

Citation: Chen Y, Feng J, Duan H, Yue Y, Zhang C, Deng T, et al. (2019) Percutaneous nephrolithotomy versus open surgery for surgical treatment of patients with staghorn stones: A systematic review and meta-analysis. PLoS ONE 14(1): e0206810. https://doi.org/10.1371/journal. pone.0206810

Editor: Shaogang Wang, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, CHINA

Published: January 31, 2019

Copyright: © 2019 Chen et al. This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Funding: The authors received no specific funding for this work.

Competing interests: The authors have declared that no competing interests exist.

Abbreviations: PCNL, Percutaneous Nephrolithotomy; OS, open surgery; WMD, Weighted mean difference; OR, Odds ratio; 95%Cl, 95% confidence interval; LE, Level of evidence; OVERVIEW

Percutaneous nephrolithotomy versus open surgery for surgical treatment of patients with staghorn stones: A systematic review and meta-analysis

Yiwen Chen¹°, Jianhua Feng²°, Haifeng Duan¹°, Youwei Yue²°, Chaofeng Zhang¹, Tuo Deng¹, Guohua Zeng 1*

1 Department of Urology, Minimally Invasive Surgery center, The First Affiliated Hospital of Guangzhou Medical University, Guangzhou, Guangdong, China, 2 Department of Urology, Longgang District Central Hospital, Shenzhen, Guangdong, China

• These authors contributed equally to this work.

* gzgyzgh@vip.tom.com

Abstract

Objectives

To compare the efficacy and safety of percutaneous nephrolithotomy (PCNL) and open surgery (OS) for surgical treatment of patients with staghorn stones based on published literatures.

Materials and methods

A comprehensive literature search of Pubmed, Embase, CNKI and Cochrane Library was conducted to identify studies comparing outcomes of PCNL and OS for treating patients with staghorn stones up to Jan 2018.

Results

There was no significant difference in final-SFR between PCNL and OS (odds ratio[*OR*]: 1.17; 95% confidence interval [*CI*]: 0.64, 2.15; p = 0.61), while PCNL provided a significantly lower immediate-SFR compared with OS (*OR*: 0.29; 95% *CI*: 0.16, 0.51; P < 0.0001). PCNL provided significantly lower overall complication rate, shorter operative times, hospitalization times, less blood loss and blood transfusion compared with OS (*OR*: 0.59; 95% *CI*: 0.41, 0.84; P = 0.004), (weighted mean difference [*WMD*]: -59.01mins; 95% *CI*: -81.09, -36.93; p < 0.00001), (*WMD*: -5.77*days*; 95% *CI*: -7.80, -3.74; p < 0.00001), (*WMD*: -138.29*mI*; 95% *CI*: -244.98, -31.6; p = 0.01) and (*OR*: 0.44; 95% *CI*: 0.29, 0.68; P = 0.00002), respectively. No significant differences were found in minor complications (Clavien I-II) (*OR*: 0.72; 95% *CI*: 0.47, 1.09; p = 0.12) and major complications (Clavien III-V) (*OR*: 0.5; 95% *CI*: 0.23, 1.08; P = 0.08). In subgroup analysis, there were no significant differences for overall complications and operative times between mini-PCNL and OS. In sensitivity analysis, there was no significant difference for overall complications between PCNL and OS.



RCT, Randomized controlled trial; SFR, stones free rate.

Conclusion

Our analysis suggested that standard PCNL turns out to be a safe and feasible alternative for patients with staghorn stones compared to OS or mini-PCNL. Because of the inherent limitations of the included studies, further large sample, prospective, multi-centric and randomized control trials should be undertaken to confirm our findings.

Introduction

Staghorn stones still represent an intractable challenge to urologists. Open surgery (OS) was once considered to be the "gold standard" for the surgical treatment of staghorn calculi. However, thanks to miniaturization of endoscopic devices, increasing quality of optic systems, advent of holmium laser use and increasing experience in endoscopic surgery, the surgical management of staghorn calculi has been revolutionized. And the American Urological Association(AUA) guidelines for the management of staghorn calculi recommend percutaneous nephrolithotomy (PCNL) as the modality of choice and standard of practice[1].

However, not only the stone burden but also the morphology of stones can significantly affect the outcomes of PCNL in the management of staghorn calculi[2,3]. This is in contrast to OS, which is little affected by the morphometric index of staghorn calculi. Due to some reasons such as the unavailability of surgical instruments, higher stone free rate(SFR) or shorter operative times, many urologists still recommend OS for patients with complex staghorn calculi[4–6].

Some previous studies[6–15] had compared PCNL versus OS. Nevertheless, all these studies were small samples, and the results were controversial and inconclusive. The optimal treatment for staghorn calculi is still under debate. No meta-analysis has investigated the efficacy and safety of those two procedures. And whether PCNL is safer or more effective when compared to the OS remains unsettled. Therefore, to provide comprehensive information about the strategy of PCNL as well as OS in the treatment of staghorn renal stones, we performed this systematic review and meta-analysis of published studies comparing the efficacy and safety of PCNL and OS for surgical treatment of patients with staghorn renal stones. We hope it may guide urologists and patients to decide on the treatment modality, and to select the optimal treatment.

Materials and methods

A prospective protocol of objectives, literature-search strategy, inclusion and exclusion criteria, study selection, data extraction, outcome measurements, and methods of statistical analysis was prepared a priori according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis[16].

Search strategy

A comprehensive literature strategy search was performed by two members (Chen and Zhang) independently in Jan 2018. The PubMed, Embase, CNKI and the Cochrane Library databases were used to identify relevant studies up to Jan 2018. Separate searches were done with the following search terms: "percutaneous nephrolithotomy' or 'PCNL' or 'PCN'" and "'Open surgery' or 'OS'" in combine with "staghorn calculi' or 'staghorn renal stones'".

