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Percutaneous Nephrolithotomy: Prone Versus Supine Position

Perkutana nefrolitotripsija – pronacijski ili supinacijski položaj

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Abstract. One of the most complex procedures in urology is percutaneous nephrolithotomy. This procedure can be performed in the patient's prone as well as supine position. The position of the patient during percutaneous nephrolithotomy affects the safety of the procedure, anaesthetic risk, hospitalization time, surgery time, and postoperative complications. The advantages of the supine PCNL are easier patient positioning, shorter surgery time, the possibility of spinal anaesthesia, lower anaesthetic risk in obese patients and patients with high cardiovascular risk, lower risk of injuries to the nervous and musculoskeletal system, and lower risk of infections and sepsis. In the supine PCNL, it is possible to perform simultaneous bilateral endoscopic surgery (SBES) and endoscopic combined intrarenal surgery (ECIRS) as well. The advantages of the prone PCNL are shorter puncture channel, which results in a lower risk of injury to the adjacent organs, the possibility of upper renal calyx puncture, and greater mobility when handling the nephroscope. Although the prone position is used more often today, modern knowledge and clinical experience should encourage us to leave our comfort zone and, considering the patient's characteristics, critically evaluate whether we will perform the procedure in the supine or prone position.

Keywords: endoscopy; nephrolithotomy, percutaneous; postoperative complications; urolithiasis

Sažetak. Perkutana nefrolitotripsija (PCNL ili PNL) jedan je od najzahtjevnijih zahvata u urologiji. Zahvat se može izvoditi u pronacijskom i supinacijskom položaju bolesnika. Položaj bolesnika tijekom perkutane nefrolitotripsije utječe na sigurnost postupka, anesteziološki rizik, duljinu hospitalizacije, trajanje operacije i poslijeoperacijske komplikacije. Prednosti PCNL-a u supinacijskom položaju jesu lakše namještanje bolesnika, kraće trajanje operacije, mogućnost spinalne anestezije, manji rizik od anestezije kod pretilih i bolesnika s povišenim kardiovaskularnim rizikom te manji rizik od ozljeda živčanog i mišićno-koštanog sustava, infekcija i sepse. Supinacijski položaj također omogućava izvođenje i simultane endoskopske bilateralne operacije (engl. *simultaneous bilateral endoscopic surgery*; SBES) i endoskopske kombinirane intrarenalne operacije (engl. *endoscopic combined intrarenal surgery*; ECIRS). Prednosti PCNL-a u pronacijskom položaju jesu kraći pristupni punkcijski kanal što rezultira manjim rizikom od ozljeda susjednih organa, mogućnost uboda gornje bubrežne čašice te veća mobilnost pri radu s nefroskopom. Unatoč učestalijoj upotrebi pronacijskog položaja bolesnika, dosadašnje kliničko iskustvo trebalo bi nas potaknuti da izađemo iz svoje „zone komfora" i, s obzirom na svakog bolesnika pojedinačno, kritički procijenimo hoćemo li zahvat izvesti u pronacijskom ili supinacijskom položaju.

Ključne riječi: endoskopija; perkutana nefrolitotripsija; poslijeoperacijske komplikacije; urolitijaza

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INTRODUCTION

Thanks to the development of endourology, diseases of the urogenital system can now be treated with a minimally invasive approach. Endourology has its origins in the 19th century, when Maximilian Nitze developed, in 1877, an instrument equipped with lenses and a water-cooled electric platinum filament lamp that enabled visualization of the interior of the bladder. The instrument was named a cystoscope[1]. The first endoscopic surgery was performed in 1881, when Josef Grünfeld removed a bladder tumour with the help of a cystoscope. This event is considered the foundation of endourology[2]. The first modern endoscopes and instruments for endourological procedures were created in the second half of the 20th century due to the multi-year collaboration between Karl Storz and Harold Hopkins[3]. Consequently, Fernström and Johansson performed the first percutaneous nephrolithotomy in 1976, and Pérez-Castro and Martinez-Piniero the first ureterorenoscopy in 1980[4, 5]. In the early days, rigid instruments were commonly used. However, with technological advancements, instruments have become more sophisticated and better adapted to the human body. This led to the development of semirigid, and eventually, flexible instruments, which are less invasive and gentler on the delicate structures of the urogenital system.

One of the most complex procedures in urology is percutaneous nephrolithotomy. This procedure can be performed in the patient's prone as well as supine position. The position of the patient during percutaneous nephrolithotomy affects the safety of the procedure, anaesthetic risk, hospitalization time, surgery time, and postoperative complications.

UROLITHIASIS

After urinary tract infections and prostate gland diseases, urolithiasis is the 3rd most common reason for visiting a urologist[6]. Risk factors for urolithiasis are dehydration, hot climate, limited physical activity, dietary habits, personal and family history, and other comorbidities such as obesity, metabolic syndrome, diabetes and hypertension. Anatomical and functional abnormalities of the urinary tract can also be a predisposing factor for the development of urolithiasis[7]. In the theory of formation of all stones, essential is the presence of an organic matrix and crystals that deposit onto this matrix, group together and form larger stones. The prerequisite for this is supersaturated urine in which particles are present in concentrations higher than their solubility. Urine saturation is influenced by the urine's pH, diuresis, also the presence of inhibitors and promoters of crystallization. Thus, all stones consist of crystals and, most commonly, of a protein matrix, although this matrix can also be cellular debris or a foreign body[8]. When discussing the chemical composition, 60-70% of urinary stones consist of calcium oxalate, and 20% consist of calcium phosphate. Other stones are far less common and include struvite (10%), urate (9%), and cystine stones (1%)[9].

