Comparison of Supracostal and Infracostal Access For Percutaneous Nephrolithotomy: A Systematic Review and Meta-Analysis

Zhaohui He[1]* Fucai Tang[1,2]* Zechao Lu[3]* Ye He[3], Genggeng Wei[4], Fangling Zhong[2], Guohua Zeng[2], Weizhou Wu[2], Lemin Yan[5], Zhibiao Li[6]

Purpose: In this meta-analysis, we aimed to compared efficacy and safety of supracostal and infracostal access for percutaneous nephrolithotomy (PCNL).

Materials and Methods: We included eligible studies from PubMed, EMBASE, Cochrane Library, Web of Science and China National Knowledge Infrastructure. Literature searching, quality assessment and data extraction were performed by two independent reviewers. Data were analyzed by RevMan software. Binary and continuous variables were calculated as odds ratios (OR) and mean difference (MD).

Results: Two prospective comparative studies and seven retrospective observational studies were included in the meta-analysis, which contained 1,024 cases of supracostal access and 1,249 cases of infracostal access for PCNL. The supracostal access resulted in a significant reduced mean hemoglobin (95% CI: 0.26-3.46, MD = 1.86 g/L, *P* = .02) and a higher incidence of hydrothorax (95% CI: 4.77-22.95: OR = 10.47, *P* < .00001) compared to infracostal access. However, there no difference between supracostal and infracostal access regarding additional procedures (95% CI: 0.70-1.69, OR = 1.09, *P* = .71), stone-free rate (95% CI: 0.80-1.72, OR = 1.18, *P* = .41), length of hospital stay (95% CI: -0.03-0.37, MD = 0.17 day, *P* = .10), and occurrence of fever (95% CI: 0.95-2.03, OR = 1.39, *P* = .09) and blood transfusion (95% CI: 0.45-1.70, OR = 0.88, *P* = .70). No publication bias was identified in the study.

Conclusion: Supracostal access was effective, but not as safe as infracostal access PCNL due to a higher risk of reduced hemoglobin and hydrothorax. Therefore, infracostal access should be the preferred safe and effective approach recommended for PCNL. When a supracostal puncture is performed, essential precautions to avoid hemoglobin loss and hydrothorax should be used.

Key words: infracostal access; supracostal access; percutaneous nephrolithotomy; Meta-Analysis

INTRODUCTION

The use of percutaneous nephrolithotomy (PCNL) was first reported by Fernströmand Johansson in 1976[1]. The overall success rates of PCNL have been > 90% since the 1980s[2]. PCNL is the first line choice to treat large or complex kidney stones (> 2 cm)[3,4], stones obstructing the kidney, hard stones and residual stones following failed shock wave lithotripsy. PCNL is also used as a treatment for kidney stones in patients with skeletal abnormalities, morbidly obese patients and patients with spinal cord injury[5-7]. Achieving suitable access to the appropriate calyx is one of the most important steps during the PCNL procedure. Effective puncture is key for the success of PCNL. Many studies have reported that supracostal access for PCNL is advantageous over infracostal access[8-13]. The greatest advantage of supracostal access is the shorter distance, creating the most direct establishment of a percutaneous tract[14]. However, pulmonary complications, such as pneumothorax, hydrothorax and lung injury, are more common with the supracostal approach[14].

In recent years, with the improvement of clinical skills, more urologists are aware of the limitations of infracostal access and have attempted to use the supracostal approach; however, whether a supracostal or infracostal approach is best remains controversial. To conduct an updated study and provide more evidence that will serve as a basis for clinical decisions, we collected pub-

1Department of Urology, The Eighth Affiliated Hospital, Sun Yat-sen University, Shenzhen, China.
2Department of Urology, Minimally Invasive Surgery Center, Guangdong Provincial Key Laboratory of Urology, The First Affiliated Hospital of Guangzhou Medical University, Guangzhou, China.
3First Clinical College of Guangzhou Medical University, Guangzhou, china.
4Department of Urology, Hongkong university-Shenzhen hospital, shenzhen, China.
5College of Stomatology, Guangzhou Medical University, Guangzhou, china.
6Third Clinical College of Guangzhou Medical University, Guangzhou, china.
*Equal contributors
*Correspondence: Department of Urology, The Eighth Affiliated Hospital, Sun Yat-sen University, Shenzhen, 518033. P.R. China.
Tel: +86 0755 83982222. Fax: +86 0755 83980805. E-mail: gzgyhzh@163.com.
Received August 2018 & Accepted January 2019

