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RESEARCH

Comparative outcomes and cost of ambulatory PCNL in select kidney stone patients

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Abstract

Limited hospital resources and access to care during the COVID-19 pandemic led us to implement a quality-improvement study investigating the feasibility, safety, and costs of same-day discharge after PCNL. The outcomes of 53 consecutive first-look PCNL patients included in a same-day discharge protocol during COVID-19 were compared to 54 first-look PCNL patients admitted for overnight observation. Control group had a similar comorbidity profile. Demographics, operative details, 30 day outcomes and readmissions, complications, and cost were compared between the two groups. Same-day discharge and one-day admission post-PCNL patients did not have significantly different baseline characteristics. The study group were more likely to have mini-PCNL (81% vs 50%, $p < 0.01$). Operative characteristics including median pre-operative stone burden (1.4 vs 1.7 cm^3, $p = 0.47$) and post-operative stone burden (0.14 vs 0.18 cm^3, $p = 0.061$) were similar between the two groups. Clavien–Dindo complication rates were lower in the study group compared to controls (0 vs 7%, $p = 0.045$). Readmission rates (2 vs 4%, $p = 0.569$) and ED visits (4 vs 6%, $p = 0.662$) were similar between the two groups. Total cost ($6,648.92 vs $9,466.07, $p < 0.01$) was significantly lower and operating margin ($4,475.96 vs $1,742.16, $p < 0.01$) was significantly higher for the same-day discharge group. Percutaneous nephrolithotomy may be performed in select patients without an increase in short-term complications, ED visits, or readmissions. Patients undergoing mini-PCNL are particularly amenable to same-day discharge, however, standard PCNL patients should not be excluded from consideration. Avoiding overnight admission decreases total cost and increased hospital operating margin.

Keywords Percutaneous nephrolithotomy · Cost · Ambulatory surgery · Nephrolithiasis · Outcomes

Introduction

Nephrolithiasis is the most common genitourinary condition, with an estimated incidence of 600,000 people in the United States, yearly. Surgical treatment options depend on location and size of stone burden. Percutaneous nephrolithotomy (PCNL) remains the treatment of choice for large renal stone burden > 2 cm [1]. Traditionally, patients were admitted for observation after PCNL to monitor for signs and symptoms of complications including systemic inflammatory response syndrome (SIRS), hemorrhage, visceral or pleural injury, among others. An international, multi-center study of almost 6000 patients using the Clinical Research of the Endourological Society (CROES) database demonstrated an overall complication rate of 21.5% after PCNL, however, almost 80% of these complications were Clavien grade 1 or 2 complications [2]. With technologic advancements and increasing experience, rates of hemorrhage are reportedly less than 2% and rates of sepsis range from 0 to

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3%. Other complications including hollow visceral injury (0.2–1%), pleural injury (0.3–1%), renal collecting system injury (up to 8%), and death (0.1–0.7%) are also uncommon and as such post-operative admission after PCNL may be unnecessary for all patients [3].

During the COVID-19 pandemic, hospital census rose rapidly at our institution necessitating that surgical patients requiring admission be triaged according to urgency. The need for resource consolidation during the pandemic led us to reconsider our standard practice of post-operative admission after PCNL. Although PCNL is typically considered an elective surgery, patients requiring this procedure often represent a high-risk population with multiple comorbidities. As such, delaying definitive management for such patients puts them at risk for significant morbidity. To mitigate the risks of delayed care for our patients in need of PCNL during the pandemic, we implemented a same-day discharge protocol as part of a quality improvement study aimed at conserving hospital resources and improving access to care. We hypothesized that we would be able to safely discharge a significant proportion of patients the same day after PCNL while maintaining equivalent post-operative complication and readmission rates relative to a standard one-day admission. We also explored differences in cost between same-day and admitted PCNL patients, as cost is a critical factor for continued implementation of our protocol.

Materials and methods

Patient selection

Following Institutional Review Board approval, we retrospectively collected data on all consecutive patients undergoing first-look PCNL, either conventional PCNL (cPCNL) or miniature PCNL (mPCNL), performed by a single surgeon at our institution from July 2019 to March 2021. We then divided these patients into two groups: those who underwent PCNL performed according to standard procedure with 23 h observation from July 2019 to May 2020 and those who underwent PCNL with same-day discharge from June 2020 to March 2021.

