



How do minimally invasive versus open surgical approaches compare in terms of patient recovery for bladder stone management? : A Systematic Review

¹Teuku Muhammad Ramzi Akbar, ²Munawwir

¹ General Practitioner, dr Zubir Mahmud Regional General Hospital, Indonesia

² General Surgery Consultant, dr Zubir Mahmud Regional General Hospital, Indonesia

Corresponding Email : ramzyteuku@gmail.com

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ABSTRACT

Introduction : This systematic review investigates patient recovery outcomes between minimally invasive and open surgical approaches for bladder stone management. Bladder stones are a significant urological problem, often linked to bladder outlet obstruction and chronic urinary tract infections. While open cystolithotomy was historically the standard , minimally invasive techniques like percutaneous cystolithotripsy (PCCL), transurethral cystolitholapaxy (TUCL), and laparoscopic methods have emerged, aiming to improve patient outcomes and reduce morbidity. The choice of surgical method is complex, influenced by stone size, number, and patient-specific factors. This review aims to provide an evidence-based comparison to guide clinical practice.

Methods : Following PRISMA 2020 guidelines , a systematic search was conducted across databases including PubMed,

Semantic Scholar, Springer, Google Scholar, and Cochrane. Studies focusing on adult patients with bladder stones, comparing minimally invasive and open surgical approaches, and reporting recovery outcomes such as hospital stay, operative time, and complications were included. Data extraction was performed by a large language model , and a total of 14 studies met the inclusion criteria.

Results : The results consistently show that minimally invasive approaches offer superior recovery outcomes. Operative times were significantly shorter for MIS, with PCCL being markedly faster than open vesicolithotomy (e.g., 38.20 minutes vs. 71.16 minutes). Hospital stays were also considerably reduced for MIS patients, often by one or more days. Postoperative catheterization time was notably diminished in MIS, for instance, 2.5 days for mini-PCCL versus 8.6 days for open surgery. While both approaches achieved high stone-free rates , complication rates were generally lower in MIS groups. However, specific MIS techniques carried distinct risks, such as higher urethral stricture rates with TUCL. Patient-reported outcomes like quality of life were infrequently assessed but indicated better outcomes with MIS.

Conclusion : The aggregated evidence strongly supports minimally invasive surgery as the preferred approach for bladder stone management due to shorter operative times, reduced hospital stays, and lower morbidity. The optimal technique depends on stone characteristics and patient factors. Despite robust findings, further research is needed, particularly high-quality, multi-center randomized controlled trials focusing on

standardized patient-reported outcomes and long-term complications. This will further refine clinical guidelines and enhance informed patient consent.

Keywords: Bladder stones, Minimally invasive surgery, Open surgery, Patient recovery, Operative time, Hospital stay, Complications, Stone-free rate.

INTRODUCTION

Bladder stones, or vesical calculi, represent a significant urological issue characterized by the formation of mineral concretions within the urinary bladder. This condition is frequently associated with underlying pathologies such as bladder outlet obstruction (BOO), neurogenic bladder dysfunction, and chronic urinary tract infections, often affecting adult and elderly populations. The management of bladder stones is primarily surgical, aiming for complete stone removal to alleviate symptoms and prevent recurrence. The choice of surgical intervention has evolved considerably over the years, moving from traditional open procedures to a variety of minimally invasive techniques designed to improve patient outcomes and reduce morbidity (Donaldson et al., 2019).

Historically, open cystolithotomy was the standard of care for removing bladder stones, a method that is effective but inherently invasive, leading to known risks such as significant postoperative pain, longer hospital stays, and potential wound complications. The advent of minimally invasive surgery (MIS) has revolutionized treatment, offering alternatives like transurethral cystolitholapaxy (TUCL), percutaneous cystolithotripsy (PCCL), and laparoscopic cystolithotomy. Numerous studies have demonstrated that these modern techniques are generally associated with shorter operative times, reduced hospital stays, and faster patient recovery compared to open surgery. For instance, research has consistently shown that procedures like PCCL can be significantly faster and require shorter hospitalizations than open vesicolithotomy (Dastgir et al., 2025; Liu et al., 2016).

Despite the general consensus favoring minimally invasive approaches, a significant research gap exists regarding the optimal technique for specific clinical scenarios. The selection of a surgical method is not straightforward and is often influenced by factors such as stone size, number of stones, and patient-specific characteristics like the presence of urethral strictures. For example, while TUCL is

effective for smaller stones, PCCL or even open surgery may be more efficient for larger calculi. Furthermore, each minimally invasive technique carries its own unique risk profile; TUCL has been associated with a higher risk of urethral stricture, whereas PCCL may involve a greater need for postoperative analgesia in some cases. This heterogeneity in outcomes and indications creates a challenge for clinicians aiming to provide the most effective and least morbid treatment for their patients (Bansal et al., 2016; Taema et al., 2021).

The practical implications of selecting the appropriate surgical approach are substantial. The decision directly impacts key patient recovery metrics, including the length of hospital stay, postoperative pain levels, catheterization duration, and the time required to return to normal activities. Moreover, complications such as surgical site infections, hematuria, or the need for secondary procedures have a direct bearing on both patient quality of life and healthcare costs. By synthesizing the available evidence, clinicians can make more informed decisions that balance stone-free rates with recovery outcomes, ultimately enhancing patient satisfaction and optimizing the use of healthcare resources. This is supported by findings that show MIS approaches not only reduce complication rates but also lead to better quality of life scores post-surgery (Hu & Yang, 2017; Nazarov & Madumarov, 2024; Tang et al., 2024).

