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REVIEW: A Functional Approach to Drainage Selection After Percutaneous Nephrolithotomy: A Narrative Review

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ABSTRACT

Postoperative drainage influences recovery after percutaneous nephrolithotomy (PCNL). This narrative review compares nephrostomy, internal ureteral stenting, short-term externalized ureteral catheterization, and totally tubeless strategies to inform drainage selection.

Targeted searches of accessible scholarly records, publisher websites, and guidelines were undertaken through 12 September 2026, with reference-list checking. Randomized trials, systematic reviews, and relevant observational studies were prioritized. No new meta-analysis was performed.

Shorter hospitalization is the most consistent benefit of avoiding nephrostomy in selected patients. Pain outcomes vary with the comparator and assessment time. Evidence for sepsis, major hemorrhage, and readmission remains insufficient to establish equivalence across patient groups. Externalized ureteral catheters may reduce stent-related symptoms when brief drainage is sufficient. Recent trials sometimes change access and drainage simultaneously, limiting attribution of benefit.

Selection should consider hemostasis, collecting-system integrity, ureteral patency, residual stones, infection, and repeat-access requirements. Nephrostomy remains appropriate when a protective function is needed; tubeless and totally tubeless approaches are reasonable after uncomplicated procedures. Future studies should assess recovery through device removal and unplanned interventions.

Introduction

Percutaneous nephrolithotomy (PCNL) is an established intervention for large renal stones. The European Association of Urology recommends tubeless or totally tubeless PCNL in uncomplicated cases, making the assessment at the end of surgery central to drainage selection. A technically successful stone procedure does not, however, establish that every patient can safely leave the operating room without drainage. Residual obstruction, bleeding, collecting-system injury, infection, and the likelihood of another procedure may change the balance between recovery and protection (1).

Historically, postoperative nephrostomy was integral to percutaneous renal surgery. Bellman and colleagues challenged its routine use with tubeless surgery, and subsequent reports by Goh and Wolf and by Limb and Bellman developed less burdensome exit strategies. These publications are milestones in the evolution of practice, rather than evidence that drainage omission is suitable for an unselected population. Their contribution was to separate the need for percutaneous

access during stone treatment from the need to maintain that access afterwards (2, 3, 4).
Contemporary debate is therefore more specific than whether PCNL should be tubeless. It concerns which drainage function remains necessary for an individual patient, which device can provide it, and for how long. This review examines that decision using comparative evidence, including the distinction between early recovery and symptoms experienced after discharge. Its central argument is that the least burdensome strategy should be chosen only after the required functions of drainage have been identified.

Material and Methods

This article is a narrative review with a targeted, non-exhaustive evidence search. Publicly accessible scholarly search results, PubMed-linked bibliographic records, journal websites, and the European Association of Urology guideline were consulted, with the last search on 12 September 2026. Searches used combinations of "percutaneous nephrolithotomy," "nephrostomy," "tubeless," "totally tubeless," "ureteral stent," "externalized ureteral catheter," "randomized trial," "meta-analysis," "infection," and "quality of life." Additional papers were identified from the bibliographies of relevant reviews. Recent searches specifically examined publications from 2024 to 2026.
Randomized comparisons and systematic reviews addressing drainage after PCNL were prioritized. Historical reports were retained to explain terminology and technical development. Observational studies were selected for clinical questions insufficiently addressed by trials, including transient obstruction and special populations. Adult PCNL was the main focus; pediatric evidence and studies of retrograde procedures were considered separately. Evidence from ureteroscopy or retrograde intrarenal surgery was used only as indirect context for infection, not as a comparative estimate of PCNL drainage effects.
The synthesis considered recovery, pain, urinary symptoms, bleeding, infection, leakage, stone clearance, reintervention, and resource use. Numerical estimates were taken from the identified publications without recalculation or statistical pooling. Full texts were reviewed where accessible; some supporting historical or bibliographic records were available through abstracts or reference lists. There was no registered protocol, independent duplicate screening, formal study-level risk-of-bias assessment, or newly conducted certainty grading. The search therefore cannot establish comprehensive coverage. Certainty terminology attributed to the Cochrane review reflects that review's published judgments, not a new assessment. (5).

