

Current advances in pain regimens for percutaneous nephrolithotomy: A comprehensive review

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ABSTRACT

Introduction: Percutaneous nephrolithotomy (PCNL) causes pain and discomfort after surgery. The primary causes of immediate postoperative pain after PCNL are visceral pain from the ureters and kidneys, and body surface discomfort from incisions. Acute, untreated pain has the potential to develop into chronic pain, which remains a considerable burden for the rehabilitation of patients. The goal of this review was to describe the current options for treating pain post-PCNL.

Methods: We conducted a literature review of all published manuscripts on pain protocols for patients undergoing PCNL and related topics; 50 published manuscripts were identified and reviewed.

Results: PCNL morbidity must be reduced by an appropriate management of postoperative pain. Opioids, multimodal therapy, tubeless PCNL, reduced size of nephrostomy tube, and regional anesthesia are currently available for reducing postoperative pain.

Conclusions: Implementing successful treatment strategies for postoperative pain after PCNL is key in reducing the morbidity and mortality of PCNL.

KEY MESSAGES

- PCNL is a minimally invasive endourological technique for treating patients with large and/or numerous renal calculi.
- The primary causes of immediate postoperative pain after PCNL are visceral pain from the ureters and kidneys and body surface discomfort from incisions.
- Postoperative pain after PCNL has significant unfavorable consequences on postoperative rehabilitation, quality of life, and economic and social situations for patients.

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is a minimally invasive endourological technique for treating patients with large and/or numerous renal calculi. PCNL is first-line therapy suggested by the European association of urology for large (> 2 cm), numerous, and inferior calyx renal stones.¹

PCNL has a greater rate of stone removal than extracorporeal shockwave lithotripsy and much less morbidity than open surgery. In the first 24 hours after PCNL, severe discomfort might develop along the nephrostomy tube route or owing to dilatation of the renal capsule and parenchyma.²

At completion of surgery, a percutaneous nephrostomy (PCN) tube is placed into the collecting system. This results in post-operative discomfort and suffering.³ Insufficient analgesia results in delayed mobility, impaired ventilation, longer hospitalization and may lead to chronic pain.²

Indication for PCNL

Indications for PCNL over other surgical procedures includes aberrant collecting system architecture, such as the presence of a stone in a calyceal diverticulum, which is often difficult to access ureteroscopically. Similarly, kidneys that cannot be readily accessible retrogradely, such as transplanted kidneys and patients with urinary diversions, often need percutaneous stone removal. Infected struvite stones have a propensity to reoccur without full removal; thus, percutaneous extraction may enhance stone-free rates and become the treatment choice for these patients as well.⁴

Contraindications

Major contraindication for PCNL include: ^{5,6}

1. Active urinary tract infection.
2. Uncorrected coagulopathy.
3. Pregnancy and inability to achieve preferred surgical positioning.

POSTOPERATIVE PAIN AFTER PCNL

Postoperative pain after PCNL may arise from the epidermis, subcutaneous tissues, muscle, or renal capsule. PCNL involves formation of a percutaneous access route via renal parenchyma resulting in parenchymal shearing, increased renal pelvic pressure, visceral discomfort secondary to autonomic nerve reactivity, and low back pain from the indwelling nephrostomy tube.⁷

Anatomical studies show that the primary causes of immediate postoperative pain after PCNL are visceral pain from the ureters and kidneys and body surface discomfort from incisions. Ureteral pain is caused by the T10-L2 spinal nerve, while renal pain is caused by the T10-L1 spinal nerve.⁸

Nevertheless, incisions and access are often made beneath the 12th rib or between the 10th and 11th ribs, where T10–11 mostly innervates the skin. Indwelling PCN results in peritubular compression of the renal cortex and dilatation of the renal capsule which may

exacerbate postoperative discomfort. Distress and anxiety relating to PCN may also worsen pain^{9,10}.

Intraoperative factors such as procedure time and intrarenal pressures may also have an impact on postoperative pain. High intrarenal pressure during lithotripsy is associated with extravasation into the retroperitoneal space, acute malabsorption, perirenal collection, and septicemia. Ideally, intrarenal pressures are kept to a minimum to optimize stone clearance and avoid the negative consequences associated with maintained, elevated pressures. During PCNL, stone fragments may inadvertently be flushed/migrate into the ureter resulting in stimulation of the mucosa of the ureter and ureteral spasm. This results in more persistent. Since the urinary system and gastrointestinal system are innervated by the same autonomic nerve, the discomfort may result in reflexive nausea and vomiting.¹¹