Patients were excluded from this study for the following reasons: (1) positive pre-operative urine culture 2 weeks prior to procedure, (2) history of ≥ 2 episodes of pyelonephritis 6 months prior to procedure, (3) history of admission for urosepsis 6 months prior to procedure, (4) history of lower urinary tract diversion, (5) patients requiring baseline ventilatory or cardiac support, (6) patients with history of neurogenic bladder secondary to spinal cord injury and associated recurrent urinary tract infections, (7) debilitating neurologic conditions or severely limited baseline mobility. Exclusion criteria are listed in Table 3. Notably, no pre-operative stone burden cutoff was used.

Operative technique

Details regarding our operative technique are outlined in a previous publication [4]. Briefly, with the patient in prone position, we begin by instilling contrast through an open-ended ureteral catheter placed previously via supine flexible cystoscopy. Percutaneous access is gained with fluoroscopy at 30 degrees angle away from the target calyx or with ultrasound guided access [5]. Conventional PCNL is defined as dilating the percutaneous tract to 30 Fr using a balloon-dilator or, in selected cases, sequential metal dilators and then performing stone fragmentation using dual ultrasound lithotripsy (Olympus ShockPulse®). Complimentary flexible nephroscopy with Ho-YAG or Thulium fiber lithotripsy was employed as needed. mPCNL is performed by dilating the percutaneous tract to either 16.5 Fr using a minimally invasive percutaneous access set (Karl Storz Endoscopy®) or to 16 or 18 Fr when using a disposable percutaneous sheath with suction attachment (Wellead Clear-Petra®). Lithotripsy is completed using a 12 Fr rigid nephroscope and Ho:YAG or Thulium fiber laser; an 8.5–10.5 Fr flexible ureteroscope or 16 Fr flexible cystoscope may also be utilized for complimentary nephoscopy and lithotripsy as needed.

Post-operative protocol

Patients in the standard protocol group were admitted to the hospital outpatient observation unit post-operatively. They were rounded on by the surgical team the evening of their surgery and the morning after. Patients in the same-day discharge group were observed in the post-anesthesia care unit (PACU) with a foley catheter in place and evaluated 60–90 min post-operatively by the surgical team. Vital signs were reviewed and a physical exam was performed. The patient was also interviewed to assess their overall readiness for discharge. Patients were considered safe for discharge if they were awake and alert, without signs of sepsis or hemorrhage/evidence of significant bleeding through the urethral catheter, adequately controlled pain, were tolerating intake *per os*, and were at their baseline mobility. Patients were discharged only if a plan was in place for them to reach home safely and have a level of care available consistent with their baseline health needs. Patients with nephrostomy tubes were scheduled to present to our clinic 24–48 h after surgery for tube removal and those with stents in 1–2 weeks with a low-dose CT scan prior to removal. If the procedure was tubeless, patients followed up at 4 weeks with a CT scan. No second look or additional procedures were performed during the same hospital stay. All patients were managed with intravenous pain medications in PACU until able

Table 1 Demographics, pre-operative stone burden and operative details

	One-day admission	Same-day discharge	*p* value
Number of patients	54	53	
Age (years), mean, SD	59 (13)	59 (14)	0.9794
BMI (kg/m^2), mean, SD	31 (7.2)	32 (7.4)	0.8163
ASA score, median (IQR)	3 (2–3)	3 (2–3)	0.165
Charlson Comorbidity Index, median, IQR	2 (1–3)	3 (1–4)	0.3382
% male patients	41%	62%	**0.0259**
% right-sided surgery	54%	26%	**0.004**
% mini-PCNL	50%	81%	**0.0007**
Operating room time (min), mean, SD	86 (33)	94 (31)	0.1992
Fluoroscopy time (s), mean, SD	265 (142)	222 (108)	0.1815
Pre-operative stone volume (cm^3), median, IQR	1.4 (0.7–2.5)	1.7 (1.1–2.6)	0.47

Bold values represent those findings that meet thresholdvalues for statistical significance

BMI body mass index, *ASA* American Society of Anesthesiologists

to tolerate oral pain medications. At this point 1000 mg oral acetaminophen was scheduled every 6 h and low-dose narcotics were provided on an as needed basis. At discharge, 3 days of low-dose narcotics were given to take as needed.

Data collection and analysis

Data for all patients were collected retrospectively. We used the electronic medical record to collect demographics, American Society of Anesthesiologists [ASA] score, Charlson comorbidity index [CCI], stone characteristics and operative details for each patient. Total initial stone volume was obtained from preoperative CT scan, and total residual stone volume was calculated from the CT scan performed between postoperative day one and 30. 3D volumetry was performed using open-source software capable of 3D rendering and segmentation of medical imaging (3D Slicer). Volumes were rendered from density-based segmentation of CT scan study using a cutoff of 127 HU to exclude noise from the surrounding tissue to prevent false volumetric information but including all the content inside the stone [6].