UROLITHIASIS TREATMENT

The choice of treatment method for urolithiasis depends on the size, number, location, composition of the stone as well as the anatomy of the renal and ureteral collecting system, and on the risk of recurrence of urolithiasis[10, 11]. Treatment should be individualized and tailored to the above-mentioned factors, symptoms, and the patient's preferences. A large number of urinary tract stones are spontaneously eliminated. The probability of spontaneous elimination according to stone size is as follows:

- 1 mm ~ 87%,
- 2 – 4 mm ~ 76%,
- 5 – 7 mm ~ 60%,
- 7 – 9 mm ~ 48%,
- > 9 mm ~ 25%[12].

Additionally, the probability of spontaneous elimination also depends on the stone's location (proximal, middle, distal part of the ureter), the anatomy of the urinary tract, and the characteristics of the patient himself. Some of the treatment options for urolithiasis include chemolysis, extracorporeal shock wave lithotripsy (ESWL), endoscopic surgery, and open surgery[13–18].

PERCUTANEOUS NEPHROLITHOTOMY

One of the most complex procedures in urology is the treatment of nephrolithiasis using the percutaneous anterograde renal access. Percutaneous nephrolithotomy (PCNL or PNL) involves a minimally invasive treatment of kidney stones by creating an "artificial" percutaneous access directly into the renal pelvicalyceal system. This method is technically very challenging and requires a high level of knowledge of the kidney's anatomy and surrounding organs, especially in cases of kidney malrotation, renal ectopia, horseshoe kidney or duplicated renal collecting system[19]. As with any type of treatment, in PCNL, we consider the patient's physical characteristics, the anatomy of renal collecting system and ureter, the size, number, and location of stones as well as the patient's preferences when determining indications and contraindications for a surgical intervention.

Indications for PCNL

Indications for PCNL are primarily kidney stones bigger than 20 mm and renal staghorn calculi[20]. It is associated with a very high stone free rate (SFR), which ranges between 76% and 98%[21]. Due to the high success rate of stone elimination and the reduced need for repeated procedures, PCNL is often indicated even for smaller stones[22].

Contraindications for PCNL

Contraindications for PCNL include pregnancy, uncorrected coagulopathies, active urinary infection, tumour diseases around the percutaneous access and renal neoplasm[22].

PCNL procedure workflow

The PCNL procedure includes the placement of a ureteral catheter, positioning the patient (in the supine or prone position), puncturing the renal collecting system, dilatation of the access tract, lithotripsy, and drainage of the renal collecting system[23].

Ureteral catheter placement

In patients under general anaesthesia, the urologist determines the position of the ureteral orifices with a cystoscope. By introducing a contrast media into the ureter, the ureter and the renal collecting system, where the stone is located, are fluoroscopically visualized. The ureteral catheter is then positioned with its tip in the renal collecting system and is fixed alongside the urinary catheter to prevent it from falling out during manipulations. The ureteral catheter serves to ensure the safe access to the pelvicalyceal system, to artificially create hydronephrosis if it is not already present, and to obstruct the ureteropelvic junction to reduce the possibility of stone migration into the ureter during lithotripsy[24].

Patient positioning

Initially, it was common to perform this procedure with the patient in the prone position. This involves turning the anesthetised patient from the supine to the prone position after placing the ureteral catheter. This position is preferred amongst urologists because it offers a better understanding of the kidney's anatomy, a bigger area for selecting the puncture site, and easier access to the posterior calyx of the kidney[25]. However, patients with morbid obesity and compromised cardiopulmonary status are not good candidates for PCNL in the prone position[26]. José Gabriel Valdivia, Spanish urologist, first described and performed PCNL in the supine position in 1987, considering PCNL in this position to be a safer procedure due to a reduced risk of injury to the descending colon during the puncture[27].

Renal collecting system puncture

The success of the procedure depends heavily on the selection and puncture of the appropriate renal calyx. The percutaneous renal access is ultrasound or fluoroscopy guided. The choice of puncture technique is based on the experience of the surgeon. In some centres, the puncture and dilatation are performed by a radiologist rather than a urologist. Preoperative imaging diagnostics are necessary for planning the puncture. The once-popular intravenous urography has been replaced by CT urography. The three-dimensional image reconstruction allows the visualization of the stone within the collecting system and the relationship of surrounding structures[28]. Typically, the posterior calyx is chosen for puncture as it is in the projection of Brodel's avascular line[29] (Figure 1). Puncture along this line carries

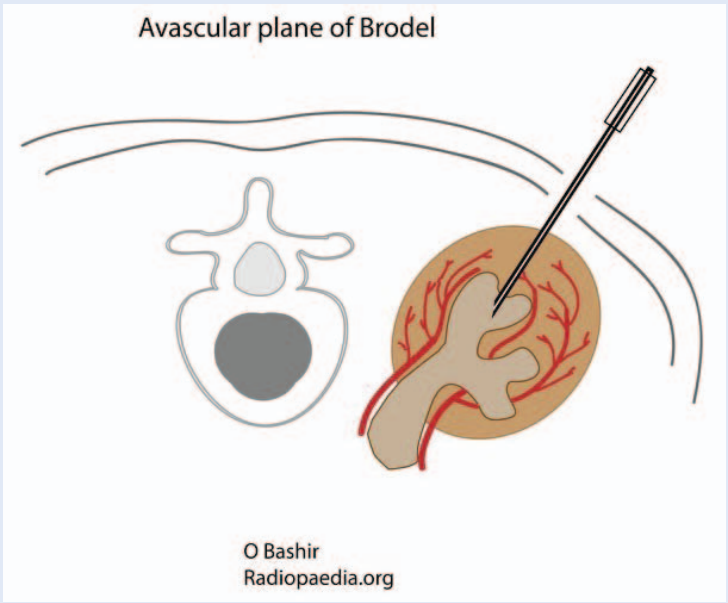

Figure 1. Punction through avascular plane of Brodel
(Source: Bashir O. Avascular plane of Brodel (diagram). Available from: https://doi.org/10.53347/rID-17859Case)