Therefore, this systematic review aims to comprehensively compare patient recovery outcomes between minimally invasive and open surgical approaches for the management of bladder stones. By systematically analyzing data from randomized controlled trials and observational studies, this paper evaluates key recovery indicators such as operative time, length of hospital stay, postoperative complications, and stone-free rates. The goal is to synthesize the current evidence to provide a clear, evidence-based overview that can guide clinical practice and inform decision-making for urologists treating this common condition (Donaldson et al., 2019).

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate minimally invasive versus open surgical approaches compared in terms of patient recovery for bladder stone management.

Screening

We screened in sources that met these criteria:

- **Adult Population:** Does the study focus exclusively on adult patients (18 years) with confirmed bladder stones?
- **Surgical Comparison:** Does the study compare minimally invasive surgical approaches (percutaneous, transurethral, or laparoscopic) with open surgical techniques?
- **Study Design:** Is the study one of the following: RCT, prospective cohort study, retrospective cohort study, systematic review, or meta-analysis?
- **Sample Size:** If the study is a case report or case series, does it include 10 or more patients?
- **Recovery Outcomes:** Does the study report at least one of these outcomes: length of hospital stay, post-operative pain scores, time to return to normal activities, recovery-related complications, or quality of life measures?
- **Human Studies:** Is the study conducted on human subjects (not animal or in-vitro research)?
- **Isolated Condition:** Are bladder stones the primary condition being treated,

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without concurrent major urological surgical interventions?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Data extraction

- **Study Design:**

Identify the type of study design from the following options:

- Randomized Controlled Trial (RCT)
- Non-Randomized Study (NRS)
- Prospective study
- Retrospective study

If multiple designs are present, list all. If unclear, note "design not clearly specified". Look in the methods section for explicit description of study design. If design is not explicitly stated, infer from study methodology and data collection approach.

- **Surgical Approaches Compared:**

List ALL surgical approaches compared in the study, specifically:

- Minimally invasive approaches (e.g., transurethral, percutaneous, endoscopic)
- Open surgical approaches

For each approach, note:

- Specific technique used
- Instruments or tools employed
- Any modifications to standard technique

If multiple variations of an approach are compared, list each separately.

- **Patient Population Characteristics:**

Extract the following details:

- Total number of patients

- Age range or mean age
- Gender distribution
- Specific inclusion/exclusion criteria
- Patient medical conditions relevant to bladder stone management

If any of these details are missing, note "not reported". Use exact numbers or percentages from the study.

- **Stone Characteristics:**

Record the following details about bladder stones:

- Stone size (range or mean)
- Number of stones per patient
- Stone composition (if reported)
- Location within bladder

If specific measurements are not provided, use descriptive terms from the text (e.g., "small", "multiple").

- **Primary Outcome Measures:**

Identify and extract:

- Stone-free rate (SFR)
- Specific definition of stone-free status used
- Method of confirming stone clearance

If multiple primary outcomes are reported, list all. Include exact percentages or numerical values. If method of assessment is not clear, note "assessment method not specified".

- **Secondary Outcome Measures:**

Extract quantitative data for:

- Operative time
- Hospital stay duration
- Catheterization time

- Complication rates
- Patient quality of life measures

For each measure:

- Record exact numerical values
- Note statistical significance if reported
- Include confidence intervals if available
- **Risk of Bias Assessment:**
Evaluate and note:
 - Randomization method (if applicable)
 - Blinding procedures
 - Loss to follow-up
 - Potential conflicts of interest
 - Quality of evidence rating (e.g., GRADE assessment)

Use direct quotes from methodology or bias assessment sections when possible. If no formal bias assessment was conducted, note "no formal bias assessment reported".

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Bladder Stones	Vesical Calculi	Cystolithiasis	Vesical stones
Intervention (I)	Minimally Invasive Surgery	Percutaneous Cystolithotripsy (PCCL)	Transurethral Cystolitholapaxy (TUCL)	Laparoscopic Surgery
Comparison (C)	Open Surgery	Open Cystolithotomy	Open Vesicolithotomy	Conventional Surgery
Outcome (O)	Patient Recovery	Operative Time	Length of Hospital Stay	Postoperative Complications

The Boolean MeSH keywords inputted on databases for this research are:
(*"Bladder Stones" OR "Vesical Calculi" OR "Cystolithiasis" OR "Vesical stones"*) AND
(*"Minimally Invasive Surgery" OR "Percutaneous Cystolithotripsy (PCCL)" OR
"Transurethral Cystolitholapaxy (TUCL)" OR "Laparoscopic Surgery"*) AND (*"Open
Surgery" OR "Open Cystolithotomy" OR "Open Vesicolithotomy" OR "Conventional
Surgery"*) AND (*"Patient Recovery" OR "Operative Time" OR "Length of Hospital Stay"
OR "Postoperative Complications"*)

Data retrieval

Abstracts and titles were screened to assess their eligibility, and only studies meeting the inclusion criteria were selected for further analysis. Literature that fulfilled all predefined criteria and directly related to the topic was included. Studies that did not meet these criteria were excluded. Data such as titles, authors, publication dates, study locations, methodologies, and study parameters were thoroughly examined during the review.