Definitions and Classification of Drainage Strategies

Table 1 distinguishes the devices left after surgery. Conventional or tubed PCNL leaves a nephrostomy, sometimes with an additional ureteral device. Tubeless PCNL omits the nephrostomy but may leave either a double-J stent or an externalized ureteral catheter. Totally tubeless PCNL leaves neither an upper-tract external drain nor an indwelling ureteral stent. A temporary bladder catheter does not itself constitute upper-tract drainage. Terms such as "modified" or "almost totally" tubeless should be interpreted from the actual devices and their removal times, rather than the label alone (3, 5, 6).

Table 1. Definitions and principal functions of postoperative drainage

Strategy	Devices remaining	Principal consideration
Nephrostomy	Percutaneous tube, with or without ureteral drainage	External diversion, tamponade, or repeat access
Tubeless with stent	Double-J stent; no nephrostomy	Internal drainage; symptoms and removal required
Tubeless with catheter	Externalized ureteral catheter; no nephrostomy	Brief drainage; monitored removal
Totally tubeless	Neither nephrostomy nor indwelling ureteral device	Requires satisfactory native drainage

Definitions are based on the devices left at completion, not the study label. A bladder catheter is not upper-tract drainage. PCNL, percutaneous nephrolithotomy. Sources: (3, 5, 6).

Comparator differences materially affect interpretation. Gauhar and colleagues allowed nephrostomy with or without ureteral drainage in the standard group, whereas the Cochrane review used a narrower nephrostomy-only comparator and focused on unilateral, single-tract procedures. Their different numbers of included studies do not represent a simple disagreement about the same dataset. Small versus large nephrostomies, overnight versus longer drainage, and the use of an internal stent all create different clinical comparisons (5, 6).

Earlier syntheses by Xun, Lee, Chen, and Shen contributed to the evidence base for reducing drainage-related morbidity. These reviews share underlying trials and must not be counted as independent replications. The network analysis by Lee and colleagues further compared several strategies through direct and indirect evidence; its rankings depend on comparability across populations and techniques. A ranking cannot establish the best choice for a patient whose operative findings would have excluded them from the contributing trials (7, 8, 9, 10).

Nephrostomy: Functions and Importance of Tube Size

A nephrostomy has three distinct purposes: diverting urine externally, providing access for subsequent endoscopy, and contributing to tamponade of the access tract. Its value is greatest when at least one of these purposes remains relevant. The randomized comparison by Desai and colleagues directly examined large-bore, small-bore, and tubeless approaches. Maheshwari and colleagues also investigated the choice between a large-bore tube and a pigtail catheter. These comparisons show why "nephrostomy" is not a uniform intervention. Tube diameter, material, position, fixation, and duration should be recorded when outcomes are compared (11, 12).

The practical inference is to match the nephrostomy to its intended purpose. A small drain used principally for urinary diversion is not equivalent to a tract deliberately maintained for repeat nephroscopy. Conversely, a large tube should not be retained solely because a large tract was used if the postoperative objective can be met by a less burdensome device. These are functional considerations, not validated diameter thresholds. A tube also cannot be regarded as definitive treatment for every cause of bleeding: persistent or severe hemorrhage may require imaging and selective arterial embolization (11, 12, 13).

Early Nephrostomy Removal as an Alternative

The relevant alternative to tubeless surgery may be brief nephrostomy drainage rather than prolonged conventional drainage. Mishra and colleagues randomized 22 selected patients to early tube removal or tubeless PCNL and used postoperative computed tomography before catheter removal. Analgesic use and hospital stay were similar, while the retained tract permitted check nephroscopy in a patient with a residual fragment. The very small sample precludes a reliable estimate of uncommon complications, but the study illustrates how the removal protocol can alter the comparison (14).

