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Original Article

Comparison of efficacy and safety of open and laparoscopic proximal ureterolithotomy for ureteral stone management: A systematic review and meta-analysis

Ahmad Maliki[1,2], Rizka Fitriani[1,2], Mohammad A. Soebadi[1,3] and Wahjoe Djatisoesanto[1,2*]

[1]Department of Urology, Faculty of Medicine, Universitas Airlangga, Surabaya, Indonesia; [2]Dr. Soetomo General Academic Hospital, Surabaya, Indonesia; [3]Universitas Airlangga Teaching Hospital, Surabaya, Indonesia

*Corresponding author: wahjoe.djatisoesanto@fk.unair.ac.id

Abstract

Despite advances in non-invasive and minimally invasive techniques, some proximal ureteral stones with impaction require open or laparoscopic surgery. No systematic reviews or meta-analyses have compared the efficacy and safety of open proximal ureterolithotomy and laparoscopic approaches. The aim of this study was to compare the efficacy and safety between open and laparoscopic proximal ureterolithotomy for ureteral stone management. Following the PRISMA guidelines, systematic searches were conducted in five databases (PubMed, Scopus, ScienceDirect, Web of Science, and ProQuest) to identify articles comparing those two surgical approaches. Operative time, blood loss, pain score, hospital stay, recovery time, and complications were collected and compared. Heterogeneity-based meta-analysis with random-effects or fixed-effects models were conducted. Two randomized controlled trials and four observational cohort studies with 386 participants met the criteria. Open surgery had significantly less time than laparoscopic ureterolithotomy (mean difference (MD): 26.63 minutes, 95%CI: 14.32, 38.94; p<0.0001). Intraoperative blood loss (MD: -1.27 ml; 95%CI: -6.64, 4.09; p=0.64) and overall complications (OR: 0.68; 95%CI: 0.41, 1.15; p=0.16) were not significantly different between two approaches. Laparoscopic ureterolithotomy reduced visual analogue scale (VAS) pain scores (MD: -2.53; 95%CI: -3.47, -2.03; p<0.00001), hospital stays (MD: -2.40 days; 95%CI: -3.42 to -1.38 days; p=0.03), and recovery time (MD: -9.67 days; 95%CI: -10.81 to -8.53 days; p<0.00001). In conclusion, open proximal ureterolithotomy had less time, but laparoscopic surgery reduced postoperative pain, hospital stay, and recovery time. Both methods had comparable intraoperative bleeding and complications.

Keywords: Ureterolith, proximal ureteral stone, laparoscopic, open ureterolithotomy, effectiveness

Introduction

Urinary calculi are a prevalent condition encountered in urological practices, with significant implications for patient morbidity and healthcare costs [1,2]. Over the past few decades, there have been substantial advancements in the management of urinary tract stones. The invention of extracorporeal shock wave lithotripsy (ESWL) and endourological procedures, including percutaneous nephrolithotomy (PCNL) and ureterorenoscopy (URS), have revolutionized the

Received: January 17, 2024 - Accepted: March 18, 2024 - Published online: March 19, 2024

treatment landscape, limiting the indications for open surgical interventions and laparoscopic approaches [1,2]. However, the choice of treatment depends on various factors, such as stone parameters, patient characteristics, and the skill of the surgeon [3].

In recent years, a paradigm shift towards minimally invasive and non-invasive modalities has been observed, resulting in a decline in the utilization of open surgical procedures to approximately 1.5% of all surgical interventions [1,2]. While ESWL and URS have proven effective for the majority of ureteral stones, there are cases involving proximal stones with larger, harder, and deeply impacted formations that require alternative surgical methods like ureterolithotomy. Consequently, this creates a niche for open surgical or laparoscopic interventions [4-6].

Impacted stones are defined as persistent stones located in the same anatomical position for at least two months, accompanied by radiographic evidence of contrast media impeded from passing distal to the stone [3]. Additional criteria for impacted stones include a size greater than 10 mm or the inability of a retrograde guide-wire to pass proximal to the stone [3,7]. Literature reports indicate that up to 24% of impacted stones may lead to ureteral stenosis [7]. The European Association of Urology guidelines for urinary tract stones suggested that laparoscopic stone removal, when performed with proper indications, may yield high stone-free rates (SFR) while minimizing the need for additional procedures [1]. Ureterolithotomy has been recommended for patients with large-sized ureteral stones that have failed with ESWL or undergone repeated endourological interventions [1].

The management of proximal ureteral stones with impaction can be achieved through open surgical or laparoscopic approaches. Proximal open ureterolithotomy, a conventional technique, involves an abdominal wall incision and direct removal of the ureteral stone. Despite its longstanding use, this procedure carries inherent risks of infection, postoperative pain, and a relatively protracted recovery period [7]. Conversely, laparoscopic ureterolithotomy offers a minimally invasive alternative, employing small abdominal incisions and endoscopic instruments to remove the ureteral stone [8]. Laparoscopic ureterolithotomy has been associated with advantages such as faster recovery, reduced postoperative pain, and lower infection rates compared to open proximal ureterolithotomy [8].