The primary outcomes measured were 30-day complications, emergency department (ED) visits, and readmissions. Other outcomes measured included pre- and post-operative stone burden, percent reduction in stone volume and costs of care.

Cost data were collected using software developed by Strata Decision Technology® 2021 and is divided into categories as listed in Table 2. Direct costs refer those costs incurred by the departments involved in the care being delivered that is specific to the patient's encounter. Indirect costs refer to the overhead departments required for running the hospital. Direct costs included perioperative costs (OR supplies, OR time, anesthesia and PACU-related costs), and non-operative costs (such as for care delivered on an inpatient unit). Operating margin was calculated by subtracting total costs from total revenues and represents the net pay to the hospital system.

We compared all data between groups discharged the same day vs. those admitted. Statistical analysis was done using t-test for nominal variables and chi square or Fisher's exact tests for categorical variables by the IBM® Statistical

Table 2 Cost data (USD)

	One-day admission	Same-day discharge	*p* value
Complication (any)	7%	0%	**0.0454**
30 day ER visit	6%	4%	0.6624
30 day readmission	4%	2%	0.5692
Postoperative stone volume (cm^3), mean, SD	0.18 (0.07)	0.14 (0.06)	0.0605
Total Cost (Direct + Indirect) ($), mean, SD	$9,466.07 ($1477.03)	$6,648.92 ($1,278.30)	**<0.01**
Direct Cost ($), mean, SD	$5,682.70 ($933.80)	$4,316.90 ($856.25)	**<0.01**
OR Cost ($), mean, SD	$472.30 ($56.16)	$317.09 ($29.90)	**<0.01**
OR supply cost ($), mean, SD	$1,483.14 ($397.68)	$1,632.22 ($639.30)	0.1102
PACU cost ($), mean, SD	$233.50 ($59.82)	$237.43 ($85.94)	0.30
Other direct costs ($), mean, SD	$3,413.75 ($811.99)	$2,076.25 ($702.98)	**<0.01**
Operating margin ($), mean, SD	$1,742.16 ($710.12)	$4,475.96 ($679.73)	**0.0108**

Post-operative complications recorded using Clavien–Dindo classification

Bold values represent those findings that meet thresholdvalues for statistical significance

Package for the Social Sciences (SPSS) version 20 (Armonk, New York).

Results

Patient demographics, stone characteristics, and operative details are listed in Table 1. A total of 107 carefully selected patients underwent first-look PCNL were included in this study. 54 patients were in the standard admission group and 53 patients were in the same day discharge group. No patients in the standard admission group required more than 1 day of post-operative observation. The two groups did not differ in mean age, BMI, ASA score, CCI, or median preoperative stone burden ($p > 0.05$). There was also no significant difference between time spent in the operating room and total fluoroscopy time between the two groups ($p > 0.05$). Patients discharged on the day of surgery were more likely to have undergone mPCNL than cPCNL (81 vs 50%, $p < 0.01$).

Complications and cost data can be found in Table 2. There were significantly fewer 30-day complications (0 vs 7%, $p = 0.045$) in the same-day discharge group. Emergency department visits (4 vs 6%, $p = 0.662$), readmissions (2 vs 4%, $p = 0.569$), and post-operative stone volume (0.14 vs 0.18 cm^3, $p = 0.061$) did not vary significantly between the two groups. Total cost was significantly lower in the same day discharge group ($6,649 vs $9,466, $p < 0.01$). This was primarily driven by lower direct costs ($4,316 vs $5,683 $p < 0.01$). OR Supply ($1,632 vs $1,483, $p = 0.31$) and PACU costs ($237 vs $234, $p = 0.31$) were not significantly different. Hospital operating margin was also greater in the same day discharge group ($4,475 vs $1742, $p < 0.01$).

Discussion

During the COVID-19 pandemic, opportunities to perform inpatient surgery at our institution were curtailed. Thus, we developed and successfully implemented a quality improvement protocol, transitioning from routine postoperative admission to routine same-day discharge of carefully selected patients undergoing PCNL. This transition occurred almost overnight, without any increase in rates of postoperative complications, readmissions, or ED visits between the two groups (Table 2). Given that surgical technique remained the same, we observed an equivalent reduction in stone burden. Additionally, we found a significant decrease in total cost and increase in operating margin in the same day discharge group which is likely related to the diminished need for hospital bed occupancy.

