Heliyon 10 (2024) e33155

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Prediction of systemic inflammatory response syndrome and urosepsis after percutaneous nephrolithotomy by urine culture, stone culture, and renal pelvis urine culture: Systematic review and meta-analysis

Yanjun Li, Linguo Xie **, Chunyu Liu *

Department of Urology, the Second Hospital of Tianjin Medical University, Tianjin, 300211, China

A R T I C L E I N F O

Keywords:
Percutaneous nephrolithotomy
Urine
Stone
Culture
SIRS
Urosepsis
Systematic review

A B S T R A C T

Background: Percutaneous nephrolithotomy (PCNL) is thought to have an increased risk of infectious complications. This study evaluates the predictability of preoperative midstream urine culture (PMUC), stone culture (SC), and renal pelvis urine culture (RPUC) for post-PCNL systemic inflammatory response syndrome (SIRS) or urosepsis.

Method: After literature search in electronic databases (Embase, PubMed, Ovid, Science Direct, and Springer), studies were selected by following precise eligibility criteria. The quality of included studies was assessed, and meta-analyses of proportions were performed to seek culture positivity rates and incidence rates of post-PCNL SIRS/urosepsis. Meta-analyses of odds ratios (OR) were performed to evaluate the odds of positivity between SC and PMUC or RPUC, and the odds of post-PCNL SIRS/urosepsis with SC versus PMUC or RPUC.

Results: Nineteen studies (4829 patients) were included. Positivity rates of PMUC, SC, and RPUC were 16 % [95 % CI: 12, 20], 21 % [95 % CI: 16, 26] and 10 % [95 % CI: 7, 14] respectively. The odds of positivity were significantly higher for SC compared to PMUC (OR 1.37 [95%CI: 1.02, 1.84]; $p = 0.037$) or RPUC (OR 1.65 [95%CI: 1.25, 2.18] $p < 0.0001$). The incidence of post-PCNL SIRS and urosepsis was 21 % [95%CI: 17, 25] and 6 % [95%CI: 3, 10] respectively. The odds of post-PCNL SIRS were significantly higher with SC compared to PMUC (OR 2.45 [95%CI: 1.12, 5.38] $p = 0.025$) or RPUC (OR 2.10 [95%CI: 1.33, 3.30]; $p = 0.001$) positivity. The odds of developing urosepsis after PCNL were not significantly different between SC and PMUC positivity (OR 1.874 [95 % CI: 0.943, 3.723]; $p = 0.073$).

Conclusion: The risk of post-PCNL SIRS is found higher with SC than with PMUC or RPUC positivity. However, the risk of urosepsis may not be different between SC and PMUC.

* Corresponding author. Department of Urology, the Second Hospital of Tianjin Medical University, NO. 23, Pingjiang Road, Hexi District, Tianjin 300211, China.

** Corresponding author. Department of Urology, the Second Hospital of Tianjin Medical University, NO. 23, Pingjiang Road, Hexi District, Tianjin, 300211, China.

E-mail addresses: xielguo@126.com (L. Xie), liuchunyu@tmu.edu.cn (C. Liu).

https://doi.org/10.1016/j.heliyon.2024.e33155
Received 23 January 2024; Received in revised form 10 June 2024; Accepted 14 June 2024
Available online 15 June 2024

1. Introduction

Formation of kidney stones, also known as urolithiasis or nephrolithiasis, constitutes an important component of renal morbidity. In the United States of America, the prevalence of kidney stones is estimated at 10 % with an increasing trend from 3.2 % in the 1980s to 10.6 % in 2016. The prevalence is higher in men than in women [1–3]. An increasing trend in the prevalence of kidney stones has also been reported for other countries such as Germany [4], Japan [5], Korea [6], and Iceland [7]. A cross-sectional study in China found the prevalence of kidney stones to be 6.4 % [8].

Minimally invasive techniques such as percutaneous nephrolithotomy (PCNL) and shockwave lithotripsy provide effective means of treating kidney stones. Although PCNL has been in use for kidney stone removal since the 1970s, the invention of shockwave lithotripsy reduced much of the volume of PCNL procedures. However, in recent years there has been an increase in the utility of PCNL due to an increase in the prevalence of kidney stones, limitations of shockwave lithotripsy, and improvements in PCNL technology [9]. PCNL offers a lower injury rate, milder pain, better efficacy, and earlier recovery. However, complications including bleeding, systemic inflammatory response syndrome (SIRS), urosepsis, injury in the renal collecting system, and renal dysfunction may arise in the post-PCNL period [9]. Although mortality is rare, sepsis is the most common cause of mortality after PCNL [10].

Several factors may affect the incidence of infectious complications after PCNL. Female sex, diabetes, preoperative stenting, elevated blood leukocyte, elevated neutrophil-to-lymphocyte ratio, hydronephrosis, multiple puncture access, positive preoperative urine culture, pyuria, stone infection, stone size, intraoperative lavage rate, positive renal pelvis urine culture (RPUC), positive stone culture (SC), infectious stones, longer operative time, postoperative residual stone, and perioperative blood transfusion are identified as the risk factors for infectious complications after PCNL [11–13]. Preoperative midstream urine culture (PMUC) results are usually examined to predict infectious complications of PCNL. Whereas some studies have reported that the antibiotic prophylaxis before PCNL does not substantially reduce the risk of infectious complications after PCNL [14,15], a meta-analysis of 5 studies found that prophylactic use of antibiotics before PCNL significantly reduced the incidence of infections after PCNL [16].

Several studies have reported the associations between PMUC and SC or RPUC positivity and infectious complications after PCNL [17–21]. However, outcomes are not always consistent, and variabilities exist in the reported outcomes of individual studies which warrant a systematic review of these outcomes. The present study aimed to evaluate the abilities of PMUC, SC, and RPUC in predicting post-PCNL SIRS/urosepsis. For this purpose, we conducted a systematic review to identify relevant studies and performed meta-analyses of statistical indices to examine the relative abilities of PMCU, SC, and RPUC in predicting post-PCNL SIRS and urosepsis.

2. Methods

2.1. Inclusion and exclusion criteria

Inclusion criteria were: a study a) recruited urolithiasis patients to treat them with PCNL; b) carried out PMUC, SC, and/or RPUC; c) reported outcome data about the incidence of post-PCNL SIRS or urosepsis; and d) reported statistical indices of the association between PMUC, SC and/or RPUC outcomes and post-PCNL SIRS/urosepsis. PICOS: Patients, urolithiasis; Intervention, PCNL; Comparison, SC versus PMUC and/or RPUC; Outcomes, post-PCNL SIRS/urosepsis risk; Studies, prospective/retrospective. Studies were excluded based on following criteria: a study a) reporting only one of three culture results without comparative or associational data; b) involving related surgical procedures other than PCNL; c) reporting the outcomes of PCNL along with other surgeries without distinction; d) reporting the outcomes that could not be used to seek association between a culture test results and post-PCNL SIRS/urosepsis; e) seeking the association between a culture type and post-PCNL fever; and f) published as congress abstract.

2.2. Reporting sources

The literature search was conducted in electronic databases (Embase, PubMed, Ovid, Science Direct, and Springer) using relevant keywords. The literature search was conducted during August and December 2023 and sought original research articles published in English from the date of database inception till December 2023.

2.3. Search strategy

The primary combination was “Percutaneous nephrolithotomy AND kidney stone AND infectious complications AND urine AND stone AND culture". Secondary searches used several other keywords including urolithiasis, nephrolithiasis, predictor, systemic inflammatory response syndrome, sepsis, and urosepsis in different combinations. The bibliography section of included studies and other related research articles were also screened for additional possibilities.

2.4. Data collection process

Demographic and clinical information, lithiasis and lithotomy characteristics, study design and conduct, study characteristics, independent and dependent variables, and other outcome data were extracted from the research articles of the included studies and were organized on datasheets for synthesis and analysis. Two authors independently searched for studies and later unified their outputs. During the study selection process, disagreements were resolved through mutual discussions.