Postoperative discomfort following PCNL is related to somatosensory and visceral pain and oftentimes warrants postoperative opioid usage.¹² Balancing appropriate opioid usage and avoidance of unfavorable consequences on postoperative rehabilitation, everyday actions, quality of life, and economic and social situations for patients is key. Inadequate analgesia may lead to higher morbidity, delayed or compromised ventilation, and longer hospitalization, all of which can raise medical expenses.¹³

In extreme circumstances, if postoperative pain is not promptly reduced, it may lead to a delay in activity, lung dysfunction, extended hospitalization, and possibly septic shock and renal failure. Importantly, the shift from acute to chronic pain may have a considerable impact on patients' quality of life.¹⁴

Risk factors

Studies assessing risk factors for moderate-to-severe postoperative pain after PCNL have noted several independent risk factors associated with postoperative discomfort following PCNL including renal calculus diameter, number of renal calculi, occurrence of remaining calculi, and operation duration. Further studies have corroborated this evidence and it is now well established that increased procedure time in a PCNL significantly increases the risk for any post-surgery complication at any grade of the Clavien-Dindo classification, and therefore can increase postoperative pain.^{13,15,16,17}

Beyond decreasing surgical time, reducing size of the percutaneous tract (miniperc or small-bore PCNL) or skipping the implantation of a nephrostomy tube entirely (tubeless PCNL) may assist in reducing postoperative pain ratings.¹⁴

CURRENT PAIN REGIMENS AFTER PCNL

1. Tubeless PCNL

Using small diameter catheters after PCNL leads to decreased pain levels in the initial postoperative phase. Furthermore, there is a need for less analgesic needs. Meta-analyses comparing tubeless PCNL to regular PCNL found that tubeless PCNL resulted in reduced postoperative discomfort. However, tubeless or entirely tubeless PCNL may increase the risk of

postoperative infection complexity. Tubeless PCNL should be done selectively and is not generally used in clinical practice.^{18,19,20}

2. Analgesics

Analgesics, like nonsteroidal anti-inflammatory medications and opioids, have adverse actions and restrictions for individuals with renal disorder.²¹

Opioid analgesics are commonly administered to manage postoperative pain; however, these medications can have unwanted side effects. The opioid crisis is a concern resulting from the widespread use of opioids for a variety of reasons. Opioids are excellent analgesics for surgical pain, but their usage perioperatively may result in ileus, nausea, vomiting, drowsiness, opioid dependence, respiratory depression, and opioid-induced hyperalgesia, which is described as an aggravation of pain despite the administration of large doses of opioids.²²

Nonsteroidal anti-inflammatory medications are used to control postoperative pain as well. However, this group of medications can negatively affect renal function by resulting in acute kidney injury, chronic kidney disease, glomerulonephritis, renal papillary necrosis, fluid retention-induced hypertension, renal tubular acidosis, hyponatremia, and hyperkalemia. 2.5 million Americans annually experience renal complications directly related to the use of nonsteroidal anti-inflammatory medication.²³

When opioids and nonsteroidal anti-inflammatory medications have been compared in clinical trials, there has not been a significant difference in pain scores, adverse side effects, or quality of life post PCNL. It was shown that when treated perioperatively with nonsteroidal anti-inflammatory medication instead of opioids, patients had a significantly shorter hospitalization post-surgery.^{24,25}

3. Paracetamol

The adverse effects of opioids might be avoided by using multimodal analgesics or a mixture of lower dosages of opioid analgesics with non-opioid analgesics. Several studies have shown that acetaminophen, with and without opioid, is effective in the treatment of postoperative pain.^{26,27} The favorable efficacy of intravenous paracetamol as part of a multimodal analgesic regimen for postoperative pain control after PCNL has been described. Six and twenty-four hours postoperatively, patients who received 1 g intravenous paracetamol had substantially lower visual analog scores than those who received placebo.²⁸

4. Local anesthetic infiltration

Regional anesthetic treatments provide an alternative for postoperative pain control following PCNL. Several urologists are using the percutaneous injection of local anesthetic for pain treatment, however, the effectiveness of local anesthetic infiltration surrounding the nephrostomy tract for postoperative pain management remains debatable.²⁹

Previous investigations of general surgery, gynecology, and anesthesia including cesarean sections, hysterectomy, mastectomy, thyroid surgery, cervical spine surgery, and total-

hip arthroplasty using bupivacaine as anesthetic agent demonstrated an advantage. The greatest advantage of bupivacaine infiltration appears to be achieved when done before the incision.³⁰ The impact of local anesthetic infiltration at the incision site (subcutaneous) during PCNL with 10 Fr nephrostomy tube was compared to saline infiltration. No variations between groups were seen with regards to pain levels or postoperative opioid usage. Studies investigating local anesthetic have been limited by small sample size and limited interpretability.³¹