Despite PCNL first being demonstrated in the ambulatory setting over 3 decades ago, it is still performed as an inpatient procedure in all but a few settings [7]. Historically, the rationale for overnight observation has been to monitor for risk of hemorrhage and sepsis. Both systematic reviews and large case series, however, have shown rates of complications after PCNL to be low at high-volume centers [8, 9]. With this understanding, multiple studies from high-volume centers have attempted ambulatory PCNL [10–15]. While these studies have reported safe and successful implementation of ambulatory PCNL, widespread implementation has not followed, likely due to regional differences in practice patterns and surgical technique, which make it harder to generalize their findings.

In the United States, our study is one of the largest comparative series to date examining inpatient versus outpatient PCNL presented in a quality improvement study ($n = 107$). Only 2 observational studies have been done in a comparable number of patients, both of which used conventional PCNL exclusively (30fr) and only 1 of which included higher risk patients [16, 17]. Of all 53 selected patients who consecutively underwent first-look PCNL in our *study group*, 53 (100%) were able to be discharged home the same day. Similarly, Bechis et al. excluded patients based primarily on baseline medical comorbidities necessitating extensive nursing and were able to successfully discharge 43/60 (72%) of the patients designated as ambulatory [16]. Shoenfeld et al. were able to discharge 47/52 (90%) of their patients same-day but included only patients with ASA < 3 [13]. While this rate of same-day discharge is exceedingly high, it is critical to remember that these patients all met inclusion criteria listed in Table 3 and were counselled appropriately in the pre-operative setting.

In their outpatient PCNL cohort patients who underwent conventional PCNL, Bechis et al. observed an 18% 30 day ED visit rate and 10% 30-day readmission rate for patients discharged the same day. Another recent study from the same group in which mPCNL was used exclusively and 37/60 (61%) were done as outpatient, the 30 day ED-visit and readmission rates were 21.7 and 18%, respectively. They experienced a 30-day complication rate of 17%, however, no complications were greater than Clavien 2 [18]. In our cohort of patients discharged the same day, 30-day rates of

Table 3 Exclusion criteria for same-day discharge

Exclusion criteria
Positive pre-operative urine culture 2 weeks prior to procedure
History of ≥2 episodes of pyelonephritis 6 months prior to procedure
History of admission for urosepsis 6 months prior to procedure
History of lower urinary tract diversion
Patients requiring baseline ventilatory or cardiac support
Patients with history of neurogenic bladder secondary to spinal cord injury and associated recurrent urinary tract infections
Debilitating neurologic conditions or severely limited baseline mobility

complications (0%), ED-visits (4%) and readmissions (2%) were similarly low and either equivalent to or better than the outcomes of those patients who were admitted. Outpatient PCNL has perhaps been best described by Beiko et al., who began developing their protocol in 2010 and have since arrived at an acceptable readmission rate, noting that complications almost never would have been avoided had the patient been admitted [10, 19, 20].

Our minimally invasive PCNL technique likely played an important role in successful same-day discharge of our patients. Of patients who went home the same day, 43 (81.1%) were done using either a 16fr or 18fr tract and only 3 (6%) had a nephrostomy tube placed. Prior studies have shown that mPCNL results in decreased blood loss and rates of transfusion compared to conventional PCNL techniques [4, 21]. While the concern has been raised by some that prolonged operative time and potentially elevated intrarenal pressures could lead to higher rates of sepsis with mPCNL, when done with the appropriated surgical technique using low intrarenal pressure, there appears to be no increased morbidity when compared to conventions PCNL in our experience [4]. Rather, patients who went home same-day experienced no complications and with no significant differences in operative time (Tables 1 and 2). In our subjective experience, smaller bore sheaths allow for greater maneuverability without causing tissue trauma or compromising visibility. In addition, we used a disposable access sheath with a suction extension to facilitate stone fragment extraction, which may be less traumatic and less time consuming than relying on basketing to remove fragments. The pre- and post-operative stone burden within the two groups were not significantly different indicating equally efficacious treatment, however, a more detailed analysis regarding the significance of residual stone burden is beyond the scope of this study. While 80% of patients in the same-day discharge group received mini-PCNL, we believe that with improved laser technology and mini-PCNL suction sheaths, mini-PCNL may be implemented where standard PCNL was previously required.