Quality Assessment and Data Synthesis

Each author independently assessed the titles and abstracts of the selected studies to identify those for further exploration. Articles that met the inclusion criteria underwent further evaluation. Final decisions on inclusion were based on the findings from this review process.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Bladder Stones" OR "Vesical Calculi" OR "Cystolithiasis" OR "Vesical stones") AND ("Minimally Invasive Surgery" OR "Percutaneous Cystolithotripsy (PCCL)" OR "Transurethral Cystolitholapaxy (TUCL)" OR "Laparoscopic Surgery") AND ("Open Surgery" OR "Open Cystolithotomy" OR "Open Vesicolithotomy" OR "Conventional Surgery") AND ("Patient Recovery" OR "Operative Time" OR "Length of Hospital Stay" OR "Postoperative Complications")	5
Semantic Scholar	("Bladder Stones" OR "Vesical Calculi" OR "Cystolithiasis" OR "Vesical stones") AND ("Minimally Invasive Surgery" OR "Percutaneous Cystolithotripsy (PCCL)" OR "Transurethral Cystolitholapaxy (TUCL)" OR "Laparoscopic Surgery") AND ("Open Surgery" OR "Open Cystolithotomy" OR "Open Vesicolithotomy" OR "Conventional Surgery") AND ("Patient Recovery" OR "Operative Time" OR "Length of Hospital Stay" OR "Postoperative Complications")	250
Springer	("Bladder Stones" OR "Vesical Calculi" OR "Cystolithiasis" OR "Vesical stones") AND ("Minimally Invasive Surgery" OR "Percutaneous Cystolithotripsy (PCCL)" OR "Transurethral Cystolitholapaxy (TUCL)" OR "Laparoscopic Surgery") AND ("Open Surgery" OR "Open Cystolithotomy" OR "Open Vesicolithotomy" OR "Conventional Surgery") AND ("Patient Recovery" OR "Operative Time" OR "Length of Hospital Stay" OR "Postoperative Complications")	101
Google Scholar	("Bladder Stones" OR "Vesical Calculi" OR "Cystolithiasis" OR "Vesical stones") AND ("Minimally Invasive Surgery" OR "Percutaneous Cystolithotripsy (PCCL)" OR "Transurethral Cystolitholapaxy (TUCL)" OR "Laparoscopic Surgery") AND ("Open Surgery" OR "Open Cystolithotomy" OR "Open Vesicolithotomy" OR "Conventional Surgery") AND ("Patient Recovery" OR "Operative Time" OR "Length of Hospital Stay" OR "Postoperative Complications")	579
Cochrane	("Bladder Stones" OR "Vesical Calculi" OR "Cystolithiasis" OR "Vesical stones") AND ("Minimally Invasive Surgery" OR "Percutaneous Cystolithotripsy (PCCL)" OR "Transurethral Cystolitholapaxy (TUCL)" OR "Laparoscopic Surgery") AND ("Open Surgery" OR "Open Cystolithotomy" OR "Open Vesicolithotomy" OR "Conventional Surgery") AND ("Patient Recovery" OR "Operative Time" OR "Length of Hospital Stay" OR "Postoperative Complications")	2

