Urologia Internationalis

Systematic Review

Urol Int 2026;110:519–531
DOI: 10.1159/000550064

Received: September 20, 2025
Accepted: November 30, 2025
Published online: December 12, 2025

Effectiveness of Pneumatic versus Laser Lithotripsy for Upper Tract Urolithiasis: A Systematic Review and Meta-Analysis

Lujza Brunaiova[a] Karl G. Sommer[a] Lukas Koneval[a] Dario Willi[a] Mirjam N. Mohr[b] Thomas Neumann[c] Laila Schneidewind[a, c] Annemarie Uhlig[b]

[a]Department of Urology, University Hospital of Bern, Bern, Switzerland; [b]Department of Urology, University Medical Center Göttingen, Göttingen, Germany; [c]Department of Hematology/Oncology, University Medical Center Greifswald, Greifswald, Germany

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

Keywords
Urolithiasis · Ureterorenoscopy · Retrograde intrarenal surgery · Percutaneous nephrolithotomy · Pneumatic lithotripsy · Laser lithotripsy

Abstract

Introduction: This meta-analysis compares the efficacy and safety of laser lithotripsy (LL) and pneumatic lithotripsy (PL) for upper tract urolithiasis. ***Methods:*** A systematic search of MEDLINE via PubMed, Embase, and the Cochrane Library identified trials comparing LL and PL. Primary outcomes included stone-free rate, operative time, and complications. A random-effects model was used, and heterogeneity was assessed using I^2 statistics. ***Results:*** The systematic literature search identified 6,420 studies of which 43 fulfilled the inclusion criteria. The studies reported data from 7,377 patients. Random effect meta-analysis for stone free rate included data from 36 studies and yielded statistically significant higher stone free rates for LL with a pooled OR = 2.19 (95% confidence interval [CI] = 1.63–2.94, $p < 0.001$). Heterogeneity was substantial ($I^2 = 62\%$; $p < 0.01$). Random effect meta-analysis for operative time included data from 31 studies and yielded no statistically significant difference in operative time with a pooled MD = −1.09 min (95% CI = −4.39–2. 20, $p = 0.5161$). Heterogeneity was considerable ($I^2 = 98\%$; $p < 0.01$). Random effect meta-analysis for complications included data from 14 studies and yielded statistically significant fewer complications for LL with a pooled OR = 0.68 (95% CI = 0.48–0.96, $p = 0.0276$). Heterogeneity was limited ($I^2 = 27\%$; $p = 0.17$). ***Conclusions:*** LL might be superior to PL in upper tract urolithiasis therapy.

© 2025 The Author(s).
Published by S. Karger AG, Basel

Plain Language Summary

Laser lithotripsy is more effective than pneumatic lithotripsy for the treatment of upper urinary tract urolithiasis (kidney and ureter) in adults as well as in children. Furthermore, laser lithotripsy is a safe procedure.

© 2025 The Author(s).
Published by S. Karger AG, Basel

Lujza Brunaiova, Karl G. Sommer, Laila Schneidewind, and Annemarie Uhlig contributed equally to this work.

karger@karger.com
www.karger.com/uin

© 2025 The Author(s).
Published by S. Karger AG, Basel

This article is licensed under the Creative Commons Attribution 4.0 International License (CC BY) (https://karger.com/Services/OpenAccessLicense). Usage, derivative works and distribution are permitted provided that proper credit is given to the author and the original publisher.

Correspondence to:
Laila Schneidewind, laila.schneidewind@uni-greifswald.de

Introduction

The introduction and advances in intracorporeal lithotripter devices, especially laser and pneumatic devices have improved the stone-free rates after percutaneous nephrolithotomy (PCNL), retrograde intrarenal surgery (RIRS), as well as ureterorenoscopy (URS) for upper tract urolithiasis and at the same time decreased the risk of complications. These intracorporeal lithotripter devices work on different principles of stone fragmentation, e.g., the principle of pneumatic lithotripter consists of direct contact between the end of the rigid probe and the stone, the energy provided by a compressor being transmitted as compressed air to a metal projectile within the handpiece as pulses which is propelled to the end of the metallic probe resulting in stone fragmentation. In the early 90s laser lithotripsy (LL) systems have been introduced with the potential of being even more effective. Unfortunately, there is a lack of comprehensive evidence which system is more effective, not only in terms of stone-free rates, but also putting into account complications, quality of life (QoL), and cost effectiveness, especially in terms of a comprehensive meta-analysis [1–5].

Consequently, we conducted a systematic review and meta-analysis addressing the following question: Are there any differences between LL versus pneumatic lithotripsy (PL) in upper tract urolithiasis concerning stone free rates, complications, and costs? Therefore, the primary aim of this study was to evaluate differences between LL and PL in primary outcomes such as stone-free rates and operation time and secondary outcomes such as complication rates. We also aimed to extract data for QoL and cost effectiveness.

Methods

Search Strategy

In May 2024, we performed a systematic literature search using MEDLINE via PubMed, Embase, and the Cochrane Library. The search algorithm broadly included the search term clusters urolithiasis, PCNL, URS and lithotripsy. The online supplementary material details the complete search algorithms (for all online suppl. material, see https://doi.org/10.1159/000550064). Reference lists of included articles, as well as review articles, were searched to identify additional records. No restrictions were made concerning language, study region, or publication type. Publication date was included after 1978, when the first pneumatic lithotripters were induced. This study was prospectively registered at PROSPERO (https://www.crd.york.ac.uk/prospero/; ID CRD 42024542375).

Study Inclusion and Exclusion Criteria

The predefined primary outcomes were visual stone-free rate, radiological stone-free rate, operating time, stone fragmentation time and length of hospital stay after stone lithotripsy (LL vs. PL) for upper urinary tract stones (ureter and kidney). We included randomized controlled trials (RCTs) as well as prospective clinical trial (non-RCTs) and retrospective cohort studies. Further exclusion criteria were not defined. The larger and more comprehensive publication was included if more than one publication evaluated the same patient cohort.

Data Extraction

An a priori defined standardized data extraction process was used for every included record. Extracted variables included author(s), year of publication, study country, population size, patient's and stone characteristics, statistical methods, as well as absolute and relative data of effect (see primary and secondary aims). Study extraction was independently performed by two review authors. Inconsistencies were resolved by a third review author. The online platform covidence (https://www.covidence.org/; Veritas Health Innovation Ltd, Melbourne, Australia) was used for the screening and data extraction process.

Study Quality Assessment

Two reviewers independently assessed the risk of bias with the ROBINS-I-tool or the Cochrane Risk of Bias tool RoB2 as appropriate [6]. The ROBINS-I tool includes seven domains of bias: risk of bias due to confounding, bias in the selection of participants into the study, bias in classification of interventions, bias due to deviations from intended interventions, bias due to missing data, bias in the measurement of outcomes, and bias in the selection of the reported results for one outcome measurement. The domains are combined to an overall risk of bias. The RoB2 tool summarizes five risk of bias domains: bias arising from randomization process, bias due to deviations from the intended intervention, bias due to missing outcome data, bias in measurement of the outcome and bias in selection of the reported results. These domains are also combined to an overall risk of bias. Any disagreements were resolved by the involvement of a third review author.

Statistical Analysis

Comparison of the differences in predefined outcome parameters (primary and secondary) was performed using the inverse variance method weighting for pooling of continuous outcome data to account for clinical heterogeneity [7]. In all provided analyses, PL was considered the referent. Between studies, heterogeneity was assessed by the

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

I^2 statistic with the associated 95% confidence interval (CI), the chi-square p values of heterogeneity and visual inspection of forest plots. Heterogeneity was interpreted as limited – I^2 = 0–40%, moderate – I^2 = 41–60%, substantial – I^2 = 61–80% and considerable I^2 = 81–100%. Subgroup analyses were conducted to identify potential sources of heterogeneity. In addition, change of pooled hazard ratio over the years of publication was assessed. Publication bias was assessed by visual inspection of the funnel plot and by Egger's test. All statistical analyses were performed with R version 4.2.1 (https://www.r-project.org/) and RStudio (RStudio, Boston, MA, USA) and the R package meta. The alpha level indicating statistical significance was predefined as 0.05 for all analyses except the assessment of heterogeneity, which was considered at alpha = 0.1. All provided p values are 2-sided.