2.5. Study risk of bias assessment

The risk of bias assessment of the included studies was performed with the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [22]. This is a 14-item tool to assess the quality of studies by appraising the clarity of the research question, participation rate, contemporaneous and eligibility of the participants, sample size justification, verification of exposure, duration of outcome assessment, exposure-outcome relationship, independent and dependent variables, blinding of assessors, and adjustment of confounders.

2.6. Certainty assessment

Certainty assessment was performed by evaluating several factors including the appropriateness of outcomes measures, assessing the risk of bias, study limitations, inconsistency in outcomes between studies (heterogeneity), and publication bias. The statistical index used to measure heterogeneity was I^2 whereas the publication bias assessment was performed with Egger's test.

2.7. Statistical analysis

To achieve overall positivity rates of PMUC, SC, and RPUC, meta-analyses of proportions were performed by using the number of positive cases and total number of tests. Freeman Tukey's double arcsine transformation of proportions was incorporated for variance stabilization in these analyses using the exact binomial method. A meta-analysis of proportions was also performed to estimate the incidence rates of post-PCNL SIRS and urosepsis in these studies.

To examine the odds of positivity between SC and PMUC or RPUC and between RPUC and PMUC, meta-analyses of odds ratios were

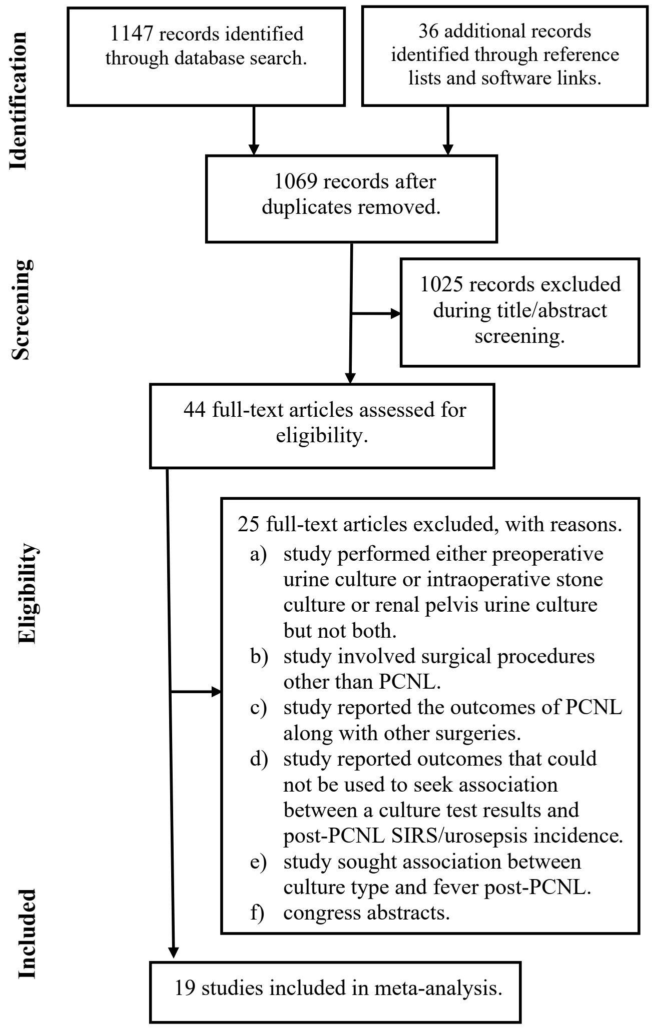

Fig. 1. A flowchart of study screening and selection process.

Table 1
Important characteristics of the included studies.

Study	n	Design	Country	Age (years)	% Females	% DM	BMI (kg/m^2)	Serum creatinine	Operation time (min)	Hospital stay (days)	Stone burden/size (mm^2)	Staghorn stones (%)	% Hydro-nephrosis
Chen 2019	802	Prospective	China	52 ± 12.2	41	9.7		118 ± 85.9	98.4 ± 35.5		1569 ± 1526		
Degirmenci 2019	729	Retrospective	Turkey	48 ± 12.9	33		26.6 ± 4.56	97.2 ± 141		3.9 ± 2.5	514 ± 518	28	87
Devraj 2016	83	Prospective	India		46						43 ± 8 (size)		
Erdil 2023	317	Retrospective	Turkey	47.4 ± 13.7	36			72.5 ± 65.4	81.7 ± 44.2	4.17 ± 2.6	458 ± 496	8.2	50
Indrawan 2014	33	Prospective	Indonesia	50.2 ± 10.4	36				81.96 ± 10.6				
Koras 2014	303	Prospective	Turkey	46.3 ± 12.4			27.3 ± 4.99		119 ± 38.2		610 ± 372		71
Kortes 2011	204	Retrospective	USA	56.4 (IQR 9, 67)	49	18.1						26.5	
Lojanapiwat 2011	200	Prospective	Thailand	51.2 ± 11.4	42		23.7 ± 3.42				33.6 ± 14.1 (size)		
Margel 2006	75	Prospective	Israel	52 (10–84)	41				178 ± 51			34.7	
Mariappan 2005	54	Prospective	UK	53 ± 15.9	48				70.7 (30–180)		32.8 (15–80) (size)		
Mishra 2023	100	Prospective	India	41.5 ± 15.7	29	11	23.2 ± 4.86		124.3 ± 36.9		35.3 ± 20.4 (size)		
Osman 2016	79	Prospective	Egypt	52 (18–72)	57	13.9							59
Ramaraju 2016	120	Prospective	India	42.18 (18–65)	39			106 (53–301)	70.32 (40–125)		28.9 (22–51) (size)		
Roushani 2014	51	Prospective	Iran	44.84 ± 11.1	43						31.2 ± 8.5	27.5	
Sen 2016	487	Retrospective	Turkey	48.5 ± 16.6	33			89.3 ± 78	108 ± 53		542 ± 753		
Shoshany 2015	206	Prospective	Israel	55 (IQR 45, 64)	37			88.4 ± 30	101 (IQR 82, 135)	5 (IQR 4, 6)	30.3 ± 9.7 (size)	38.8	38
Singh 2019	78	Randomized	India	35.2 ± 13	33	5	22.5 ± 4.4		58 ± 13	5 ± 3.4	2.23 ± 0.97 (size)		97
Walton-Diaz 2017	122	Prospective	Chile	51.2	35	8			92 ± 22			45.1	
Zhu 2020	786	Retrospective	China	55.4 ± 14.6	38	15.6	23.9 ± 4.3	96.9 ± 58.7	90.3 ± 23.6		1300 ± 715	28.4	28

Table 2
Risk of bias assessment of the included studies.

Criteria		Study reference number																		
		17	18	19	20	21	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	Was the research question or objective in this paper clearly stated?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2	Was the study population clearly specified and defined?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
3	Was the participation rate of eligible persons at least 50 %?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4	Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?	N	N	N	Y	N	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	N	Y	Y
5	Was a sample size justification, power description, or variance and effect estimates provided?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N
6	For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
7	Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
8	For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?	Y	Y	Y	N	N	N	N	N	N	N	N	Y	Y	N	N	Y	Y	N	Y
9	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y	Y	N	Y	N	Y	N	N	Y	N	Y	Y	Y	Y	Y	Y
10	Was the exposure(s) assessed more than once over time?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
11	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
12	Were the outcome assessors blinded to the exposure status of participants?	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
13	Was loss to follow-up after baseline 20 % or less?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
14	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	N	Y	Y	N	N	N	N	N	N	N	N	Y	N	Y	N	Y	Y	N	Y

Legends: NA, not applicable; N, no; Y, yes.