Table1. The basic characteristic of included studies

Study	Design	Age		No.of patient		Mean stone size		Gender(n)		Side		Comparability	Study quality (score)
		Supracostal	Infracostal	Supracostal	Infracostal	Supracostal	Infracostal	Male	Female	Right	Left		
R.John 2011(19)	R	52.2 ± 13.4	53.5 ± 15.2	154	164	695 ± 629 mm^2	596 ± 843 mm^2	184	134	182	136	1, 2, 3, 4, 5, 6, 7	******
Difu 2005(20)	R	42.4 ± 17.5	45.3 ± 2.35	40	43	7.98 ± 2.29 cm^2	7.56 ± 2.35 cm^2	NA		NA		1, 2	****
Sinha 2016(23)	P	NA	41.05 ± 15.43	366	334	P < .05		NA		379	321	1, 5, 6, 7	******
Faruk 2017(25)	R	42 ± 15	38 ± 16	49	49	27.1 ± 11.3 mm	27.5 ± 11.1 mm	67		31	NA	1, 2, 4	******
B. Lojanapiwat 2006(14)	R	51.64 ± 11.93	52.05 ± 12.56	170	294	41.5 ± 18 mm	38.2 ± 15.5 mm	293	171	229	235	1, 2, 3, 7	******
Rohit 2015(24)	P	39.84 ± 10.42	39.53 ± 10.23	43	51	39.02 ± 6.27 mm	39.53 ± 7.17 mm	61	33	49	45	2, 3, 4, 5, 6, 7	******
Ravi 2001(26)	R	47(7-84)		98	202	NA		132	108	106	140	6, 7	****
jing zhang2012(21)	R	56.5 ± 9.2	58.1 ± 9.8	70	82	3.78 ± 1.7	3.51 ± 1.5	85	67	73	79	1, 5, 6, 7	******
Yangwen zeng	R	42-72	45-78	34	30	0.9-2.5 cm	0.7-2.4 cm	40	24	NA		1, 6	*****

Abbreviations: R, retrospective; P, prospective; NA, not available; 1, Stone-free; 2, Additional procedure; 3, Length of hospital stay; 4, Reduced mean hemoglobin; 5, Fever; 6, Blood transfusion; 7, Hydrothrax.

lished studies reporting on the treatment of upper urinary calculi using supracostal and infracostal PCNL. A meta-analysis was performed to evaluate the outcomes of the procedures.

PATIENTS AND METHODS

Literature search

Because the current study was a meta-analysis based on the published articles, the consents of patients and approval of Institutional Review Boards were not included. A literature search of PUBMED, EMBASE,Web of science, CNKI and the Cochrane library was performed to identify relevant studies. No time or language restrictions were applied. The following subject headings and keywords "Percutaneous Nephrostomy", "supracostal" and "supracostal", were used for each electronic databases. The full electronic search strategy in PubMed that were "(((((((Percutaneous Nephrostomy) OR Nephrostomies Percutaneous) OR Percutaneous Nephrostomies) OR Nephrolithotomy Percutaneous) OR Nephrolithotomies Percutaneous) OR Percutaneous Nephrolithotomies) OR Percutaneous Nephrolithotomy) AND (supracostal OR infracostal). " Articles were also identified using the 'related articles' function. The latest date of this search was 3 March 2017, without lower date limit. The reference lists of retrieved articles were manually searched to identify related articles. The review was limited to the published studies.

Study selection criteria

Our search was not restricted to randomized controlled trials (RCTs). Controlled clinical trials and comparative studies were also included. Review articles, meeting abstracts, editorials, case reports and commentaries were excluded. Using the patient, intervention, comparison, outcome and study design (PICOS) method[15], the PICOS evidence base consisted of the following features: P, patients with upper urinary calculi; I, the use of PCNL or miniaturized percutaneous nephrolithotomy (MPCNL; with an access diameter of 14F-20F); C, comparing supracostal with infracostal access; O, safe and effective operation outcomes. Eligible trials included patients harboring upper urinary calculi with an indication for PCNL or MPCNL. There was no restriction on the gender and age of patients. The studies should have included a controlled analysis of supracostal approaches and infracostal approaches for PCNL. The inclusion criteria were as follows:(1) patients with upper urinary calculi;(2) comparing supracostal with infracostal access;(3) relative data that were reported or could be calculated. The exclusion criteria were as follows: (1) conference abstracts, no control group and incomplete data;(2) inclusion criteria were not met. The citations, abstracts and full text of all potentially relevant studies were independently evaluated and independently selected by two reviewers (Tang and Lu). The final selection of the included studies was achieved through a consensus between the reviewers.

Data extraction and assessment of study quality

The studies were screened according to the inclusion and exclusion criteria. Two reviewers (Tang and Lu) independently assessed, extracted and tabulated data from each article using a predefined data extraction form. Data regarding the following factors were obtained: first author, country, year of publication, baseline patient characteristics, intervention, outcome measures, statistical methods and results, and study conclusions. The outcome parameters assessed were additional procedures (such as shock wave lithotripsy, spontaneous passage, flexible ureterorenoscopy and others), Length of hospital stay, reduced mean hemoglobin, stone-free, postoperative hydrothorax, fever and blood transfusion.

Assessment of study quality

The methodological quality of the studies was assessed using the Newcastle-Ottawa scale[16] for observational studies. The scale consists of three domains indicating the study quality as: selection (4 points), comparability (2 points) and outcome (3 points) for a total score of 9 points (with 9 representing the highest quality). Studies scoring 0-3 points, 3-6 points, 7-9 points were set as low, moderate and high quality, respectively.