Results

Study Characteristics

The systematic literature search identified 6,420 studies of which 43 fulfilled the inclusion criteria. Figure 1 presents the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart. The characteristics of the included studies are summarized in the SP [8–50].

The studies were published between 2000 and 2024 and reported data 7,377 patients. All studies were published in English language. The majority of the studies were full-text articles, whereas only 3 studies were conference abstracts. The study size ranged from 36 to 880 patients.

A total of 26 studies were cohort studies, while 17 studies were RCTs. Almost half of the studies (n = 21) were designed as prospective studies. The majority of the studies were monocentric, while only three derived data from a multicentric setting. The study regions were mostly Asia (n = 24), followed by Europe (n = 10) and Middle East (n = 8).

The outcomes evaluated were stone-free rate (39 studies), late stone-free rate (10 studies), operative time (34 studies), length of hospital stay (24 studies), double J (DJ) stenting (5 studies), complications (19 studies), stone migration (5 studies), blood loss (3 studies), fragmentation time (4 studies) and costs (3 studies). Pooling was possible for the outcomes stone-free rate (36 studies), late stone-free rate (8 studies), operative time (31 studies), length of hospital stay (18 studies), DJ stenting (5 studies), complications (14 studies), stone migration (5 studies), and fragmentation time (4 studies).

Pooled Analysis for Stone-Free Rate

Random effect meta-analysis for stone-free rate included data from 36 studies and yielded statistically significant higher stone-free rates for LL with a pooled OR = 2.19 (95% CI = 1.63–2.94, $p < 0.001$). Heterogeneity was substantial (I^2 = 62%; $p < 0.01$). This analysis is illustrated in Figure 2. Visual inspection of the funnel plot and Egger's test yielded no evidence of publication bias (Egger's test p = 0.1026), see online supplementary Figure A.

Pooled Analysis for Late Stone-Free Rate

Random effect meta-analysis for late stone free rate included data from 8 studies and yielded statistically significant higher stone free rates for LL with a pooled OR = 2.39 (95% CI = 1.51–3.80, $p < 0.001$). No relevant heterogeneity was found (I^2 = 0%; p = 0.84). Visual inspection of the funnel yielded no evidence of publication bias. This analysis is illustrated in online supplementary Figure B.

Pooled Analysis for Operative Time

Random effect meta-analysis for operative time included data from 31 studies and yielded no statistically significant difference in operative time with a pooled MD = −1.09 min (95% CI = −4.39–2. 20, p = 0.5161). Heterogeneity was considerable (I^2 = 98%; $p < 0.01$). Visual inspection of the funnel plot and Egger's test yielded no evidence of publication bias (Egger's test p = 0.4477). This analysis is illustrated in online supplementary Figure C.

Pooled Analysis for Length of Hospital Stay

Random effect meta-analysis for length of hospital stay rate included data from 18 studies and yielded a statistically significant shorter hospital stay for LL with a pooled MD = −0.24 days (95% CI = −4.39–2. 20, p = 0.5161). Heterogeneity was considerable (I^2 = 98%; $p < 0.01$). This analysis is illustrated in Figure 2. Even though visual inspection of the funnel plot suggested publication bias with the true estimate lying even closer to a MD of 0, Egger's test yielded no evidence of publication bias (Egger's test p = 0.4542), see online supplementary Figure D.

Pooled Analysis for DJ Stenting

Random effect meta-analysis for DJ stenting included data from 5 studies and yielded statistically significant fewer stenting for LL with a pooled OR = 0.19 (95% CI = 0.07–0.48, $p < 0.001$). Heterogeneity was considerable (I^2 = 85%; $p < 0.01$). Visual

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

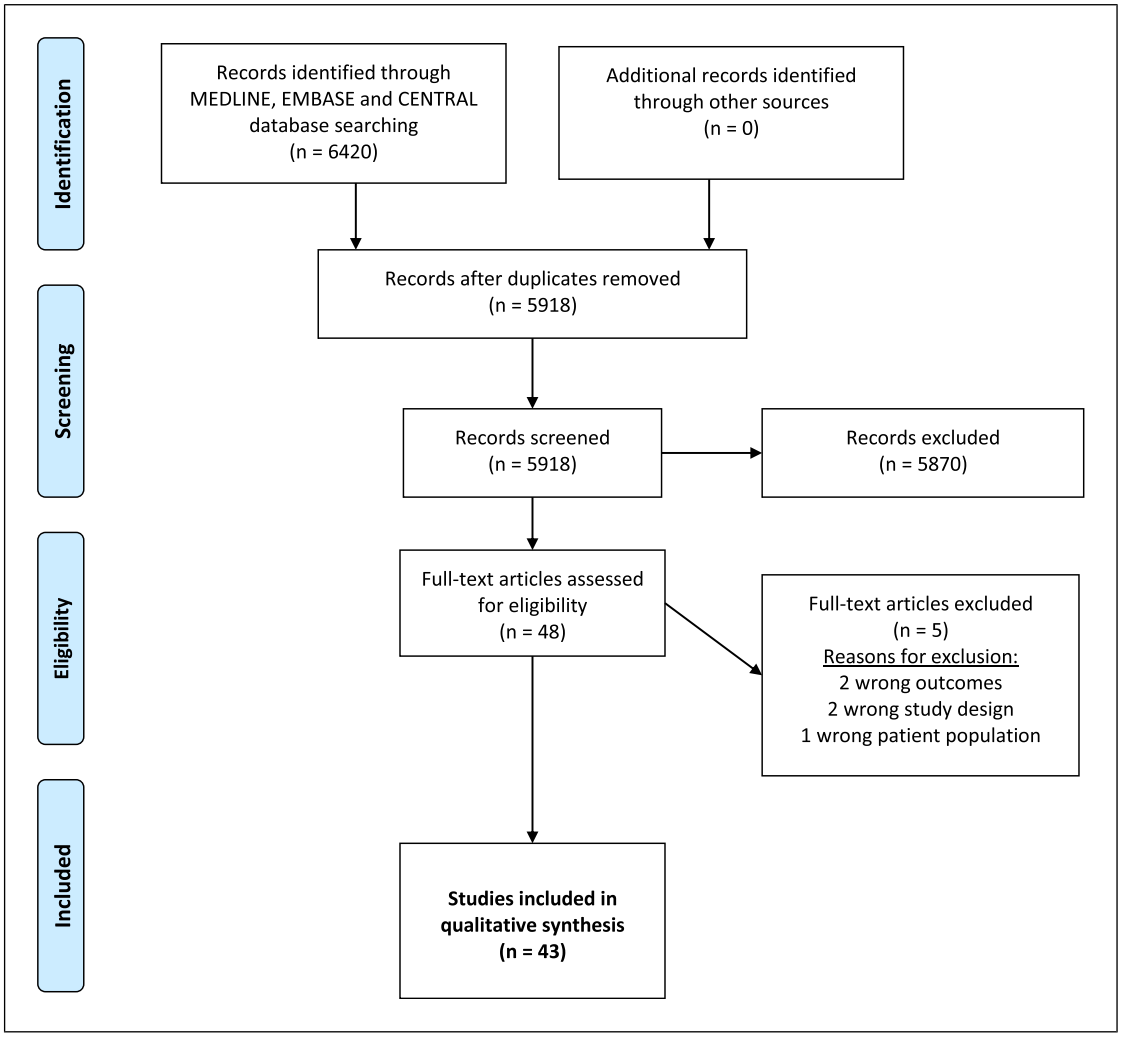


Fig. 1. PRISMA flowchart.

inspection of the funnel yielded no evidence of publication bias. This analysis is illustrated in online supplementary Figure E.