Currently, there is a lack of systematic review studies and meta-analyses comparing the efficacy and safety of open proximal ureterolithotomy and laparoscopic ureterolithotomy for managing proximal ureteral stones with impaction. The aim of this systematic review and meta-analysis was to compare the effectiveness and safety of these two surgical approaches.

Methods

Study design and protocol registration

This systematic review and meta-analysis were performed in accordance with the Cochrane Handbook for Systematic Reviews and Interventions, in adherence to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [9]. The protocol has been registered in the International Prospective Register of Systematic Reviews (PROSPERO), CRD42023446767. The AMSTAR 2 checklist has been completed to enhance the methodological quality of this systematic review and meta-analysis; the level is moderate [10].

Literature search strategy and eligibility criteria

Two independent authors systematically searched for relevant articles comparing laparoscopic and open ureterolithotomy for proximal ureter stones, with the assessed outcomes including mean operation time, blood loss, pain score, length of hospital stay, recovery time, and overall complications. A preliminary search ensured novelty and avoided duplication. Research articles in five English databases, PubMed, Scopus, ScienceDirect, Web of Science, and ProQuest, were systematically searched. The search strategy was combining with the following terms without language restriction: (‘laparoscopic ureterolithotomy’ OR ‘LU’) AND (‘proximal’ OR ‘upper’) AND (’ureteral stone’ OR ‘ureteral stones’ OR ‘ureteral calculi’ OR ‘ureteral calculus’ OR ‘ureteral lithiasis’); (‘open ureterolithotomy’) AND (‘proximal’ OR ‘upper’) AND (’ureteral stone’ OR ‘ureteral stones’ OR ‘ureteral calculi’ OR ‘ureteral calculus’ OR ‘ureteral lithiasis’).

Inclusion criteria of the studies to be included were: (a) studies assessing between laparoscopic and open ureterolithotomy for duration of surgery, amount of blood loss, visual analogue scale (VAS) pain score, length of hospital stay, recovery time, or overall complications; (b) design study experimental (randomized controlled trial (RCT) and observational study (prospective observational); (c) report on the primary outcome and at least one of the secondary outcome measures mentioned below. Reviews, animal studies, case reports, and non-comparative studies were excluded.

Data collection and quality assessment

Data extraction was independently performed by authors using a comprehensive form. Discrepancies were resolved by a third author. Extracted data included study characteristics, patients' information, interventions, and quantitative outcome measures. The quality of each article was assessed using appropriate bias risk assessment tools for study design RCT or observational studies). The risk of bias in the included studies was assessed using the Cochrane risk of bias (RoB) version 2.0 tool for RCTs and the Newcastle-Ottawa Scale (NOS) for observational studies.

Study variables

In this study, laparoscopic proximal ureterolithotomy was defined as minimally invasive surgery using laparoscopic equipment to locate and remove stones trapped in the ureter. Laparoscopic included the transperitoneal [2] and retroperitoneal approaches [2,3]. Open proximal ureterolithotomy is defined as surgery on ureteral stones using an open surgical technique by making an incision in the skin of the lumbar area according to the position of the stone [3].

The outcomes of this study were duration of surgery, amount of blood loss, VAS pain score, length of hospital stay, recovery time, and overall complications. The duration of surgery is defined as the average length of time required to complete surgery, with each approach calculated in minutes [4]. VAS is defined as a subjective measure used to assess pain intensity using a continuous line with endpoints indicating no pain and the worst possible pain [3]. Length of stay (LOS) is defined as the average number of days spent in the hospital in the intervention and comparison groups [11]. Length of recovery time is defined as the average number of days it takes a patient from post-surgery to being able to carry out normal activities [12]. Overall complications are defined as the overall number of complications in the form of quantitative data that occurred in post-operative patients. The occurrence of any adverse events or unwanted outcomes related to surgery, including bleeding, fever, ileus, and stone migration, damage to ureter and adjacent organs [5].

Data synthesis

Quantitative data synthesis and statistical analysis employed meta-analysis based on pooled analysis. Odds ratios (OR) and mean differences (MD) with a 95% confidence interval (CI) were used for dichotomous and continuous data outcomes. Heterogeneity was assessed by using I^2, and a random-effects model was applied for $I^2>50\%$, and a fixed-effects model for $I^2<50\%$. Results were presented using forest plots and descriptive narratives. Review Manager® version 5.4.1 for Windows software was used for data processing.

Results

Systematic search results

The systematic searches using predefined keywords in five databases (PubMed, Scopus, ScienceDirect, Web of Science, and ProQuest) yielded a total of 1,326 studies. After removing 451 duplicate articles, 875 articles were subjected to primary screening based on titles and abstracts. Further evaluation of the full text was carried out on 15 articles, and finally, six studies [2-5,11,12] met the inclusion criteria and were included in the analysis of this study. The PRISMA flowchart illustrating the study selection process is presented in **Figure 1**.