Figure 2. Fluoroscopic confirmation of puncture of the renal calyx

the lowest risk of intraoperative bleeding. It is also preferred due to the nearly 0° angle it forms with the infundibulum (the neck of the calyx) and the renal pelvis, which significantly reduces the need for nephroscope angulation during the procedure, thereby also decreasing the possibility of iatrogenic injury[30, 31]. After puncturing the renal collecting system, a contrast agent is used to confirm that the appropriate calyx has been punctured (Figure 2). A guide wire is then introduced through the puncture needle. For the further course of the procedure, it is ideal to insert the guide wire into ureter or renal pelvis, but sometimes it is only possible to coil it inside the punctured calyx.

Percutaneous access tract dilatation

For the dilatation procedure, Amplatz, Alken or balloon dilatators are used. Regardless of the type of dilatator used, fluoroscopy must be employed during this step to control the position of the dilatator and avoid injury to the renal parenchyma or perforation of the collecting system. In our centre, metal coaxial Alken dilatators are commonly used. During the dilatation process, a secondary safety wire is placed through a specially designed double-lumen dilatator. The advantage of metal Alken dilatators is their reusability after sterilization and easier puncture in patients with severe perinephric scarring. The downside of using these dilatators is the increased risk of injury to the renal collecting system, especially for less experienced surgeons[32].

Stone fragmentation (lithotripsy)

The surgeon decides which lithotripter to use based on the nephroscope's width and the stone's size and hardness. The available options include pneumatic, electrohydraulic, ultrasonic, and laser lithotripters[33]. Given that we are most often discussing lithotripsy of stones larger than two centimetres, or the lithotripsy of staghorn calculi, it is recommended to use the ultrasonic or combined ultrasonic/ballistic lithotripters. These devices allow simultaneous aspiration of smaller fragments as well as irrigation fluid, which helps prevent the increase of intrarenal pressure and the reflux of bacteria and endotoxins into the systemic circulation, thereby reduc-

ing the probability of postoperative fever and urosepsis[34, 35].

Drainage of upper urinary tract

At the end of the surgery, fluoroscopy is used to check for the presence of residual stones and any extravasation of contrast media that would indicate an iatrogenic injury to the renal collecting system. After the procedure, small stone fragments and minor clots remain in the renal collecting system, which can compromise urine flow through the ureter. Additionally, the access route through the skin, subcutaneous tissue, muscle, and renal parenchyma is prone to bleeding after the nephroscope's "sheath" is removed. Due to both reasons, the surgery concludes with the placement of a nephrostomy tube, which ensures proper urine diversion in the early postoperative period, prevents the formation of urinomas, and compresses the access route, thereby contributing to haemostasis. The nephrostomy tube also allows for subsequent fluoroscopic imaging of the collecting system with contrast media to verify that the contrast flows unobstructedly to the bladder and, if necessary, facilitates re-entry into the renal collecting system[35, 36].

Prone PCNL

Fernström and Johansson performed the first PCNL in 1976, but the earliest descriptions of percutaneous treatment of kidney stones date back to 1941 and 1955[4, 37, 38].

The advantages of the prone position include a better understanding of kidney anatomy, a wider surgical field for choosing the puncture site, an easier access to the posterior calyx, the possibility to puncture the upper calyx, a greater scope for the nephroscope angulation, and a reduced likelihood of the visceral organs injury[39] (Figure 3).

The drawbacks of the prone position are mainly related to the time needed to prepare the patient, specifically the need to turn the anaesthetised patient from the supine to the prone position, which significantly prolongs the operation time. Such procedures also require a larger number of staff to assist in turning the anaesthetized patient. It is important to note that during

Figure 3. Prone PCNL

the turning of the patient, accidental injuries can occur to both the patient and the staff. The most common patient injuries are nerve injuries due to limb manipulation, joint dislocations, and vision damage[40, 41]. Staff injuries often involve musculoskeletal injuries due to the overexertion while turning heavy patients. The negative implications of PCNL in the prone position are also related to anaesthetic procedures. These patients must be under general anaesthesia as it is impossible to convert the anaesthetic procedure from spinal to general anaesthesia in this position due to the inability to intubate while prone. Additionally, any hemodynamic instability of the patient during the procedure, or the need for resuscitation is significantly complicated and requires turning the patient back to the supine position[42]. In the prone position, especially in obese patients, there is a lower cardiac preload, relaxation of the left ventricle as well as the lower stroke volume due to the reduced left ventricle relaxation and increased cardiac afterload, which occurs due to the increased intra-abdominal and intrathoracic pressure[43]. Although the prone position is often used in patients with acute respiratory insufficiency, in anaesthetised obese patients, this position can lead to ventilation

Figure 4. Supine PCNL

problems[44]. During the prone PCNL, a nephroscope is located above the patient's body line, in an anti-gravity position. This results in a poorer fluid outflow and increased pressure in the renal pelvis, which can lead to the reflux of infected urine into the systemic circulation[44, 45]. In patients undergoing PCNL in the prone position, it is very difficult or impossible to achieve the retrograde access for the purpose of performing endoscopic combined intrarenal surgery (ECIRS).