Pooled Analysis for Complications

Random effect meta-analysis for complications included data from 14 studies and yielded statistically significant fewer complications for LL with a pooled OR = 0.68 (95% CI = 0.48–0.96, p = 0.0276). Heterogeneity was limited (I^2 = 27%; p = 0.17). Visual inspection of the funnel plot suggested publication bias with the true estimate lying closer to an OR of 1 and Egger's test yielded evident publication bias (Egger's test intercept = 0.4454, t = −2.25, p = 0.0440). This analysis is illustrated in Figure 3.

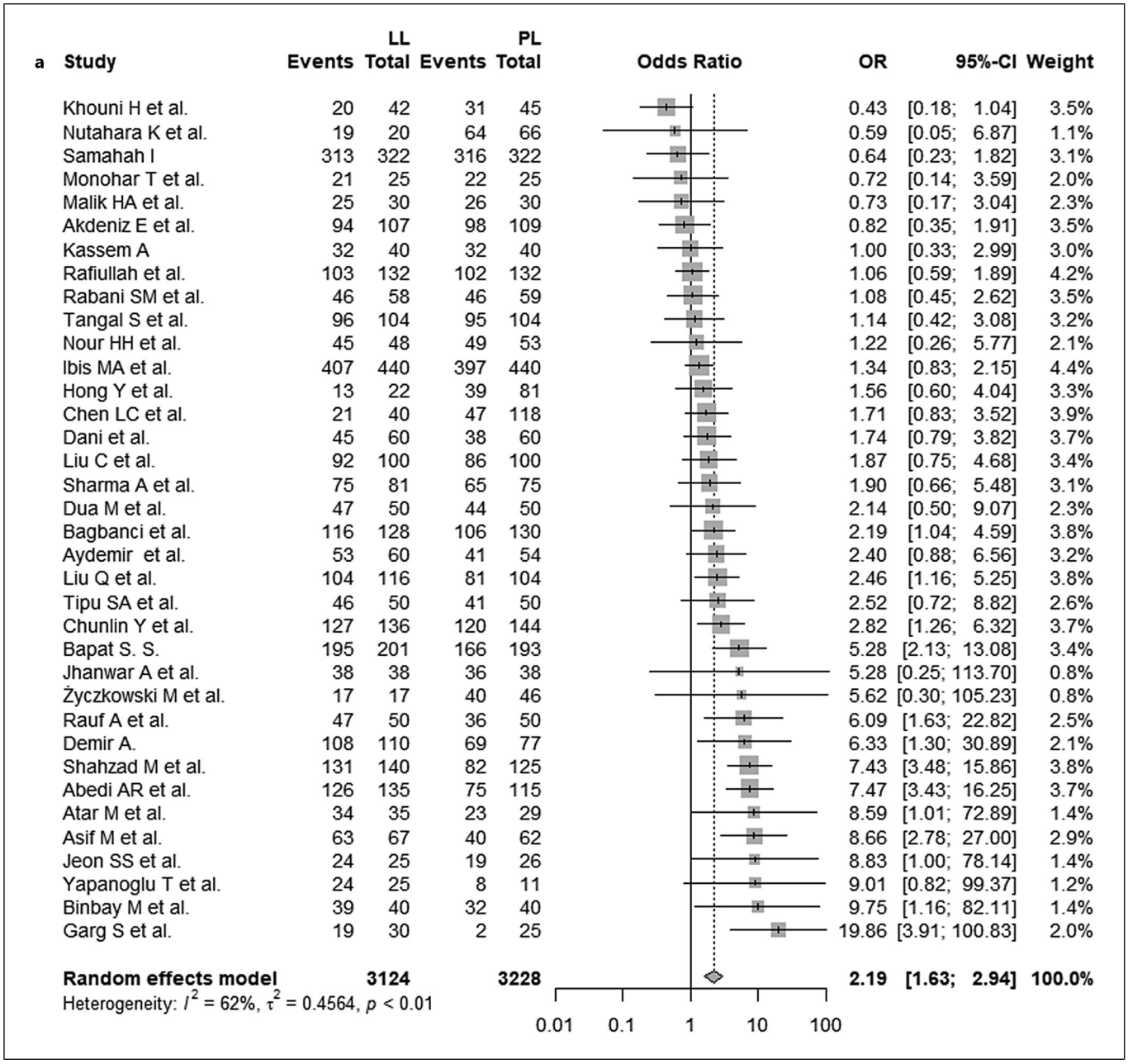
Pooled Analysis for Stone Migration

Random effect meta-analysis for stone migration included data from 5 studies and yielded no statistically significant difference in stone migration rates with a pooled OR = 0.93 (95% CI = 0.19–4.58, p = 0.9276). Heterogeneity was considerable (I^2 = 91%; p < 0.01). Visual inspection of the funnel plot did not suggest any publication bias. This analysis is illustrated in online supplementary Figure F.

Pooled Analysis for Fragmentation Time

Random effect meta-analysis for fragmentation time included data from 4 studies and yielded no statistically significant difference in fragmentation time with a pooled MD = −0.26 min (95% CI = −3.40–3.93, p = 0.8875). Heterogeneity was considerable (I^2 = 95%;

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026



(Figure continued on next page.)

$p < 0.01$). Visual inspection of the funnel plot did not suggest any publication bias. This analysis is illustrated in online supplementary Figure G.

Subgroup Analyses

A detailed subgroup analysis including stone-free rates, operative time, length of hospital stay, and complications is given in the SP. Subgroup analyses for operative time revealed that some of the heterogeneity was driven by the laterality of the stones. Among the 3 pooled studies including only unilateral stones (vs. uni- and bilateral or bilateral only), statistically significant shorter operative time was evident for PL with a pooled MD = 5.31 (95% CI = 4.00–26.62). No Heterogeneity was evident (I^2 = 0%; p = 0.84). The results of the subgroups analysis are depicted in the online supplementary appendix Figure I.