Study characteristics

The included studies consisted of two RCTs [2,11] and four observational cohort studies involving 386 patients with proximal ureter stones [3-5,12]. The interventions evaluated in these studies were laparoscopic ureterolithotomy and open proximal ureterolithotomy. The characteristics and outcome data extracted from each included study are presented in **Table 1**.

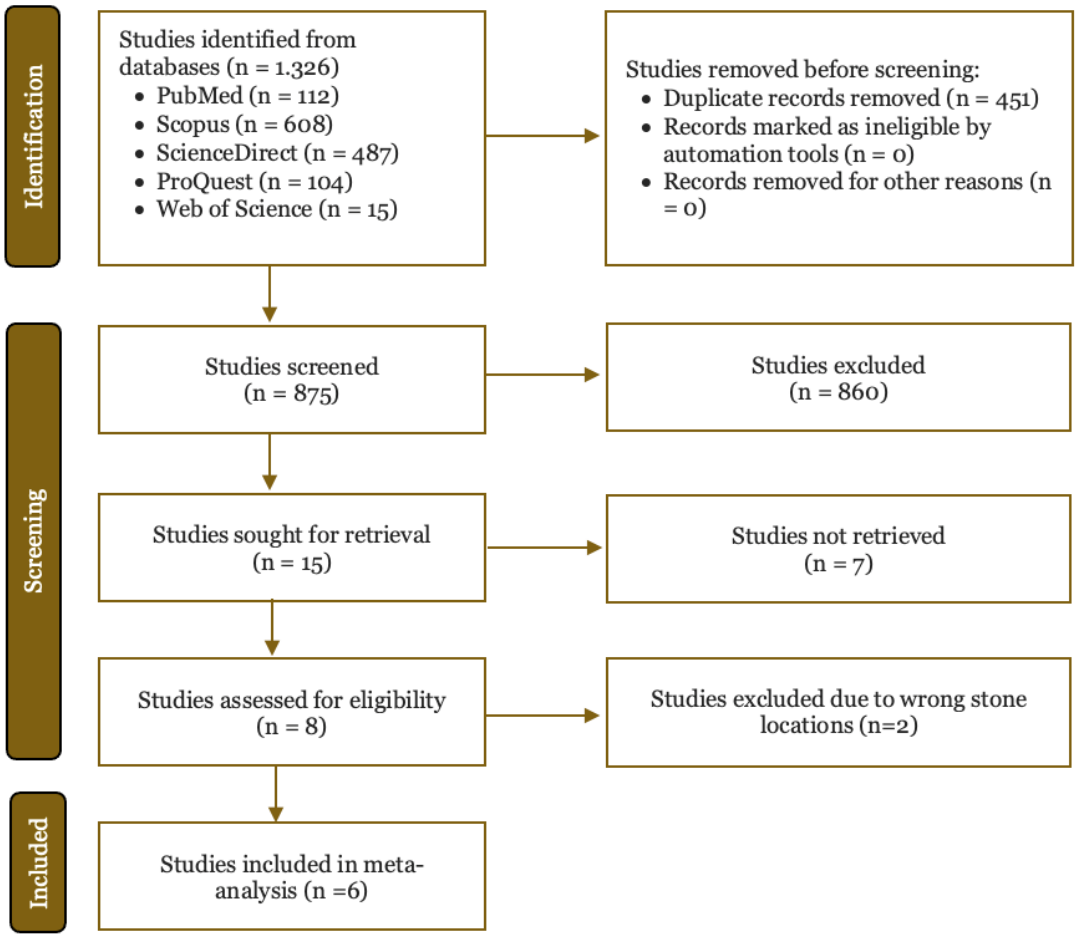

Figure 1. PRISMA flow diagram showing the study selection process.

Risk of bias

According to RoB version 2.0 tool, the overall bias of the RCT by Prakash *et al.* [2] had some concerns, while the study by Giri *et al.* [11] had a high risk of bias due to methodological limitations, particularly inadequate randomization and outcome measurement bias. This finding may have implications for the reliability and generalizability of the meta-analysis results. Therefore, careful interpretation of the findings should be conducted to address potential biases and their impact on the overall meta-analysis conclusions. The risk of bias assessment using the RoB version 2.0 tool is presented in **Figure 2**.