Supine PCNL

Considering high-risk patients for anaesthesia procedures, Valdivia Uría and colleagues began performing PCNL in the supine position in 1987 and reported their first experiences in 1998[46]. By analysing the position of the colon and other abdominal organs in the supine position, they concluded that the possibility of injury of these organs is equal to or less than when performing PCNL in the prone position. In 2007, Ibarluzea and colleagues described a modification of the Valdivia position called the Galdakao Modified Supine Valdivia Position (GMSVP), which provided a greater access to the lumbar region, making the puncture and nephroscope manipulation significantly easier[46, 47]. The Barts position offers additional rotation of the patient's torso towards the surgical table. In this position, the kidney is more mobile, making puncture and dilatation more difficult, but the accessibility to the calyces for puncture and the nephroscope mobility are significantly increased[48].

The advantages of performing PCNL in the supine position include easier patient positioning, which significantly reduces the surgery time (Figure 4). High-risk, obese, and cardiac patients tolerate the supine position better, and the anaesthesiologist can manage anaesthesia comfortably because this way the airway is easily accessible, and patients are more likely to remain hemodynamically stable[42, 43]. Due to the horizontal or "downward" position of the nephroscope, fluid drainage from the kidney's collecting system is better, resulting in lower pressure within the renal pelvis and a lower rate of urinary infections[45]. Moreover, the supine PCNL allows the surgeon and technician to sit, which is ergonomically more favourable, especially considering the need to wear heavy lead aprons during the procedure. One of the most important advantages of PCNL in the supine position is the possibility of performing ECIRS (endoscopic combined intrarenal surgery) and SBES (simultaneous bilateral endoscopic surgery).

The downside of the supine PCNL is the smaller area available for puncture and the difficulty of puncturing the upper calyx. In this position, the kidney is more mobile, which can make puncture and dilatation challenging. Additionally, due to the much longer access tract, longer instruments must be used, and their angulation is sometimes limited by the patient's position on the table[49, 50]. Due to its complexity and the need for specialized surgical expertise, supine PCNL is performed in tertiary medical centers, where the necessary resources and experienced personnel are available to ensure patient safety and optimal outcomes.

Impact of prone and supine PCNL on procedure safety

When discussing procedure safety, we consider both the patient and the medical staff. Safe diagnostic and therapeutic procedures are those with the lowest risk of adverse events[51]. The safety of PCNL is related to the patient's position, anaesthetic procedures, the effort required by medical and non-medical staff for patient positioning, ra-

diation exposure, postoperative complications, and the need for repeat procedures due to residual lithiasis.

The supine position undeniably provides a greater comfort for the patient during anaesthesia and the procedure itself, while reducing the risk of injuries when turning the patient into the prone position. The PCNL typically begins in the supine position. However, turning the patient into the prone position requires a team of at least six people (one controlling the head during the turning, two on each side participating in turning and one controlling the legs), which defines a larger number of people than required for performing such procedure[42]. Extreme neck rotation during turning can lead to the compression of the carotid and vertebral arteries, potentially causing injuries to the central nervous system, particularly in patients with subclinical stenosis of the arteries. Also, the position of the head during anaesthesia in the prone position can cause dislocations of the vertebral discs and overstrain of the cervical spinal cord with consequent ischemia and neurological outcome. Peripheral nerve injuries are most often the result of their stretching or compression of the nerves against a hard surface. During the prone PCNL, the most frequent injury is to the brachial plexus due to the extension and abduction of the upper extremities. During the procedures of longer duration, special attention should be paid to parts of the body that are in direct contact with a hard surface (ears, chest, malleolar region, genitals, iliac crest…) to avoid the formation of dermatitis or even skin necrosis[43].

The fear of colon injury during puncture and dilatation of the access tract was the main reason for favoring prone PCNL due to the belief that it is impossible to injure the colon in this position. Analysing CT images, Hopper and his colleagues showed that the retrorenal colon was found in 1,9% of patients in the supine position compared to 10% of patients in the prone position[52]. Tuttle and colleagues showed the retrorenal colon in 6% of patients in the supine position versus 15% of patients in the prone position[53]. Although this anatomical placement of the colon would suggest a higher rate of injuries during puncture and dilatation in prone position, so far, no statistically significant difference in colon injuries has been found regarding patient's position[54].

Although there are no studies comparing the radiation exposure of surgeons during prone and supine PCNL procedures, it is obvious that the surgeon's hands are directly in the radiation field during the puncture, access tract dilatation and lithotripsy in the prone PCNL. In the supine position, the instruments are placed more laterally, hence the surgeon's hands are not in the radiation field. This position allows the surgeon to be seated while operating which is not insignificant when considering the need to wear heavy lead aprons during the procedure[50].

Main disadvantages of the supine PCNL are greater kidney mobility and limited space for puncture while the advantages are easier patient positioning, the possibility of performing the procedure under spinal anaesthesia, simultaneous ECIRS and SBES, a higher stone free rate and a shorter duration of surgery.

Numerous studies and meta-analyses that compared stone free rate (SFR) generally did not find dominance of one over the other position during PCNL. In the supine position, the SFR was 78,1%, and in the prone position 80%, with no statistical significance[55].