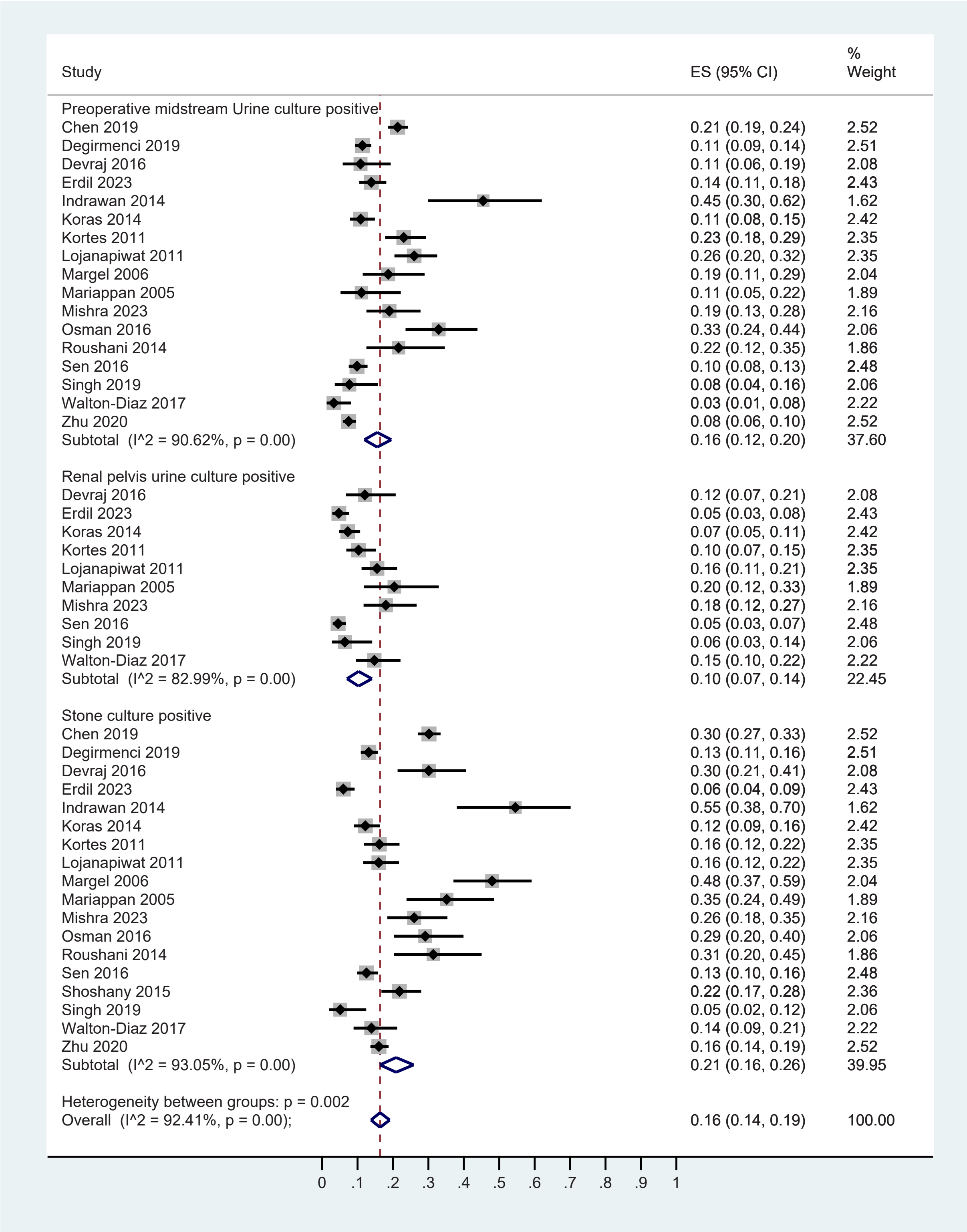

Fig. 2. A forest graph showing the positivity rates of preoperative midstream urine culture, stone culture, and renal pelvis urine culture.

performed using positivity rates data with the Dersimon-Liard method. Meta-analyses of odds ratios were also performed to evaluate the odds of developing post-PCNL SIRS or urosepsis between SC and PMUC or RPUC and between RPUC and PMUC.

Metaregression analyses were performed to evaluate the association between the incidence of SIRS and study sample size, age, sex, and operation duration in the overall population and SC-positive individuals. All analyses were performed with Stata software (Stata Corporation, College Station, Texas, USA).

3. Results

Nineteen studies [17–21,23–36] were included in the meta-analysis. A PRISMA flowchart of the study screening and selection

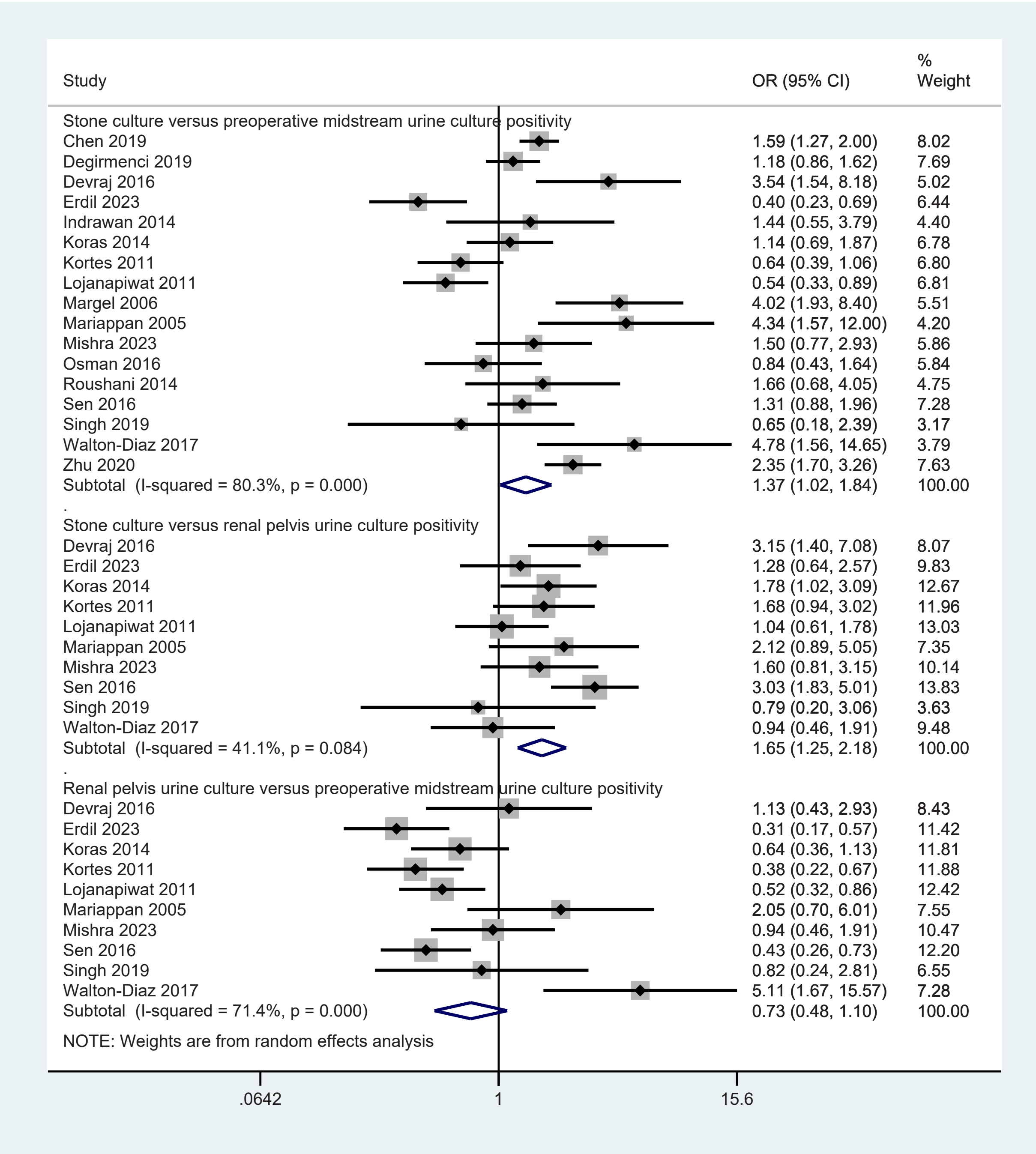

Fig. 3. A forest graph showing the odds of positivity between stone culture and preoperative midstream urine culture or renal pelvis urine culture.

process is given in Fig. 1. In these studies, 4829 patients were treated with PCNL. Ten studies reported on PMUC, SC, and RPUC and seven studies reported on PMUC, and SC outcomes. The age of these patients was 48.9 years [95 % confidence interval (CI): 47.1, 50.7] and 39 % [95 % CI: 36, 41] of these patients were female. The procedure duration was 99.6 min [95 % CI: 89.8, 109.4]. Important characteristics of the included studies are presented in Table 1.