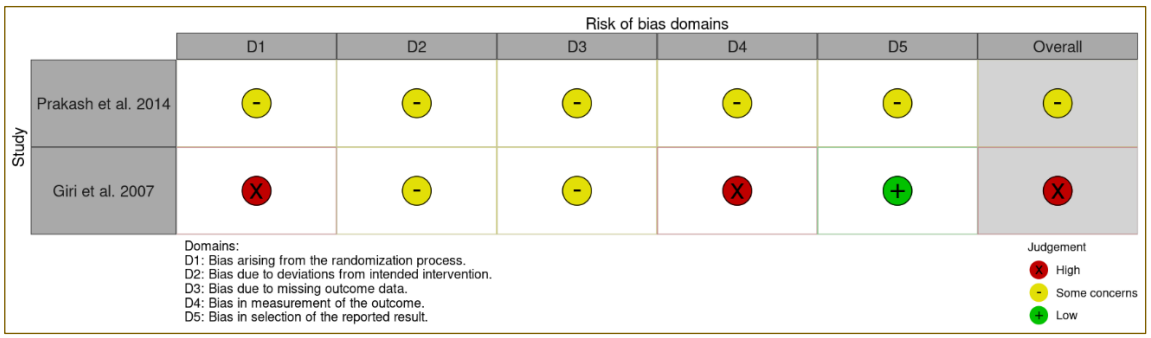

Figure 2. Risk of bias of the included randomized controlled trials (RCTs) using Cochrane risk of bias (RoB) version 2.0.

Table 1. Study characteristics and outcome data of included studies

Study	Year	Country	Study design	Sample size	Intervention	Number of surgeons	Mean stone size+SD (mm)	n	Outcome
Prakash *et al.* [2]	2014	India	Randomized controlled trial	70	Retroperitoneoscopic laparoscopic ureterolithotomy	Not reported	20±3.2	35	Mean operative time, amount of blood loss, VAS pain score, length of hospital stay, recovery time, and overall complications.
					Mini-incision open ureterolithotomy	Not reported	21±3.6	35	
Falahatkar *et al.* [4]	2011	Iran	Prospective observational study	40	Laparoscopic ureterolithotomy	Not reported	NR	20	Mean operative time, length of hospital stay, recovery time, and overall complications.
					Open ureterolithotomy	Not reported	NR	20	
Almeida *et al.* [3]	2009	Brazil	Prospective observational study	110	Laparoscopic ureterolithotomy (transperitoneal + retroperitoneal)	1	13.3 (10–20)	35	Mean operative time, amount of blood loss, length of hospital stay, and overall complications.
					Open ureterolithotomy	2	11.5 (10–30)	76	
Giri *et al.* [11]	2007	Nepal	Randomized controlled trial	42	Trans-peritoneal Laparoscopy Ureterolithotomy	Not reported	17±5	21	Mean operative time, VAS pain score, length of hospital stay, and overall complications.
					Open Ureterolithotomy	Not reported	15±5.2	21	
Skrepetis *et al.* [5]	2001	Greece	Prospective observational study	36	Transperitoneal laparoscopic ureterolithotomy	1	19 (12–31)	18	Mean operative time, length of hospital stay, recovery time, and overall complications.
					Open ureterolithotomy	Not reported		18	
Goel *et al.* [12]	2001	India	Prospective observational study	81	Retroperitoneal laparoscopic ureterolithotomy	Not reported	21 (7–33)	55	Mean operative time, amount of blood loss, length of hospital stay, recovery time, and overall complications.
					Open ureterolithotomy	Not reported	24 (7–34)	26	

The observational studies [3-5,12] were rated with NOS scores ranging from 7 to 8, indicating good quality. The aspects of patient selection, comparability, and outcome assessment were well-reported in all included studies, with adequate follow-up duration and low dropout rates. The risk of bias assessment using the NOS is summarized in **Table 2**.

Table 2. Risk of bias of the observational studies using the Newcastle-Ottawa Scale assessment

Study	Selection	Comparability	Outcome	Total score
Almeida *et al.* 2009 [3]	****	**	**	8
Goel *et al.* 2001 [12]	****	**	***	8
Skrepetis *et al.* 2001 [5]	***	**	**	7
Falahatakar 2011 [4]	***	**	**	7

Comparison of mean operative time

In the RCTs subgroup, the overall pooled estimate showed that the mean operative time was 28.19 min shorter in the open group, with a 95%CI ranging from 3.99 to 52.39 min (p=0.020) (**Figure 3**). Similarly, in the observational studies subgroup, the overall pooled estimate had a shorter operative time in the open group by 26.62 min (95%CI: 11.05, 41.53 min; p<0.0007) (**Figure 3**).

The combined pooled analysis of two RCTs and four observational studies indicated that the mean operative time in the open surgical approach was significantly shorter than the laparoscopic surgical approach (MD: 26.63 min; 95%CI: 14.32, 38.94; p<0.0001) (**Figure 3**). In this analysis, a random-effect model was used due to high heterogeneity among the observed studies (I^2: 67%; p=0.010).