Inclusion and exclusion criteria

The selected studies were included based on the following criteria: (1) studies reported comparison between PCNL and OS in patients with staghorn calculi; (2) the outcome measures consisted of at least two of the following things: complications, SFR, hospitalization times, operative times, blood loss, and blood transfusion. Exclusion criteria are as follows: (1) repeated publications or conference proceedings; (2) non-published materials, editorials or reviews; (3) studies containing patients with serious urinary infection, renal insufficiency, musculoskeletal deformities, solitary kidney or congenital abnormalities.

Study selection and data extraction

We screened the studies according to inclusion and exclusion criteria. Two authors (Feng and Yue) independently extracted data and appraised both quality and content. We contacted the authors of relevant studies to supplement incomplete data. Where disagreement arose, papers were re-examined and discussed, and the consensus was reached by the adjudicating senior authors (Zeng and Chen). The extracted data including: first author, year of publication, base-line patient characteristics, study period, study design, interventions, outcome measures, variations in PCNL techniques, statistical methods, and study conclusions. The outcomes included complications, SFR, hospitalization times, operative times, blood drop, and blood transfusion.

Quality assessment and statistical analysis

The level of evidence (LE) of all included studies was assessed by the criteria provided by the Oxford Centre for Evidence-based Medicine[17]. And the quality of non-randomized controlled trials (non-RCTs) was assessed by Newcastle-Ottawa Scale.[18] The Cochrane risk of bias tool was applied to assess the methodological quality of RCTs.[19] All the meta-analyses were performed using Review Manager 5.2 software. The odds ratio (OR) and weighted mean difference (WMD) were used to compare dichotomous and continuous variables, respectively. All results were reported with 95% confidence intervals (CIs). Chi-square test and I-square test were used for testing heterogeneity between studies. If heterogeneity was not significant (P > 0.10, $I^2 < 50\%$), fixed-effect model was employed, otherwise, random-effect will be adopted. The results of the meta-analysis were expressed using forest graphs or tables. The Z-test determined the pooled effects, and P < 0.05 was considered statistically significant. Sub-group analyses were performed to compare standard PCNL and mini-PCNL with OS. Funnel plots were used to screen for potential publication bias. Sensitivity analysis was undertaken using studies of high quality. Only outcomes with three or more than three studies were included in the sensitivity analysis.

Results

The search strategy generated 790 studies. After an initial screening of title and abstract, 13 studies were thought to meet the inclusion criteria. After further screening of full text, we excluded 3 articles because of unavailable data. 10 studies[6–15], which included 921 patients (531 cases for PCNL and 390 cases for OS) fulfilled the predefined inclusion criteria, and were included in the final analysis (Fig 1). Examination of the references listed for these studies and for the review articles did not yield any further studies for evaluation. Table 1 shows the baseline characteristics and quality assessment of all included studies. Among 10 included studies available for meta-analysis, 2 were prospective case-control studies[8,15] (LE: 3b), 7 were retrospective case-control studies[6,9–14] (LE: 3b) and 1 was RCT[7] (LE: 2b). The methodological qualities of included studies were relatively high for six of the nine non-randomized studies



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

https://doi.org/10.1371/journal.pone.0206810.g001

[6,8–10,14,15] (NOS: 6 of 9 points), whereas three studies[11–13] were moderate quality with 5 scores. And the only one RCT[7] was high quality for 5 points (the Cochrane risk of bias tools: score from 0 to 7).

Surgical technique for PCNL among all including studies varied in terms of image guidance, type of dilator, sheath size, type of lithotripsy, postoperative stent, and postoperative nephrostomy tube (Table 2). In 4 studies[8,9,11,15], percutaneous accesses were achieved under fluoroscopic guidance, 4 studies[6,12–14] under ultrasound, 1 study[10] were combined fluoroscopic guidance with ultrasound and one study[7] was not recorded. Tract dilation was accomplished using Amplatz dilators in 7 studies[6,8–11,14,15]. One studies[12] used Metal dilators. And one study[7] was not recorded. Three studies[10,11,14] were mini-PCNL with sheath sizes less than 24Fr, while 7 studies[6–9,12,13,15] were standard PCNL with sheath sizes greater than or equal to 24Fr. Fragmentation and stone removal was accomplished by pneumatic energy in 9 studies[6–9,11–15]. After completion of PNL, a nephrostomy tube was routinely placed in all including studies. A double-J stent was routinely placed in 5 studies[10– 13,15].

	ONE
--	-----

Study	country	Study period	Study design	LE	Mean age ± SD (years)		Mean stone size	Gender (male/ female)		cases, n		Study quality	
					PCNL	OS	PCNL	OS	PCNL	os	PCNL	os	
AL-KOHLANY KM et al 2005	Egypt	2001-2003	RCT	2b	48.6±8.5	48.7±10.9	$18.7\pm6.9~{\rm cm}^3$	18.8±8.1 cm ³	17/26	23/ 22	43	45	5#
Aminsharifi A et al 2016	Iran	2010-2015	PCCS	3b	48±8.57	48.21 ±7.87	79.06 ± 15.63 mm	77.0 ± 14.33 mm	13/3	11/3	16	14	7*
El-Nahas AR et al 2014	Egypt	2000-2013	RCCS	3b	7.1±2.93	7.6±3.31					28	28	6*
Falahatkar S et al 2009	Iran	2005-2006	PCCS	3b	46.5±13.4	46.04 ±13.6			35/37	19/ 29	72	48	6*
Zhang FBY et al 2017	Taiwan	2007-2013	RCCS	3b	54.3 ±411.6	50.5±11.1	19.8±5.6 cm ²	$19.7\pm6.4 \text{ cm}^2$	21/40	3/8	61	11	7*
Cao GZ et al 2008	China	2003-2007	RCCS	3b	43.00 ±12.57	45.00 ±10.36	38.38 ±7.85cm	40.04 ±9.64cm	14/46	12/ 36	60	48	6*
Fei X et al 2012	China	2003-2011	RCCS	3b	46.5±14.5	42.3 ±10.5	3.7±1.6 cm ²	3.5±1.4cm ²			54	48	5*
liang TS et al 2010	China	2003-2008	RCCS	3b	46.37 ±14.75	48.35 ±14.13	3.17±1.8cm	2.94±1.50cm	47/32	24/ 17	79	41	6*
Yang X et al 2014	China	2010-2012	RCCS	3b	45.1±3.2	43.6±3.8	37.9±2.5mm	36.7±2.6mm	26/20	25/ 15	46	40	5*
Zheng B et al 2011	China	2007-2010	RCCS	3b	45.56 ±10.23	44.32 ±11.11	41.01±7.30mm	42.34±6.96mm	39/33	39/ 31	72	70	5*

Table 1. The baseline characteristics and quality assessment of all included studies.