Until recently, in cases of bilateral urolithiasis it was common to perform the procedure first on one side, and then on the other side. Sometimes, the procedure on the other kidney would have been postponed or planned for another hospitalisation. However, nowadays it is common to perform procedures on both sides simultaneously, e.g. one surgeon performs PCNL while the other performs ureterorenoscopy (URS), flexible ureterorenoscopy, or RIRS on the other side. These procedures are effective in terms of the high SFR and safety[56]. Furthermore, the advantage of these procedures is anaesthetising the patient only once, reducing the total hospitalization time and the radiation dose received[57]. During ECIRS, one surgeon performs PCNL, while the other surgeon uses the retrograde approach for fragmentation of those stones that cannot be reached by the anterograde approach. With the retrograde

approach, the surgeon can also mobilise stones from the harder-to-reach parts of the kidney to a position more favourable for the anterograde lithotripsy. In this way, the need for additional punctures and dilatations is reduced, as well as the possibility of complications. ECIRS brings a higher SFR in just one procedure, reduces the need for additional punctures and lowers the need for repeat procedures[58, 59].

Impact of prone and supine PCNL on anaesthesia risk

In most healthcare institutions in the world, PCNL is performed dislocated from the central operating theatre, often in the radiology department. As previously mentioned, when turning the patient in the prone position unintentional injuries may occur, most commonly injuries of the cervical spine, brachial plexus nerves, and dislocation of the shoulder joint[60, 61].

In some centres the supine PCNL is performed under spinal anaesthesia which is associated with fewer complications compared to the general, less need for the postoperative analgesia and a shorter hospitalization time. However, if needed it is possible for anaesthesiologist to intubate the patient and convert to general. Nonetheless, the choice of anaesthesia will depend on the preference of the surgeon, the anaesthesiologist and the patient himself[62].

During the COVID-19 pandemic, many patients with respiratory failure were rotated into the prone position to improve oxygenation[63]. The prone position during PCNL generally has no effect on the ventilation of the patient under general anaesthesia, but, if mechanical complications with the tube or unintentional extubation occur, it is difficult to re-secure the airway in this position. For the anaesthesiologist, the biggest challenge is the hemodynamic stability of patients in the prone position, especially in obese patients. Namely, after turning the patient into the prone position, hemodynamic changes occur due to the lower cardiac preload as well as the lower cardiac output. It is hard to maintain the hemodynamic stability in these conditions. In case that a more invasive monitoring is needed due to the occurrence of cardiovascular complications, the placement of arterial lines in this position is almost impossible. Resuscitation in the prone position is also impossible[64].

Impact of prone and supine PCNL on hospitalisation time

Studies have not shown a statistically significant difference in the number of hospitalisation days between the patients operated on in the prone and supine position[65–67].

Impact of prone and supine PCNL on duration of operative procedure

Patients operated on in the prone position spent more time under anaesthesia compared to those operated on in the supine position. The time difference occurs mainly due to the need to reposition the patient from the lithotomy to the prone position. During the supine PCNL, the nephroscope is directed towards the ground, which facilitates the flow of fluid and the elimination of stone fragments, unlike the prone PCNL, where the nephroscope is in the anti-gravity position, which makes it difficult to eliminate fragments and prolongs the procedure time[68].

The duration of the operative procedure is statistically significantly shorter in supine compared to the prone position due to the above-mentioned reasons, and because of the possibility of ECIRS, which reduces the need of additional punctures. In obese patients, this time difference becomes even more obvious. A randomized controlled study conducted by Al-Dassoukey et al. showed that the duration of procedure in the prone position was 111,7 minutes compared to 86,2 minutes in the supine position[69]. Yuan et al. came to the same conclusion in the meta-analysis of 13 studies[66].

Impact of prone and supine PCNL on postoperative complications

Postoperative pain is a significant factor used to determine patient morbidity after a procedure. Good postoperative pain control not only reduces the need for analgesics, but also increases patient satisfaction, accelerates recovery of physiological functions, patient rehabilitation and it reduces treatment costs[70]. Mulay et al. showed that patients operated on in the supine position had a lower intensity of postoperative pain, but

Table 1. Prone vs supine PCNL

	Prone PCNL	Supine PCNL
anaesthesia	general	spinal, general if needed
risk of injuries while positioning the patient	high	low
kidney puncture, nephroscope mobility	the posterior calyx, greater mobility while handling the nephroscope	limited puncture space and mobility while handling the nephroscope
operation duration	statistically longer	statistically shorter
risk of postoperative infections	high	low
simultaneous operation (e.g. ECIRS, SBES)	no	yes
stone free rate	80%	78.1%

ECIRS – endoscopic combined intrarenal surgery; SBES – simultaneous bilateral endoscopic surgery

there was no significant difference between these two groups of patients[65]. Kanan et al. found that the group of patients operated on in the supine position also had a lower intensity of pain compared to the prone group, and the difference was statistically significant (p=0.04)[71].

The meta-analysis of the supine versus prone PCNL by Falahatkar et al. found a higher rate of postoperative febrility in the prone group of patients (p<0.001)[71]. This data is not surprising considering higher intrarenal pressure during the prone PCNL and the consequent reflux of urine into the systemic bloodstream. Similar data were obtained by other authors[45, 66–68].