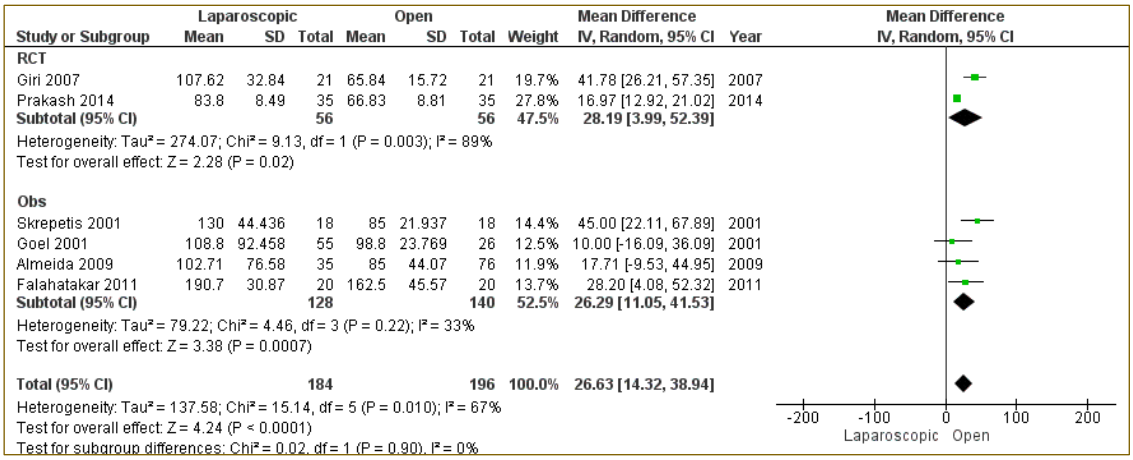

Figure 3. Forest plot comparing the mean operative time (minutes) between open proximal ureterolithotomy and laparoscopic.

Comparison of mean blood loss volume

In the RCT subgroup, the mean amount of blood loss favored the laparoscopic group, with a difference of -2.00 ml (95%CI: -8.28 to 4.28 ml, p=0.53) (**Figure 4**). This suggests that the difference in blood loss between the laparoscopic and open groups observed in the RCT was not statistically significant. Similarly, in the subgroup of observational studies there was no statistically significant difference in blood loss between the laparoscopic and open groups (p=0.90) (**Figure 4**). The combined pooled analysis of one RCT and two observational studies also showed that there was no significant difference in the amount of bleeding between the laparoscopic approach and the open surgical approach (MD -1.27 ml; 95%CI: -6.64, 4.09 ml; p=0.64) (**Figure 4**). A fixed-effect model was used in this analysis due to high heterogeneity among the studies (I^2: 0%; p=0.39).

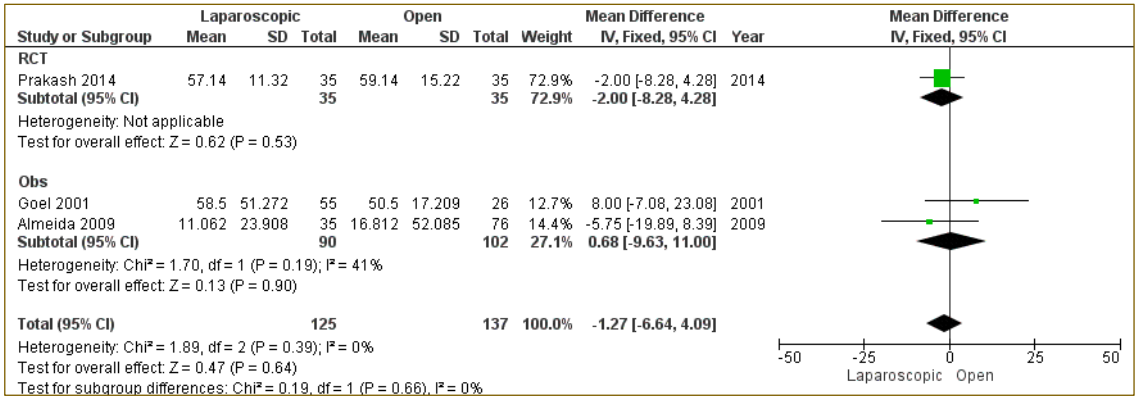

Figure 4. Forest plot comparing the mean amount of blood loss (milliliters) between open proximal ureterolithotomy and laparoscopic.

Comparison of mean VAS pain score

In the RCTs subgroup, the overall pooled estimate showed that the mean VAS pain score favored the laparoscopic group, with a difference of -2.59 points on the VAS scale (95%CI: -3.47, -1.71 points, p<0.0001) suggesting a highly statistically significant difference in VAS pain scores, favoring the laparoscopic group (**Figure 5**). Similarly, in the subgroup of observational studies, the overall pooled estimate indicated significant difference in VAS pain scores, favoring the laparoscopic group (MD: -2.44 points; 95%CI: -3.47, -1.42 points; p<0.00001) (**Figure 5**).

The combined pooled analysis indicated that the VAS pain score in the laparoscopic surgical approach was significantly lower than the open surgical approach (MD: -2.53, 95% CI -3.47, -2.03; p<0.00001) (**Figure 5**) based on a random-effect model.