Traditionally, nephrostomy tube placement has been used both to monitor for hemorrhage postoperatively and to provide tamponade to the access tract. As evidenced by multiple large studies, however, routine placement of nephrostomy tube is not necessary most patients and can lead to worsened pain and quality of life [22–24]. At our institution, we place nephrostomy tubes at the end of the procedure only for clear indications such as concerns for bleeding, infection or potential need for a second look.

Our study is the first to compare the cost of outpatient PCNL relative to inpatient PCNL in the US. Prior studies have assessed many factors that affect cost of PCNL, but none have specifically studied cost relating to outpatient PCNL [25]. We found a significant decrease in total cost when discharging patients undergoing PCNL with same day discharge versus those admitted for observation. This is reflected in the decrease in direct costs. Operating room related costs were not significantly different between the two groups which is not surprising given OR time was similar. Conversely, PACU related costs were surprisingly no different between the two groups. Given our protocol entailed a longer than standard PACU dwell, similar costs between the two groups implies that our protocol does not incur greater hospital expenditure for post-operative monitoring. Additionally, we noted a significant increase in operating margin for same-day discharge patients which we believe is largely driven by decrease in requirement for inpatient stay.

This study has several limitations. First, this is a retrospective study and is therefore subject to a lack of standardization between groups as well as biases inherent to retrospective data collection such as more frequent selection for mPCNL for same day discharge group. Secondly, our criteria for admission are somewhat subjective and may benefit in the future from stricter protocolization. Despite these limitations, we believe that our study suggests that appropriately selected patients can be safely discharged on the same day following PCNL while improving operating margins. Larger, prospective randomized trials are warranted to define parameters for admissions in patients undergoing PCNL.

Ultimately, in this study we show that a large portion of selected patients undergoing PCNL can be safely discharged on the day of surgery after a 60–90 min observation period, without increased short-term post-op complications, ED visits, or hospital readmissions. Patients undergoing mPCNL may be especially amenable to same-day discharge. At our institution, outpatient PCNL is associated with a significant increase in operating margins, which is likely driven by the cost of overnight admission.

Author contributions P.T., P.M., and J.G. conceptualized the project, P.T. and G.C. collected data, P.T. and R.D. completed statistical analysis and prepared tables 1-3 and P.T. and P.M. prepared the manuscript. All authors reviewed the manuscript.

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Declarations

Competing interests The authors declare no competing interests.

Conflict of interest J.G. is a consultant for Olympus Corporation of the Americas, Cook Medical and Zhuhai Pusen Medical Technology Co. P.T., P.M., R.D., and G.C. have no conflicts of interest to declare.

References

1. Assimos D, Krambeck A, Miller NL, Monga M, Murad MH, Nelson CP et al (2009) Surgical management of stones: American urological association/endourological society guideline, PART 1. J Urol 196:1153–1160. https://doi.org/10.1016/j.juro.2016.05.090