The quality of the included studies was moderate in general. The included studies exhibited variabilities in some appraisal items including the eligibility criteria, exposure-outcome relationship, inconsistencies in reporting independent variables, and adjustments of potential confounding variables (Table 2). Egger's test identified significant publication bias (coefficient 30.8 [95 % CI: 8.5, 53.1]; p = 0.01).

The positivity rates of PMUC, SC, and RPUC were 16 % [95 % CI: 12, 20], 21 % [95 % CI: 16, 26] and 10 % [95 % CI: 7, 14] respectively (Fig. 2). The odds of positivity were significantly higher with SC in comparison with PMUC (OR 1.368 [95 % CI: 1.019, 1.837]; p = 0.037) or RPUC (OR 1.646 [95 % CI: 1.245, 2.175] p < 0.0001). On the other hand, the odds of positivity were not significantly different between RPUC and PMUC (OR 0.726 [95 % CI: 0.477, 1.103]; p = 0.133) (Fig. 3).

The incidence of post-PCNL SIRS was 21 % [95 % CI: 17, 25] (Fig. 4). The odds of developing SIRS after PCNL were significantly higher with SC in comparison with PMUC (OR 2.450 [95 % CI: 1.117, 5.374] p = 0.025) or RPUC (OR 2.099 [95 % CI: 1.334, 3.300]; p = 0.001) positivity. On the other hand, the odds of post-PCNL SIRS were not significantly different between RPUC-positive and PMUC-positive (OR 0.750 [95 % CI: 0.460, 1.222]; p = 0.248) cases (Fig. 5).

The incidence of post-PCNL urosepsis was 6 % [95 % CI: 3, 10] (Fig. 4). The odds of developing urosepsis after PCNL were not

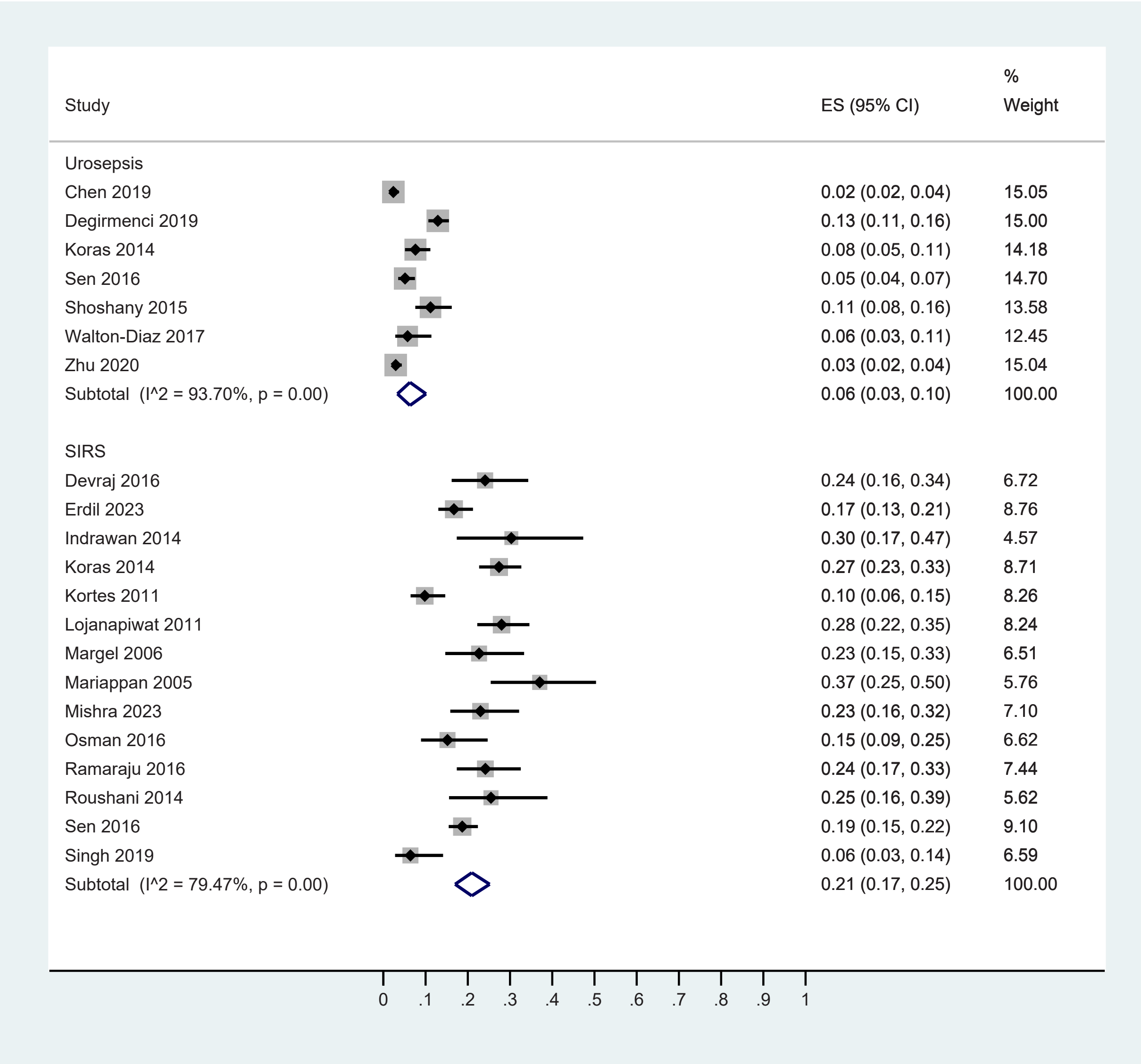

Fig. 4. A forest graph showing the outcomes of the meta-analysis of the incidence rates of SIRS and urosepsis after PCNL in kidney stone patients.