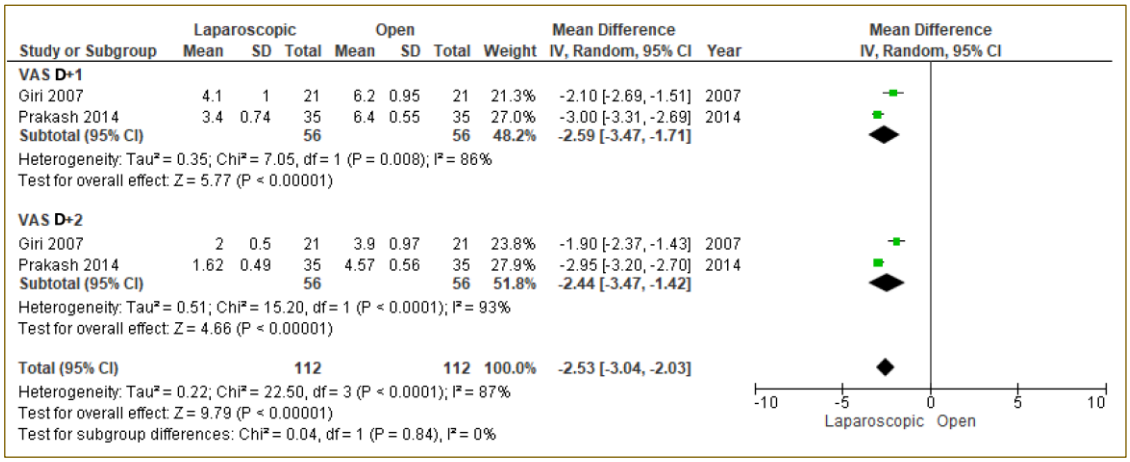

Figure 5. Forest plot comparing the mean visual analog scale (VAS) pain score between open proximal ureterolithotomy and laparoscopic.

Comparison of mean length of hospital stay

In the RCTs subgroup, the overall pooled estimate showed that the laparoscopic approach had a significantly shorter mean length of hospital stay compared to the open surgical (MD: -2.81 days; 95%CI: -3.06, -2.56 days; p<0.00001) (**Figure 6**). Similarly, in the subgroup of observational studies also indicated that the laparoscopic approach had a significantly shorter mean length of hospital stay compared to the open surgical (MD: -2.23 days; 95%CI: -4.20 to -0.26 days; p=0.03) (**Figure 6**). The pooled analysis of the mean length of hospital stay from two RCTs and four observational studies also demonstrated that the laparoscopic approach has a significantly shorter mean length of hospital stay compared to the open surgical approach. The laparoscopic group showed a mean reduction in hospital stay by 2.40 days (95% CI -3.42, -1.38; p<0.00001) (**Figure 6**), using a random-effect model.

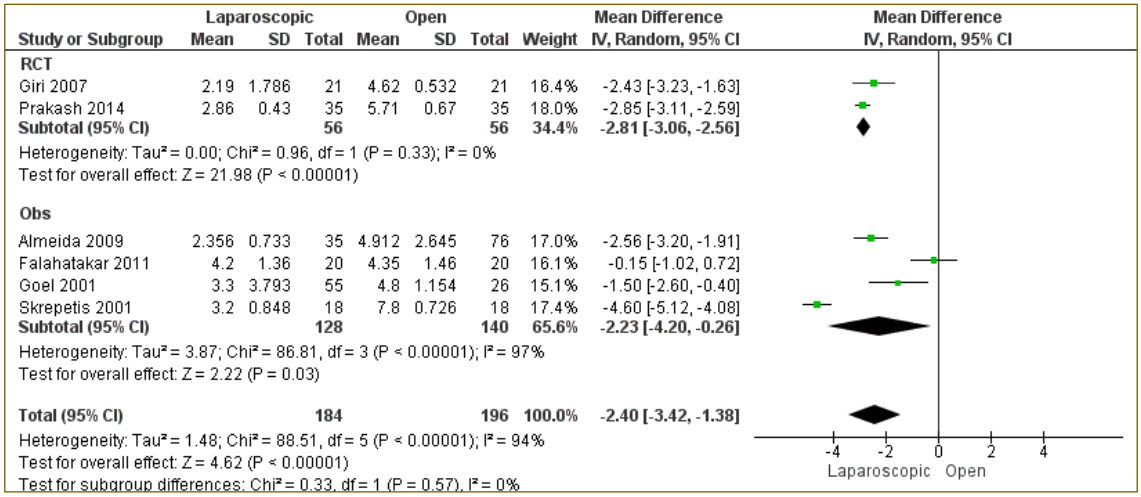

Figure 6. Forest plot comparing the mean length of hospital stay (days) between open proximal ureterolithotomy and laparoscopic.

Comparison of mean recovery time

Both RCT and observational study subgroups indicated that the overall pooled estimate showed that the mean recovery time favored the laparoscopic group, with a reduction of -11.82 days and -8.94 days, respectively (**Figure 7**). The pooled analysis of the mean recovery time from two RCTs and three observational studies showed that the average time to return to normal activities in laparoscopic surgery was significantly shorter by 9.67 days compared to open surgical approaches (95%CI: -10.81, -8.53; p<0.00001) (**Figure 7**). A fixed-effect model was used for this analysis due to low heterogeneity among the studies (I^2: 46%; p=0.13).