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

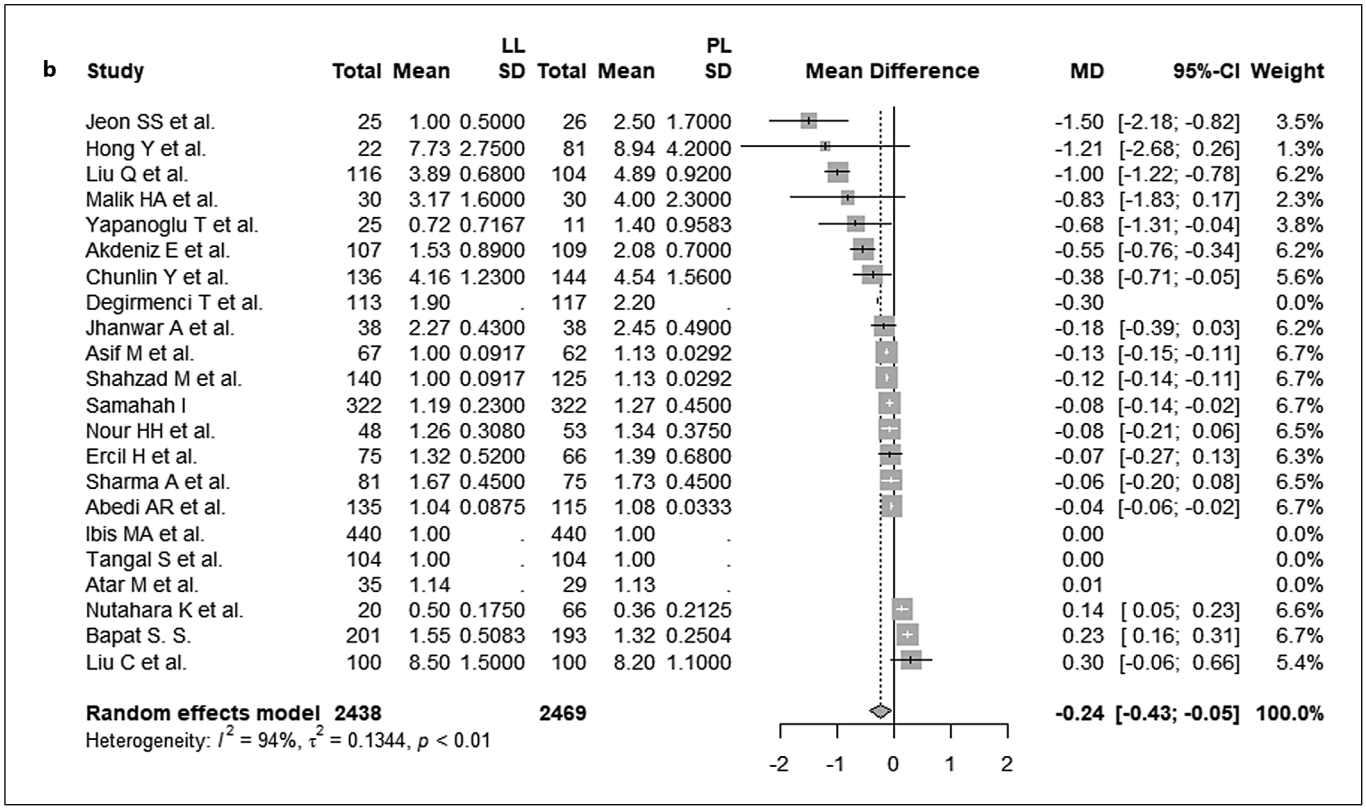


Fig. 2. Meta-analysis for stone-free rate (**a**) and length of hospital stay (**b**).

Furthermore, and due to clinical relevance, we performed analyses comparing the urinary tract access. Of the studies including PCNL only versus RIRS only: Of the 43 included studies, 37 studies (86%) reported results from RIRS only, whereas a total of six studies reported results from PCNL only. None of the studies mixed both access types. The subgroup analyses for stone free rate showed that some of the heterogeneity was driven by urinary tract access. Among the six pooled studies with PCNL, no statistically significant difference between LL and PL was evident anymore (OR = 1.40, 95% CI: 1.01–1.95) with an I^2 = 0%; p = 0.88. Additionally, subgroup analyses for complications revealed that some of the heterogeneity was driven by urinary tract access. Among the four pooled studies with PCNL, no statistically significant difference between LL and PL was evident anymore (OR = 1.00, 95% CI: 0.64–1.55) with an I^2 = 0%; p = 0.55.

Sensitivity Analyses

Cumulative meta-analysis for stone-free rate and late stone-free rate showed statistically significant effect from 2009 onwards, for stone migration since 2018, for length of hospital stay since 2022, for complications and for fragmentation time statistical significance was present from the beginning. The results of the sensitivity analysis can be found in online supplementary Figure L.

Non-Pooled Outcome Parameters (Expenses)

Hospitalization expenses in the study of Chunlin et al. [14]: PL is cheaper with a mean of CNY 8.24 thousand compared to LL with a mean of CNY 9.25 thousand (chi-square p = 0.014). Cost of surgery in the study of Demir et al. [17]: PL is cheaper with a mean of USD 2.16 (SD 66.13) compared to LL with a mean of USD 311.7 (SD 51.97), p = 0.001. Costs to attain stone-free status in the study of Nour et al. [36]: PL is cheaper with a mean of EGP 3404.11 versus LL with a mean of EGP 7,286.17, p < 0.001.

Detailed Information about Complications

More specific information about complications was available from several studies. Nutahara et al. [50] found statistically significant less days of postoperative gross hematuria in LL (mean 2.5 ± 1.8 vs. 4.3 ± 2.0 days, p < 0.01). Bapat et al. [48] found no statistically significant difference in urosepsis rates comparing PL and LL.