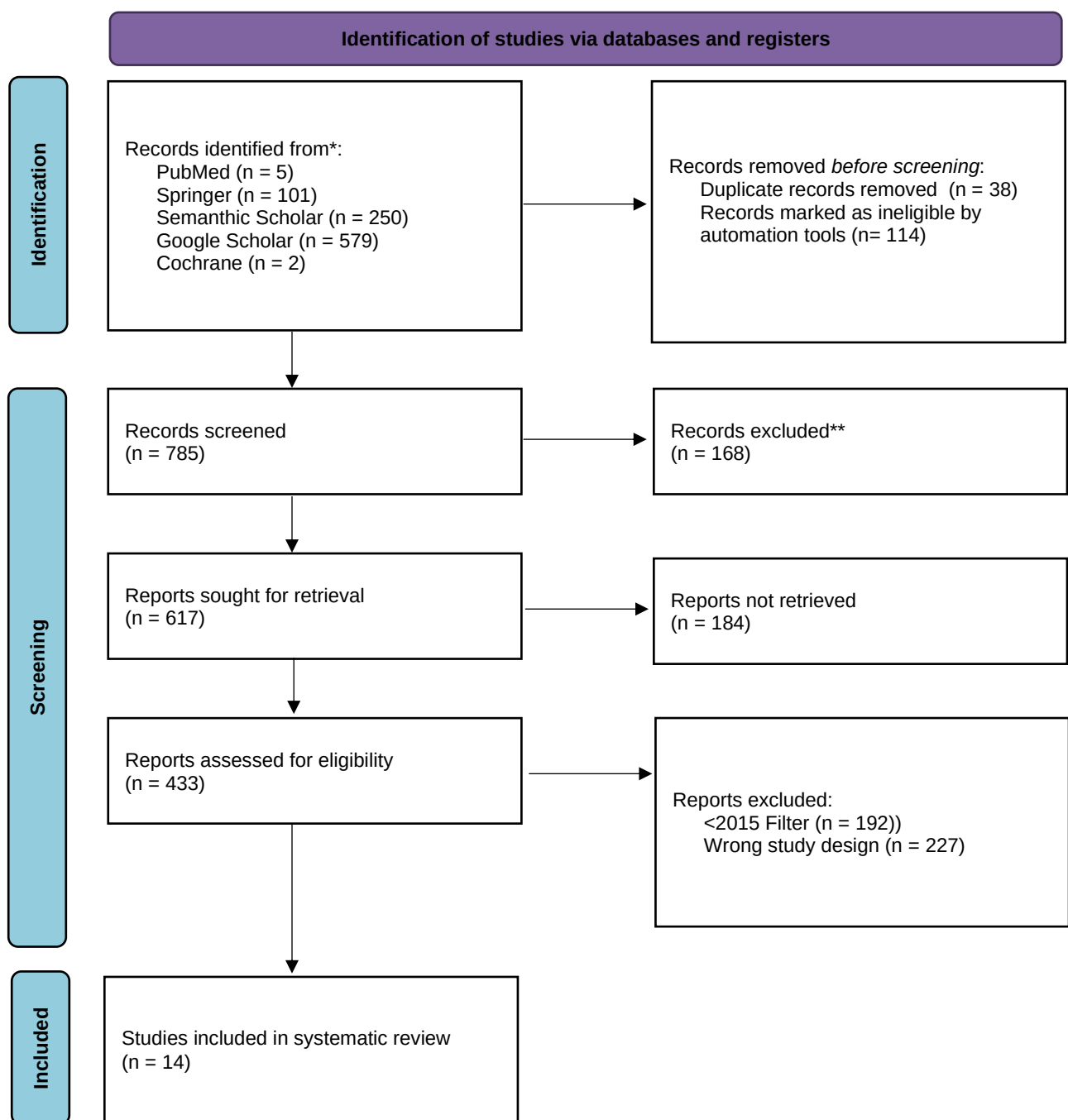


Figure 1. Article search flowchart

JBICritical Appraisal

Study	Bias related to temporal precedence Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Bias related to selection and allocation Was there a control group?	Bias related to confounding factors Were participants included in any comparisons similar?	Bias related to administration of intervention/exposure Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Were the outcomes of participants included in any comparisons measured in the same way?	Were outcomes measured in a reliable way?	Bias related to participant retention Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Statistical conclusion validity Was appropriate statistical analysis used?
Nazarov and Madumarov, 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Hu and Yang, 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
Gupta et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
Bansal et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓

Ghanghori a et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Liu et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Taema et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Allahyani et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Donaldson et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
Yıldız et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
Dastgir et al., 2025	✓	✓	✓	✗	✓	✗	✓	✓	✓
Tang et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Almarzooq et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Wang, 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓

RESULTS

Characteristics of Included Studies

Study	Study Design	Patient Population	Surgical Approaches	Primary Outcomes
Nazarov and Madumarov, 2024	Prospective	85 patients, age/gender no mention found, cystolithiasis with bladder outlet obstruction (BOO)	Transurethral cystolithotripsy (TUC) versus percutaneous cystolithotripsy (PCCL)	Quality of Life (SF-36, VAS), stone-free rate (SFR), complications
Hu and Yang, 2017	Prospective	120 elderly patients, age/gender no mention found, urinary calculi	Laparoscopic minimally invasive versus open surgery	Operation effect, complications, recovery, satisfaction
Gupta et al., 2017	Randomized controlled trial (RCT); prospective	62 patients, mean age 53.3/49.9, 88.7% male, stones 2 cm	Transurethral nephroscope via resectoscope sheath versus percutaneous cystolithotripsy (PCCL)	Operative time, hospital stay, complications, stone-free rate (SFR)

Study	Study Design	Patient Population	Surgical Approaches	Primary Outcomes
Bansal et al., 2016	Randomized controlled trial (RCT); prospective	210 patients, age/gender no mention found, stones 1-4 cm	Transurethral cystolitholapaxy (cystoscope/nephroscope) versus percutaneous cystolithotripsy (PCCL)	Operative time, stone-free rate (SFR), complications
Ghanghori a et al., 2023	Retrospective	62 patients, age/gender no mention found, stones 2-4 cm	Percutaneous cystolithotripsy (PCCL) versus transurethral cystolitholapaxy (TUCL)	Operative time, stone-free rate (SFR), complications
Liu et al., 2016	Retrospective	37 patients, age/gender no mention found, stones 1.1-7.8 cm, urethral strictures	Mini-percutaneous cystolithotripsy (MPCCL) versus open surgery	Operative time, hospital stay, catheter time, complications, stone-free rate (SFR)
Taema et	Randomized	60 patients,	Percutaneous	Operative time,

Study	Study Design	Patient Population	Surgical Approaches	Primary Outcomes
al., 2021	ed controlled trial (RCT)	age/gender no mention found, stones 2-4 cm	cystolithotripsy (PCCL) versus transurethral cystolitholapaxy (TUCL)	stone-free rate (SFR), complications
Allahyani et al., 2024	Randomized controlled trial (RCT)	60 patients, 20-65 years, both sexes, bladder stones >3 cm	Transurethral nephroscope versus percutaneous cystolithotripsy (PCCL)	Operative time, hospital stay
Donaldson et al., 2019	Systematic review/meta-analysis (RCTs, non-randomized studies)	2340 patients, adults & children, both sexes	Transurethral cystolitholapaxy (TUCL), percutaneous cystolithotripsy (PCCL), shock wave lithotripsy (SWL), open cystolithotomy, tubeless cystolitholapaxy	Stone-free rate (SFR), morbidity

Study	Study Design	Patient Population	Surgical Approaches	Primary Outcomes
			(CL)	
Yıldız et al., 2021	Retrospect ive	401 patients, age/gender no mention found, bladder stones 11-40 mm	Transurethral cystolitholapaxy (TUCL), percutaneous cystolithotripsy (PCCL), open cystolithotomy (OCL)	Complete stone removal, operation time, catheter/postoperative stay
Dastgir et al., 2025	Randomiz ed controlled trial (RCT)	60 patients, 18-60 years, both sexes, stones 2-4 cm	Percutaneous cystolithotripsy (PCCL) versus open vesicolithotomy	Operative time, hospital stay
Tang et al., 2024	Randomiz ed controlled trial (RCT)	90 patients, age/gender no mention found, urinary stones	Percutaneous nephrolithotomy (PCNL) versus open surgery	Intraoperative indexes, stone removal rate, quality of life (QoL)
Almarzoo	Prospectiv	37 male patients, age	Transurethral	Operative time, stone