Statistical analysis

Review Manager (RevMan 5.0.2: Cochrane Library Software, Oxford, UK) software was used to perform the meta-analysis. Outcomes were presented as the mean difference (MD) for continuous data and odds ratio (OR) for categorical data with 95% confidence intervals (CI). Considering the high likelihood of inter-study variance for differences in study design and study population, a random effects model, rather than a fixed ef-

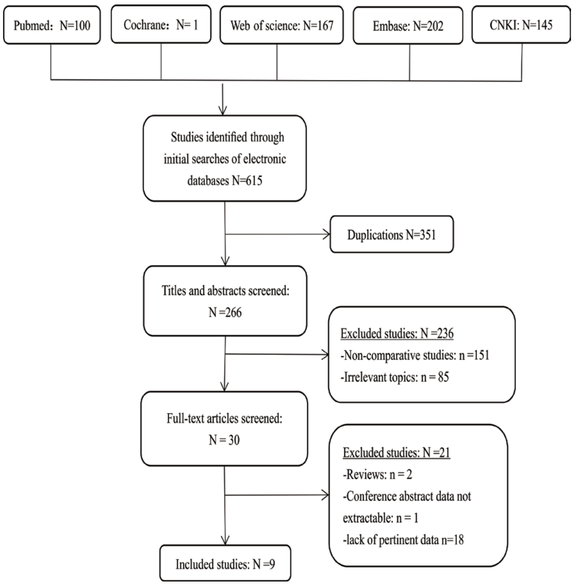

Figure 1. Flow diagram of studies identified, included and excluded.

fects model, was used in the present study. A statistic for measuring heterogeneity was calculated using the I2 method; 25-50% was considered low-level, 50-75% moderate-level and >75% high-level heterogeneity[17]. The Z-test was used to analyze the overall effect on OR and MD, and *P* < .05 was considered statistically significant. The results of the meta-analysis are expressed using forest plots. In addition, publication bias analysis was visually assessed using funnel plots of effect estimates, and Begg's and Egger's tests[18]. The statistical analysis was performed using Stata (version 13.0; StataCorp LP, College Station, TX, USA).

RESULTS

The publication dates of the studies included in the meta-analysis varied from 2001 to 2017, and the reports originated from Canada[19], China[20-22], India[23-24], Turkey[25], Thailand[14] and the USA[26]. **Figure 1** illustrates the process of literature identification and selection as a flow diagram. Finally, nine studies[14,19-26] were included in the meta-analysis. Two studies[23, 24] were prospective and the remaining studies were retrospective observational studies. The basic characteristics of the included studies are presented in **Table 1**[14,19-26]. There were 2,273 patients, of which 1,024 patients underwent PCNL with supracostal access, and 1,249 patients underwent PCNL with infracostal access. Two studies performed minimally invasive PCNL[20,25] and one study used the novel prone-flexed position for PCNL[19].

For the observational studies, the risk of bias was evaluated using the modified Newcastle-Ottawa scale. Each study included in the meta-analysis was judged on three broad perspectives: the selection of the study cases, the comparability of the study populations and the ascertainment of either the exposure or outcome of interest. Four studies[14,21,24,25] received a score of 7 and were considered to be of high quality (**Table 1**).

Meta-analysis

Stone-free outcome

The data from seven studies[14,19-23,25] were pooled to assess the stone-free outcome between the supracostal access groups and the infracostal access groups. These studies were divided into PCNL and MPCNL subgroups according to whether PCNL or MPCNL was performed. In general, heterogeneity analysis produced I2 = 48% and *P* = .07. There was no significant difference between supracostal and infracostal groups (95% CI: 0.80-1.72, OR = 1.18, *P* = .41; **Figure 2**). In the MPCNL subgroup, there was no significant difference between the supracostal and infracostal groups (95% CI: 0.48-2.54, OR = 1.11, *P* = .81; **Figure 2**), In the

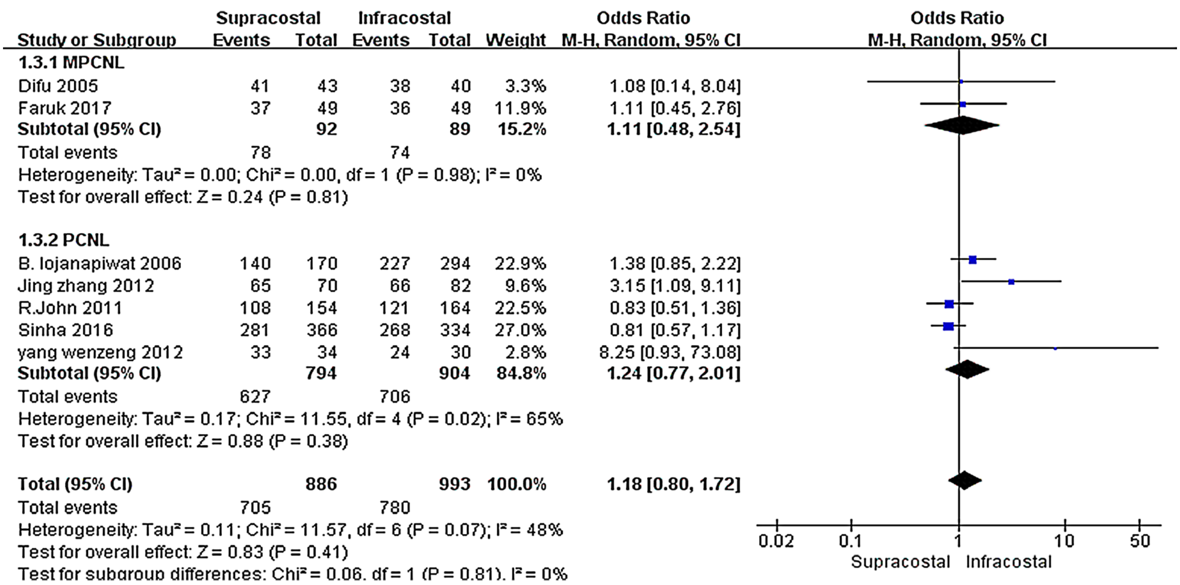

Figure 2. Forest plot showing the stone-free rate of supracostal and infracostal access for PCNL