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

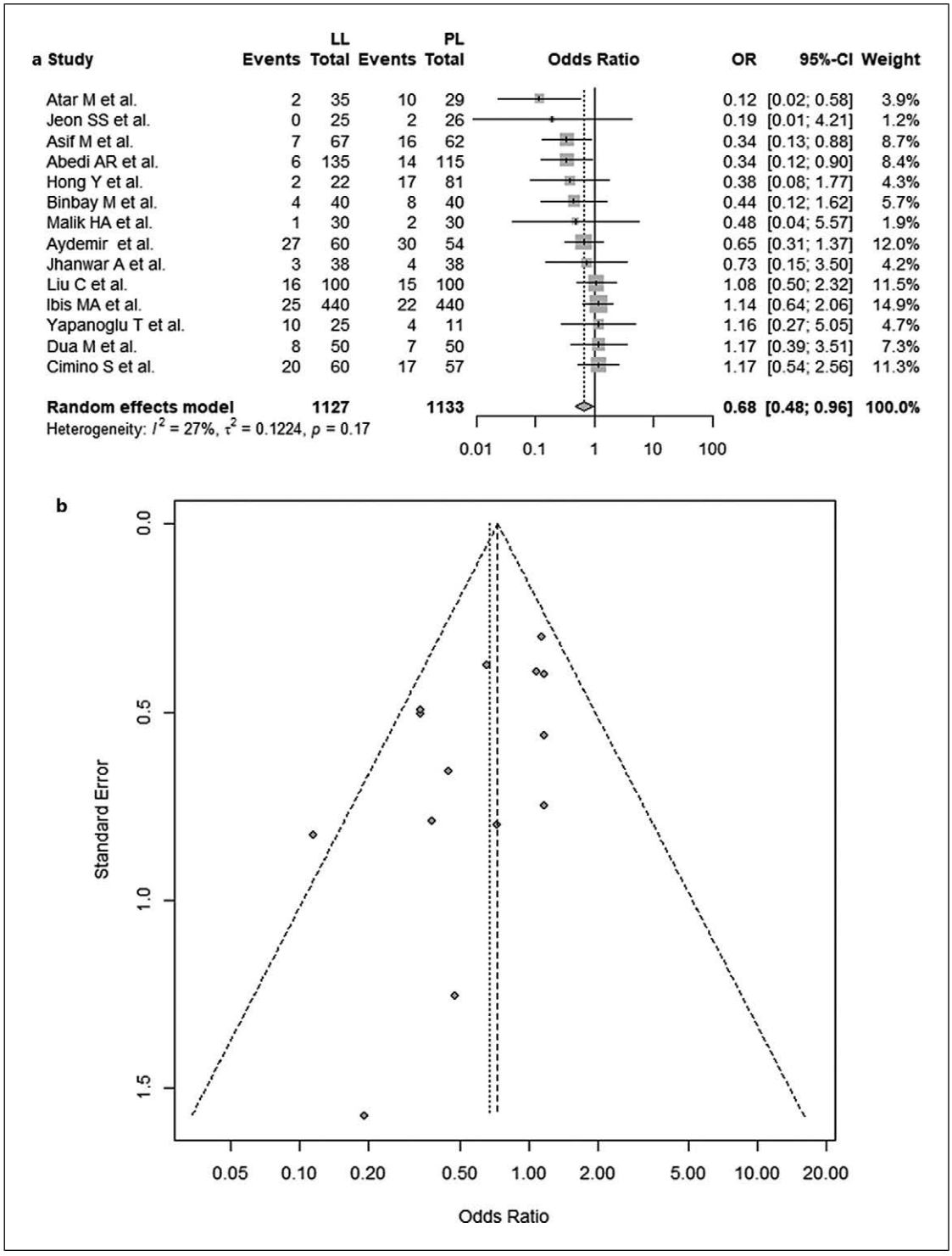


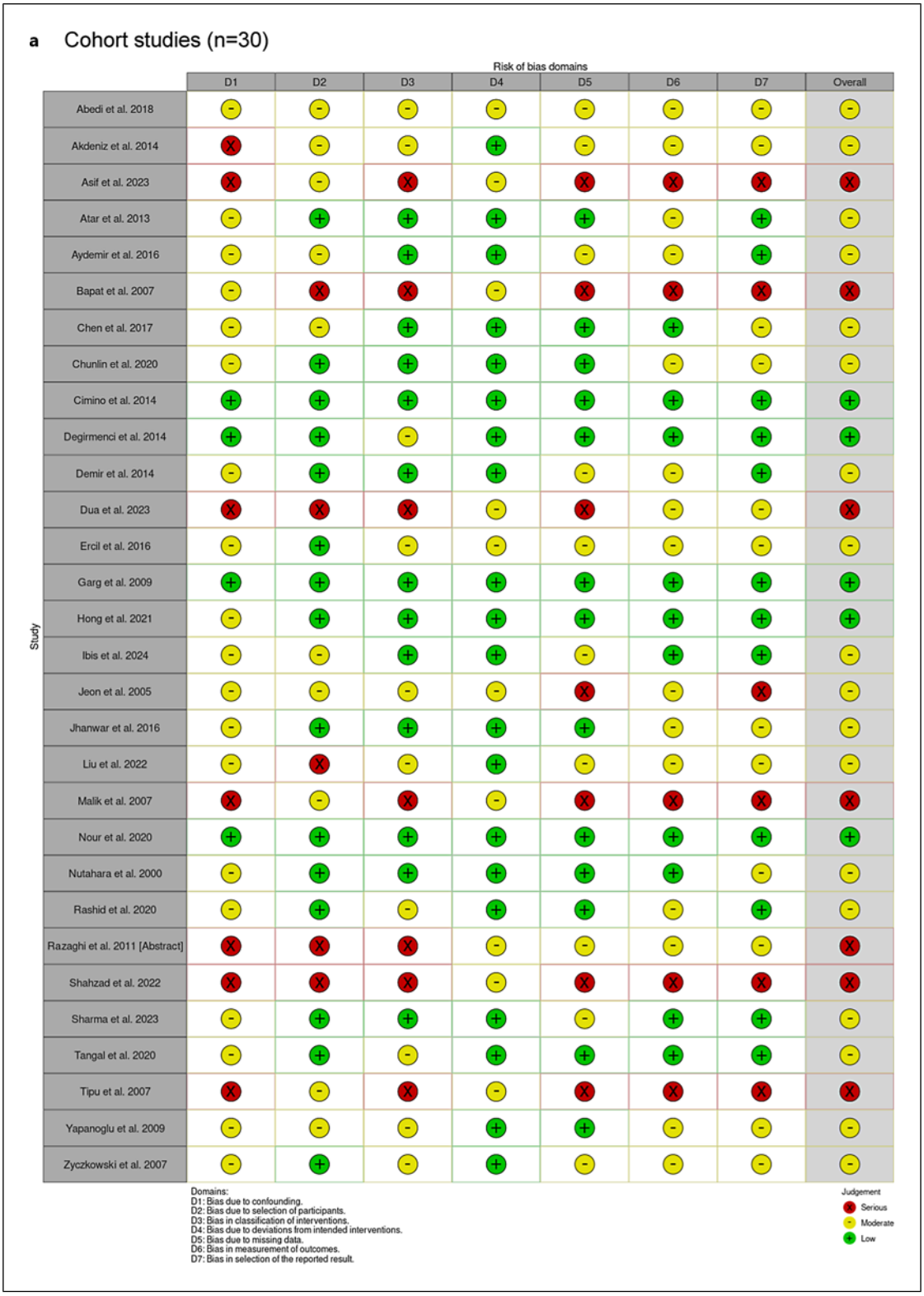
Fig. 3. Meta-analysis for complications (**a**) with corresponding funnel plot for publication bias (**b**).

Binbay et al. [12] found no difference in ureteral strictures. Kassem et al. [30] found no statistically significant difference in intraoperative perforation.

Further Study Aims

None of the studies reported QoL data or results from postoperative pain assessment.

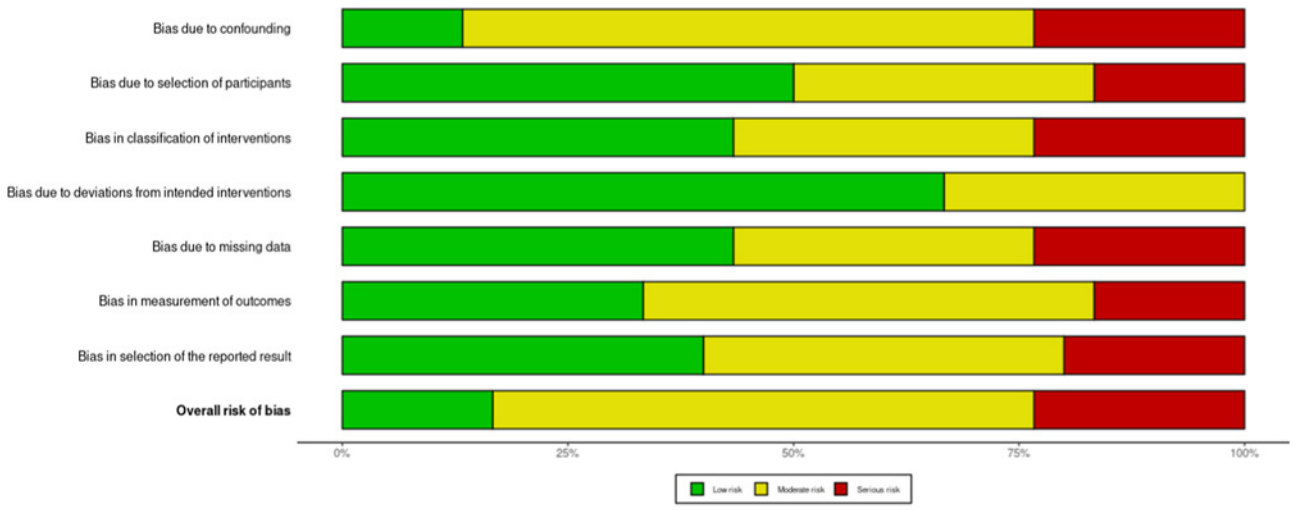
Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026