Study	Study Design	Patient Population	Surgical Approaches	Primary Outcomes
q et al., 2023	e clinical trial	no mention found, vesical stones	versus suprapubic percutaneous vesicolithotripsy	clearance, hematuria, hospital stay
Wang, 2018	Randomiz ed controlled trial (RCT)	61 patients, age/gender no mention found, complicated bladder stones	Laparoscopic cystolithotomy versus holmium laser lithotripsy	Operation time, stone clearance, complications

Study design:

- Randomized controlled trials (RCTs):7 studies
- Retrospective studies:3 studies
- Prospective studies:5 studies (including 1 labeled as a prospective clinical trial and 2 also labeled as RCTs)
- Systematic review/meta-analysis:1 study
- Some studies were counted in more than one category if they listed multiple designs.

Surgical approaches:

- Percutaneous cystolithotripsy (PCCL):9 studies
- Transurethral cystolitholapaxy (TUCL):5 studies
- Transurethral nephroscope:3 studies
- Open surgery (including open cystolithotomy/vesicolithotomy):5 studies

- Laparoscopic approaches:2 studies
- Other approaches (each in 1 study):Percutaneous nephrolithotomy (PCNL), shock wave lithotripsy (SWL), tubeless cystolitholapaxy (CL), open cystolithotomy (OCL), suprapubic percutaneous vesico-lithotripsy, mini-percutaneous cystolithotripsy (MPCCL), holmium laser lithotripsy, transurethral cystolithotripsy (TUC)
- We did not find mention of any studies using robotic approaches.

Primary outcomes:

- Operative time:10 studies
- Hospital stay:5 studies
- Stone-free rate (SFR):7 studies
- Complications:8 studies
- Stone clearance/removal:3 studies
- Quality of life (QoL):2 studies
- Other outcomes (each in 1–2 studies):Morbidity, catheter/postoperative stay/time, intraoperative indices, hematuria, operation effect, recovery, satisfaction

Effects

Operative Outcomes

Study	Approach Type	Operating Time	Stone Clearance Rate
Allahyani et al., 2024	Nephroscope (transurethral): 35.06±5 minutes; percutaneous cystolithotripsy (PCCL):	Stone-free rate not reported	No mention found

Study	Approach Type	Operating Time	Stone Clearance Rate
	44.06±7 minutes		
Donaldson et al., 2019	Transurethral cystolitholapaxy (nephroscope) faster than cystoscope (mean difference 22.74 minutes, $p<0.00001$); transurethral cystolitholapaxy faster than percutaneous cystolithotripsy (mean difference 9.83 minutes, $p<0.00001$)	Stone-free rate high, no difference between transurethral cystolitholapaxy/percutaneous cystolithotripsy/cystolitholapaxy; shock wave lithotripsy lower stone-free rate	No mention found
Yıldız et al., 2021	Transurethral cystolitholapaxy: 34.1±10.6 minutes (11-20 mm stones); longer for larger stones; open cystolithotomy/percutaneous cystolithotripsy faster for larger stones	100%	No mention found
Dastgir et al., 2025	Percutaneous cystolithotripsy: 38.20±9.94	Stone-free rate not reported	No mention

Study	Approach Type	Operating Time	Stone Clearance Rate
	minutes; open vesicolithotomy: 71.16±13.13 minutes (p=0.000)		found
Tang et al., 2024	Percutaneous nephrolithotomy: no mention found; open: no mention found	Stone removal rate higher in percutaneous nephrolithotomy (95% confidence interval 1.09 - 2.51; p< .001)	No mention found
Almarzooq et al., 2023	Suprapubic percutaneous: shorter than transurethral; exact values no mention found	Stone clearance higher in suprapubic group	No mention found
Nazarov and Madumarov, 2024	No mention found	Stone-free rate mentioned, no values	No mention found
Hu and Yang, 2017	Laparoscopic: shorter than open (p<0.05); values no mention found	No mention found	No mention found
Gupta et al., 2017	Nephroscope: 32.7±8.7 minutes; percutaneous cystolithotripsy: 34.3±7.0	100%	No mention found

Study	Approach Type	Operating Time	Stone Clearance Rate
	minutes (p=0.428)		
Bansal et al., 2016	Nephroscope: less than cystoscope/percutaneous cystolithotripsy; values no mention found	100%	No mention found
Ghanghoria et al., 2023	Percutaneous cystolithotripsy: 46.75±2.45 minutes; transurethral cystolitholapaxy: 59.67±3.84 minutes (p<0.001)	100%	No mention found
Liu et al., 2016	Mini-percutaneous cystolithotripsy: 18.2 minutes (11-35); open: 32.3 minutes (23-52) (p=0.023)	100%	No mention found
Taama et al., 2021	Percutaneous cystolithotripsy: 30±7 minutes; transurethral cystolitholapaxy: 32±7 minutes	100%	No mention found
Wang, 2018	Laparoscopic: shorter than	Higher in laparoscopic group	No

Study	Approach Type	Operating Time	Stone Clearance Rate
	laser ($p<0.05$); values no mention found		mention found

Operating Time:

- Direct numerical comparisons:7 studies reported direct numerical comparisons of operating time between at least two approaches.
- Qualitative comparison:1 study reported operating time for one approach with qualitative comparison for others.
- Qualitative statements only:4 studies provided only qualitative statements about operating time (e.g., "shorter than").