Some believe that lower intrarenal pressure, a more mobile kidney and a longer access channel during the supine PCNL are risk factors for increased intraoperative and postoperative bleeding. Others believe that the compression of the inferior vena cava during the prone position and venous blood stasis is the reason for increased bleeding during the prone PCNL. Bleeding during and after the procedure is influenced by the number of punctures, the width of the access channel, whether the puncture was performed through the avascular Brodel line and the time of the procedure[72]. Numerous randomized controlled clinical trials and meta-analyses that compared the need for blood transfusion in patients operated on in the prone or supine position have mostly found no statistically significant differences in postoperative bleeding[26, 55, 73, 74]. The meta-analysis by Falahatkar et al. showed that the need for blood transfusion was lower in the supine PCNL (p=0.01), while Li et al.'s meta-analysis from 2019 showed that there was no statistically significant difference between these two groups[55, 67].

CONCLUSION

For the first time the successful removal of kidney stones through the percutaneous anterograde route was performed in 1976. Today PCNL is the method of choice in the treatment of stones bigger than 2 cm and staghorn calculi. Until recently, it was common to perform the prone PCNL, however, nowadays, it is increasingly performed in the supine position, especially with complex stones and bilateral urolithiasis when it is necessary to perform SBES or ECIRS (Table 1). The biggest restrictions of the supine PCNL are greater mobility of the kidney in that position and limited space for puncture and movements when handling the nephroscope, while the advantages are numerous and include easier positioning of the patient, the possibility of performing the procedure under spinal anaesthesia, performing ECIRS and SBES, a higher rate of complete elimination of stones in the same procedure and its shorter duration. This position has proven to be particularly useful and safe in obese patients and patients with high cardiovascular risk, all while providing lower risk of thromboembolic events and postoperative infections. The advantages of the prone PCNL are a shorter length of the dilatation channel, bigger available area and easier puncturing of the appropriate renal calyx, and greater mobility when handling the nephroscope.

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REFERENCES

1. Spaner SJ, Warnock GL. A brief history of endoscopy, laparoscopy, and laparoscopic surgery. J Laparoendosc Adv S 1997;7:369-73.
2. Herr HW. Early history of endoscopic treatment of bladder tumors from Grunfeld's polypenkneipe to the Stern-McCarthy resectoscope. J Endourol 2006;20:85-91.
3. Ellis H. The Hopkins Rod-Lens System. J Perioper Pract 2007;17:272-274.
4. Fernström I, Johansson B. Percutaneous pyelolithotomy: a new extraction technique. Scand J Urol Nephrol 1976; 10:257-9.
5. Pérez-Castro EE, Martinez-Piniero JA. Transurethral ureteroscopy—a current urological procedure. Arch Esp Urol 1980;33:445-60.
6. Stoller ML. Urinary Stone Disease. *In*: McAninch JW, Lue TF (eds). Smith&Tanagho's General Urology. 19th Edition. New York: McGraw Hill; 2020.
7. Bokhari AA, Aldarwish HA, Alsanea SA, Al-Tufaif MA, Alghaslan SA, Alghassab AA et al. Prevalence and Risk Factors of Urolithiasis Among the Population of Hail, Saudi Arabia. Cureus 2022;14:26983.
8. Shastri S, Patel J, Sambandam KK, Lederer ED. Kidney Stone Pathophysiology, Evaluation and Management: Core Curriculum 2023. Am J Kidney Dis 2023;82:617-34.
9. Chung MJ. Urolithiasis and nephrolithiasis. JAAPA 2017;30:49-50.
10. Türk C, Petřík A, Sarica K, Seitz C, Skolarikos A, Straub M et al. EAU Guidelines on Diagnosis and Conservative Management of Urolithiasis. Eur Urol 2016;69:468-74.
11. European Association of Urology [Internet]. Arnhem: EAU Guidelines on Urolithiasis 2024 [cited 2024 Nov 24]. Available from: https://uroweb.org/eau-guidelines.
12. Coll DM, Varanelli MJ, Smith RC. Relationship of spontaneous passage of ureteral calculi to stone size and location as revealed by unenhanced helical CT. AJR Am J Roentgenol 2002;178:101-3.
13. Gupta M, Bolton DM, Stoller ML. Etiology and management of cystine lithiasis. Urology 1995;45:344-55.