5. Regional techniques

A multimodal approach utilizing localized techniques and nonopioid drugs is favored for postoperative analgesia to reduce unwanted effects related to opioids.³²

Regional analgesia is a crucial component of effective postoperative pain treatment because it reduces the need for opioids, which are associated negative effects including nausea, vomiting, respiratory depression, and delay of bowel function. Trends in postoperative pain treatment have shifted from epidural analgesia to newer regional blocks which may be easier to administer and have fewer associated risks.³³

The choice of anesthetic method relies on patient and physician preference, the technique's viability in a specific patient, the expertise of the anesthesiologists, and cost. Anesthetic options for PCNL include general anesthesia, spinal anesthesia, epidural anesthesia, and several regional blocks.³⁴

General anesthesia has a greater incidence of complications and higher costs than regional anesthesia. Data comparing general anesthesia to mixed spinal epidural anesthesia show that spinal anesthesia is less complicated, less time-consuming, less costly, and results in shorter hospital stays. Epidural anesthesia necessitates the use of a qualified anesthesiologist but offers the benefit of extending the duration of anesthesia. Epidurals have the added benefit of facilitating postoperative analgesia.³⁵

Epidural block anesthesia

In this procedure, a Tuohy needle is introduced through a paramedian route, and the epidural space is verified through the absence of air resistance. The epidural catheter is placed and secured 4 cm inside the T10-T11 region. A test dosage is administered with 3 cc of 2% lignocaine, and further doses were administered proportionally to attain T-6 sensory level.³⁶

After obtaining a satisfactory sensory level, the patient is positioned prone and an epidural infusion of 0.25 percent bupivacaine at a rate of 5ml/hr is initiated. For postoperative analgesia, epidural buprenorphine 60-90 mcg is administered every 12 hours after surgery. Epidural catheters are removed on the second day following epidural.³⁷

Segmental epidural anesthesia

Segmental epidural anesthesia (SEA) specifically blocks pain fibers from the surgical site, allowing for a lower anesthetic dosage while maintaining restricted motor and sympathetic blocking. Respiratory, cardiac, gastrointestinal, and metabolic advantages are associated with selective sympathetic blockade.³⁸

Transversus abdominis plane block

When the 7th to 11th intercostal nerves (T7–T11) are blocked by transversus abdominis plane (TAP) block, the subcostal nerve, the ilioinguinal nerve, and the iliohypogastric nerve (L1–L2) are all relieved of pain.³²

With improvements and incorporation of ultrasonography into anesthetic procedures, intervention sites have shifted. Hebbard described the subcostal TAP block, which has been mostly used for upper abdominal procedures. TAP block is beneficial for abdominal skin, muscle, and parietal peritoneum discomfort, but it is ineffective for visceral pain.^{32,39}

This procedure is conducted on the ipsilateral side of the kidney stone. The linear ultrasound probe is positioned beneath the costal border between the xyphoid and rectus abdominis, and the external oblique, internal oblique, and transversus abdominis muscles are identified.⁴⁰

One ml of saline solution diluted to 0.9% is injected to highlight the needle's position. The region between the transversus abdominis and internal oblique muscle fascia receives a 20-ml injection of bupivacaine 0.0125 percent.

Quadratus lumborum block III for postoperative pain after PCNL

Blanco was the first to describe a quadratus lumborum block (QLB) guided by ultrasonography (US) for control of postoperative pain after abdominal surgery. By developing the Shamrock sign, Sauter et al introduced a unique lumbar plexus block approach. Using the Shamrock sign, the transmuscular quadratus lumborum block was delineated.^{42,43} In the original technique defined by Blanco, the local anesthetic (LA) was injected into the anterolateral margin of the quadratus lumborum (QL) muscle. However, in the transmuscular quadratus lumborum block (QLB III), LA is injected between the QL and psoas major (PM) muscles under ultrasound guidance. It has been found that QLB is effective for peri-operative analgesia in pyeloplasty procedures.⁴⁴

Using a 26-gauge pencil spinal needle in the L3–L4 or L4–L5 intervertebral region, patients receive 15 mg hyperbaric bupivacaine and 20 g fentanyl as spinal anesthetic. Patients are positioned in the semi-lateral posture such that the kidney undergoing QLB is in an inverted position. In accordance with surgical sterilizing guidelines, the convex probe is moved upward until the three-walled muscle can be viewed. The probe is moved in a posterolateral direction till the hook indication is noticed. The Shamrock sign is identified by using the processus lateralis of the spine as a marker, and anesthetic is delivered between the QL and the PM by hydro dissection with a transmuscular technique.³⁰