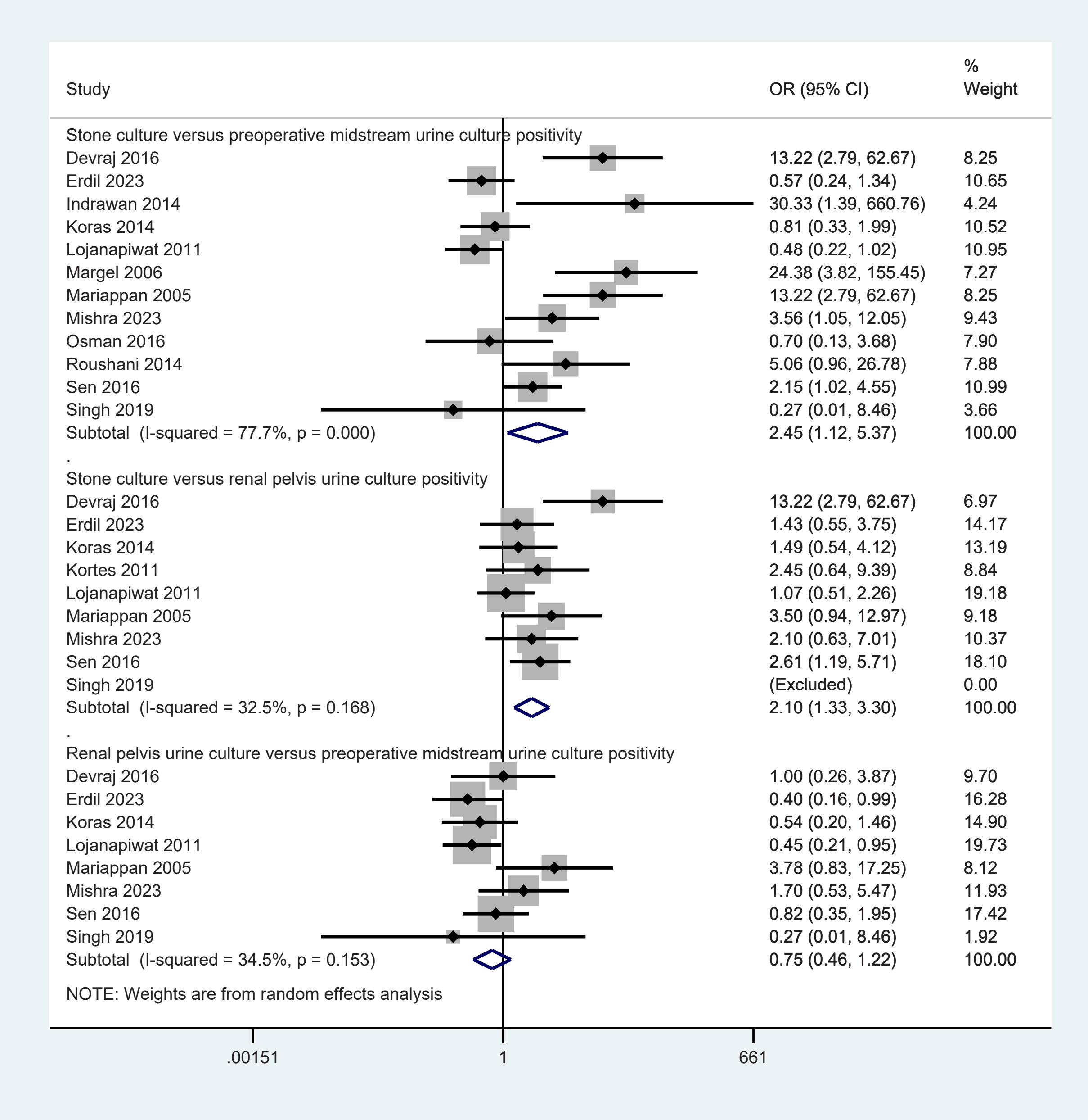

Fig. 5. A forest graph showing the odds of developing SIRS between stone culture and preoperative midstream urine culture or renal pelvis urine culture.

significantly higher in SC-positive than with PMUC-positive cases (OR 1.874 [95 % CI: 0.943, 3.723]; p = 0.073; Fig. 6). However, in a sensitivity analysis, the odds of developing urosepsis after PCNL were significantly higher in SC-positive in comparison with PMUC-positive cases (2.189 [95 % CI: 1.300, 3.686]; p = 0.002). The odds of developing post-PCNL urosepsis were not significantly different between SC-positive and RPUC-positive (OR 2.010 [95 % CI: 0.763, 5.295]; p = 0.158) cases or between RPUC- and PMUC-positive (OR 0.518 [95 % CI: 0.203, 1.321]; p = 0.169) cases (Fig. 6).

In metaregression analyses, the incidence of SIRS was not associated with the age of patients (metaregression coefficient (MC): 0.39 [95 % CI: −0.58, 1.36); p = 0.394), the percentage of females (MC: −0.14 [95 % CI: −0.91, 0.62); p = 0.689), or the operation duration (MC: 0.02 [95 % CI: −0.19, 0.23]; p = 0.835) in overall population. Incidence of SIRS was also not related to age (MC: 2.16 [95 % CI: −1.10, 5.41); p = 0.170), the percentage of females (MC: −0.21 [95 % CI: −2.86, 2.45]; p = 0.866), or operation duration (MC: 0.23 [95 % CI: −0.66, 1.12]; p = 0.550) in SC positive individuals. However, inverse relationships were observed between the study sample size and SC positivity rate (MC: −0.02 [95 % CI: −0.04, 0.003]; p = 0.089), RPUC positivity rate (MC: −0.03 [95 % CI: −0.05, −0.01]; p = 0.005), and the incidence rate of SIRS in SC positive individuals (MC: −0.12 [95 % CI: −0.24, −0.005]; p = 0.043).

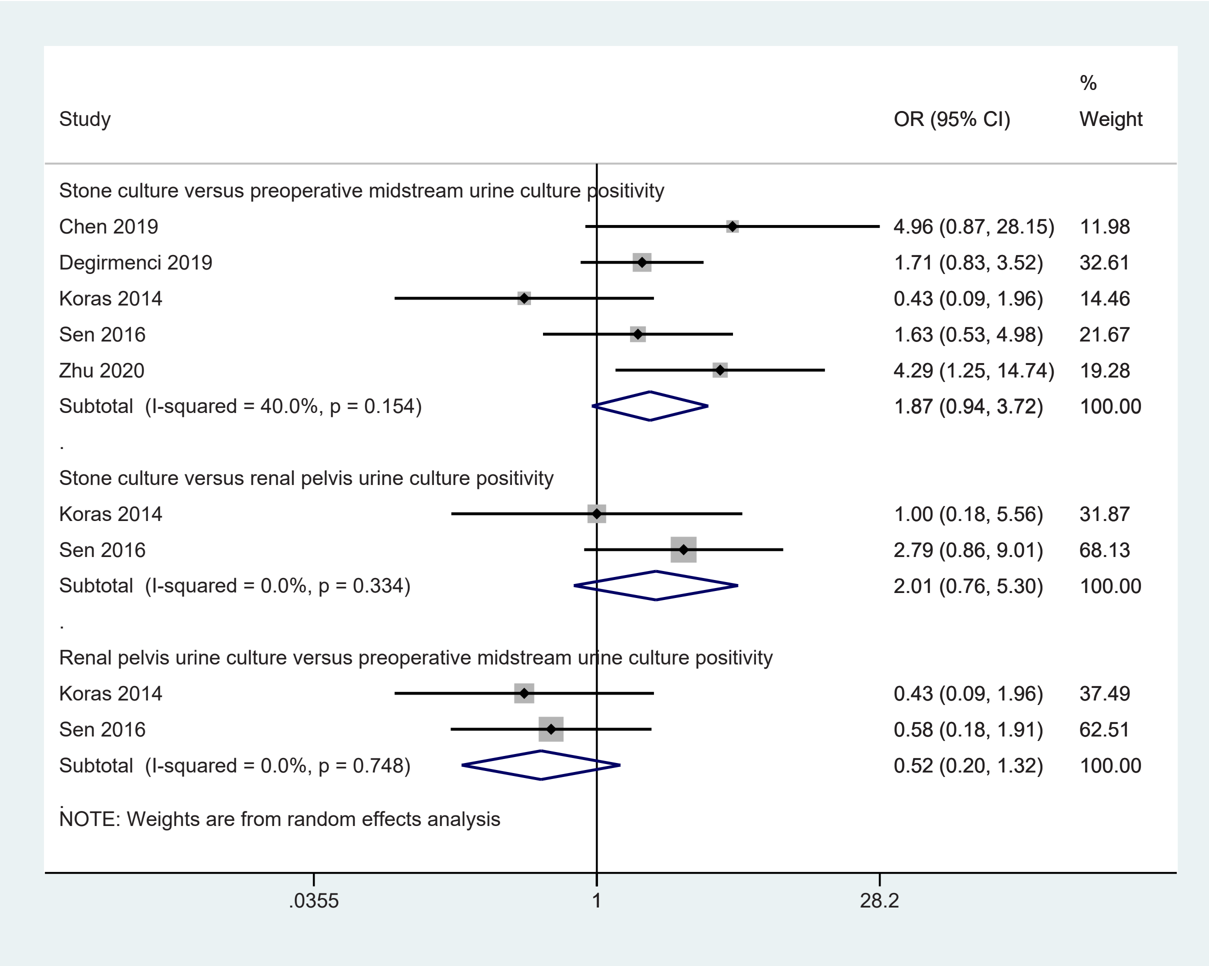

Fig. 6. A forest graph showing the odds of developing urosepsis between stone culture and preoperative midstream urine culture or renal pelvis urine culture.

Many of the included studies also reported the logistic regression outcomes of the association between a type of culture and the development of SIRS or urosepsis in the post-PCNL period. These outcomes are presented in Table 3.

