: 90.8% vs. >2cm 76.3%); however secondary stone-free rates are fairly comparable (<2cm: 98.9% vs. >2cm 94.6%) [34]. Stone size will clearly have an impact on operative time when using mini-PCNL. Abdelhafez et al. (n=191) reported a mean operative time of 69.9 minutes in stones <2cm versus 97.4 minutes in stones >2cm, however this was not compared with standard PCNL [34]. For stones between 1-2cm, mean operative time is shorter in standard PCNL. Misra et al. (n=55) reported that in mini-PCNL mean operative times in 1-2cm stones were longer (mini-PCNL: 45.2 minutes vs. standard PCNL: 31 minutes) [37]; Knoll et al. (n=50) also showed a tendency (non-significant) towards longer operative times in mini PCNL patients (mean stone size = 18mm, mean operative time = 59 minutes) in comparison to standard PCNL (mean stone size = 22mm, mean operative time = 49

minutes) with uncomplicated solitary renal calculi [38]. The prolonged operative time may be related to the need for more extensive stone fragmentation. Screening times are comparable. Abdelhafez investigated the use of mini-PCNL in stones >2cm (mean 36.7mm), separating them into complex and simple stones with comparable screening times (complex: 210 seconds, simple: 222.0 seconds) [39]. Standard PCNL fluoroscopic screening times can vary from 96 to 611 seconds and are longer with larger stone burden or multiple tracts [40,41]. Knoll showed that tubeless mini-PCNL could decrease length of stay by 0.9 day (mean stay = 3.8 days standard PCNL versus 2.9 tubeless mini PCNL) [38].

Complication rates of mini-PCNL of 26.5% were reported by Abdelhafez. Of these, the majority were Clavien 1 (77%) and no grade 4 or 5 complications occurred in this group [39]. This is similar to CROES data. Of 5724 PCNL patients 20.5% experienced one or more complications, the majority of which (54%) were Clavien grade 1 [42]. As suspected, several studies report lower transfusion rate in mini-PCNL compared to standard PCNL. Abdelhafez reported transfusion rate of 1.2% in mini-PCNL [39] whilst Wang et al. reported a 1.8% transfusion rate in mini-PCNL versus 7.2% standard PCNL [43]. Zimmermann et al. presented a series of 650 mini-PCNL cases, reporting a transfusion rate of 1.4% with two cases of embolisation [44]. The difference may be less marked when dealing with larger calculi; the haemoglobin drop in <2cm stones was 1.3g/dL compared to 1.7g/dL in >2cm stones in mini-PCNL (P=0.015) [34]. As with supine PCNL, there are limited data on the learning curve for mini-PCNL – what we do know is that it takes more than 35 cases to gain competence for a novice [45].

### Microperc

Bader et al. presented their experience using the 'all-seeing needle' to confirm the quality of the access prior to dilatation of the operating tract [46]. This was then developed further and Desai et al. reported using this 4.85Fr needle to perform a single step microperc to treat renal calculi [7]. The proposed area of use, although not

**“With all the potential benefits of microperc it is also important to bear in mind some of the potential flaws.”**



specified in the current EAU guidelines, is as an alternative in patients with moderate stone burden (1-2cm) [47]. With regards to length of stay in hospital, microperc patients stay for between one and three days [47], with one study of 140 renal units stating a mean of 1.76 days [36].

When examining stone-free rates with microperc there has been variable success. Campobasso et al. looked at multiple series of microperc patients. They identified a total of 196 treated renal units showing a primary stone-free rate of between 82.14% and 97.7% [47]. Hatipoglu (n=140) showed comparable stone-free rate across a variety of sizes of stone ( $\leq 10\text{mm}$ : 87.1, 10-20mm: 83.8% and  $\geq 20\text{mm}$  87.1%) [36]. It is important to bear in mind paucity of the data when examining the current evidence for microperc. Operative times with microperc have been reported between 55.7 minutes (mean stone size = 15.0mm) to 63.5 minutes (mean stone size = 17.9mm) [36,48]. With regards to fluoroscopic screening times and microperc means vary from 107.4 (mean stone size = 15.07mm) to 150.5 seconds (mean stone size = 17.8mm) [36,49]. Hatipoglu et al. also reported a total of 20 complications (14.28%) in patients treated with microperc – the majority (55%) were Clavien grade 1 (35%) or 2 (20%) [36]. A very low transfusion rate was shown in microperc patients of 1/140 (0.7%) [36].

With all the potential benefits of microperc it is also important to bear in mind some of the other potential flaws. The smaller tract can lead to the inability to retrieve all fragments, which can lead to an increase in the percentage of patients requiring ureteric stenting [47]. The smaller tract may also lead to an increase in intra renal pelvic pressure and this pressure leads to a greater chance of transient bacteremia and subsequent sepsis [50]. Overall the initial data for microperc seems promising. The low complication rates and high success rates that have been demonstrated are to be balanced against a smaller tract but preferably more randomised data are needed.

## FURS versus PCNL

Stones <2cm in the renal pelvis have been traditionally approached with ESWL and then flexible ureterorenoscopy (FURS), with miniaturised tracts now joining the armamentarium. Percutaneous access

may have definite advantages over FURS to access calyceal diverticulae or lower calyces with acute infundibular angles, and appear otherwise comparable except for hospital stay. When comparing mini-PCNL and FURS we can see that there are certain advantages to mini-PCNL. In a small prospective but non-randomised study, Knoll (n=46) showed that operative time, number of procedures and immediate stone-free rates were lower in a mini-PCNL group in comparison to FURS for comparable stone sizes (mini-PCNL mean: 18mm, FURS mean: 19mm). There were no major complications in either group and Clavien I and II complications were surprisingly lower, although non-significant, in the mini-PCNL group (mini-PCNL: 16%, FURS: 23.8% (P=0.13)) [51]. In one randomised controlled trial (n=70) comparing microperc to FURS for stones <1.5cm, operative times and stone clearance rates were comparable (microperc 97.1% vs. FURS 94.1%). There was a higher requirement for postoperative stenting in the FURS group, where as microperc was associated with a higher haemoglobin loss and increased pain and analgesic requirements [52]. Bozkurt et al. (n=79) compared standard PCNL to retrograde intrarenal surgery (RIRS) in lower pole stones of 15-20mm, finding that the primary stone-free rate was not significantly different (92.8% PCNL vs. 89.2% RIRS), complication rate was comparable, operative time was significantly higher in RIRS and hospital stay was longer in the PCNL group [53].

Historically, 2-3cm stones would have been tackled by PCNL, but RIRS is now considered a viable alternative for selected patients, although with the caveat that primary stone-free rates are lower (Giusti: mean stone size 2.7cm, primary stone-free rate RIRS 66% [54]; Akman: stone size 2-4cm, primary stone-free rate 73.5% RIRS vs. 91.2% PCNL [55]), operative times are longer (58.2 minutes RIRS vs. 38.7 minutes PCNL [55]) and multiple sessions (usually day-cases) are likely to be required.

## Conclusion

The exact role for smaller tracts has not yet been ascertained (in keeping with recent EAU guidelines). But what the limited research presented here alludes to, is a possible, future role for microperc and mini-PCNL. The exact

application of these tools will only come with further more substantial research including randomised controlled trials but it would seem to lie in the treatment of stones <2cm. As stone surgery progresses, and with the advent and application of stone multidisciplinary meetings, stone units will be able to apply the most appropriate technique for any particular stone, be it an endoscopic or percutaneous approach, small or standard tract or supine versus prone approach.

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