Erector spinae plane block

One of the first regional anesthesia methods to be utilized for the relief of chronic thoracic neuropathic pain was the erector spinae plane block (ESPB). ESPB is a readily administered block with little adverse effect and has shown to be beneficial for postoperative pain control following PCNL. Studies measuring pain using a dynamic visual analog scale (DVAS) in

patients who underwent PCNL after ESPB have demonstrated a relationship between postoperative pain and peak expiratory flow rate (PEFR).⁴⁵

ESPB lowers postoperative 24-hour morphine consumption and intraoperative fentanyl, and numerical rating scale (NRS) ratings were considerably reduced at the second and twelfth hours in the ESPB group. Randomized controlled trials comparing the administration of ESPB with standard intravenous analgesia following PCNL surgery has shown ESPB to be more effective. Studies have demonstrated that pain ratings in the first 24 hours were considerably minor in ESPB groups, that the period of initial analgesic usage was lengthened, and that total tramadol and paracetamol intake reduced.⁴⁶

Meta-analyses have corroborated these findings showing better short time (1-2 hours) and long time (24 hours) pain control based on visual analog scale, less fentanyl/tramadol/paracetamol use, and longer time to first rescue analgesic.⁴⁷ Before inducing general anesthesia, the block is accomplished using ultrasonography with a linear probe. After cleansing the skin, ESPB is conducted at the T11 level using the in-plane approach with the patient positioned in the prone position. Before the procedure, 3 ml of 2% lidocaine is given to the patient's skin topically.⁴⁸

In the in-plane approach, a 21G 100 mm insulated needle is introduced in the cranial-caudal direction till contact with the T11 transverse protrusion. A 15 ml saline solution was used for hydrodissection. Then, as a local anesthetic, 15 ml of 0.5 percent bupivacaine is administered. The needle tip placement is validated by withdrawing the erector spinae muscle from the transverse process bone shadow and monitoring the local anesthetic dispersion in cranial and caudal directions.⁴⁹

Paravertebral block

Paravertebral blocks (PVB) have classically been used in thoracic and breast surgery; however, they are becoming increasingly popular in renal surgery. Though the technique is relatively new, studies have shown paravertebral blocks to be reproducible, reliable, and safe. To perform a paravertebral block, local anesthetic is injected into both sides of the vertebral body near the spinal nerve roots out of the intravertebral foramen. The goal is to achieve analgesic by blocking the paravertebral spinal nerve. Meta-analyses have demonstrated that PVB for management of PCNL pain results in reduced postoperative analgesic consumption and use of additional analgesics, prolonged time to first analgesic, and reduced 24-hour postoperative opioid consumption.⁵⁰

CONCLUSIONS

A goal of appropriate postoperative pain management following PCNL is the reduction of morbidity and mortality and attenuation of the physiological stress response provoked by surgery. The combination of surgical and anesthetic strategies can optimize pain management and facilitate improved outcomes with minimized pain scores, fewer pain-related complications, and decreased incidence of chronic pain.

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FIGURES AND TABLES

Technique	Pros	Cons
Tubeless PCNL	Intraoperative, urology led intervention Lower postoperative opioid consumption	May increase postoperative infection Patient selection important
Opioid analgesics	Commonly used	Ongoing opioid crisis Negative side effects (ileus, nausea/vomiting, constipation, etc.)
Paracetamol	Lower postoperative opioid consumption Effective in multimodal management of postoperative pain	Potentially expensive
Local anesthetic infiltration	Intraoperative, urology led intervention	Questionable effectiveness

PCNL: percutaneous nephrolithotomy.

Technique	Injection site	Analgesic coverage	Pros	Cons
Epidural block	Epidural space inside the T10-T11 region	Below T6 sensory level	Provide true anesthesia Allow patient movement (as compared to spinal block) Long lasting	Back pain Hypotension Urinary retention Require postoperative anesthesia management
Transversus abdominis plane (TAP) block	Between internal oblique and transvers abdominis muscle	Abdominal wall	Simple technique Applicable to multiple locations	No effect on visceral pain
Quadratus lumborum block	Between quadratus lumborum and psoas major	Abdominal wall	Somatic and visceral anesthesia	May be more technically challenging

Erector spinae plane block	Between the erector spinae muscle and thoracic transverse processes	Abdominal wall	Somatic and visceral anesthesia	May be more technically challenging
Paravertebral block	Both sides of vertebral body near spinal nerve roots out of intravertebral foramen	Abdominal wall	Somatic and sympathetic anesthesia	May be more technically challenging

PCNL: percutaneous nephrolithotomy.

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