Discussion The present study found that the positivity rate was higher for SC (21 %) in comparison with PMUC (16 %) or RPUC (10 %) in urolithiasis patients who underwent PCNL. In this population, approximately 21 % of patients developed SIRS, and 6 % developed urosepsis. The odds of the incidence of SIRS were higher with SC than with PMUC or RPUC. Fewer studies reported on the associations between culture positivity and the development of post-PCNL urosepsis. The odds of post-PCNL urosepsis were not significantly different between SC and PMUC. In SC-positive individuals, the incidence of SIRS was not related to the age, the percentage of females, or the operation duration. However, inverse relationships were observed between the study sample size and the positivity rate of SC, the positivity rate of RPUC, and the incidence rate of SIRS in SC-positive individuals.

Authors of the included studies reported a 3- to 11-fold risk of developing SIRS after PCNL with SC positivity (2.5-fold [20]; 3-fold [33]; 10-fold [32]; and 11-fold [29]). Shoshany et al. [34] who found positive SC to be the only predictor of post-PCNL sepsis noticed that in a subgroup of patients with positive SC results, stone burden and operative time were positively associated with post-PCNL sepsis. Other included studies have also found significantly longer operation duration in patients who later developed SIRS/urosepsis [17,19,25,33,36]. Some of the included studies also observed an association between the higher stone burden and SIRS/urosepsis after PCNL [19,20,33,36]. Authors of recent reviews have also found higher stone burden and longer operation time to be influencing factors of infectious complications after PCNL [12,13].

Among the included studies, Kortes et al. [20], Roushani et al. [32], and Sen et al. [33] reported significant associations between female sex and the incidence of post-PCNL SIRS. However, Degirmenci et al. [18] reported that SIRS was more common in males than in females. On the other hand, Chen et al. [17] and Zhu et al. [36] found a significant association between female sex and the incidence of post-PCNL urosepsis. In Roushani et al. [32], SC positivity was higher in females than in males. Other studies did not find any significant association between sex and the incidence of SIRS or urosepsis. We also did not find a significant association between the percentage of females and the incidence of SIRS in the overall population or individuals with positive SC in metaregression analyses.

Table 3
Logistic regression outcomes showing the associations of culture positivity with the development of SIRS or urosepsis after post-percutaneous nephrolithotomy.

Study	Variate	Condition	Positivity	Odds ratio [95 % CI]	p-value
Mishra 2023	Multivariate	SIRS	PMUC	1.24 [0.159, 9.678]	0.834
Ramaraju 2016	Multivariate	SIRS	PMUC	0.917 [0.305, 2.756]	
Sen 2016	Multivariate	SIRS	PMUC	0.85 [0.34, 2.12]	0.727
Kortes 2011	Multivariate	SIRS	SC	2.55 [0.43, 3.95]	0.12
Mishra 2023	Multivariate	SIRS	SC	10.99 [1.482, 81.54]	0.019
Ramaraju 2016	Multivariate	SIRS	SC	0.384 [0.106, 1.393]	
Roushani 2014	Multivariate	SIRS	SC	9.96 [2.37, 41.85]	0.002
Sen 2016	Multivariate	SIRS	SC	3.06 [1.35, 6.92]	0.07
Kortes 2011	Multivariate	SIRS	RPUC	1.74[0.62, 4.21]	0.29
Mishra 2023	Multivariate	SIRS	RPUC	0.912 [0.065, 12.81]	0.946
Sen 2016	Multivariate	SIRS	RPUC	0.99 [0.29, 3.54]	0.985
Kortes 2011	Univariate	SIRS	SC	3.81 [1.37, 10.61]	0.01
Kortes 2011	Univariate	SIRS	RPUC	3.39 [1.08, 10.64]	0.03
Chen 2019	Multivariate	Urosepsis	PMUC	3.2 [1.2, 11.3]	0.036
Koras 2014	Multivariate	Urosepsis	PMUC	1.03 [0.18, 5.73]	0.98
Sen 2016	Multivariate	Urosepsis	PMUC	1.17 [0.29, 4.7]	0.821
Shoshany 2015	Multivariate	Urosepsis	PMUC	0.912 [0.3, 2.74]	0.869
Chen 2019	Multivariate	Urosepsis	SC	8 [1.6, 41.5]	0.013
Sen 2016	Multivariate	Urosepsis	SC	7.83 [2.28, 26.82]	0.001
Shoshany 2015	Multivariate	Urosepsis	SC	6.89 [2.31, 20.59]	0.001
Sen 2016	Multivariate	Urosepsis	RPUC	0.92 [0.17, 5.05]	0.922
Shoshany 2015	Univariate	Urosepsis	PMUC	2.58 [1.06, 6.31]	0.037
Shoshany 2015	Univariate	Urosepsis	SC	7.63 [3.03, 19.18]	<0.001

Similar results are also found by the authors of a meta-analysis of studies that involved surgical interventions for urolithiasis using PCNL or retrograde intrarenal surgery [37]. PCNL may have a higher risk of infectious complications than other surgical or endourological procedures because the bacterial presence in large renal stones might not permit sterilization of the urine before PCNL in many patients [38]. In patients with large stones, drainage of infected materials remains difficult due to obstructed urinary system. Moreover, high intrarenal pressure during micro-/mini-PCNL can cause tubular, lymphatic, and venous backflow from the pelvis due to which bacteria can enter systemic circulation [38]. The entrance of released endotoxins occurs due to the openings in the vessels (hemorrhage) during the PCNL. Multiple access sites are also found to be associated with an increased risk of SIRS [20].

Infectious complications after PCNL may develop when the stone colonizing bacteria and endotoxins are released in irrigation solution during stone fragmentation and enter systemic flow due to positive pressure within the pelvis [17,27]. PMUC is usually examined to predict the incidence of SIRS after PCNL. However, its effectiveness in preventing post-PCNL SIRS is not adequate even after intensive prophylaxis [27]. Moreover, PMUC has been shown to be an unreliable method of predicting SC results [39–41]. Bacteremia develops within 6 h postoperatively, whereas results of intraoperative cultures are usually available after 48 h. Thus, waiting time for obtaining the results of SC and RPUC remains a major limitation in routinely using these tests as predictors of SIRS/urosepsis [42,43]. However, in patients in which fever persists for 48 h, SC results can be used to direct treatment. At present, the clinical value of SC outcomes in refining treatment plans appears to be more important than prediction of SIRS/urosepsis [30].

Methods of rapid microbial assessment such as the Matrix-assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry (MALDI-TOF MS) which provides a speedy, easier, and cost-effective method of pathogen identification have been under evaluation. MALDI-TOF MS is found to be the most useful for Gram-negative bacteria. In a study of over 500 urine samples that were subjected to MALDI-TOF MS after flow cytometry, the direct identification of germs was possible in 92 % of the samples with *Escherichia coli* being the most prevalent followed by *Klebsiella pneumoniae* [44]. Similar results have been achieved in other studies. A lower rate of the identification of Gram-positive bacteria with MALDI-TOF MS is still a limitation that may improve with time [45,46].

Among the foremost limitations of the included studies, the observation of high statistical heterogeneity in the meta-analyses is an important consideration. Variations in sample size, stone burden, stone type, operation features, and other renal/urinary characteristics might have contributed to the heterogeneity. Because of the less availability of required data, sources of heterogeneity could not be traced statistically for all possible variables. Although age, and sex were not associated with outcomes, the study sample size was found to be significantly associated with outcomes in at least three metaregression analyses. The quality of the included studies was variable, especially with regard to reporting eligibility criteria, description of independent variables, and in accounting for confounding variables. Not all studies reported the associational point estimates and very few studies reported the sensitivity, specificity, and positive/negative predictive values. Moreover, fewer studies were found in the literature to seek the relationship between urine or stone culture positivity and the incidence of urosepsis.

4. Conclusion

SC positivity rate is found to be considerably higher than PMUC or RPUC. The odds of post-PCNL SIRS incidence were higher with SC in comparison with PMUC or RPUC positivity. However, the risk of post-PCNL urosepsis may not be different between SC and PMUC positivity. More data will be required to refine the outcomes of the present study as we found a higher risk of urosepsis with SC than in

PMUC in a sensitivity analysis. Moreover, high statistical heterogeneity, variabilities in study quality, and the observation of significant publication bias also emphasize the need for the refinement of these outcomes in future studies.