LE = level of evidence, PCNL = Percutaneous nephrolithotomy, OS = open surgery, PCCS = prospective case controlled study, RCCS = retrospective case controlled study, RCT = randomized controlled trial.

* Using Newcastle-Ottawa Scale (score from 0 to 9). # Using The Cochrance collaboration's tool (score from 0 to 7).

https://doi.org/10.1371/journal.pone.0206810.t001

Primary outcomes

SFR

Four studies [6–8,15] that assessed 310 patients reported on *immediate-SFR* (Fig 2A). PCNL provided a significantly lower immediate-SFR compared with OS (*OR*: 0.29; 95% *CI*: 0.16, 0.51; *P* < 0.0001), with no significant between-study heterogeneity ($\chi^2 = 6.08$, df = 3, p = 0.11, $I^2 = 51\%$).

Table 2. Variations in PCNL techniques, as stated in the methods section: An overview.

Studies	Imaging	Dilator			sheath size(Fr)	Lithot				
		Balloon	Metal	Amplatz		Pneumatic	Ultrasonic	Laser	Postoperative US	NT(Fr)
AL-KOHLANY KM et al 2005					24	Y	Y			18
Aminsharifi A et al 2016	F			Y	30	Y				18
El-Nahas AR et al 2014	F			Y	24/30	Y				18
Falahatkar S et al 2009	F			Y	30	Y			Y	18
Zhang FBY et al 2017	US			Y	24	Y	Y			16
Cao GZ et al 2008	F/US			Y	18			Y	Y	14/16
Fei X et al 2012	US				24	Y	Y			12
liang TS et al 2010	US			Y	16/18	Y			Y	16/18
Yang X et al 2014	US		Y		24	Y	Y		Y	12
Zheng B et al 2011	F			Y	18	Y			Y	18

F = fluoroscopy, US = Ultrasound, NT = nephrostomy tube, US = ureteral stent, PCNL = Percutaneous nephrolithotomy, Y = yes

https://doi.org/10.1371/journal.pone.0206810.t002

a

	PCNL OS				Odds Ratio	Odds Ratio				
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Fixed, 95% Cl	M-H, Fixed, 95% Cl			
Alkohlany KM.2005	21	43	30	45	34.6%	0.48 [0.20, 1.13]				
Aminsharifi A.2016	7	16	13	14	18.0%	0.06 [0.01, 0.57]				
Falahatkar S.2009	58	72	44	48	23.7%	0.38 [0.12, 1.22]				
Zhang FBY.2017	8	61	7	11	23.8%	0.09 [0.02, 0.36]				
							•			
Total (95% CI)		192		118	100.0%	0.29 [0.16, 0.51]	•			
Total events	94		94							
Heterogeneity: Chi ² :	= 6.08, df =	= 3 (P =	0.11); I ²∶	= 51%						
Test for overall effect	t: Z = 4.16	(P ≤ 0.0	0001)				Eavours [OSI] Eavours [PCNL]			
1										
b										
	PCNL		OS			Odds Ratio	Odds Ratio			
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Random, 95% Cl	M-H, Random, 95% Cl			
1.2.1 standard PCNL										
Alkohlany KM.2005	32	43	37	45	15.0%	0.63 [0.23, 1.76]	_			
Aminsharifi A.2016	16	16	14	14		Not estimable				
El-Nahas AR.2014	20	28	22	28	12.8%	0.68 [0.20, 2.31]				
Fei X.2012	45	54	42	48	13.9%	0.71 [0.23, 2.18]	·			
Yang X.2014	41	46	28	40	13.6%	3.51 [1.11, 11.08]	_			
Zhang FBY.2017	51	61	11	11	3.7%	0.21 [0.01, 3.91]				
Subtotal (95% CI)		248		186	59.0%	0.92 [0.43, 1.98]				
Total events	205		154							
Heterogeneity: Tau ² =	0.33; Chi ^z	= 7.15,	df = 4 (F	² = 0.13); l² = 449	6				
Test for overall effect: .	Z = 0.22 (F	P = 0.83	i) Ì		, , , , , , , , , , , , , , , , , , ,					
1.2.2 mini-PCNL										
Cao GZ.2008	51	60	33	48	16.2%	2.58 [1.01, 6.56]	│			
liang TS.2010	72	79	40	41	6.2%	0.26 [0.03, 2.17]				
Zheng B.2011	58	72	46	70	18.6%	2.16 [1.01, 4.64]				
Subtotal (95% CI)		211		159	41.0%	1.71 [0.70, 4.21]				
Total events	181		119							
Heterogeneity: Tau ² =	0.30; Chi ^z	= 3.97,	df = 2 (F	² = 0.14); I ^z = 509	6				
Test for overall effect:	Z = 1.17 (F	^o = 0.24	b)							
Total (95% CI)		459		345	100.0%	1.17 [0.64, 2.15]	-			
Total events	386		273							
Heterogeneity: Tau ² =	0.37; Chi ^z	= 14.4	7, df = 7 ((P = 0.0	4); I² = 52	.%				
Test for overall effect:	Z=0.51(P	P = 0.61)				Eavours [OS] Eavours [PCNL]			
Test for subaroup diffe	erences: C	≿hi² = 1.	.07. df = 1	1 (P = 0	.30), I z = I	6.5%				
Fig 2. Forest plot and meta-	analysis of i	mmediat	e SFR(a) a	nd final	SFR(b).					

https://doi.org/10.1371/journal.pone.0206810.g002

Data on final SFR were available in 9 studies [6-14], which evaluated 804 patients (Fig 2B). Meta-analysis of the 9 studies indicated that there was no significant difference between the two groups (OR: 1.17; 95% CI: 0.64, 2.15; p = 0.61), with significant betweenstudy heterogeneity ($\chi^2 = 14.47$, df = 7, P = 0.04, $I^2 = 52\%$). In subgroup analysis, the results of the subgroup of standard PCNL and mini-PCNL were consistent with the overall results, with the pooled OR values of 0.92(95%*CI*: 0.43, 1.98; *P* = 0.83) and 1.71(95%*CI*: 0.7, 4.21; P = 0.24), respectively. However, the between-study heterogeneity was significantly reduced in subgroup analysis.