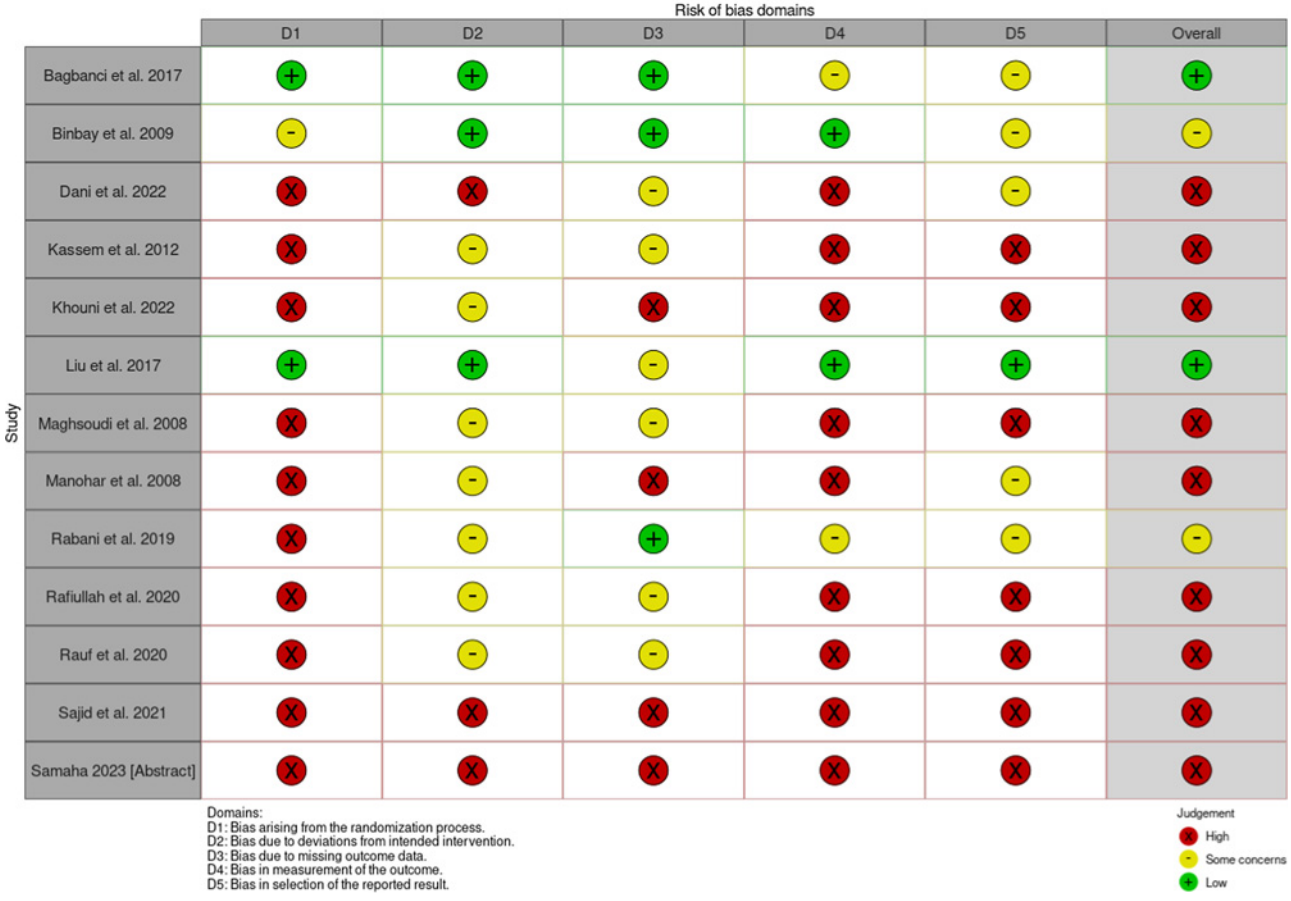
4

(Figure continued on next page.)

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026



b RCTs (n=13)



4

(Figure continued on next page.)

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

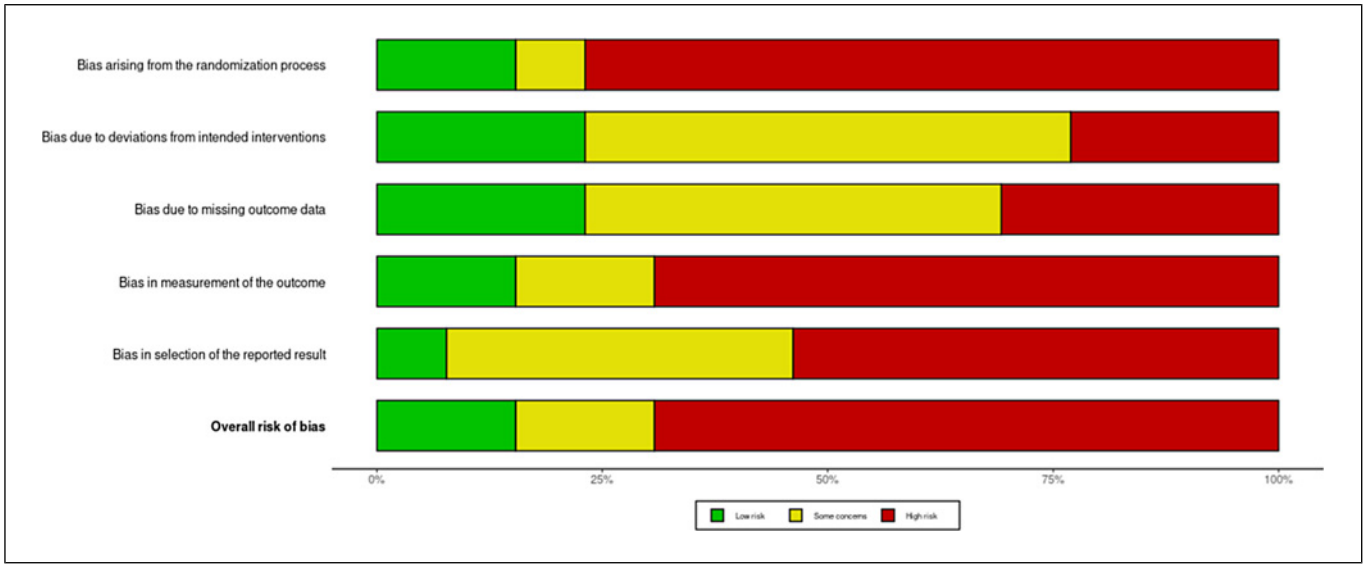


Fig. 4. Risk of bias assessment for the included studies for cohort studies using RONBINS-I tool (**a**) and for RCTs using ROB2 tool (**b**).

Quality Assessment

The overall risk of bias was moderate to high with reasons for limited quality being mainly due to retrospective study design of some studies and reporting bias. Figure 4 shows the detailed risk of bias assessment of the included studies.

Discussion

We conducted a systematic review and meta-analysis to assess differences in various outcomes, such as stone-free rate, operation time, and complications, between LL and PL. This topic is of great scientific interest as both techniques are used to treat urolithiasis of the upper urinary tract, and it remains unclear whether one intervention is superior to the other. However, the current European Association of Urology (EAU) guideline gives a strong recommendation to use holmium: yttrium-aluminium-garnet or thulium fiber laser LL for (flexible) URS or RIRS, but there is no explicit recommendation for PL, semirigid procedures or PCNL. Additionally, and to the best of our knowledge, this is first systematic review and meta-analysis addressing the question in upper tract stones and including adult patients as well as children.

The meta-analysis and the assessment of pooled data yielded several important findings: LL is superior to PL with respect to stone free rate and late stone free rate, complication rate, and fewer DJ stenting for LL. Yet, subgroup analyses for complication rates revealed no statistically significant difference for RCTs, studies with stones only in the kidney and studies with low risk of bias. However, the low numbers of pooled studies (twice 3 studies and once 5 studies) might have left the analyses underpowered. No difference in operative time except for unilateral stones where operative time was shorter for PL, length of hospital stay except for studies with bilateral stones only and RCTs and studies from the Middle East with a statistically significant shorter hospital stay for LL, stone migration, and fragmentation time. Nevertheless, our results are difficult to compare because, at least to our knowledge, there is no meta-analysis available addressing this question. Additionally, there were no significant differences in fragmentation time or stone migration rates. These nuanced findings support the idea that both devices may be suitable depending on the clinical scenario.

Our comprehensive subgroup analyses revealed some changes in effect size or statistically significance but the analyses for operative time remained the only case in which PL turned out to be superior to LL. In cases of missing statistical significance, the small size of some subgroups might have left the analyses underpowered what claims for further research on this topic to generate more evidence.

Unfortunately, no useful subgroup analyses were possible for publication language (all studies were published in English), abstract versus full publication (only three abstracts), uni- versus multicentricity (only three multicenter studies), type of laser used (only two

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

studies with other than Holmium lasers), or adults versus children. Too few information was available for subgroup analyses by stone characteristics, previous therapies, risk of stone recurrence, and different types of PL used, e.g., PL together with a suction device.

However, the limitations of the analyzed data were that there was no pooling possible for cost effectiveness and there were no data available on pain assessment as wells as QoL data. Furthermore, the included studies did not report long-term outcomes, e.g., ureteral stricture rates, or recurrences of stones. Still, it would be of interest to also have information on the stone composition for choosing the best lithotripter device. Additionally, we reported that some of the heterogeneity was driven by the urinary tract access, so further research should focus on RIRS or PCNL alone when comparing lithotripter devices. Lastly, there was a great heterogeneity in the devices and their instrument settings.

On the basis of our findings, clinical implications are that LL seems to be more effective than PL with fewer complication rates, but subgroup analysis revealed that PL might be superior in operating time in complex bilateral stone disease. Additionally, there are hints from three studies that PL is more cost-effective than LL [14, 17, 36]. Consequently, further research is needed here addressing the question if PL might be the better and cheaper choice for complex and high stone burden in upper tract stones. Against the background of high economic pressure in the health care systems, this is of special interest. These further studies should also provide data on QoL, stone composition as well as long-term results.

We must assume that our study has also several limitations like the high risk in reporting bias and the heterogeneity of the included studies, so we attempted to mitigate this through detailed subgroup analyses and sensitivity testing, as documented in the SP. Our meta-analysis is the first to provide a head-to-head comparison of LL and PL in upper tract urolithiasis across both adult and pediatric and adult populations. It offers valuable insights and highlights areas requiring further investigation.