Shoma and Elshal likewise evaluated nephrostomy placement in a prospective randomized study. Together with earlier randomized work on different PCNL techniques, this literature supports treating drainage as a planned postoperative intervention with a reassessment point, rather than an automatic consequence of access creation. Early removal requires clinical review of bleeding, drainage, obstruction, and remaining treatment needs; an arbitrary removal time cannot substitute for those assessments (15, 16).

Tubeless PCNL with a Double-J Stent

An internal stent preserves a route from the collecting system to the bladder while avoiding an external renal drain. It can be useful when percutaneous access is no longer needed but transient ureteral compromise is a concern. Its burdens include urinary urgency, frequency, dysuria, hematuria, flank discomfort, and the need for removal. The symptom literature described by Joshi and colleagues makes clear that tolerability cannot be assessed from an early pain score alone (17).

PCNL-specific randomized studies by Zhao and colleagues and by Jiang and colleagues incorporated health-related quality of life into drainage comparisons. These studies broaden the relevant outcome beyond the duration of admission: a patient discharged sooner may still experience symptoms while a stent remains in place. Future comparisons should therefore follow patients through device removal and recovery, using a validated instrument and reporting the timing of assessment. This interpretation also explains why an internal device should not be assumed to be preferable simply because it is invisible externally (18, 19).

Before selecting a double-J stent, the operative team should specify the indication, anticipated duration, removal arrangement, and responsibility for follow-up. This is a proposed implementation standard arising from the device's temporary role. Without that plan, the apparent convenience of tubeless surgery can shift work and discomfort from the admission to a later visit. Patient preference matters particularly when the expected clinical benefit of prolonged internal drainage is small.

Externalized Ureteral Catheter

Short-term externalized ureteral drainage is an intermediate option when sustained internal stenting is unnecessary. Tania and colleagues included nine studies, comprising six randomized trials and three observational studies. Their pooled analysis of three trials found fewer stent-related symptoms with an external ureteral catheter; the estimate is presented in Table 2. Other measured outcomes did not differ significantly, but the review identified heterogeneity and insufficient long-term information. Thus, the results support a symptom advantage in selected settings without proving interchangeability for prolonged drainage (20).

In the trial by Habib and colleagues, stent-related symptoms occurred in 22.5% of patients with an externalized catheter and 62.5% with a double-J stent. The study enrolled 80 participants; other comparisons, including fever and leakage, were not statistically significant. Zhou and colleagues also studied these alternatives in minimally invasive PCNL. Their work reinforces the need to distinguish the benefits of avoiding an indwelling stent from the separate decision to omit a nephrostomy (21, 22).

An externalized catheter requires secure fixation and a monitored removal plan. It may be inconvenient for mobility and generally serves a shorter drainage interval than an internal stent. The choice should reflect the expected duration of ureteral vulnerability. If drainage is likely to be required after discharge, catheter logistics may outweigh its symptom advantage; if only overnight drainage is needed, avoiding a later stent-removal encounter can be attractive.

Totally Tubeless PCNL

Early reports by Karami and Gholamrezaie and by Aghamir and colleagues explored leaving no upper-tract drainage device. Subsequent comparisons, including the three-arm randomized study by Bhat and colleagues, examined totally tubeless, stented tubeless, and conventional approaches. These techniques remove different sources of morbidity and should remain separate in reporting and clinical counseling (23, 24, 25).
Eslahi and colleagues retrospectively compared 216 selected patients and reported less pain, narcotic use, and hospitalization with the totally tubeless approach. However, patients with major bleeding, collecting-system perforation, and several complex clinical features were excluded. The study therefore describes outcomes after favorable selection; it cannot support omission of drainage in precisely the situations omitted from its population. Its nonrandomized design also leaves the potential for treatment-selection bias (26).
The principal attraction of totally tubeless surgery is avoidance of both an external tube and subsequent stent symptoms or removal. The corresponding concern is that urine must drain through the native ureter without device support. Its suitability depends on the condition of the collecting system and ureter at the end of treatment. Absence of visible residual stone is only one component of this judgment and does not establish normal drainage by itself.