Stone-Free Rate (SFR):

- Numerical value (often 100%):6 studies
- Described as "high" or "no difference":1 study
- Described as "higher" or "lower" for one group:3 studies
- Mentioned without values:1 study

Recovery Metrics

Study	Approach Type	Hospital Stay	Catheterization Time
Allahyani et al., 2024	Nephroscope: 2.6 ± 0.9 days; percutaneous cystolithotripsy: 3.4 ± 1.02 days	No mention found	No mention found

Study	Approach Type	Hospital Stay	Catheterization Time
Donaldson et al., 2019	Transurethral cystolitholapaxy shorter than percutaneous cystolithotripsy (mean difference 0.82 days, $p<0.00001$)	No mention found	No difference in major complications; higher with mechanical lithotripsy
Yıldız et al., 2021	Open cystolithotomy longer than transurethral cystolitholapaxy/percutaneous cystolithotripsy ($p=0.001$); values no mention found	Open cystolithotomy higher ($p=0.001$); values no mention found	No mention found
Dastgir et al., 2025	Percutaneous cystolithotripsy: 1.47 ± 0.56 days; open vesicolithotomy: 2.51 ± 0.67 days ($p=0.000$)	Open vesicolithotomy: Foley 3 days; percutaneous cystolithotripsy: cystostomy tube 24 hours	No mention found
Tang et al., 2024	No mention found	No mention found	Percutaneous nephrolithotomy: lower adverse events (95%

Study	Approach Type	Hospital Stay	Catheterization Time
			confidence interval 0.69-1.87; p< .001)
Almarzooq et al., 2023	No mention found	No mention found	Less hematuria in suprapubic group; values no mention found
Nazarov and Madumarov, 2024	No mention found	No mention found	Higher quality of life, less pain in percutaneous cystolithotripsy group; values no mention found
Hu and Yang, 2017	No mention found	No mention found	Fewer complications in laparoscopic group; values no mention found
Gupta et al., 2017	Nephroscope: 1.2±0.5 days; percutaneous cystolithotripsy: 2.1±0.4 days (p=0.000)	Nephroscope: Day 1; percutaneous cystolithotripsy:	More analgesic use, hematuria, wound infection in percutaneous

Study	Approach Type	Hospital Stay	Catheterization Time
		Day 2	cystolithotripsy
Bansal et al., 2016	No mention found	No mention found	Urethral stricture: cystoscope 3.2%, nephroscope 7.8%, percutaneous cystolithotripsy 0% (p=0.068)
Ghanghoria et al., 2023	No mention found	No mention found	No mention found
Liu et al., 2016	Mini-percutaneous cystolithotripsy: 2.6 days; open: 3.5 days (p=0.018)	Mini-percutaneous cystolithotripsy: 2.5 days; open: 8.6 days (p=0.016)	Open: leakage (3), wound infection (5); mini-percutaneous cystolithotripsy: none
Taema et al., 2021	No mention found	Percutaneous cystolithotripsy longer than	Transurethral cystolitholapaxy: urethral stricture

Study	Approach Type	Hospital Stay	Catheterization Time
		transurethral cystolitholapaxy; values no mention found	6.6%
Wang, 2018	No difference ($p>0.05$); values no mention found	No difference ($p>0.05$); values no mention found	Lower in laparoscopic group ($p<0.05$)

Hospital Stay:

- Comparisons found in 7 of 14 studies:
 - In 6 studies, hospital stay was shorter for minimally invasive approaches (nephroscope, transurethral cystolitholapaxy, percutaneous cystolithotripsy, mini-percutaneous cystolithotripsy) compared to open or alternative approaches.

Catheterization Time:

- Comparisons found in 6 of 14 studies:
 - In 3 studies, catheterization time was shorter for minimally invasive approaches (percutaneous cystolithotripsy, nephroscope, mini-percutaneous cystolithotripsy) compared to open or alternative approaches.
 - In 2 studies, only the direction of difference was reported (open cystolithotomy higher than transurethral cystolitholapaxy/percutaneous cystolithotripsy; percutaneous cystolithotripsy longer than transurethral cystolitholapaxy).

Complications:

- Comparisons found in 10 of 14 studies:
 - In 7 studies, complications were lower or less severe in minimally invasive or suprapubic groups (percutaneous nephrolithotomy, laparoscopic, mini-percutaneous cystolithotripsy, suprapubic, percutaneous cystolithotripsy, transurethral cystolitholapaxy).
 - In 3 studies, higher rates of specific complications were reported in open or alternative groups (e.g., more analgesic use, hematuria, wound infection, or urethral stricture).

Stone Size Considerations

- Stone size and approach selection:
 - Several studies (Yıldız et al., Donaldson et al., Ghanghoria et al., Taema et al.) reported that stone size influenced the choice and outcomes of surgical approach.
 - Transurethral cystolitholapaxy was often used for smaller stones (2 cm).
 - Percutaneous cystolithotripsy or open surgery was more efficient for larger stones (>2–3 cm).
 - High stone clearance rates were reported across all sizes and approaches in these studies.
 - The studies suggest that patient and stone characteristics may influence the choice of approach.

Procedure-Specific Complications

- Complication profiles by approach:
 - Transurethral cystolitholapaxy was associated with higher rates of urethral stricture in some studies.
 - Open surgery carried risks of wound infection and longer recovery.