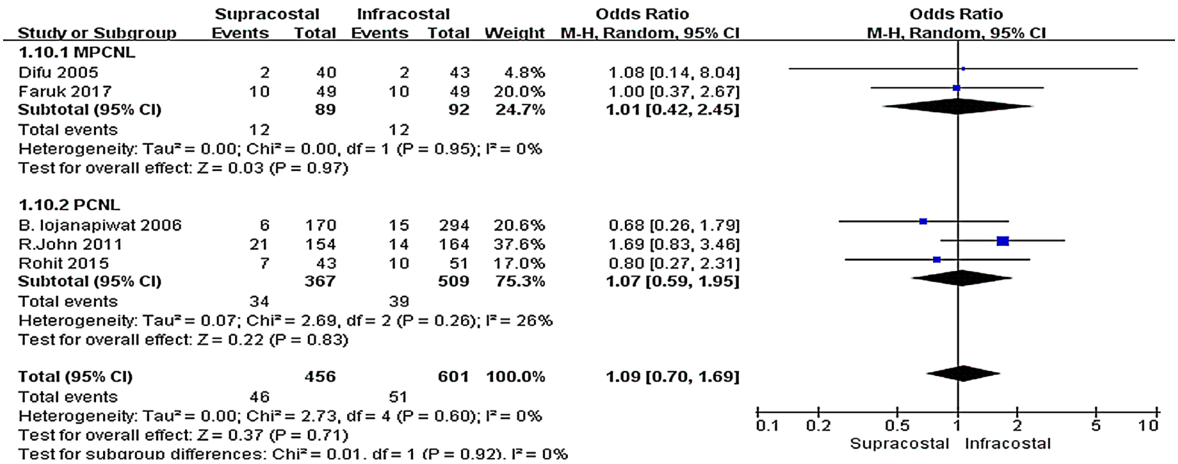

Figure. 3. Forest plot showing the additional procedure of supracostal and infracostal access for PCNL

PCNL subgroup, there was no significant difference between the supracostal and infracostal groups (95% CI: 0.77-2.01, OR = 1.24, *P* = .38; **Figure 2**).

Additional procedures

Five studies[14,19,20,24,25] compared the additional procedures between the supracostal and the infracostal access groups. Heterogeneity analysis produced I2 = 0%, and *P* = .60. The meta-analysis of additional procedures showed no difference between the supracostal and infracostal access groups (95% CI,: 0.70-1.69, OR = 1.09, *P* = .71; **Figure 3**). In the MPCNL subgroup, there was no significant difference between the supracostal and infracostal groups (95% CI: 0.42-2.45, OR = 1.01, *P* = .97; **Figure 3**). In the PCNL subgroup, there was no significant difference between the supracostal and infracostal groups (95% CI: 0.59-1.95, OR = 1.07, *P* = .83; **Figure** 3).

Length of hospital stay

The length of hospital stay following supracostal and infracostal access PCNL was compared in three studies[14,19,24,25]. A heterogeneity test revealed that no significant heterogeneity existed among the studies (I2 = 0.0% and *P* = .65). A pooled analysis revealed that no significant difference existed in the length of hospital stay between the supracostal access and the infracostal access groups (95% CI: -0.03-0.37, MD = 0.17 day, *P* = .10; **Figure 4**).

Reduced mean hemoglobin

Figure 5 presents a comparison of the hemoglobin decrease between the supracostal and the infracostal access groups. Heterogeneity analysis revealed no heterogeneity (I2 = 2.0% and *P* = .36). A pooled analysis revealed that there was less of a hemoglobin decrease in the infracostal access group compared with the supracostal access group (95% CI: 0.26-3.46, MD = 1.86 g/L, *P* = .02; **Figure 5**)[19,24-25].

Postoperative complications

A heterogeneity test revealed that no significant heterogeneity existed among the studies for each of the postoperative complications analyzed (fever, I2 = 0.0% and *P* = .86; blood transfusion, I2 = 8.0% and *P* = .36; hydrothorax, I2 = 0.0% and *P* = .91).There was no significant difference in the occurrence of fever between the supracostal access and the infracostal access groups (95% CI: 0.95-2.03, OR = 1.39; *P* = .09; **Figure 6A**) (19,21,23,24), or in the occurrence of blood transfusion (95% CI: 0.45-1.70, OR = 0.88, *P* = .70; **Figure 6B**) [19,21-24,26]. However, compared with infracostal access, PCNL with supracostal access was associated with a higher risk of hydrothorax (95% CI: 4.77-22.95, OR = 10.47, *P* < .00001; **Figure 6C**)[14,19,21,23,24,26].