14. Ong A, Brown G, Tokas T, Hameed BMZ, Philip J, Somani BK. Selection and Outcomes for Dissolution Therapy in Uric Acid Stones: A Systematic Review of Literature. Curr Urol Rep 2023;24:355-63.
15. Sotošek S, Ahel J, Rubinić N, Smolić K, Markić D. Extracorporeal shock wave lithotripsy. Med Flum 2017;53:285-91.
16. Luo Z, Jiao B, Zhao H, Huang T, Zhang G. Comparison of retrograde intrarenal surgery under regional versus general anaesthesia: A systematic review and meta-analysis. Int J Surg 2020;82:36-42.
17. Ulvik Ø, Rennesund K, Gjengstø P, Wentzel-Larsen T, Ulvik NM. Ureteroscopy with and without safety guide wire: should the safety wire still be mandatory? J Endourol 2013;27:1197-202.
18. Alivizatos G, Skolarikos A. Is there still a role for open surgery in the management of renal stones? Curr Opin Urol 2006;16:106-11.
19. Prakash G, Sinha RJ, Jhanwar A, Bansal A, Singh V. Outcome of percutaneous nephrolithotomy in anomalous kidney: is it different? Urol Ann 2017;9:23-6.
20. Ganpule AP, Vijayakumar M, Malpani A, Desai MR. Percutaneous nephrolithotomy (PCNL) a critical review. Int J Surg 2016;36:660-4.
21. Michel MS, Trojan L, Rassweiler JJ. Complications in percutaneous nephrolithotomy. Eur Urol 2007;51:899-906.
22. Sabler IM, Katafigiotis I, Gofrit ON, Duvdevani M. Present indications and techniques of percutaneous nephrolithotomy: What the future holds? Asian J Urol 2018;5:287-94.
23. Fišer A. Pronacijski ili supinacijski položaj bolesnika u perkutanoj nefrolitotripsiji – prednosti i nedostatci. Rijeka: Fakultet zdravstvenih studija, 2024. Final thesis.
24. Mirani KK, Ather MH, Kazmi Z, Aziz W. Access and Fluoroscopy Time Difference in Patients Undergoing Prone Percutaneous Nephrolithotomy (PCNL) With Ureteric Catheter Placement in Supine Versus Lithotomy Position. Cureus 2022;14:26220.
25. Miano R, Scoffone C, De Nunzio C, Germani S, Cracco C, Usai P et al. Position: prone or supine is the issue of percutaneous nephrolithotomy. J Endourol 2010;24:931-8.
26. Wang Y, Wang Y, Yao Y, Xu N, Zhang H, Chen Q et al. Prone versus modified supine position in percutaneous nephrolithotomy: a prospective randomized study. Int J Med Sci 2013;10:1518-23.
27. Valdivia JG, Scarpa RM, Duvdevani M, Gross AJ, Nadler RB, Nutahara K et al. Croes PCNL Study group. Supine versus prone position during percutaneous nephrolithotomy: a report from the clinical research office of the endourological society percutaneous nephrolithotomy global study. J Endourol 2011;25:1619-25.
28. Thiruchelvam N, Mostafid H, Ubhayakar G. Planning percutaneous nephrolithotomy using multidetector computed tomography urography, multiplanar reconstruction and three-dimensional reformatting. BJU Int 2005;95:1280-1284.
29. Sampaio FJ, Zanier JF, Aragão AH, Favorito LA. Intrarenal access: 3-dimensional anatomical study. J Urol 1992;148: 1769-73.
30. Miller NL, Matlaga BR, Lingeman JE. Techniques for fluoroscopic percutaneous renal access. J Urol 2007;178:15-23.
31. Ko R, Soucy F, Denstedt JD, Razvi H. Percutaneous nephrolithotomy made easier: a practical guide, tips and tricks. BJU Int 2008;101:535-9.
32. Davidoff R, Bellman GC. Influence of technique of percutaneous tract creation on incidence of renal hemorrhage. J Urol 1997;157:1229-31.
33. Mustafa M, Al Zabadi H, Mansour S, Nabulsi A. Endoscopic Management of Upper and Lower Ureteric Stones Using Pneumatic Lithotripter: A Retrospective Medical Records Review. Res Rep Urol 2023;15:77-83.
34. Zhong W, Zeng G, Wu K, Li X, Chen W, Yang H. Does a smaller tract in percutaneous nephrolithotomy contribute to high renal pelvic pressure and postoperative fever? J Endourol 2008;22:2147-51.
35. Kreydin EI, Eisner BH. Risk factors for sepsis after percutaneous renal stone surgery. Nat Rev Urol 2013;10:598-605.
36. Srinivasan AK, Herati A, Okeke Z, Smith AD. Renal drainage after percutaneous nephrolithotomy. J Endourol 2009;23: 1743-9.
37. Rupel E, Brown R. Nephroscopy with removal of stone following nephrostomy for obstructing calculus anuria. J Urol 1941;46:177-82.
38. Goodwin WE, Casey WC, Woolf W. Percutaneous trocar (needle) nephrostomy in hydronephrosis. J Am Med Assoc 1955;157:891-4.
39. de la Rosette JJ, Tsakiris P, Ferrandino MN, Elsakka AM, Rioja J, Preminger GM. Beyond prone position in percutaneous nephrolithotomy: a comprehensive review. Eur Urol 2008;54:1262-9.