Complications

Nine studies[6–12,14,15] that assessed 822 patients reported on *overall complications* (Fig 3C). PCNL provided significantly lower overall complications compared with OS (*OR*: 0.59; 95% *CI*: 0.41, 0.84; *P* = 0.004), with no significant between-study heterogeneity ($\chi^2 = 11.91$, *df* = 8, *p* = 0.16, *I*² = 33%). In subgroup analysis, the result of the subgroup of standard PCNL was consistent with the overall results, with the pooled OR values of 0.55(95%*CI*: 0.35, 0.85; *P* = 0.008), but with moderate between-study heterogeneity ($\chi^2 = 9.48$, *df* = 5, *p* = 0.09, *I*² = 47%). However, there was no significant difference between mini-PCNL and OS (*OR*: 0.67; 95% *CI*: 0.36, 1.25; *p* = 0.21), with no between-study heterogeneity ($\chi^2 = 2.2$, *df* = 2, *P* = 0.33, *I*² = 9%).

Data on *minor complications (Clavien I-II)* were available in 7 studies [6–9,11,12,14,15], which evaluated 628 patients (Fig 3D). Meta-analysis of the 7 studies indicated that there was no significant difference between the two groups (*OR*: 0.72; 95% *CI*: 0.47, 1.09; p = 0.12), with no between-study heterogeneity ($\chi^2 = 5.5$, df = 6, P = 0.48, $I^2 = 0\%$). In subgroup analysis, the results of the subgroup of standard PCNL and mini-PCNL were consistent with the overall results, with no between-study heterogeneity respectively.

Six studies[6,7,9,11,14,15] reported *major complications*(*Clavien III-V*) (Fig 3E). There was no significant difference between the two groups (OR: 0.5; 95% CI: 0.23, 1.08; P = 0.08), with no between-study heterogeneity ($\chi^2 = 3.25$, df = 4, P = 0.52, $I^2 = 0\%$). In subgroup analysis, the results of the subgroup of standard PCNL and mini-PCNL were consistent with the overall results, with no between-study heterogeneity respectively.

Secondary outcomes

Operative times

Nine studies[6–8,10–15] assessed 868 patients and reported on *operative times* (Fig 4F) between the two groups favouring the PCNL(*WMD*: -59.01min; 95% *CI*: -81.09, -36.93; p < 0.00001), with significant between-study heterogeneity ($\chi^2 = 363.51$, df = 8, p < 0.00001, $I^2 = 98\%$). In subgroup analysis, the results of the subgroup of standard PCNL were consistent with the overall results, with significant between-study heterogeneity. However, there was no significant difference between mini-PCNL and OS (*WMD*: -25.02min; 95% *CI*: -61.27, 11.23; p < 0.00001), with significant between-study heterogeneity.

Hospitalization times

Ten studies[6–15] assessed 924 patients and reported on *hospitalization times* (Fig 4G) between the two groups favouring the PCNL(*WMD*: -5.77d; 95% *CI*: -7.80, -3.74; p < 0.00001), with significant between-study heterogeneity ($\chi^2 = 439.01$, df = 9, p < 0.00001, $I^2 = 98\%$). In subgroup analysis, the results of the subgroup of standard PCNL and mini-PCNL were consistent with the overall results, with significant between-study heterogeneity respectively.

Blood loss

Four studies[6,12–14] assessed 380 patients and reported on *blood loss* (Fig 5H) between the two groups favouring the PCNL(*WMD*: -138.29*ml*; 95% *CI*: -244.98, -31.6; p = 0.01), with significant between-study heterogeneity ($\chi^2 = 466.1$, df = 3, p < 0.00001, $I^2 = 99\%$). In subgroup analysis, the results of the subgroup of standard PCNL and mini-PCNL were consistent with the overall results, with no significant between-study heterogeneity.