Effect Size and Uncertainty About Harm

Table 2 provides selected published estimates rather than a new pooled analysis. Across major syntheses, shortening of hospital stay is more consistent than improvement in every pain outcome. Xun and colleagues reported improved recovery measures but substantial heterogeneity for hospital stay and pain. Differences in clinical pathways, discharge policies, instruments, and assessment times plausibly contribute to that variability (7).
Gauhar and colleagues synthesized 26 randomized studies involving 1,839 participants and found shorter admission with tubeless PCNL. There were no statistically significant differences in several safety outcomes or stone-free rate. This is reassuring for the studied populations, but a nonsignificant result is not proof that clinically important harm has been excluded. The confidence interval and the number of events remain relevant, particularly for sepsis, embolization, and readmission (6).
The Cochrane review judged evidence for several uncommon outcomes to be very uncertain. For severe adverse events in tubeless versus standard PCNL, the confidence interval was particularly wide. Consequently, a review should avoid replacing uncertainty with categorical claims that either strategy prevents major complications. Published certainty judgments also vary by outcome: greater confidence in a shorter admission cannot be transferred automatically to confidence about sepsis (5).

Recent Trials and Concurrent Changes in the Operative Pathway

Fu and colleagues randomized 99 patients without significant hydronephrosis to a totally tubeless approach without retrograde ureteral catheter insertion or traditional PCNL. Hospital stay, operating time, and costs favored the intervention, while complications and stone-free rate were not significantly different. The report was published online in 2024 and in a 2025 issue. Because both retrograde preparation and postoperative drainage differed, its findings cannot isolate the effect of drainage omission alone. The trial was also retrospectively registered. (27)
Jin and colleagues reported a 2026 trial involving 210 patients with definite hydronephrosis. The intervention omitted both retrograde ureteral catheterization and nephrostomy drainage but retained an internal double-J stent. Operating time and hospitalization were shorter, and hydrothorax

was less frequent. Active urinary infection and several complex conditions were excluded. This study extends the evidence for a selected combined pathway; it does not support totally tubeless surgery, nor does its reduction in operating time represent a pure exit-strategy effect (28).

Table 2. Selected published comparative estimates

Comparison and source	Outcome	Effect estimate (95% CI)
Tubeless vs standard Wilhelm et al. (5)	Hospital stay	MD -0.90 days (-1.45 to -0.35) Low certainty
Tubeless vs standard Wilhelm et al. (5)	Severe adverse events	RR 1.53 (0.14 to 16.46) Very low certainty
Totally tubeless vs standard Wilhelm et al. (5)	Hospital stay	MD -1.55 days (-1.82 to -1.29) Moderate certainty
Tubeless vs standard Gauhar et al. (6)	Hospital stay	MD -1.10 days (-1.48 to -0.71)
External catheter vs double-J Tania et al. (20)	Stent-related symptoms	RR 0.32 (0.19 to 0.54)

CI, confidence interval; MD, mean difference; RR, risk ratio. Negative MD favors the first strategy. Estimates are reproduced from published analyses, not recalculated; reviews overlap and eligibility differs. Certainty labels are the Cochrane authors' ratings. The symptom estimate uses three randomized trials (235 participants).

Obstruction and Management of Residual Stones

Obstruction deserves assessment independent of apparent stone clearance. Nizzardo and colleagues evaluated 263 patients after mini-PCNL in whom nephrostomy was the sole drainage strategy. Antegrade imaging on postoperative day two showed transient obstruction in 55 patients, with larger stone volume and renal pelvic location associated with impaired canalization. These findings cannot be interpreted as the failure rate of totally tubeless PCNL, because that strategy was not studied. They nevertheless identify a clinically relevant reason to consider drainage when postoperative ureteral patency is uncertain (29).