2. de la Rosette J, Assimos D, Desai M, Gutierrez J, Lingeman J, Scarpa R, Tefekli A, CROES PCNL Study Group (2011) The clinical research office of the endourological society percutaneous nephrolithotomy global study: indications, complications, and outcomes in 5803 patients. J Endourol 25:11. https://doi.org/10.1089/end.2010.0424
3. Taylor E, Miller J, Chi T, Stoller ML (2012) Complications associated with percutaneous nephrolithotomy. Trans Androl Urol 1:223–228. https://doi.org/10.3978/j.issn.2223-4683.2012.12.01
4. Lange JN, Gutierrez-Aceves J (2018) Comparative outcomes of convential and miniature percutaneous nephrostolithotomy for the treatment of kidney stones- does a miniaturized tract improved quality of care? Urology Practice 5:205–209. https://doi.org/10.1016/j.urpr.2017.04.003
5. Mues E, Gutierrez-Aceves J, Loske AM (2007) Percutaneous renal access: a simplified approach. J Endourol 21:1271–1275. https://doi.org/10.1089/end.2007.9887
6. Jendeberg J, Geijer H, Alshamari M, Lidén M (2018) Prediction of spontaneous ureteral stone passage: automated 3D-measurements perform equal to radiologists, and linear measurements equal to volumetric. Eur Radiol 28(6):2474–2483. https://doi.org/10.1007/s00330-017-5242-9
7. Preminger GM, Clayman RV, Curry T, Redman HC, Peters PC (1986) Outpatient percutaneous nephrostolithotomy. J Urol 136:355–357. https://doi.org/10.1016/s0022-5347(17)44867-1
8. Seitz C, Desai M, Hacker A, Hakenberg OW, Laitsikos E, Nagele U et al (2012) Incidence, prevention, and management of complications following percutaneous nephrolithopaxy. Eur Urol 61:146–148. https://doi.org/10.1016/j.eururo.2011.09.016
9. Emmott AS, Brotherhood HL, Paterson RF, Lange D, Chew BH (2018) Complications, Re-Intervention rates, and natural history of residual stone fragments after nephrolithotomy. J Endourol 32:28–32. https://doi.org/10.1089/end.2017.0618
10. Beiko D, Lee L (2010) Outpatient tubeless percutaneous nephrolithotomy: the initial case series. Can Urol Association J 4:E86-90. https://doi.org/10.5489/cuaj.886
11. Sharour W, Andonian S (2010) Ambulatory percutaneously nephrolithotomy: initially series. Urology 76:1288–1292. https://doi.org/10.1016/j.urology.2010.08.001
12. Fahmey A, Rashad M, Algebaly O, Sameh W (2017) Can percutaneous nephrolithotomy be performed as an outpatient procedure? Arab. J Urol 15:1–6. https://doi.org/10.1016/j.aju.2016.11.006
13. El-Tabey MA, Abd-Allah OAW, Ahmed AS, El-Barky EM, Noureldin YAS (2013) Preliminary study of percutaneous nephrolithotomy on an ambulatory basis. Curr Urol 7:117–121. https://doi.org/10.1159/000356261
14. Singh I, Kumar A, Kumar P (2005) "Ambulatory PCNL" (tubeless PCNL under regional anesthesia) – a preliminary report of 10 cases. Int Urol Nephrol 37:35–37. https://doi.org/10.1007/s11255-004-6706-9
15. Wu X (2020) Day Surgery percutaneous nephrolithotomy: a high-volume center retrospective experience. World J Urol 38:1323–1328. https://doi.org/10.1007/s00345-019-02942-0
16. Schoenfeld D, Zhou T, Stern JM (2019) Outcomes for patients undergoing ambulatory percutaneous nephrolithotomy. J Endourol 33:189–193. https://doi.org/10.1089/end.2018.0579
17. Bechis SK (2018) Outpatient percutaneous nephrolithotomy: the UC San Diego Health Experience. J Endourol 32:394–401. https://doi.org/10.1089/end.2018.0056
18. Holst DD, Bechis SK, Zupkas P, Zupkas R, Dipina T, Flores A et al (2001) Minimally Invasive Percutaneous nephrolithotomy: initially north American experience. J Endourol 35:596–600. https://doi.org/10.1089/end.2020.0574
19. Beiko D, Elkoushy MA, Kokorovic A, Roberts G, Robb S, Andonian S (2015) Ambulatory percutaneous nephrolithotomy: what is the rate of readmission. J Endourol 29:410–414. https://doi.org/10.1089/end.2020.0574
20. Wang J, Zhang C, Tan D, Tan G, Yang B, Chen W et al (2016) The effect of local anesthetic infiltration around nephrostomy tract on post operative pain control after percutaneous nephrolithotomy a systematic review and meta-analysis. Urol Int 97:125–133. https://doi.org/10.1159/000447306
21. Feng D, Hu X, Tang Y, Han P, Wei X (2020) The efficacy and safety of miniaturized percutaneous nephrolithotomy versus standard percutaneous nephrolithotomy: a systemic review and meta-analysis of randomized controlled trials. Investig Clin Urol 61:115–126. https://doi.org/10.4111/icu.2020.61.2.115
22. Beiko D, Andonian S (2015) Getting started with ambulatory PCNL: a Can MEDS perspective. Can Urol Assoc J 9:223–225. https://doi.org/10.5489/cuaj.3198
23. Choi SW, Choi KS, Kim JH, Park YH, Bae WJ, Hong SH et al (2014) Totally tubeless versus standard percutaneous nephrolithotomy for renal stones: analysis of clinical outcomes and cost. J Endourol 28:1487–1494. https://doi.org/10.1089/end.2014.0421
24. Li Q, Gao L, Li J, Zhang Y, Jiang Q (2012) Totally tubeless versus standard percutaneous nephrolithotomy: a meta-analysis. J Endourol 27:420–426. https://doi.org/10.1089/end.2012.0421
25. Leow JJ, Valiquette AS, Chung BI, Chang SL, Trinh QD, Korets R et al (2018) Cost variations for percutaneous nephrolithotomy in the US from 2003–2015: a contemporary analysis of an all-payer discharge database. Can Urol Assoc J 12:407–414. https://doi.org/10.5489/cuaj.5280