Publication bias

Publication bias analysis was assessed by the Begg's

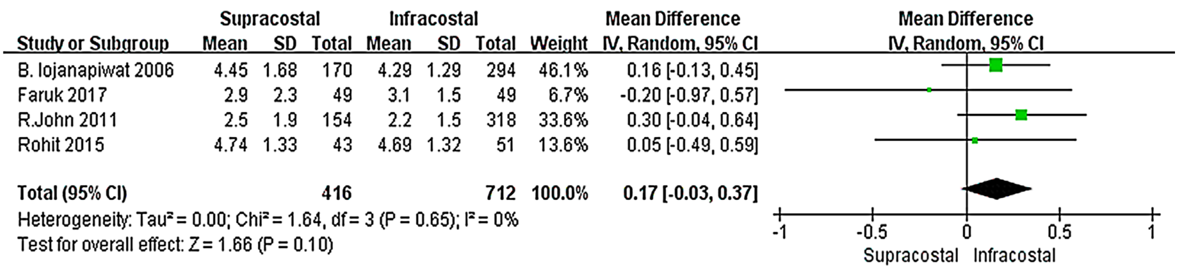

Figure 4. Forest plot showing the length of hospital stay of supracostal and infracostal access for PCNL

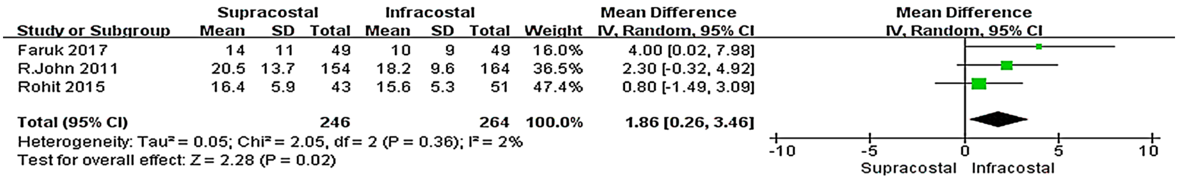

Figure 5. Forest plot showing the reduced mean hemoglobin of supracostal and infracostal access for PCNL

and Egger's test. Visualization of the funnel plot indicated that both Begg' s rank correlation test and Egger' s linear regression yielded non-significant publication bias in the overall meta-analysis of Stone-free(Begg' s, *P* > |z| = .072; Egger bias = 2.33, 95% CI: -0.44-8.84, *P* > |t| = .067), Additional procedure (Begg' s, *P* > |z| = 1.000; Egger bias = -1.04, 95% CI: -6.31-3.20, *P* > |t| = .375) , Length of hospital stay(Begg' s, *P* > |z| = .734; Egger bias = -2.08, 95% CI: -5.06-1.77, P > |t| = .174) , reduced mean hemoglobin(Begg' s, *P* > |z| =1.000; Egger bias = 0.45, 95% CI: -21.38-22.96, *P* > |t| =.729), fever(Begg' s, *P* > |z| = .734; Egger bias= 0.39, 95% CI: -2.75-3.29, *P* > |t| = .735),blood transfusion(Begg' s, *P* > |z| = 1.00; Egger bias = 0.05, 95% CI: -4.29-4.44, *P* > |t| = .960) , and hydrothorax(Begg' s, *P* > |z| = .060; Egger bias = -2.05, 95% CI: -16.93-2.53, *P* > |t| =.109)

DISCUSSION

PCNL has replaced the use of open surgery for removing large and complex renal or upper ureteral calculi, as it is a minimally invasive technique[(27)]. Gaining optimal and atraumatic access to the desired calyx is the first step in a successful PCNL. A safe and effective PCNL puncture is defined as one that provides the shortest and straightest access to all calculi, avoiding major vessels, the bowel and lungs, and achieves minimal parenchymal damage[(23)]). Access guided by ultrasonography can be effective and safe as it allows clear visualization of the kidney and calyceal system to obtain optimum access to the stone/s[(28,29)].

In the present meta-analysis, supracostal and infracostal access were evaluated to compare their efficacy and safety as approaches for PCNL. Nine studies were included in the analysis with a total study population of 2,273 patients. Fan et al.[(20)] previously reviewed the results of 98 mPCNLs and their results revealed that there was no negative effect on any intraoperative and postoperative parameters, or any increase complication rates when comparing supracostal and infracostal access. However, Ozgor et al.[(25)] reviewed 83 cases involving treatment with mPCNL and found that there were several advantages of infracostal access, including increased accuracy in establishing a percutaneous tract, safety, speed, convenience and flexibility in moving the patented sheath. Sinha et al.[(23)] performed a retrospective review of 777 patients who underwent PCNL and suggested that the avoidance of the supracostal approach was unnecessary, although there was an increase in thoracic complications when the supra 11th approach (between the 10th and 11th ribs) was used, compared with the infracostal approach. Munver et al.[(26)] retrospectively reviewed the outcomes of 300 patients treated with PCNL. Complications included blood transfusion in 7 patients and intraoperative hemothorax/hydrothorax in 5 patients. Their report demonstrated that the supracostal approach provided relatively safe access when subcostal angulation was not feasible. Lojanapiwat et al.[(14)] reported on 464 cases treated