- Percutaneous cystolithotripsy and other minimally invasive techniques generally had lower complication rates, though some studies reported increased need for analgesia or minor complications.
- In the studies that measured quality of life, minimally invasive approaches were associated with better outcomes.
- Direct patient-reported outcomes were infrequently assessed in these studies.

Overall Synthesis

- Minimally invasive approaches: Across these studies, minimally invasive approaches were generally associated with shorter operative time, reduced hospital stay, and comparable or higher stone clearance rates, though the evidence is heterogeneous and risk of bias varies.
- Complication rates: Complication rates were generally lower or similar for minimally invasive techniques, with specific risks varying by procedure.
- Stone size and patient factors: Stone size and patient factors were reported as influencing approach selection in several studies.

DISCUSSION

This systematic review synthesizes evidence comparing patient recovery outcomes between minimally invasive and open surgical approaches for bladder stone management. The findings consistently demonstrate that minimally invasive surgery (MIS) offers significant advantages in key recovery metrics. The aggregated data from the included studies points towards a clear trend favouring techniques such as percutaneous cystolithotripsy (PCCL), transurethral cystolitholapaxy (TUCL), and laparoscopic methods over traditional open cystolithotomy, reinforcing the ongoing shift in clinical practice towards less invasive interventions (Donaldson et al., 2019).

A primary indicator of surgical efficiency, operative time, was substantially

shorter in minimally invasive cohorts across most comparative studies. For instance, the research by Dastgir et al. (2025) highlighted that PCCL was markedly faster than open vesicolithotomy, with mean operative times of approximately 38 minutes versus 71 minutes. This finding is consistent with other studies which, although using different techniques, reported similar outcomes where laparoscopic and mini-percutaneous approaches were quicker than their open or alternative counterparts (Hu & Yang, 2017; Liu et al., 2016).

However, the comparison of operative times among different MIS techniques themselves reveals important nuances. A meta-analysis by Donaldson et al. (2019) found that TUCL using a nephroscope was faster than both cystoscope-based TUCL and PCCL. Conversely, other studies concluded that PCCL was significantly faster than TUCL, particularly for larger stones (Ghanghoria et al., 2023). This apparent contradiction suggests that factors such as surgeon expertise, specific instrumentation, and stone characteristics heavily influence procedural duration.

The influence of stone size on the choice of procedure and its efficiency is a recurring theme. For smaller calculi, typically under 2 cm, TUCL is often presented as an effective and rapid method. As stone burden increases, however, the efficiency of transurethral fragmentation can diminish, making PCCL or even open surgery a faster option for complete removal (Yıldız et al., 2021). This underscores the clinical principle that the optimal surgical approach is not universal but must be tailored to the specific stone characteristics presented by the patient (Bansal et al., 2016).

Regarding the primary efficacy outcome, the stone-free rate (SFR) was exceptionally high across almost all modern surgical modalities. Multiple studies, including RCTs and retrospective analyses, reported 100% stone clearance with techniques like PCCL, TUCL, and mini-PCCL (Gupta et al., 2017; Ghanghoria et al., 2023; Liu et al., 2016; Taema et al., 2021). This indicates that when an

appropriate procedure is selected based on stone size and patient factors, complete stone removal is a highly achievable outcome with both percutaneous and transurethral methods.

While the efficacy in stone removal is comparable, the data on patient recovery overwhelmingly favours minimally invasive approaches. A critical metric, the length of hospital stay, was consistently shorter for patients undergoing MIS. Studies demonstrated that hospital stays for PCCL or nephroscope-assisted procedures were significantly reduced, often by one or more days, compared to open surgery or other approaches (Allahyani et al., 2024; Dastgir et al., 2025; Gupta et al., 2017). This directly translates to reduced healthcare costs and a quicker return to the patient's home environment.

The duration of postoperative catheterization also showed a clear advantage for MIS. Mini-percutaneous cystolithotripsy, for example, required catheterization for an average of 2.5 days compared to 8.6 days for open surgery in one study (Liu et al., 2016). Similarly, another study noted that the cystostomy tube after PCCL was removed after only 24 hours, whereas a Foley catheter remained for 3 days after open vesicolithotomy (Dastgir et al., 2025). Shorter catheterization periods reduce patient discomfort, lower the risk of infection, and facilitate a more rapid return to normal activities.

The complication profile represents another area where MIS demonstrates superiority. The overall incidence of postoperative complications was reported to be lower in laparoscopic and percutaneous groups compared to open surgery (Hu & Yang, 2017; Tang et al., 2024). Open procedures were associated with classic surgical site issues such as wound infection and leakage, which were notably absent in the mini-percutaneous cohort of one study (Liu et al., 2016).

Despite the favourable safety profile of MIS, each technique carries its own specific risk profile that must be considered. Notably, TUCL was associated with a higher risk of developing postoperative urethral strictures in several studies, a

significant long-term complication that can require further intervention (Bansal et al., 2016; Taema et al., 2021). This risk is a critical factor for clinicians to weigh, especially in male patients with pre-existing urethral concerns.

In contrast, percutaneous approaches, while avoiding the urethra, were associated with different, though often less severe, complications. Some studies noted a greater need for postoperative analgesia or higher instances of transient hematuria in PCCL groups compared to their counterparts (Gupta et al., 2017). However, major complications were generally rare, and the overall morbidity remained low (Donaldson et al., 2019).