40. Awan AS, Khalid S, Khan SA, Mithani S, Shaikh J, Sharif I. Supine PCNL is the Way Forward, with Reduced Anesthesia and Operative Times As Compared to Prone PCNL, Along with Comparable Blood Loss and Stone Free Rates. J Urol Surg 2019;6:1-6.
41. Agah M, Ghasemi M, Roodneshin F, Radpay B, Moradian S. Prone position in percutaneous nephrolithotomy and postoperative visual loss. Urol J 2011;8:191-6.
42. Atkinson CJ, Turney BW, Noble JG, Reynard JM, Stoneham MD. Supine vs prone percutaneous nephrolithotomy: an anaesthetist's view. BJU Int 2011;108:306-8.
43. Edgcombe H, Carter K, Yarrow S. Anaesthesia in the prone position. Br J Anaesth 2008;100:165-83.
44. Yucepur S, Kepekci AB, Erbin A, Ozenc E. Effects of lithotomy and prone positions on hemodynamic parameters, respiratory mechanics, and arterial oxygenation in percutaneous nephrolithotomy performed under general anesthesia. Folia Med (Plovdiv) 2023;65:427-33.
45. Farkouh A, Park K, Buell MI, Mack N, De Guzman C, Clark T et al. Prone vs supine percutaneous nephrolithotomy: does position affect renal pelvic pressures? Urolithiasis 2024;52:66.
46. Valdivia Uría JG, Valle Gerhold J, López López JA, Villarroya Rodriguez 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.
47. 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.
48. Sabnis R, Desai MR, Singh A. Supine Percutaneous Nephrolithotomy. J Endourol 2022;36:35-40.
49. Mourmouris P, Berdempes M, Markopoulos T, Lazarou L, Tzelves L, Skolarikos A. Patient positioning during percutaneous nephrolithotomy: what is the current best practice? Res Rep Urol 2018;10:189-193.
50. Proietti S, Rodríguez-Socarrás ME, Eisner B, De Coninck V, Sofer M, Saitta G et al. Supine percutaneous nephrolithotomy: tips and tricks. Transl Androl Urol 2019;8:381-388.
51. Shojania KG, Duncan BW, McDonald KM, Wachter RM, Markowitz AJ. Making health care safer: a critical analysis of patient safety practices. Evid Rep Technol Assess (Summ) 2001;43:1-668.
52. Hopper KD, Sherman JL, Luethke JM, Ghaed N. The retrorenal colon in the supine and prone patient. Radiology 1987;162:443-6.
53. Tuttle DN, Yeh BM, Meng MV, Breiman RS, Stoller ML, Coakley FV. Risk of injury to adjacent organs with lower-pole fluoroscopically guided percutaneous nephrostomy: evaluation with prone, supine, and multiplanar reformatted CT. J Vasc Interv Radiol 2005;16:1489-92.
54. Birowo P, Tendi W, Widyahening IS, Rasyid N, Atmoko W. Supine versus prone position in percutaneous nephrolithotomy: a systematic review and meta-analysis. F1000Res 2020;9:231.
55. Li J, Gao L, Li Q, Zhang Y, Jiang Q. Supine versus prone position for percutaneous nephrolithotripsy: A meta-analysis of randomized controlled trials. Int J Surg 2019;66:62-71.
56. Proietti S, de la Rosette J, Eisner B, Gaboardi F, Fiori C, Kinzikeeva E et al. Bilateral endoscopic surgery for renal stones: a systematic review of the literature. Minerva Urol Nefrol 2017;69:432-45.
57. Bagrodia A, Raman JD, Bensalah K, Pearle MS, Lotan Y. Synchronous bilateral percutaneous nephrostolithotomy: analysis of clinical outcomes, cost and surgeon reimbursement. J Urol 2009;181:149-53.
58. Leng S, Xie D, Zhong Y, Huang M. Combined Single-Tract of Minimally Percutaneous Nephrolithotomy and Flexible Ureteroscopy for Staghorn Calculi in Oblique Supine Lithotomy Position. Surg Innov 2018;25:22-7.
59. Schulster M, Small AC, Silva MV, Abbott JE, Davalos JG. Endoscopic Combined Intrarenal Surgery Can Accurately Predict High Stone Clearance Rates on Postoperative CT. Urology 2019;133:46-9.
60. King-Robson J, Bates E, Sokolov E, Hadden RDM. Prone position plexopathy: an avoidable complication of prone positioning for COVID-19 pneumonitis? BMJ Case Rep 2022;15:243798.
61. Ali AA, Breslin DS, Hardman HD, Martin G. Unusual presentation and complication of the prone position for spinal surgery. J Clin Anesth 2003;15:471-3.
62. Indra Rachman R, Birowo P, Nurullah G, Cho PSY, Atmoko W, Widyahening IS et al. General versus spinal anesthesia in percutaneous nephrolithotomy: A systematic review and meta-analysis. F1000Res 2023;12:281.
63. Hadaya J, Benharash P. Prone Positioning for Acute Respiratory Distress Syndrome (ARDS). JAMA 2020;324:1361.
64. Sunder-Plassmann G, Locker GJ, Muhm M, Thalhammer F, Laczika K, Frass von Friedenfeldt M. Central venous catheterization in a patient in the prone position. Crit Care Med 1997;25:1439-40.
65. Mulay A, Mane D, Mhaske S, Shah AS, Krishnappa D, Sabale V. Supine versus prone percutaneous nephrolithotomy for renal calculi: Our experience. Curr Urol 2022;16:25-9.
66. Yuan D, Liu Y, Rao H, Cheng T, Sun Z, Wang Y et al. Supine Versus Prone Position in Percutaneous Nephrolithotomy for Kidney Calculi: A Meta-Analysis. J Endourol 2016;30:754-63.
67. Falahatkar S, Mokhtari G, Teimoori M. An Update on Supine Versus Prone Percutaneous Nephrolithotomy: A Meta-analysis. Urol J 2016;13:2814-22.
68. Liu L, Zheng S, Xu Y, Wei Q. Systematic review and meta-analysis of percutaneous nephrolithotomy for patients in the supine versus prone position. J Endourol 2010;24:1941-6.
69. Al-Dessoukey AA, Moussa AS, Abdelbary AM, Zayed A, Abdallah R, Elderwy AA et al. Percutaneous nephrolithotomy in the oblique supine lithotomy position and prone position: a comparative study. J Endourol 2014;28:1058-63.
70. Gan TJ. Poorly controlled postoperative pain: prevalence, consequences, and prevention. J Pain Res 2017;10:2287-98.
71. Kannan D, Quadri M, Sekaran PG, Paul R, Panneerselvam A, Jain N. Supine Versus Prone Percutaneous Nephrolithotomy (PCNL): A Single Surgeon's Experience. Cureus 2023;15:41944.
72. Poudyal S. Current insights on haemorrhagic complications in percutaneous nephrolithotomy. Asian J Urol 2022;9:81-93.
73. Falahatkar S, Moghaddam AA, Salehi M, Nikpour S, Esmaili F, Khaki N. Complete supine percutaneous nephrolithotripsy comparison with the prone standard technique. J Endourol 2008;22:2513-7.
74. Wu P, Wang L, Wang K. Supine versus prone position in percutaneous nephrolithotomy for kidney calculi: a meta-analysis. Int Urol Nephrol 2011;43:67-77.