Residual fragments raise two different questions: whether urine can drain and whether another percutaneous procedure is planned. A retained nephrostomy is especially useful when repeat access is intentional. Conversely, a small fragment does not inevitably require maintenance of a percutaneous tract if the treatment plan is observation or a different approach. Imaging modality and the definition of "stone-free" should be reported explicitly, since intraoperative visual clearance and postoperative computed tomography can yield different classifications (14, 15).

Miniaturized PCNL and Special Populations

Tract miniaturization and drainage omission are separate interventions. Sebaey and colleagues conducted a randomized comparison of standard and tubeless drainage within mini-PCNL. The existence of this study also illustrates why a review that finds no eligible mini-PCNL comparison under its own criteria should not be paraphrased as showing that no mini-PCNL trials exist. Smaller instruments do not eliminate the possibility of ureteral edema, impaired drainage, or infection. Contemporary studies should report tract size and drainage in both groups (5, 29, 30).

The pediatric meta-analysis by Fang and colleagues included 13 studies and 661 patients, with observational designs predominating. Tubeless surgery was associated with shorter admission and favorable results for some other outcomes. Higher stone-clearance rates in the tubeless group should be interpreted cautiously: selection of less complex cases for drainage omission is a plausible explanation, because the postoperative drain itself does not fragment stones. Pediatric findings warrant separate consideration rather than direct application to adults (31).

Kara and colleagues studied totally tubeless surgery in elderly patients, showing that age-specific evaluation has been attempted.

Nevertheless, chronological age alone is an inadequate decision rule. Frailty, renal reserve, bleeding vulnerability, infection, and the ability to return for assessment are more relevant to the proposed clinical framework. Evidence remains limited for solitary kidneys, complex multitract procedures, major collecting-system injury, and other situations underrepresented in randomized comparisons. Favorable reports in selected subgroups do not establish a universal indication. (8, 32)

Infection and Indirect Evidence from Retrograde Surgery

Drainage choice does not replace infection prevention or treatment. Mariappan and colleagues compared bladder, pelvic urine, and stone cultures in relation to post-PCNL urosepsis, emphasizing the additional information obtained from upper-tract and stone sampling. A negative bladder culture cannot guarantee that the stone or collecting system is sterile. Antibiotic planning, microbiological sampling, and prompt recognition of deterioration remain necessary regardless of the exit strategy. (33,34)

The review by Younesi Rostami and colleagues, "Fever and Infection Following Ureteroscopy and Retrograde Intrarenal Surgery: A Systematic Review," reported associations involving positive preoperative urine culture, diabetes, stent placement, and longer procedures. These findings are relevant as indirect evidence of infection vulnerability in endourology. They do not demonstrate that a postoperative PCNL stent causes infection or that removing it prevents sepsis. Stenting may mark a more complex or previously obstructed case, and the retrograde route differs from PCNL in access, pressure, and tissue effects. No quantitative estimate from that review is transferred to PCNL here. (35)

For a patient with clinical deterioration and suspected obstructed infection, the question is whether effective drainage and source control are present, not whether the operation was originally designated tubeless. Urgent decompression, cultures, and immediate antimicrobial treatment are priorities. In elective cases, active infection should be treated before definitive stone surgery. The general PCNL complication literature further supports evaluating infection alongside bleeding and organ injury rather than interpreting fever as a device-specific event. (1, 13)

Functional Framework for Drainage Selection

The evidence supports a conditional approach. Table 3 and Figure 1 organize a proposed end-of-procedure assessment around the remaining functions of drainage. The figure is an unvalidated conceptual synthesis, not a tested prediction rule. First, determine whether the patient needs percutaneous access or external diversion because of bleeding, injury, planned second-look treatment, or concern about reliable drainage. If so, retain a nephrostomy suited to that purpose. If these needs are absent, assess whether temporary ureteral support is still desirable. A short-term external catheter or an internal stent may be appropriate depending on the anticipated duration. Complete omission of upper-tract devices is a consideration only after an uncomplicated procedure with satisfactory native drainage (1, 11, 15).