Funding

This work was sponsored by the Tianjin Health Research Project (TJWJ2022ZD004) and the Tianjin Institute of Urology Talent Funding Program (MYSRC202313).

Ethics statement

N/A.

Data availability

Data are available upon reasonable request.

CRediT authorship contribution statement

Yanjun Li: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Linguo Xie:** Writing – review & editing, Formal analysis, Conceptualization. **Chunyu Liu:** Writing – review & editing, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

None.

References

[1] W. Kittanamongkolchai, L.E. Vaughan, F.T. Enders, T. Dhondup, R.A. Mehta, A.E. Krambeck, C.H. McCollough, T.J. Vrtiska, J.C. Lieske, A.D. Rule, The changing incidence and presentation of urinary stones over 3 decades, Mayo Clin. Proc. 93 (3) (2018) 291–299, https://doi.org/10.1016/j.mayocp.2017.11.018.
[2] A. Chewcharat, G. Curhan, Trends in the prevalence of kidney stones in the United States from 2007 to 2016, Urolithiasis 49 (1) (2021) 27–39, https://doi.org/10.1007/s00240-020-01210-w.
[3] National Kidney Foundation, Kidney stones, Available at: https://www.kidney.org/atoz/content/kidneystones#. (Accessed 11 January 2024).
[4] A. Hesse, E. Brandle, D. Wilbert, K.U. Kohrmann, P. Alken, Study on the prevalence and incidence of urolithiasis in Germany comparing the years 1979 vs. 2000, Eur. Urol. 44 (6) (2003) 709–713, https://doi.org/10.1016/s0302-2838(03)00415-9.
[5] T. Yasui, M. Iguchi, S. Suzuki, A. Okada, Y. Itoh, K. Tozawa, K. Kohri, Prevalence and epidemiologic characteristics of lower urinary tract stones in Japan, Urology 72 (5) (2008) 1001–1005, https://doi.org/10.1016/j.urology.2008.06.038.
[6] B.S. Tae, U. Balpukov, S.Y. Cho, C.W. Jeong, Eleven-year cumulative incidence and estimated lifetime prevalence of urolithiasis in Korea: a National Health Insurance Service-national sample cohort-based study, J Korean Med Sci. 33 (2) (2018) e13, https://doi.org/10.3346/jkms.2018.33.e13.
[7] V.O. Edvardsson, O.S. Indridason, G. Haraldsson, O. Kjartansson, R. Palsson, Temporal trends in the incidence of kidney stone disease, Kidney Int. 83 (1) (2013) 146–152, https://doi.org/10.1038/ki.2012.320.
[8] G. Zeng, Z. Mai, S. Xia, Z. Wang, K. Zhang, L. Wang, Y. Long, J. Ma, Y. Li, S.P. Wan, W. Wu, Y. Liu, Z. Cui, Z. Zhao, J. Qin, T. Zeng, Y. Liu, X. Duan, X. Mai, Z. Yang, Z. Kong, T. Zhang, C. Cai, Y. Shao, Z. Yue, S. Li, J. Ding, S. Tang, Z. Ye, Prevalence of kidney stones in China: an ultrasonography based cross-sectional study, BJU Int. 120 (1) (2017) 109–116, https://doi.org/10.1111/bju.13828.
[9] E. Taylor, J. Miller, T. Chi, M.L. Stoller, Complications associated with percutaneous nephrolithotomy, Transl. Androl. Urol. 1 (4) (2012) 223–228, https://doi.org/10.3978/j.issn.2223-4683.2012.12.01.
[10] L. Whitehurst, P. Jones, B.K. Somani, Mortality from kidney stone disease (KSD) as reported in the literature over the last two decades: a systematic review, World J. Urol. 37 (5) (2019) 759–776, https://doi.org/10.1007/s00345-018-2424-2.
[11] D. Puia, Ş. Gheorghincă, G.D. Radavoi, V. Jinga, C. Pricop, Can we identify the risk factors for SIRS/sepsis after percutaneous nephrolithotomy? A meta-analysis and literature review, Exp. Ther. Med. 25 (3) (2023) 25, https://doi.org/10.3892/etm.2023.11809, 110.
[12] Y. Zhong, L. Li, J. Zheng, H. Li, M. Ju, Related risk factors for systemic inflammatory response syndrome after percutaneous nephrolithotomy: a meta-analysis, Arch Clin Psychiatry 50 (5) (2023) 52–65.
[13] G. Zhou, Y. Zhou, R. Chen, D. Wang, S. Zhou, J. Zhong, Y. Zhao, C. Wan, B. Yang, J. Xu, E. Geng, G. Li, Y. Huang, H. Liu, J. Liu, The influencing factors of infectious complications after percutaneous nephrolithotomy: a systematic review and meta-analysis, Urolithiasis 51 (2023) 17, https://doi.org/10.1007/s00240-022-01376-5.
[14] H. Patel, P.A. Shekar, D. Reddy, A. Dumra, K.S. Shivakumar, A randomised controlled trial comparing two protocols of preoperative antibiotics in patients with positive urine culture undergoing percutaneous nephrolithotomy, World J. Urol. 41 (8) (2023) 2225–2232, https://doi.org/10.1007/s00345-023-04483-z.
[15] C. Yang, H. Wei, H. Zhan, T. Luan, W. Wan, S. Yuan, J. Chen, Effect of preoperative prophylactic antibiotic use on postoperative infection after percutaneous nephrolithotomy in patients with negative urine culture: a single-center randomized controlled trial, World J. Urol. 41 (12) (2023) 3687–3693, https://doi.org/10.1007/s00345-023-04623-5.
[16] A. Danilovic, T.B. Talizin, F.C.M. Torricelli, G.S. Marchini, C. Batagello, F.C. Vicentini, W.C. Nahas, E. Mazzucchi, One week pre-operative oral antibiotics for percutaneous nephrolithotomy reduce risk of infection: a systematic review and meta-analysis, Int. Braz J. Urol. 49 (2) (2023) 184–193, https://doi.org/10.1590/S1677-5538.IBJU.2022.0544.