С	PCNL	05			Odds Ratio	Odds Ratio
Study or Subgroup	Events Tota	I Events	Total	Weight	M-H, Fixed, 95% Cl	M-H, Fixed, 95% Cl
3.2.1 standard PCNL						
Alkohlany KM.2005 Aminahasi5 A.2016	15 4	0 0'	45	25 7%	0.24 [0.10, 0.59]	
ELNahas AR 2016	2 1	0 4 8 9	28	4 9%	0.36 0.05, 2.34]	
Falahatkar S.2009	19 7	2 1 ⁷	48	12 7%	1.21 [0.51, 2.83]	
Yang X.2014	2 4	6 8	40	10 7%	0.18 0.04 0.91]	
Zhang FBY.2017	25 6	1 5	11	65%	0.83 [0.23, 3.03]	
Subtotal (95% CI)	26	6 60	186	68.9%	0.55 [0.35, 0.85]	•
Heterogeneity: ChR=	1) 9 48 df= 5 (P	58 =≊I∵(90.0 =	47%			
Test for overall effect.	Z = 2.87 (P = 0	- 0.03),1 - 1.008)	41.0			
3.2.2 minii-PCNL						
Cao GZ.2008	76	0 7	48	90%	0.77 [0.25, 2.33]	
liang TS.2010	11 7	95	41	74%	1.16 0.38 3.61	
Zheng B. 2011 Subtotal 195% (1)	5 /	2 12	159	14 8%	0.36 [0.12, 1.03]	•
Total events	23	24		0	olor [oloo, h2o]	-
Heterogeneity: ChF =	2.20, df= 2 (P	= 0.33); I ² =	9%			
l est for overall effect: .	2 = 1.26 (P = l	1.21)				
Total (95% CI)	47	7	345	100.0 %	0.59 [0.41, 0.84]	•
Total events	94	92				
Heterogeneity: Chif =	11.91, df = 8 (i 7 - 2.01 /P - 6	P = 0.16);	= 33%			0.02 0.1 1 10 50
Test for subaroup diffe	z = z.⊗T (P = l arendes: Chi²:	= 0.27 df=	1 (P =	0.60° P=	0%	Favours [PCNL] Favours [OS]
4			10 A.			
u	PCNL	05	_		Odds Ratio	Odds Ratio
Study or Subgroup	Events Tota	i Events	Total	Weight	M-H, Fixed, 95% Cl	M-H, Fixed, 95% Cl
4.2. i stanuard PCNL Alkohlany KM 2005	10 4	3 22	45	32.0%	0321013-070	
Aminsharifi A.2016	2 1	5 <u>22</u> 6 4	14	7.2%	0.36 [0.05, 2.34]	
El-Nahas AR.2014	6 2	8 7	28	10.7%	0.82 [0.24, 2.84]	
Falahatkar S.2009	19 7	2 11	48	18.9%	1.21 [0.51, 2.83]	
Zhang FBY.2017	19 6	1 4	11	9.1%	0.79 [0.21, 3.03]	
Subtotal (95% CI)	56	U 49	146	11.9%	0.66 [0.41, 1.07]	
Heterogeneity: Chi ² =	4.97. df = 4 (P	40 = 0.29); ² =	20%			
Test for overall effect:	Z = 1.69 (P = 0	.09)				
4.2.2 mini-PCNL						
liang TS.2010	10 7	95	41	11.2%	1.04 [0.33, 3.28]	
Zheng B.2011 Subtotal (95% CI)	5 7	26	70	11.0%	0.80 [0.23, 2.74]	
Total events	15	11		22.170	0.52 [0.40, 2.12]	
Heterogeneity: Chi ² =	0.10, df = 1 (P	= 0.75); l ² =	0%			
Test for overall effect:	Z = 0.19 (P = 0	.85)				
Total (05% CI)	27	4	257	100.0%	0 72 10 47 4 001	
Total (95% CI)	71	59	257	100.0%	0.72 [0.47, 1.09]	•
Heterogeneity: Chi ² =	5.50, df = 6 (P	= 0.48); ² =	0%			
Test for overall effect:	Z = 1.56 (P = 0	.12)				U.05 U.2 1 5 20 Eavours (PCNL) Eavours (OS)
Test for subaroup diffe	erences: Chi ^z :	= 0.46. df =	1 (P =	0.50). I ^z =	0%	
е	DOM				Odd- D-C	Odda Dati-
Study or Subgroup	PCNL Events Tota	US Events	Total	Weight	Odds Ratio	Odds Ratio MLH Fixed 95% Cl
5.2.1 standard PCNL	Evente 1910	LYCING	rotal	aroignt	m-11(11/104(357/0 CI	
Alkohlany KM.2005	54	39	45	42.4%	0.53 [0.16, 1.72]	
El-Nahas AR.2014	2 2	8 2	28	10.1%	1.00 [0.13, 7.64]	
Falahatkar S.2009 Zhang EPV 2047	07	2 O	48	0.00	Not estimable	
Subtotal (95% CI)	20	4	132	60.8%	0.68 [0.27, 1.69]	•
Total events	13	12				
Heterogeneity: Chi ^z =	0.49, df = 2 (P	= 0.78); l ² =	0%			
Test for overall effect:	Z = 0.82 (P = 0	1.41)				
5.2.2 mini-PCNL						
liang TS.2010	1 7	90	41	3.5%	1.59 [0.06, 39.80]	
Zheng B.2011	0 7	26	70	35.7%	0.07 [0.00, 1.24]	
Subtotal (95% CI)	15	1	111	39.2%	0.20 [0.04, 1.08]	
Heterogeneity: Chi²=	1 2.10. df = 1 (P	ە = 1150° 12=	52%			
Test for overall effect:	Z = 1.86 (P = 0)	1.06)	02 W			
Total (95% CI)	35	5	243	100.0%	0.50 [0.23, 1.08]	•
Total events	14	18				
Heterogeneity: Chi ² =	3.25, df = 4 (P	= 0.52); l ² =	0%			
Fest for overall effect: . Test for subgroup diffe	L = 1.78 (P = 0)	1.08) -1.55 Af-	1 (P -	0.211 8-	35.4%	Favours [PCNL] Favours [OS]
restion suburoup diffe	sences. Cril*:	- 1.55. ui =	- u* =	0.21).17=		
Fig 3. Forest plot a (e).	and meta-a	nalysis o	f ove	rall con	nplications(c), n	ninor complications(d) and major complications