This is an unvalidated clinical synthesis, not a scoring system. Nephrostomy does not replace definitive management of severe hemorrhage. Sources (1, 11, 13, 15, 29).

This sequence avoids using successful tubeless surgery as a performance target. A surgeon who retains a nephrostomy for a documented reason has not failed to modernize care. Equally, continuing a device without a remaining purpose can impose avoidable burden. The decision should be revisited after surgery because bleeding, drainage, and the treatment plan evolve. The proposed framework is intended to make that reasoning explicit and auditable, not to replace operative judgment with a numerical score.

Table 3. Proposed assessment before choosing the exit strategy

Finding at completion	Implication for selection
Bleeding, injury, or planned second-look nephroscopy	Consider nephrostomy for a defined purpose; escalate persistent bleeding.
No percutaneous access need, but ureteral patency uncertain	Consider ureteral drainage; match duration to the anticipated need.
Uncomplicated procedure and satisfactory native drainage	Totally tubeless surgery may be considered with reliable follow-up.
Infection concern or postoperative deterioration	Evaluate promptly; confirm effective drainage and treat infection.
Complex anatomy, solitary kidney, or limited follow-up access	Individualize; evidence from selected routine cases may not apply.

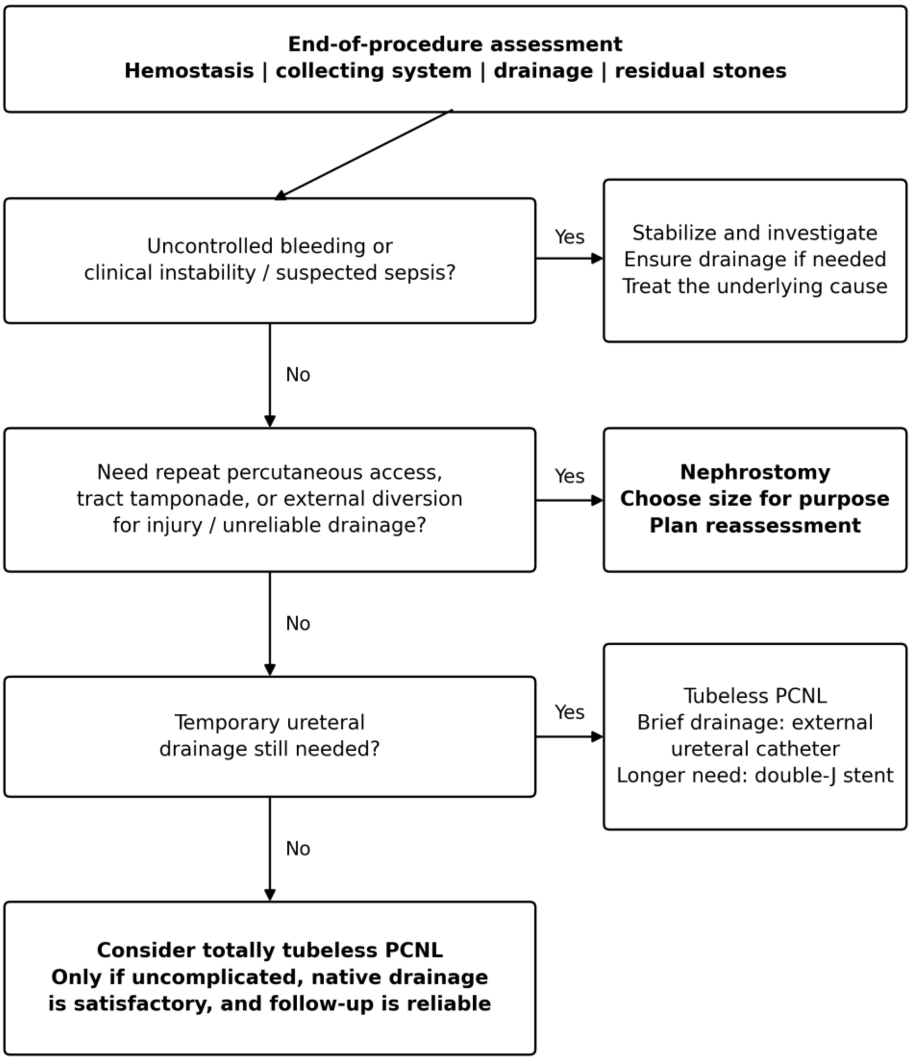

Figure 1. Proposed functional approach to drainage selection after percutaneous nephrolithotomy. The sequence distinguishes the need for percutaneous access or external diversion from the need for temporary ureteral drainage. It is a conceptual synthesis, has not been validated, and supplies no numerical eligibility thresholds. PCNL, percutaneous nephrolithotomy. Sources: (1, 11, 13, 15, 29).

Recovery Beyond Hospitalization

Discharge is only one point in recovery. Ambulatory PCNL reports, including the initial series by Shahrour and Andonian, demonstrate the feasibility of selected outpatient pathways. They do not establish that omission of a nephrostomy alone makes discharge safe. Clinical stability, oral intake, pain control, reliable follow-up, and access to reassessment remain relevant. A shorter admission accompanied by unplanned emergency care or a burdensome stent-removal pathway may offer less benefit than the length-of-stay result suggests. (36)

Future economic comparisons should count device costs, nursing care, removal, transport, time away from work, and unplanned encounters. These outcomes cannot be inferred reliably from operating time. Likewise, patient-reported outcomes should distinguish incisional pain from bladder symptoms and should be assessed at prespecified intervals through device removal. A clinically meaningful advantage would combine adequate drainage with recovery that matters to patients, rather than improving a single hospital metric. (17, 18, 19)