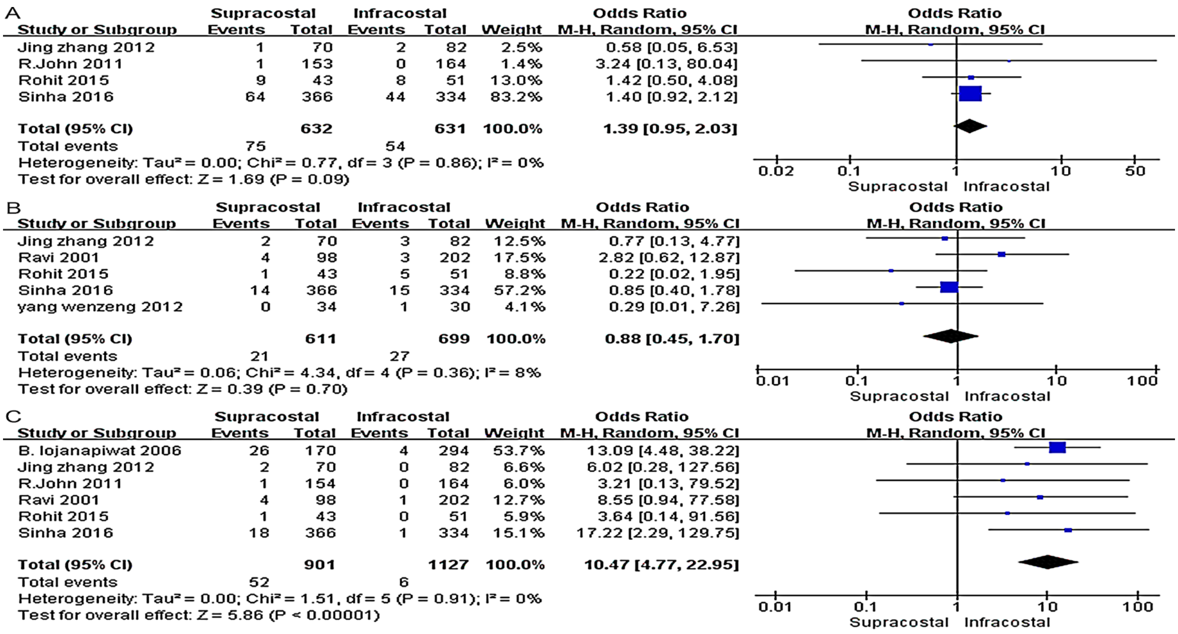

Figure 6. Forest plot showing the postoperative complications of supracostal and infracostal access for PCNL. A: Fever. B: Blood transfusion. C: Hydrothorax.

with PCNL, with subsequent hydrothorax occurring in 26 supracostal puncture cases and 4 subcostal access cases. The rate of pulmonary complications was higher following supracostal access, indicating that supracostal access should be used with caution if unavoidable. Honey et al.[19] performed 318 PCNL procedures using the novel prone-flexed patient position PCNL, and confirmed that supracostal access was a safe alternative to infracostal access when the risk of pleural complications was acceptable. Singh et al.[24] collected clinical data from 94 patients that underwent PCNL to treat complex renal stones and suggested that upper calyceal puncture through the supra 12th rib was a feasible option in patients with complex/large staghorn calculi, which might minimize lung/pleural injury and obtain a better clearance rate. Zhang and Zhao[21] reported that supracostal access provided a straight path and the shortest distance to the pelvis, which resulted resulted in a higher rate stone-free status and reduced operating time in 152 PCNL cases. Yang et al.[22]) retrospectively reviewed 64 patients with upper ureter calculi treated using PCNL. Their study also reported that supracostal access PCNL was safe and effective for the treatment of upper ureter stones.

To the best of our knowledge, this study was the first meta-analysis to compare the safety and efficacy of supracostal and infracostal access PCNL for the treatment of upper urinary stones. Our study showed the was no significant difference between groups in terms of stone-free outcome, additional procedures required, the length of hospital stay and postoperative complications (fever, blood transfusion), which was similar to the findings of previous studies. However, the mean hemoglobin reduction and rate of hydrothorax were significantly increased when using the supracostal approach, compared with infracostal access. These results indicated that supracostal puncture was effective, but not as safe as infracostal access for PCNL.

The present study showed that supracostal access was more likely to cause reduced postoperative hemoglobin levels compared to infracostal access ($P < 0.05$), but the need for blood transfusion was not associated with the postoperative hemoglobin decrease. Some studies have reported that blood transfusion rates were up to 17.5% in patients that underwent PCNL(30,31). Bleeding was thought to be predominantly caused by intercostal artery injury; however our study revealed that appropriate supracostal puncture did not increase bleeding as a post-operative complication. In our meta-analysis, patients that received PCNL with supracostal access had a higher rate of hydrothorax compared with infracostal access, and Lojanapiwat et al.[14] and Cocuzza et al.[32] reported similar results in their respective studies. However, many researchers believe that these complications could be reduced to a minimum by using appropriate precautionary techniques[14,33].