https://doi.org/10.1371/journal.pone.0206810.g003

f										
±		CNL			os			Mean Differen	ice	Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	lotal	weight	IV, Random	, 95% CI	IV, Random, 95% Cl
7.2.1 standard PCNL										
Alkohlany KM.2005	127	30	43	204	31	45	11.2%	-77.30 [-89.75	-64.25	-
Aminsharifi A.2016	79.7	19.2	16	183.57	22.2	14	11.1%	-103.87 [-118.83	-88.91	-
Falahatkar 8.2003	101.67	35.13	72	120	20.15	48	11.4%	-18.33 [-28.2	5,-8.41	-
Fei X.2012	73.6	14.8	54	146.7	18.2	48	11.5%	-73.10 [-79.59	-66.61	
Yang X.2014	72.7	13.1	46	145.3	17.8	40	11.5%	-72.30 [-79.29	-65.91	
Zhang FBY.2017	156.6	41.2	61	282.1	54.5	11	9.1%	-125.53 [-159.33]	-91.67	
Subtotal (95% CI)			292			206	65.8%	-75.88 [-97.76,	-53.99]	•
Heterogeneity: Tau ² =	684.60;	Chi ² = 1	35.36,0	df = 5 (P	< 0.000	01); I* = !	96%			
Test for overall effect:	Z = 6.80	(P < 0.0	0001)							
7.2.2 mini-PCNL										
Cao GZ.2008	137.33	30.47	60	127.92	23.61	48	11.4%	9.41 (-0.79	, 19.61	-
liang TS.2010	75.29	17.14	79	103.61	27.42	41	11.4%	-28.32 [-37.52]	-19.12	-
Zheng B.2011	112	21	72	168	34	70	11.4%	-56.30 [-65.33	-46.67	-
Subtotal (95% CI)			211			159	34.2%	-25.02 [-61.27	, 11.23]	-
Heterogeneity: Tau ² =	1002.54	ChF=	86.17,0	df=2 (P	< 0.000	01); I ^z = !	98%			
Test for overall effect:	Z=1.35	(P = 0.1	8)							
										•
Total (95% CI)			503			365	100.0%	-59.01 [-81.09,	-36.93]	· · · · · · · · · · · · · · · · · · ·
Heterogeneity: Tau ² =	1090.15	ChF=	363.51	df = 8 (F	< 0.00	001); 🖻 =	= 98%			-100 -50 0 50 100
Test for overall effect:	Z= 5.24	(P < 0.0	0001)							Eavours IPCNUL Eavours (OS)
Test for subaroup diff	erences:	Chi ^z = 5	54. df	= 1 (P =	0.02) F	= 82.0%	, ,			rateasti onej rateasteoj
ď										
8		-		00						Mana Difference
Study or Subaroun	Maan	ED T	atal M	03	D Tete	I Main	ive n/	an Dirierence		Mean Difference
6.2.4 standard DCN	mean	30 1		ean 3	0 1012	n vverg	nic iv.	Random, 95% CI		IV. Rahuolik 95% Ci
Bliceblery I/M 2005	R 4	10	40	40 4	2 4	5 0.0	200	001500 104		
Alkoniany Kill. 2005	0.4	4.2	43	10 4	.2 4	0 8.0	- 070	3.00 (-5.30, -1.84)		
Aminshami A.2016	3.56	0.62	10 1	0.85 1	19 1	4 10.2	(%)	2.28 [-3.03, -1.55]		
El-Inarias AR.2014	2.02	2.3	20	0.0 4	.1 2	0 8.0 0 40.0	070 -0	0.00 (-0.04, -2.00)		-
Falanatkar 8.2009	3.93	1.76	12 5	140 0	4	8 10.2	176 -1 107 40	1.15 [-1.95, -0.35]	-	-
Fel X.2012	4.2	1.0	54	14.3 2	.8 4	8 10.2	(96 -10.	10 [-11.00, -9.20]	-	
Yang X.2014	4.5	1.5	40	14./ 3	.1 4	0 10.1	96 -10.	20 [-11.25, -9.15]		-
Zhang FBY.2017 Subtatel (05% CD	b.2	2.1	220	10.3 1	.8 1	1 10.0	J%0 -4	110 -5.36, -2.84		
Subtotal (95% CI)	40.00.0		320		2.3	4 09.8	9% -3 00/	.04[-0.11,-1.97]		
Helerogeneity. Tau-=	10.80, 0	m-= 30	5.19, UI	= 0 (P <	0.0000	1), F = 9	0 70			
rest for overall effect.	2 = 3.22	(P = 0.0	01)							
6.2.2 mini DCNI										
Can 07 2008	6.22	1.62	60	121 11	54 A	9 10 2	296	79 69 40 -7 18	-	
liana TC 2010	0.12	2.67	70 1	675 5	04 4	1 0.5	x	62 1 10 42 -6 02		_
Thong P 2011	7.40	0.06	70 1	2 41 24	1 7	0 10 2	00.	00 [6 67 6 41]		•
Subtotal (05% CB	7.42	0.00	244	3.41 2.4	46	0 10.3	10/ 7	33[0.07, -3.41]	-	
Heterogeneity Tau?-	1.62.0%	- 20 C	5 df-	2/2 ~ 0	0001\-9	- 00%		.55[-0.05,-5.01]		
Test for sucrell offect	1.02, Cfi 7 = 0.46	(D ~ 0.0	00043	2 (F < U.	0001), P	- 90%				
rest or overall effect.	2 = 9.45	(= = 0.0	0001)							
Total (95% CI)			531		39	3 100 0	0% -5	77 [-7.803.74]		•
Heterogeneity Tau?-	10.37.0	hi≅ = ∦2	0 N1 AF	= 9 /P -	0.0000	1) F = 0	296			
Test for overall effect:	7=558	(P < 0 0	0001)	(0.0000		0.00		-10	-5 0 5 10
Test for subgroup diff	z = 0.00	Chi# = 1	71 df	= 1 (P -	n 19) ⊯	= 41 494			Favou	s [PCNL] Favours [OS]
rest of Suburoup unit	sistices.	201 - 1		- 10 -	0. F 0), F	- 41.470	·			

Fig 4. Forest plot and meta-analysis of operative times(f) and hospitalization times(g).

https://doi.org/10.1371/journal.pone.0206810.g004

Blood transfusion

Data on *blood transfusion* were available in 8 studies[6–12,15], which evaluated 702 patients (Fig 5I). Meta-analysis indicated that PCNL provided less blood transfusion compared with OS (*OR*: 0.44; 95% *CI*: 0.29, 0.68; *P* = 0.00002), with no between-study heterogeneity (χ^2 = 8.11, *df* = 7, *P* = 0.32, *I*² = 14%). In subgroup analysis, the results of the subgroup of standard PCNL and mini-PCNL were consistent with the overall results.