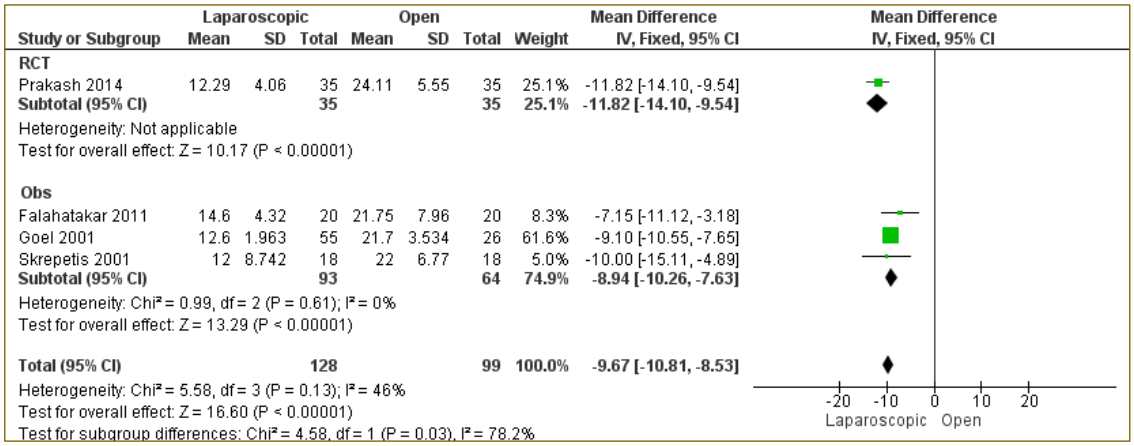

Figure 7. Forest plot comparing the mean recovery time (days) between open proximal ureterolithotomy and laparoscopic.

Comparison of overall complications

In both RCT and observational study subgroups, the difference in overall complications between the laparoscopic and open groups observed in RCTs was not statistically significant (**Figure 8**). Similarly, the pooled analysis of overall complication rates of combined RCTs and observational studies showed that there was no significant difference in overall complication rates between laparoscopic and open surgical approaches (OR: 0.68; 95%CI: 0.41, 1.15; p=0.16) (**Figure 8**). A fixed-effect model was used for this analysis because of low heterogeneity among the studies (I^2: 32%; p=0.20).

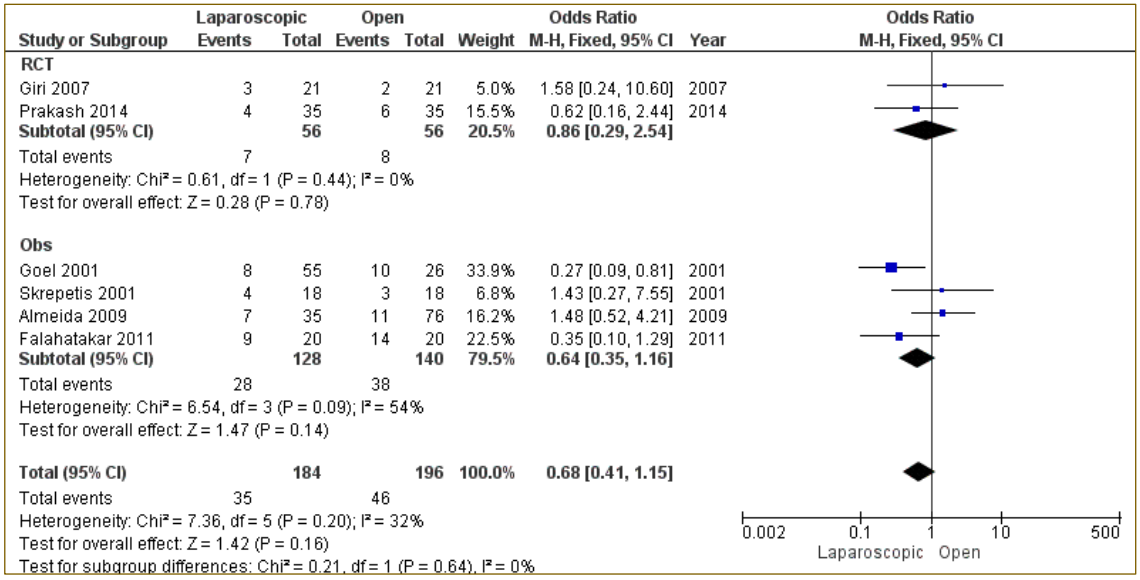

Figure 8. Forest plot comparing the overall complications between open proximal ureterolithotomy and laparoscopic.