Research Priorities and Limitations

The main evidence gaps concern eligibility, rare harms, and contemporary comparators. Multicenter trials should randomize after intraoperative eligibility is established, use a common definition of uncomplicated PCNL, and distinguish small-bore nephrostomy with early removal from prolonged conventional drainage. Tubeless stenting, short-term ureteral catheterization, and totally tubeless surgery should be separate groups. Combining changes in access, positioning, retrograde preparation, and drainage makes it difficult to identify which component produces the observed benefit.

Trials should capture severe bleeding, sepsis defined separately from fever, rescue drainage, unplanned procedures, emergency visits, and readmission. They should report residual stone criteria, imaging, antibiotic protocols, tract size and number, stent dwell time, and validated patient-reported recovery. Sufficient follow-up is needed to evaluate the complete treatment episode. Infrequent serious events may require large collaborative studies or carefully designed prospective registries, with adjustment for why a device was selected.

This narrative review is limited by targeted searching and variable access to original reports. It does not provide a complete trial inventory or an independent formal assessment of bias. Historical references explain development of the techniques but may not represent current equipment or recovery pathways. The proposed selection framework incorporates clinical interpretation that has not been prospectively validated. These limitations are particularly relevant when applying results to complex stones, infection, impaired renal reserve, or patients whose postoperative support differs from that in the published studies.

Conclusion

Postoperative drainage after PCNL should be selected according to a documented clinical purpose. Nephrostomy remains valuable for repeat access, external diversion, and selected bleeding or injury concerns. Tubeless strategies can shorten recovery in appropriately selected patients, but the presence and duration of a ureteral device influence symptoms after discharge. Totally tubeless PCNL is a distinct option for uncomplicated procedures with satisfactory native drainage. Current evidence supports selective use rather than universal omission, and uncertainty about rare serious outcomes should remain visible in counseling and research. The next generation of studies should evaluate the whole recovery period, including device removal and unplanned care.

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Authorship

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Conflicts of interest

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Declaration of Generative AI use

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