LL might be more effective and associated with fewer complications than PL in treating upper tract urolithiasis. However, PL may be more time-efficient in unilateral cases and more cost-effective in complex, bilateral, or high stone burden scenarios. These findings warrant further research to determine the optimal use of each modality, especially with respect to cost-efficiency, QoL, stone composition, and long-term outcomes.

Acknowledgments

The authors would like to thank Dr. Julia Lackner from UroEvidence from the German Society of Urology (DGU) for her guidance in the development of search strategies and validation of search strategies.

Statement of Ethics

Regarding this systematic review and meta-analysis, a statement of ethics is not applicable because this study is based exclusively on published literature.

Conflict of Interest Statement

All authors declare that they have no conflict of interest regarding this work.

Funding Sources

This review received no external funding.

Author Contributions

L.S. and A.U.: conception, data validation, analysis, and supervision. L.B., K.G.S., L.K., D.W., M.N.M., T.N., L.S., and A.U.: data extraction, critical review of the data, writing, and reviewing the manuscript.

Data Availability Statement

All data generated or analyzed during this systematic review and meta-analysis are included in this article and its supplementary material. Further inquiries can be directed to the corresponding author (L.S.).

References

1 Yadav BK, Basnet RB, Shrestha A, Shrestha PM. Comparison between shockpulse and pneumatic lithotripsy in percutaneous nephrolithotomy. World J Urol. 2021;39(3):915–9. https://doi.org/10.1007/s00345-020-03239-3

2 Mykoniatis I, Pyrgidis N, Tzelves L, Pietropaolo A, Juliebø-Jones P, De Coninck V, et al. Assessment of single-probe dual-energy lithotripters in percutaneous nephrolithotomy: a systematic review and meta-analysis of preclinical and clinical studies. World J Urol. 2023;41(2):551–65. https://doi.org/10.1007/s00345-023-04278-2

3 Chen X, He L, Yu X, Bo Y, Yu L, Chen Q, et al. Effects of thermal insulation on recovery and comfort of patients undergoing holmium laser lithotripsy. Med Sci Monit. 2024;30:e942836. https://doi.org/10.12659/MSM.942836

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

4 Abushamma F, Zyoud SH. Analyzing global research trends and focal points in the utilization of laser techniques for the treatment of urolithiasis from 1978 to 2022: visualization and bibliometric analysis. Urolithiasis. 2024;52(1):67. https://doi.org/10.1007/s00240-024-01568-1
5 Tang X, Wu S, Li Z, Wang D, Lei C, Liu T, et al. Comparison of thulium fiber laser versus holmium laser in ureteroscopic lithotripsy: a meta-analysis and systematic review. BMC Urol. 2024;24(1):44. https://doi.org/10.1186/s12894-024-01419-6
6 Cochrane Germany, Institut für Medizinische Biometrie und Statistik, Freiburg, Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften- Institut für Medizinisches Wissensmanagement, Ärztliches Zentrum für Qualität in der Medizin. Manual zur Bewertung des Biasrisikos in Interventionsstudien. 2. Edition 2021. Cochrane Germany: https://www.cochrane.de/de/literaturbewertung
7 Shu D, Young JG, Toh S, Wang R. Variance estimation in inverse probability weighted cox models. Biometrics. 2021;77(3):1101–17. https://doi.org/10.1111/biom.13332
8 Asif M, Khattak JJ, Khan Z, Anwar K, Bibi R, Rehman S. Ureteric stones less than 1.5 cm: comparison of laser vs. pneumatic lithotripsy: a single center study. Pakistan J Med Health Sci. 2023;17(5):175–6. https://doi.org/10.53350/pjmhs2023175175
9 Atar M, Bodakci MN, Sancaktutar AA, Penbegul N, Soylemez H, Bozkurt Y, et al. Comparison of pneumatic and laser lithotripsy in the treatment of pediatric ureteral stones. J Pediatr Urol. 2013;9(3):308–12. https://doi.org/10.1016/j.jpurol.2012.03.004
10 Aydemir H, Budak S, Hirik E, Kumsar S, Celik O, Adsan O. Upper ureteral stone treatment: effectiveness and complications of holmium laser and pneumatic lithotripsy. J Clin Anal Med. 2016;7:46–9.
11 Bagbanci S, Dadali M, Dadalı Y, Emir L, Gorgulu O, Karabulut A. Does a retropulsion prevention device equalize the surgical success of Ho:YAG laser and pneumatic lithotripters for upper ureteral stones? A prospective randomized study. Urolithiasis. 2017;45(5):473–9. https://doi.org/10.1007/s00240-016-0930-5
12 Binbay M, Singh A, Tepeler A, et al. Comparative evaluation of pneumatic versus holmium: YAG laser lithotripsy for impacted ureteral stones. J Endourology. 2009;1:A71.
13 Chen LC, Chiu AW, Lin WR, Lin WC, Yang S, Hsu JM, et al. Comparison of pneumatic and holmium laser ureteroscopic lithotripsy for upper third ureteral stones. Urol Sci. 2017;28(2):101–4. https://doi.org/10.1016/j.urols.2017.02.002
14 Chunlin Y, Wanlin D, Jinhua D. Analysis of the efficacy of holmium laser and pneumatic ballistic in the treatment of impacted ureteral calculi. Med. 2020;99(36):e21692. https://doi.org/10.1097/MD.0000000000021692
15 Dani T, Patel MK, Purohit D, et al. Comparison of holmium laser and pneumatic lithotripsy using semirigid scope in managing ureteric calculus. J Cardiovasc Dis Res. 2022;13:1343–52.
16 Degirmenci T, Gunlusoy B, Kozacioglu Z, Arslan M, Koras O, Arslan B, et al. Comparison of Ho:YAG laser and pneumatic lithotripsy in the treatment of impacted ureteral stones: an analysis of risk factors. Kaohsiung J Med Sci. 2014;30(3):153–8. https://doi.org/10.1016/j.kjms.2013.08.007
17 Demir A, Karadağ MA, Ceçen K, Uslu M, Arslan OE. Pneumatic versus laser ureteroscopic lithotripsy: a comparison of initial outcomes and cost. Int Urol Nephrol. 2014;46(11):2087–93. https://doi.org/10.1007/s11255-014-0787-x
18 Dua M, Periwal A, Khurana N, et al. Assessment of percutaneous nephrolithotomy with pneumatic lithotripsy and holmium laser: a hospital based study. Int J Acad Med Pharm. 2023;5:610–2.
19 Ercil H, Alma E, Bas O, Unal U, Sener NC, Vuruskan E, et al. Safety and efficacy of pneumatic lithotripters versus holmium laser on multiple ureteral calculi. Arch Iran Med. 2016;19(11):786–90.
20 Garg S, Mandal AK, Singh SK, Naveen A, Ravimohan M, Aggarwal M, et al. Ureteroscopic laser lithotripsy versus ballistic lithotripsy for treatment of ureteric stones: a prospective comparative study. Urol Int. 2009;82(3):341–5. https://doi.org/10.1159/000209369
21 Hong Y, Lin H, Yang Q, Zhou D, Hou G, Chen X, et al. Pneumatic lithotripsy versus holmium laser lithotripsy in percutaneous nephrolithotomy for patients with guy's stone score grade IV kidney stone. Urol Int. 2021;105(1–2):45–51. https://doi.org/10.1159/000509043
22 Liu Q, Guo X, Li J. Holmium laser lithotripsy reduces complications and relieves postoperative pain in elderly patients with urinary calculi. Am J Transl Res. 2022;14(8):5614–21.
23 Rashid AO, Attar A, Mohammed KS, Fakhralddin SS, Abdulla LN, Buchholz N. Direct comparison of pneumatic and Ho:YAG laser lithotripsy in the management of lower ureteric stones. Urol Int. 2020;104(9–10):765–8. https://doi.org/10.1159/000508419
24 Rauf A, Khan FUR, Rana AUR, et al. Efficacy and safety of holmium: yag laser in comparison with pneumatic lithoclast for ureteric calculi. Pakistan J Med Health Sci. 2020;14:617–20.
25 Razaghi, Razi, Mazlomfard MAM, et al. Transureteral ureterolithotripsy of ureteral calculi: which is best, pneumatic or holmium laser technique? Urology. 2011;1:S369–70.
26 Shahzad M, Khan FU, Ghani AA, Wahab F, Khan ZA, Akram A. Analyzing the effectiveness of laser and pneumatic lithotripsy in the treatment of ureteral stones smaller than 1.05 centimetres in diameter a multi-center study. Pakistan J Med Health Sci. 2022;16(12):421–2. https://doi.org/10.53350/pjmhs20221612421
27 Tipu SA, Malik HA, Mohhayuddin N, Sultan G, Hussain M, Hashmi A, et al. Treatment of ureteric calculi - use of holmium: YAG laser lithotripsy versus pneumatic lithoclast. J Pak Med Assoc. 2007;57(9):440–3.
28 Yapanoglu T, Aydin HR, Aksoy Y, et al. Ureteroscopic management of distal ureteral stones in children: holmium:yag laser vs. pneumatic lithotripsy. Turk J Med Sci. 2009;39:623–8.
29 Cimino S, Favilla V, Russo GI, Saita A, Sortino G, Castelli T, et al. Pneumatic lithotripsy versus holmium: YAG laser lithotripsy for the treatment of single ureteral stones: a prospective, single-blinded study. Urol Int. 2014;92(4):468–72. https://doi.org/10.1159/000355828
30 Kassem A, Elfayoumy H, Elsaied W, Elgammal M, Bedair A. Laser and pneumatic lithotripsy in the endoscopic management of large ureteric stones: a comparative study. Urol Int. 2012;88(3):311–5. https://doi.org/10.1159/000336254
31 Khouni H, Boulma R, Ben Kadhi S. Holmium-YAG laser lithotripsy versus ballistic lithotripsy for treatment of proximal ureteral calculi: a prospective, randomized, bicentric and comparative study. Eur Urol Open Sci. 2022;39:S73. https://doi.org/10.1016/s2666-1683(22)00145-8
32 Liu C, Zhou H, Jia W, Hu H, Zhang H, Li L. The efficacy of percutaneous nephrolithotomy using pneumatic lithotripsy vs. the holmium laser: a randomized study. Indian J Surg. 2017;79(4):294–8. https://doi.org/10.1007/s12262-016-1473-2
33 Maghsoudi R, Amjadi M, Norizadeh D, Hassanzadeh H. Treatment of ureteral stones: a prospective randomized controlled trial on comparison of Ho: YAG laser and pneumatic lithotripsy. Indian J Urol. 2008;24(3):352–4. https://doi.org/10.4103/0970-1591.39549
34 Malik HA, Tipu SA, Mohayuddin N, Sultan G, Hussain M, Hashmi A, et al. Comparison of holmium: yag laser and pneumatic lithoclast in percutaneous nephrolithotomy. J Pak Med Assoc. 2007;57(8):385–7.
35 Manohar T, Ganpule A, Desai M. Comparative evaluation of Swiss LithoClast 2 and holmium: YAG laser lithotripsy for impacted upper-ureteral stones. J Endourol. 2008;22(3):443–6. https://doi.org/10.1089/end.2007.0288
36 Nour HH, Kamel AI, Elmansy H, Badawy MH, Shabana W, Abdelwahab A, et al. Pneumatic vs laser lithotripsy for mid-ureteric stones: clinical and cost effectiveness results of a prospective trial in a developing country. Arab J Urol. 2020;18(3):181–6. https://doi.org/10.1080/2090598X.2020.1749800