[17] D. Chen, C. Jiang, X. Liang, F. Zhong, J. Huang, Y. Lin, Z. Zhao, X. Duan, G. Zeng, W. Wu, Early and rapid prediction of postoperative infections following percutaneous nephrolithotomy in patients with complex kidney stones, BJU Int. 123 (6) (2019) 1041–1047, https://doi.org/10.1111/bju.14484.
[18] T. Degirmenci, I.H. Bozkurt, S. Celik, S. Yarimoglu, I. Basmaci, E. Sefik, Does leaving residual fragments after percutaneous nephrolithotomy in patients with positive stone culture and/or renal pelvic urine culture increase the risk of infectious complications? Urolithiasis 47 (4) (2019) 371–375, https://doi.org/10.1007/s00240-018-1063-9.
[19] O. Koras, I.H. Bozkurt, T. Yonguc, T. Degirmenci, B. Arslan, B. Gunlusoy, O. Aydogdu, S. Minareci, Risk factors for postoperative infectious complications following percutaneous nephrolithotomy: a prospective clinical study, Urolithiasis 43 (1) (2014) 55–60, https://doi.org/10.1007/s00240-014-0730-8.
[20] R. Korets, J.A. Graversen, M. Kates, A.C. Mues, M. Gupta, Post-percutaneous nephrolithotomy systemic inflammatory response: a prospective analysis of preoperative urine, renal pelvic urine and stone cultures, J. Urol. 186 (5) (2011) 1899–1903, https://doi.org/10.1016/j.juro.2011.06.064.
[21] A. Walton-Diaz, J.I. Vinay, J. Barahona, P. Daels, M. González, J.P. Hidalgo, C. Palma, P. Díaz, A. Domenech, R. Valenzuela, F. Marchant, Concordance of renal stone culture: PMUC, RPUC, RSC and post-PCNL sepsis—a non-randomized prospective observation cohort study, Int. Urol. Nephrol. 49 (2017) 31–35, https://doi.org/10.1007/s11255-016-1457-y.
[22] National Institutes of Health. National Heart, Lung, and Blood Institute. Quality Assessment tolls. Available at: https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools. Last accessed on March 20, 2024.
[23] R. Devraj, K. Tanneru, C.H. Ramreddy, Renal stone culture and sensitivity is a better predictor of potential urosepsis than pelvic or midstream urine culture and sensitivity, J NTR Univ Health Sci. 5 (2016) 261–264.
[24] T. Erdil, Y. Bostanci, E. Ozden, F. Atac, Y.K. Yakupoglu, A.F. Yilmaz, S. Sarikaya, Risk factors for systemic inflammatory response syndrome following percutaneous nephrolithotomy, Urolithiasis 41 (2013) 395–401, https://doi.org/10.1007/s00240-013-0570-y.
[25] T. Indrawan, S. Hardjowijoto, D.M. Soebadi, J. Budiono, Correlation of routine urine culture, stone culture, and postoperative SIRS, Indonesian J Urol. 21 (1) (2014) 20–26.
[26] B. Lojanapiwat, P. Kitirattrakarn, Role of preoperative and intraoperative factors in mediating infection complication following percutaneous nephrolithotomy, Urol. Int. 86 (4) (2011) 448–452, https://doi.org/10.1159/000324106.
[27] D. Margel, Y. Ehrlich, N. Brown, D. Lask, P.M. Livne, D.A. Lifshitz, Clinical implication of routine stone culture in percutaneous nephrolithotomy–a prospective study, Urology 67 (1) (2006) 26–29, https://doi.org/10.1016/j.urology.2005.08.008.
[28] P. Mariappan, G. Smith, S.V. Bariol, S.A. Moussa, D.A. Tolley, Stone and pelvic urine culture and sensitivity are better than bladder urine as predictors of urosepsis following percutaneous nephrolithotomy: a prospective clinical study, J. Urol. 173 (5) (2005) 1610–1614, https://doi.org/10.1097/01.ju.0000154350.78826.96.
[29] A. Mishra, J. Mittal, S. Tripathi, S. Paul, Factors predicting infective complications following percutaneous nephrolithotomy and retrograde intrarenal surgery according to systemic inflammatory response syndrome and quick sequential organ failure assessment: a prospective study, Urol. Ann. 15 (3) (2023) 295–303, https://doi.org/10.4103/ua.ua_150_22.
[30] Y. Osman, A.M. Elshal, M.M. Elawdy, H. Omar, A. Gaber, E. Elsawy, A.R. El-Nahas, Stone culture retrieved during percutaneous nephrolithotomy: is it clinically relevant? Urolithiasis 44 (4) (2016) 327–332, https://doi.org/10.1007/s00240-016-0858-9.
[31] K. Ramaraju, A.K. Paranjothi, D.B. Namperumalsamy, I. Chennakrishnan, Predictors of systemic inflammatory response syndrome following percutaneous nephrolithotomy, Urol. Ann. 8 (2016) 449–453, https://doi.org/10.4103/0974-7796.192108.
[32] A. Roushani, S. Falahatkar, S.H.H. Sharifi, L. Mahfoozi, S.M.S. Saadat, A. Allahkhah, N.R. Herfeh, K.G. Moghaddam, Intra-operative stone culture as an independent predictor of systemic inflammatory response syndrome after percutaneous nephrolithotomy, Urolithiasis 42 (5) (2014) 455–459, https://doi.org/10.1007/s00240-014-0688-6.
[33] V. Sen, I.H. Bozkurt, O. Aydogdu, T. Yonguc, S. Yarimoglu, P. Sen, O. Koras, T. Degirmenci, Significance of preoperative neutrophil-lymphocyte count ratio on predicting postoperative sepsis after percutaneous nephrolithotomy, Kaohsiung J. Med. Sci. 32 (10) (2016) 507–513, https://doi.org/10.1016/j.kjms.2016.08.008.
[34] O. Shoshany, D. Margel, C. Finz, O. Ben-Yehuda, P.M. Livne, R. Holand, D. Lifshitz, Percutaneous nephrolithotomy for infection stones: what is the risk for postoperative sepsis? A retrospective cohort study, Urolithiasis 43 (2015) 237–242, https://doi.org/10.1007/s00240-014-0747-z.
[35] I. Singh, S. Shah, S. Gupta, N.P. Singh, Efficacy of intraoperative renal stone culture in predicting postpercutaneous nephrolithotomy urosepsis/systemic inflammatory response syndrome: a prospective analytical study with review of literature, J. Endourol. 33 (2) (2019) 84–92, https://doi.org/10.1089/end.2018.0842.
[36] Z. Zhu, Y. Cui, H. Zeng, Y. Li, F. Zeng, Y. Li, Z. Chen, C. Hequn, The evaluation of early predictive factors for urosepsis in patients with negative preoperative urine culture following mini-percutaneous nephrolithotomy, World J. Urol. 38 (2020) 2629–2636, https://doi.org/10.1007/s00345-019-03050-9.
[37] D. Castellani, J.Y.C. Teoh, M.P. Pavia, E. Pretore, L. Dell'Atti, A.B. Galosi, V. Gauhar, Assessing the optimal urine culture for predicting systemic inflammatory response syndrome after percutaneous nephrolithotomy and retrograde intrarenal surgery: results from a systematic review and meta-analysis, J. Endourol. 36 (2) (2022) 158–168, https://doi.org/10.1089/end.2021.0386.
[38] E.I. Kreydin, B.H. Eisner, Risk factors for sepsis after percutaneous renal stone surgery, Nat. Rev. Urol. 10 (2013) 598–605, https://doi.org/10.1038/nrurol.2013.183.
[39] H.S. Dogan, F. Guliyev, Y.S. Cetinkaya, M. Sofikerim, E. Ozden, A. Sahin, Importance of microbiological evaluation in management of infectious complications following percutaneous nephrolithotomy, Int. Urol. Nephrol. 39 (2007) 737–742, https://doi.org/10.1007/s11255-006-9147-9.
[40] P. Mariappan, C.W. Loong, Midstream urine culture and sensitivity test is a poor predictor of infected urine proximal to the obstructing ureteral stone or infected stones: a prospective clinical study, J. Urol. 171 (2004) 2142–2145, https://doi.org/10.1097/01.ju.0000125116.62631.d2.
[41] J.E. Paonessa, E. Gnessin, N. Bhojani, J.C. Williams, J.E. Lingeman, Preoperative bladder urine culture as a predictor of intraoperative stone culture results: clinical implications and relationship to stone composition, J. Urol. 196 (3) (2016) 769–774, https://doi.org/10.1016/j.juro.2016.03.148.
[42] J. Liu, C. Zhou, W. Gao, H. Huang, X. Jiang, D. Zhang, Does preoperative urine culture still play a role in predicting post-PCNL SIRS? A retrospective cohort study, Urolithiasis 48 (2020) 251–256, https://doi.org/10.1007/s00240-019-01148-8.
[43] N. Jakjaroenrit, M. Tanthanuch, T. Bejrananda, Predictive model for early urosepsis prediction by using systemic inflammatory response syndrome after percutaneous nephrolithotomy, Formosan J Surg 56 (2023) 3, https://doi.org/10.1097/FS9.0000000000000045.
[44] A.A. Ilki, S. Ozsoy, G. Gelmez, B. Aksu, G. Soyletir, An alternative for urine cultures: direct identification of uropathogens from urine by MALDI-TOF MS, Acta Microbiol. Immunol. Hung. 67 (3) (2020) 193–197, https://doi.org/10.1556/030.2020.01184.
[45] Y. Kim, K.G. Park, K. Lee, Y.J. Park, Direct identification of urinary tract pathogens from urine samples using the Vitek MS system based on Matrix-Assisted Laser Desorption Ionization-Time of Flight Mass Spectrometry, Ann Lab Med 35 (4) (2015) 416–422, https://doi.org/10.3343/alm.2015.35.4.416.
[46] J. Haiko, L.E. Savolainen, R. Hilla, A. Patari-Sampo, Identification of urinary tract pathogens after 3-hours urine culture by MALDI-TOF mass spectrometry, J. Microbiol. Methods 129 (2016) 81–84, https://doi.org/10.1016/j.mimet.2016.08.006.