Sensitivity analysis

When high quality studies were assessed, no change in terms of the significance of each of the outcomes except for overall complications. Meta-analysis of 7 high quality studies[6–10,14,15] revealed that there was no significant difference between the two groups for surgical treatment of patients with staghorn stones, with no between-study heterogeneity. Between-study heterogeneity was significantly reduced by the sensitivity analysis for final SFR and blood loss. While heterogeneity remained statistically significant in operative times and hospitalization times. (Table 3)

Publication bias outcomes

Funnel plots were conducted to assess the publication bias in this meta-analysis that reported overall complications (Fig 6). All studies lie inside the 95% CIs, with an even distribution around the vertical, indicating no obvious publication bias.

11	F	CNL			os			Me	an Difference	Mean Diffe	rence
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight		V, Random, 95% Cl	IV, Random	95% CI
10.2.1 standard PCNL											
Fei X.2012	84.7	26.7	54	287.1	48.6	48	30.8%	-202.4	0 [-217.88, -186.92]		
Yang X.2014	82.8	24.6	46	290.2	45.9	40	30.8%	-207.4	0 [-223.30, -191.50]		
Zhang FBY.2017	695.5	531.8	61	613.6	528.7	11	7.5%	81.9	0 [-257.84, 421.64]		-
Subtotal (95% CI)			161			99	69.1%	-204.2	8 [-219.66, -188.90]	+	
Heterogeneity: Tau ² =	59.33; C	hi² = 2.	93, df=	2 (P = 0).23); P	= 32%	,				
Test for overall effect:	Z = 26.0	3 (P < 0	.00001)							
10.2.2 mini-PCNL											
liang TS.2010	80	16.8	79	139	20.4	41	30.9%	-59	3.00 [-66.26, -51.74]		
Subtotal (95% CI)			79			41	30.9%	-59	.00 [-66.26, -51.74]	•	
Heterogeneity: Not ap	plicable										
Test for overall effect:	Z = 15.9	3 (P < 0	.00001)							
Total (95% CI)			240			140	100.0%	-138.3	29 [-244.98, -31.60]	-	
Heterogeneity: Tau ² =	9561.12	; Chi ² =	466.10), df = 3	(P < 0.0	00001)	; F= 99%				100000
Test for overall effect:	Z = 2.54	(P = 0.)	01)							-200 U	100200
Test for subaroup diff	erences	Chi ^z =	280.26	df=1 (P < 0.0	0001).	² = 99.69	6		Favours (PGNL) F	avours [05]
т											
1	PCM	л	0	s			Odds Ra	tio	Odds F	Patio	
Study or Subaroun	Evente	Total	Event	e Total	Mair	iht M	H Fived	05% CL	M H Eived	1.95% C1	
8.2.1 standard PCNI	Lacing	Total	LYGIIL		TTON	anc m	TI, TIAGU,	33 4 61	M-IL INCO	1 33 / 61	
Alkohlany KM 2005	8	43	1	5 46	18/	196	0.46.00.1	7 1 2 31			
Amincharifi & 2016	2	16		3 1/	10.4	296	0.5210.0	7 3 701			
ELNabac AR 2014	4	29		1 29	1 1	296	1 50 10 47	12 001	_		
Epiphotkar C 2000	10	70		0 40	143	006	0 70 10 2	6 1 071		_	
Yong X 2014	10	10		5 40 6 40	0.7	7.00	0.1210.0	1 1 1 01			
Tang A2014 Zhang EBV 2017	12	40		0 40 A 44	0.0	100	0.13 [0.0	4 4 741		_	
Entertal (05% CI)	12	266		4 11	56	170	0.43 [0.1	2 0 0 41	-		
Subtotal (95% CI)	07	200		100	50.	470	0.56 [0.5.	5, 0.94]	•		
Total events	37	-	0.000.0	8							
Heterogeneity: Chr=	5.60, df =	= 5 (P =	0.35);1	= 11%							
lest for overall effect:	Z= 2.17	(P = 0.)	13)								
8.2.2 mini-PCNL											
Cao GZ.2008	13	60	2	0 48	26.8	3%	0.39 [0.1	7, 0.90]			
Zheng B.2011	2	72	1	1 70	16.7	7%	0.15 [0.0	3, 0.72]			
Subtotal (95% CI)		132		118	43.	6%	0.30 [0.14	4, 0.61]	-		
Total events	15		3	1							
Heterogeneity: Chi ² =	1.09, df :	= 1 (P =	0.30); I	²=8%							
Test for overall effect:	Z = 3.28	(P = 0.)	001)								
Total (95% CI)		398		304	100.	0%	0.44 [0.29	9, 0.68]	•		
Total events	52		6	9							
Heterogeneity: Chi ² =	8.11, df :	= 7 (P =	0.32):1	² =14%							
Test for overall effect.	Z= 3.76	(P = 0.)	0002)						0.01 0.1 1	10 100	
Test for subgroup diffe	oroncos	ChP-	1.88 dt	- 1 /P -	0.17)	2 - 46	996		Favours [PCNL]	Favours [OS]	

Fig 5. Forest plot and meta-analysis of blood loss(h) and blood transfusion(I).

https://doi.org/10.1371/journal.pone.0206810.g005

Discussion

This meta-analysis of 10 studies, which included 921 patients from 1 RCT, 2 prospective casecontrol studies and 7 retrospective case-control studies, comparing the efficacy and safety of PCNL and OS for patients with staghorn stones. The pooled data showed that there was no significant difference in final-SFR between PCNL and OS, while PCNL provided a significantly lower immediate-SFR compared with OS. PCNL provided significantly lower overall complication rate compared with OS. However, no significant differences were found in minor complications (Clavien I-II) and major complications (Clavien III-V). PCNL provided

Table 3. Sensitivity analysis according to high quality studies comparing PCNL and OS.