Entering under the 12th rib is the first choice for the establishment of a percutaneous tract for PCNL, and many scholars believe that the infracostal access approach to should be used to avoid thoracic complications, including pneumothorax, hydrothorax and lung injury. However, with infracostal access it can be difficult to achieve a good stone clearance rate for complex upper urinary tract stones, including simple kidney calculi and staghorn calculi. The 11th intercostal access and 10th intercostal access shorten the distance required to establish a percutaneous tract. This was also one of the reasons why many scholars advocate using supracostal access[11,13,34]. Lang et al.[35] reported that the use of supracostal puncture for PCNL had a high stone clearance rate; however, supracostal puncture could increase the rate of complications[36]. Due to the anatomical locations involved, supracostal puncture can easily penetrate the diaphragm, and might damage the pleura and lungs. Some studies have reported that supracostal puncture for PCNL has a risk of pleural injury between 0 and 12.5%[32].

However, due to scientific and technological improvements, the complications caused by supracostal access can be tolerated; therefore, an increasing number of clinicians choose to use supracostal access. Lojanapiwat et al.[14] reported that intercostal access applied to reach the target calyx had the shortest distance, and this approach can reduce thoracic complications to a minimum. Pedro et al.[37] reported that preoperative retrograde or anterograde pyelography can be applied to determine the anatomy of the renal pelvis, and X-ray guidance can reduce the incidence of thoracic complications. Lang et al.[35] suggested that by using CT guidance, the application of ureteroscopy for PCNL surgery could reduce the supracostal access complication rate. Therefore, taking steps to avoid thoracic complications is key to successful supracostal access for PCNL, which requires more surgical skills.

There are certain limitations to our study. Firstly, the scarcity of RCTs comparing supracostal and infracostal access for PCNL was the main shortcoming when creating this meta-analysis. Additionally, the sample size of most studies was highly variable, so the statistical power to identify differences in the outcomes was limited. Furthermore, some data were reported in the studies as "range"; these data may not be normally distributed, and the bias of the pooled effect should be considered. Finally, we cannot guarantee that all the relevant articles have been searched and included in our study, as nonsignifcant a unpublished. Despite these limitations, no publication bias was identified in our study.

CONCLUSIONS

In conclusion, infracostal access is the preferred approach recommended for PCNL, and is safe and effective. Moreover, the supracostal approach for PCNL did not cause a significant difference in intraoperative and postoperative factors, or complications rates (fever, blood transfusion). Supracostal access was effective, but did lead to a higher risk of reduced hemoglobin levels and hydrothorax when compared to infracostal access. Therefore, infracostal access should be the preferred option for PCNL surgery. Essential precautions to avoid hemoglobin loss and hydrothorax are required when supracostal puncture is chosen. However, further high quality RCTs, with larger sample sizes, are required to compare the effectiveness of supracostal and infracostal access and confirm these findings.

ACKNOWLEDGEMENT

Funding This study was supported by Science and Technology Planning Project of Guangdong Province (No.2017B030314108).

Ethical statements This is a systematic review and meta-analysis article, all analyses were based on previous published studies. Therefor, this article does not con-

tain any studies with human participants or animals performed by any of the authors. thus no ethical approval and patient consent are required.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