Discussion

Ureteral stones are a common urological condition that may lead to significant morbidity and decreased quality of life [13]. Various surgical approaches have been developed for the management of proximal ureteral stones, specifically in impacted stone, including open and laparoscopic ureterolithotomy [7,11,14]. However, there is no consensus on the comparative effectiveness and associated complications of these techniques. This meta-analysis highlighted the superiority of the open surgical approach in terms of shorter operative time indicating potential advantages including reduced anesthesia exposure, improved cost-effectiveness, and enhanced operating room efficiency. In a study by Yasui *et al.* [15], laparoscopic ureterolithotomy via the retroperitoneal route achieved successful outcomes with a mean operative time of around 130 minutes, with most cases falling within a range of 90–130 minutes. However, certain cases required longer durations due to complexities, highlighting the importance of extensive training for the laparoscopic approach [15]. The limited working space in laparoscopic procedures and the complexity of laparoscopic ureterolithotomy, including patient preparation and postoperative care, as well as the need for more extensive experience to perform the procedure efficiently, may contribute to these findings [2,16].

In terms of bleeding, this meta-analysis indicated no significant difference between the laparoscopic and open surgical approaches. A previous study by Goel *et al.* (2001) reported comparable results between the two approaches. Yasui *et al.* [15] successfully completed all ureterolithotomy procedures laparoscopically without the need for an open operation, with a mean blood loss (including urine) of 64.4±78.2 ml and a range of 3–212 ml. A study by Almeida *et al.* [3] demonstrated successful management and favorable outcomes in all subgroups without any need for blood transfusions, thereby strengthening the evidence that both laparoscopic and open surgical techniques are equally effective in terms of bleeding control.

This study result also revealed that the laparoscopic approach was associated with lower postoperative pain levels and reduced analgesic requirements. The reduced incisional pain in the laparoscopic group may be attributed to the laparoscopic technique, which involves less muscle cutting and splitting during the procedure. Consequently, patients in the laparoscopic group also required notably lower total analgesic requirements, indicating better patient tolerance towards the laparoscopic approach [2].

The meta-analysis revealed significant advantages of laparoscopic ureterolithotomy in terms of hospital stay and recovery time compared to open surgical approaches. The pooled analysis showed a statistically significant reduction in hospital stay by approximately 2.4 days favoring the laparoscopic approach over open proximal ureterolithotomy. Previous research studies found that laparoscopic patients experienced shorter hospital stays ranging from 2 to 4 days, while open

surgery patients had longer stays ranging from 5 to 8 days [2,4,17,18]. Additionally, the laparoscopic group exhibited a faster mean recovery time of approximately 9.67 days.

Notably, the study conducted by Wani and Durrani also made an important observation that patients in the laparoscopic group experienced earlier recovery of oral intake by 2–3 hours compared to the open surgical approach [2,4,17,18]. This, along with smaller surgical incisions, fewer direct tissue manipulations, reduced postoperative pain, and early mobilization, could potentially contribute to the shorter hospital stay and faster recovery associated with the laparoscopic approach [19,20].

Additionally, the overall complication rates between the two approaches were comparable, suggesting that laparoscopic ureterolithotomy offers similar safety outcomes to open surgery. Several prior studies have reported variations in the incidence of complications between open surgical and laparoscopic approaches for ureteral stone management [2,14,21,22]. For example, Prakash *et al.* found a complication rate of 11.4% for the laparoscopic approach and 17.4% for the open approach [2]. Conversely, Almeida *et al.* [3] demonstrated that the complication rates for laparoscopic ureterolithotomy and open ureterolithotomy were comparable. Laparoscopic ureterolithotomy, despite sharing similarities with open surgery, presents distinct advantages such as smaller incision size, faster postoperative recovery, and reduced direct tissue manipulation, which may lead to a lower incidence of complications [19]. Another promising approach for the proximal ureteral stone is the antegrade percutaneous ureterolithotripsy that offers better outcomes in stone free rate than the retrograde ureterolithotripsy, but further study is needed to confirm if it is superior than the laparoscopic or open ureterolithotomy [23].

This study is not without limitations. Firstly, most of the included studies were in retrospective design. The nature of this design may lead to several biases, therefore more RCT studies are warranted. Secondly, the influence of operator experience, which may alter the outcome, could not be entirely controlled or analyzed leaving the possibility that this factor may influence the outcomes.

Conclusion

This meta-analysis offers invaluable insights into the comparison between open and laparoscopic surgical approaches for proximal ureterolithotomy. Notably, the open surgical approach demonstrated significantly shorter operative times, while the laparoscopic approach exhibited advantages such as lower postoperative pain, shorter hospital stays, and faster recovery times. More RCTs are needed to validate these findings and enhance evidence-based management of proximal ureteral stones with impaction.

Ethics approval

Not required.

Acknowledgments

None.

Competing interests

No conflict of interest was declared by the authors.

Funding

The authors received no specific funding for this work.

Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

How to cite

Maliki A, Fitriani R, Soebadi MA, *et al*. Comparison of efficacy and safety of open and laparoscopic proximal ureterolithotomy for ureteral stone management: A systematic review and meta-analysis. Narra J 2024; 4 (1): e679 - http://doi.org/10.52225/narra.v4i1.679.

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