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026

37 Rabani SM, Rabani S, Rashidi N. Laser versus pneumatic lithotripsy with semi-rigid ureteroscope; A comparative randomized study. J Lasers Med Sci. 2019;10(3):185–8. https://doi.org/10.15171/jlms.2019.29
38 Rafiullah BNA, Khan MB, et al. Comparison of effectiveness of intracorporeal holmium laser versus pneumatic lithotripsy in management of ureteric stone. Pakistan J Med Health Sci. 2020;14:599–602.
39 Sajid MT, Ameen M, Murtaza B, Alvi MS, Khan Z, Kiani F. Comparison of mean operative time in patients undergoing ho: YAG laser lithotripsy and pneumatic lithotripsy in ureterorenoscopy for ureteric calculus. Pak J Med Sci. 2021;37(2): 415–20. https://doi.org/10.12669/pjms.37.2.3049
40 Samaha I. Ultraslim pneumatic lithoclast probe through single channel with dormia trapping the stone versus laser uerterolithotripsy in the treatment of ureteric stones; multicenter study. Eur Urol. 2023;83: S1768. https://doi.org/10.1016/s0302-2838(23)01257-5
41 Ibis MA, Özsoy AF, Özkaya MF, Erdem E, Erkmen S, Güler AD, et al. Comparison of lithotripsy methods during mini-PNL: is there a role for ballistic lithotripsy in the era of high-power lasers. BMC Urol. 2024;24(1): 54. https://doi.org/10.1186/s12894-024-01443-6
42 Sharma A, Giri A, Garg G, Sadasukhi N, Sadasukhi TC, Gupta H, et al. A prospective comparative study to evaluate safety and efficacy of pneumatic versus laser lithotripsy in mini-percutaneous nephrolithotomy. Am J Clin Exp Urol. 2023;11(3):258–64.
43 Tangal S, Sancı A, Baklacı U, Babayiğit M, Karaburun MC, Kubilay E, et al. What is the optimum lithotripsy method for high density stones during mini-PNL? Laser, ballistic or combination of both. Lasers Med Sci. 2020; 35(8):1765–8. https://doi.org/10.1007/s10103-020-02971-x
44 Abedi AR, Razzaghi MR, Allameh F, Aliakbari F, FallahKarkan M, Ranjbar A. Pneumatic lithotripsy versus laser lithotripsy for ureteral stones. J Lasers Med Sci. 2018;9(4):233–6. https://doi.org/10.15171/jlms.2018.42
45 Życzkowski M, Bogacki R, Nowakowski K, Muskała B, Rajwa P, Bryniarski P, et al. Application of pneumatic lithotripter and holmium laser in the treatment of ureteral stones and kidney stones in children. BioMed Res Int. 2017;2017:2505034. https://doi.org/10.1155/2017/2505034
46 Jhanwar A, Bansal A, Sankhwar S, Kumar M, Kanodia G, Prakash G. Outcome analysis of holmium laser and pneumatic lithotripsy in the endoscopic management of lower ureteric calculus in pediatric patients: a prospective study. Int Braz J Urol. 2016; 42(6):1178–82. https://doi.org/10.1590/S1677-5538.IBJU.2016.0211
47 Akdeniz E, İrkılata L, Demirel HC, Saylık A, Bolat MS, Şahinkaya N, et al. A comparison of efficacies of holmium YAG laser, and pneumatic lithotripsy in the endoscopic treatment of ureteral stones. Turk J Urol. 2014;40(3):138–43. https://doi.org/10.5152/tud.2014.46548
48 Bapat SS, Pai KV, Purnapatre SS, Yadav PB, Padye AS. Comparison of holmium laser and pneumatic lithotripsy in managing upper-ureteral stones. J Endourol. 2007;21(12): 1425–7. https://doi.org/10.1089/end.2006.0350
49 Jeon SS, Hyun JH, Lee KS. A comparison of holmium:YAG laser with lithoclast lithotripsy in ureteral calculi fragmentation. Int J Urol. 2005;12(6):544–7. https://doi.org/10.1111/j.1442-2042.2005.01087.x
50 Nutahara K, Kato M, Miyata A, Murata A, Okegawa T, Miura I, et al. Comparative study of pulsed dye laser and pneumatic lithotripters for transurethral ureterolithotripsy. Int J Urol. 2000;7(5):172–5. https://doi.org/10.1046/j.1442-2042.2000.00163.x

Downloaded from karger.com/uin/article-pdf/110/5/519/4480997/000550064.pdf by guest on 09 November 2026