1. Fernstrom I, Johansson B. Percutaneous pyelolithotomy. A new extraction technique. Scand J Urol Nephrol.1976; 10:257-259.
2. Alken P, Hutschenreiter G, Gunther R, Marberger M. Percutaneous stone manipulation. J Urol. 1981;125:463-466.
3. Atis G, Culpan M, Pelit ES, et al. Comparison of Percutaneous Nephrolithotomy and Retrograde Intrarenal Surgery in Treating 20-40 mm Renal Stones. Urol J. 2017;14:2995-2999
4. Sari S, Ozok HU, Cakici MC, et al. A Comparison of Retrograde Intrarenal Surgery and Percutaneous Nephrolithotomy for Management of Renal Stones > 2 CM. Urol J. 2017;14:2949-2954
5. Maghsoudi R, Etemadian M, Kashi AH, Ranjbaran A. The Association of Stone Opacity in Plain Radiography with Percutaneous Nephrolithotomy Outcomes and Complications. Urol J. 2016;13:2899-2902
6. Schultz-Lampel D, Lampel A. The surgical management of stones in children. BJU Int. 2001; 87:732-740.
7. Mousavi-Bahar SH, Amirhasani S, Mohseni M, Daneshdoost R. Safety and Efficacy of Percutaneous Nephrolithotomy in Patients with Severe Skeletal Deformities. Urol J. 2017;14:3054-6058.
8. Sukumar S, Nair B, Ginil KP, Sanjeevan KV, Sanjay BH. Supracostal access for percutaneous nephrolithotomy: less morbid, more effective. Int Urol Nephrol. 2008; 40:263-267.
9. Mousavi-Bahar SH, Mehrabi S, Moslemi MK. The safety and efficacy of PCNL with supracostal approach in the treatment of renal stones. Int Urol Nephrol. 2011; 43:983-987.
10. Golijanin D, Katz R, Verstandig A, Sasson T, Landau EH, Meretyk S. The supracostal percutaneous nephrostomy for treatment of staghorn and complex kidney stones. J Endourol. 1998; 12:403-405.
11. Kekre NS, Gopalakrishnan GG, Gupta GG, Abraham BN, Sharma E. Supracostal approach in percutaneous nephrolithotomy: experience with 102 cases. J Endourol. 2001;15:789-791.
12. Jun-Ou J, Lojanapiwat B. Supracostal access: does it affect tubeless percutaneous nephrolithotomy efficacy and safety? Int Braz J Urol. 2010;36:171–176
13. Munver R, Delvecchio FC, Newman GE, Preminger GM. Critical analysis of supracostal access for percutaneous renal surgery. J Urol. 2001;166:1242-1246.
14. Lojanapiwat B, Prasopsuk S. Upper-pole access for percutaneous nephrolithotomy: comparison of supracostal and infracostal approaches. J Endourol. 2006;20:491-4.
15. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. PLoS Med. 2009; 6:e1000100.
16. GA Wells, B Shea, D O'Connell, et al. The Newcastle–Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. http://www.ohri.ca/programs/clinical_epidemiology/oxford.asp. Accessed 23 Nov 2014
17. Higgins JP, Thompson SG, Deeks JJ et al. Measuring inconsistency in meta-analyses. BMJ. 2003; 327: 557.
18. Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple. graphicaltest.BMJ. 1997; 315:629–34.
19. Honey RJ, Wiesenthal JD, Ghiculete D, Pace S, Ray AA, Pace KT. Comparison of supracostal versus infracostal percutaneous nephrolithotomy using the novel prone-flexed patient position. J Endourol. 2011;25:947-954.
20. Fan D, Song L, Xie D, et al. A comparison of supracostal and infracostal access approaches in treating renal and upper ureteral stones using MPCNL with the aid of a patented system. BMC Urol. 2015;15:102.
21. Zhang Jing, Zhao Chunli. Applied Anatomy and Clinical Application of Supracostal Approach for Percutaneous Nephrolithotomy .University Of Hebei. 2012. 1367.
22. Yang Wen-zeng, ZHANG Jing, ZHAO Chun-li. To Evaluate the Safety and Efficacy of the Supracostal Access for PCNL in the Treatment of Upper Ureter Calculi. Chinese General Practice. 2012;15:316-317.
23. Sinha M, Krishnappa P, Subudhi SK, Krishnamoorthy V. Supracostal percutaneous nephrolithotomy: A prospective comparative study. Indian J Urol. 2016;32:45-9.
24. Singh R, Kankalia SP, Sabale V, et al. Comparative evaluation of upper versus lower calyceal approach in percutaneous nephrolithotomy for managing complex renal calculi. Urol Ann. 2015;7:31-35.
25. Ozgor F, Tepeler A, Basibuyuk I, et al . Supracostal access for miniaturized percutaneous nephrolithotomy: comparison of supracostal and infracostal approaches. Urolithiasis. 2017;46:279-283.
26. Munver R, Delvecchio FC, Newman GE, Preminger GM. Critical analysis of supracostal access for percutaneous renal surgery. J Urol. 2001;166:1242-1246.

27. Galvin DJ, Pearle MS. The contemporary management of renal and ureteric calculi. BJU Int. 2006;98:1283-1288.

28. Basiri A, Nouralizadeh A, Kashi AH, et al. X-Ray Free Minimally Invasive Surgery for Urolithiasis in Pregnancy. Urol J. 2016;13:2496-501.

29. Hosseini MM, Hassanpour A, Eslahi A, Malekmakan L. Percutaneous Nephrolithotomy During Early Pregnancy in Urgent Situations: Is It Feasible and Safe?. Urol J. 2017;14:5034-5037

30. Michel MS, Trojan L, Rassweiler JJ. Complications in percutaneous nephrolithotomy. Eur Urol 2007**.**51 (4):899-906; discussion 906.

31. Aron M, Yadav R, Goel R, et al. Multi-tract percutaneous nephrolithotomy for large complete staghorn calculi. Urol Int. 2005;75:327-332.

32. Cocuzza M, Colombo JR Jr, Cocuzza AL, et al. Outcomes of flexible ureteroscopic lithotripsy with holmium laser for upper urinary tract calculi. Int Braz J Urol. 2008;34:143-9.

33. Shaban A, Kodera A, El Ghoneimy MN, Orban TZ, Mursi K, Hegazy A. Safety and efficacy of supracostal access in percutaneous renal surgery. J Endourol. 2008;22:29-34.

34. Golijanin D, Katz R, Verstandig A, Sasson T, Landau EH, Meretyk S. The supracostal percutaneous nephrostomy for treatment of staghorn and complex kidney stones. J Endourol. 1998;12:403-405.

35. Lang E, Thomas R, Davis R, et al. Risks, advantages, and complications of intercostal vs subcostal approach for percutaneous nephrolithotripsy. Urology. 2009;74:751-755.

36. Weizer AZ, Auge BK, Silverstein AD, et al. Routine postoperative imaging is important after ureteroscopic stone manipulation. J Urol. 200;168:46-50.

37. Pedro RN, Netto NR. Upper-pole access for percutaneous nephrolithotomy. J Endourol. 2009;23:1645-1647.