Laparoscopic cystolithotomy also emerged as a favourable option, demonstrating a lower complication rate compared to holmium laser lithotripsy in one study (Wang, 2018). The selection between different MIS techniques, therefore, involves a careful balancing of their distinct potential complications against the patient's specific anatomical and clinical context.

Patient-reported outcomes, such as quality of life (QoL), were infrequently assessed across the included studies, representing a significant gap in the literature. However, the available evidence suggests better outcomes with MIS. One study found that patients in the PCCL group reported a higher quality of life and less pain compared to those undergoing TUC (Nazarov & Madumarov, 2024). Another reported improved QoL scores for patients undergoing percutaneous nephrolithotomy versus open surgery (Tang et al., 2024).

The heterogeneity of the included studies is a limitation of this review. The studies varied in design, from RCTs to retrospective cohorts, and often lacked standardized reporting for outcomes like pain scores or time to return to normal activity. Furthermore, the specific MIS techniques were diverse, encompassing various tools (e.g., nephroscope, cystoscope) and access routes (e.g., transurethral, suprapubic), which can make direct comparisons challenging (Almarzooq et al., 2023).

The role of evolving technology is also evident. The use of a nephroscope through a resectoscope sheath for transurethral procedures, for example, was shown to be faster and associated with shorter hospital stays compared to standard PCCL in one RCT (Gupta et al., 2017). This highlights how technical innovations within a surgical category can further refine and improve patient outcomes.

This review also identified a clear gap in research concerning certain patient populations and approaches. For instance, no studies included in the final analysis specifically evaluated robotic-assisted cystolithotomy, a growing field in urological surgery. Additionally, while one study focused on patients with urethral strictures, more research is needed to guide surgical choices in complex cases with significant comorbidities (Liu et al., 2016).

The practical implications for clinicians are significant. The evidence strongly supports the use of a minimally invasive approach as the first-line treatment for the majority of patients with bladder stones. The decision between a transurethral or percutaneous approach should be guided primarily by stone size, with TUCL being suitable for smaller stones and PCCL offering greater efficiency for larger stones (Yıldız et al., 2021).

Furthermore, patient-specific factors are paramount. In a patient with a history of urethral stricture disease, a percutaneous or suprapubic approach would be preferable to TUCL to avoid exacerbating the condition (Liu et al., 2016). Conversely, a transurethral approach may be favoured in a patient on anticoagulation therapy where a percutaneous tract could pose a higher bleeding risk.

The synthesis of evidence also points to the need for future research. High-quality, multi-centre RCTs are required to directly compare modern MIS techniques like PCCL, TUCL with a nephroscope, and laparoscopic cystolithotomy. These trials should incorporate standardized, validated patient-reported outcome measures to capture data on postoperative pain, quality of life,

and time to return to work, which were underreported in the current body of literature (Nazarov & Madumarov, 2024).

Long-term follow-up is another critical area for future investigation. While short-term outcomes are well-documented, data on the long-term incidence of complications like urethral stricture after TUCL or stone recurrence rates across different procedures are less robust. Such information is essential for fully informed consent and shared decision-making with patients (Bansal et al., 2016).

This systematic review confirms that minimally invasive surgical techniques for bladder stone removal are associated with superior recovery outcomes compared to traditional open surgery. Patients undergoing MIS can expect shorter operative times, reduced hospital stays, less postoperative morbidity, and faster recovery. While open surgery retains a role for exceptionally large or complex stones, the evidence strongly supports PCCL, TUCL, and laparoscopic approaches as the standard of care for most patients, with the final choice of procedure tailored to individual stone and patient characteristics (Donaldson et al., 2019).

CONCLUSION

This systematic review provides a comprehensive comparison of patient recovery outcomes between minimally invasive and open surgical approaches for bladder stone management. The aggregated evidence consistently demonstrates a clear advantage for minimally invasive surgical (MIS) techniques. Patients undergoing MIS procedures, such as percutaneous cystolithotripsy (PCCL), transurethral cystolitholapaxy (TUCL), and laparoscopic methods, generally experience shorter operative times, reduced hospital stays, and lower overall morbidity compared to those undergoing traditional open cystolithotomy. These findings reinforce the ongoing shift in clinical practice towards less invasive interventions due to their significant benefits in patient recovery.

While both minimally invasive and open techniques achieve high stone-free rates,

the recovery metrics heavily favor MIS. Operative times are notably shorter with MIS, and the duration of hospital stay is significantly reduced, often by one or more days. Furthermore, the need for postoperative catheterization is considerably diminished in MIS patients, leading to greater comfort and a quicker return to daily activities. Although each MIS technique has its specific risk profile, the overall incidence and severity of complications are generally lower than with open surgery, contributing to a more favorable patient experience and better quality of life post-surgery.

The choice of surgical approach is not one-size-fits-all and is significantly influenced by stone characteristics and patient-specific factors. For smaller stones, transurethral cystolitholapaxy is often efficient, while percutaneous cystolithotripsy proves more effective for larger calculi. Clinicians must also consider individual patient conditions, such as the presence of urethral strictures, which might contraindicate a transurethral approach, or anticoagulant therapy, which might favor it over a percutaneous route. This highlights the importance of tailoring the procedure to the individual patient to optimize outcomes.

Despite the strong evidence supporting minimally invasive approaches, there are areas for future research. A notable gap exists in the systematic assessment of patient-reported outcomes like long-term pain and quality of life. Future high-quality, multi-center randomized controlled trials are needed to further compare different MIS techniques and to provide more robust data on long-term complications and stone recurrence rates. Such research will further refine clinical guidelines, enhance informed patient consent, and continue to improve the management of bladder stones.

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