	Number	patients			WMD/OR (95% CI)	p value	Study hete	Study heterogeneity				
	studies	PCNL	OS	Total			χ^2	df	I ² %	p-value		
Final SFR	6	287	187	474	0.8(0.34,1.91)	0.62	7.79	4	49	0.1		
Over complications	7	359	235	594	0.69(0.46,1.03)	0.07	8.51	6	29	0.2		
Minor complications	6	299	187	486	0.71(0.45,1.1)	0.13	5.47	5	9	0.36		
Major complications	5	283	173	456	0.73(0.31,1.74)	0.48	0.73	3	0	0.87		
Operative times	6	331	207	538	-55.56(-89.95,-21.17)	0.002	236.26	5	98	< 0.00001		
Hospitalization times	7	359	235	594	-4.46(-6.86,-2.06)	0.0003	231.7	6	97	< 0.00001		
Blood loss	2	140	52	192	-58.94(-66.19,-51.68)	< 0.00001	0.66	1	0	0.42		
Blood transfusion	6	280	194	474	0.55(0.35,0.88)	0.01	4.49	5	0	0.48		

WMD = weighted mean difference, OR = odds ratio, 95% CI = 95% confidence interval

https://doi.org/10.1371/journal.pone.0206810.t003





https://doi.org/10.1371/journal.pone.0206810.g006

significantly shorter operative times and hospitalization times compared with OS. And PCNL provided significantly less blood loss and blood transfusion compared with OS. In subgroup analysis, there was no significant difference for overall complications and operative times between mini-PCNL and OS. In sensitivity analysis, there was no significant difference for overall complications between PCNL and OS.

In the application of urolithiasis surgery, SFR represents a paramount important parameter. Al-Kohlany KM et al.[7] also found that both PCNL and OS were comparable in regard to SFRs at discharge home and at follow-up. However, Zhang FBY et al.[6] found that OS provided a significantly higher final SFR compared with PCNL (97.5% vs 76.1, p < 0.001). Our pooled data showed that although OS provided a significantly higher immediate-SFR compared with PCNL, no significant difference was found in final-SFR. And the results of the subgroup and sensitivity analysis of standard PCNL and mini-PCNL were consistent with the overall results.

The safety of the patients is also an important parameter. Our pooled data showed that PCNL provided significantly lower overall complication rate compared with OS. And no significant differences were found in minor complications (Clavien I-II) and major complications (Clavien III-V). However, there was no significant difference for overall complications in subgroup analysis between mini-PCNL and OS. And no significant difference was found for overall complications between PCNL and OS in sensitivity analysis. Our pooled data also found that although PCNL provided significantly shorter operative times compared with OS, no significant difference was found for operative times between mini-PCNL and OS in subgroup analysis. The disadvantage of small instruments is that it is necessary to fragment staghorn stones into smaller pieces that fit through the narrower sheaths, which would increase the operative times of the mini-PCNL. Prolonged operating times lead the trend towards higher complications for mini-PCNL compared with standard PCNL.

A great deal of studies[12–14] found that PCNL provided significantly less blood loss compared with OS. While Zhang FBY et al.[6] found that OS provided less blood loss compared with OS, though with no statistically significant. However, our pooled data showed that PCNL provided significantly less blood loss and blood transfusion compared with OS. And the results of the subgroup and sensitivity analysis of standard PCNL and mini-PCNL were consistent with the overall results.

Several limitations of our meta-analysis should be taken into consideration when interpreting the results. First of all, nine of ten studies were non-RCTs. Those results should be interpreted with caution given the potential for selection and treatment bias due to the non-RCT heterogeneous nature. Heterogeneity among studies were found to be high for several parameters, including final SFR, operative times, hospitalization times, and blood loss. Although between-study heterogeneity was significantly reduced by the sensitivity analysis for final SFR and blood loss, heterogeneity of operative times and hospitalization times remained statistically significant. The differences in surgical technique and surgical experience, and outcome definitions have all acted an important role in the heterogeneity. The surgical technique for PCNL and OS, the diameters and location of stones were not similar across the different studies. Overall, only 10 studies with 921 patients could be included in the meta-analysis. Such a small number of studies were unable to make strong conclusion. Thus, further large sample prospective, multi-centric studies and RCTs should be undertaken to confirm our findings.

Nevertheless, our meta-analysis was conducted at an appropriate time. Ten data have accumulated for analysis. We applied multiple strategies to identify studies, strict criteria to include and evaluate the methodological quality of the studies, and subgroup analysis to minimize the heterogeneity. Hence, we provide the most up-to-date information in surgical treatment of patients with staghorn calculi, and this could guide urologists and patients to decide on the surgical method, and to select the optimal therapy.

Conclusion

Our systematic review and meta-analysis demonstrated that standard PCNL seems to be a safe and feasible alternative compared to OS or mini-PCNL for patients with staghorn stones with many advantages, such as shorter hospitalization times and operative times, less blood loss and blood transfusion, and without increasing complications nor decreasing final SFR. However, our conclusion should be treated prudently and further large sample prospective, multi-centric studies and randomized control trials should be undertaken to confirm our findings.

Supporting information

S1 Checklist. PRISMA checklist. (DOC)

Acknowledgments

We thank the data provided by the authors of included studies.

Author Contributions

Conceptualization: Yiwen Chen, Guohua Zeng.

Data curation: Yiwen Chen, Jianhua Feng, Haifeng Duan, Youwei Yue, Chaofeng Zhang, Tuo Deng, Guohua Zeng.

Formal analysis: Yiwen Chen, Haifeng Duan, Tuo Deng, Guohua Zeng.

Investigation: Yiwen Chen, Haifeng Duan, Chaofeng Zhang, Tuo Deng.

Methodology: Yiwen Chen, Jianhua Feng, Youwei Yue, Tuo Deng.

Project administration: Yiwen Chen.

Resources: Yiwen Chen.

Software: Yiwen Chen, Haifeng Duan, Tuo Deng.

Supervision: Guohua Zeng.

Writing - original draft: Yiwen Chen.

Writing - review & editing: Guohua Zeng.

References

- Preminger GM, Assimos DG, Lingeman JE, Nakada SY, Pearle MS, Wolf JS (2005) Chapter 1: AUA guideline on management of staghorn calculi: diagnosis and treatment recommendations. J Urol 173: 1991–2000. PMID: 15879803
- Mishra S, Sabnis RB, Desai M (2012) Staghorn morphometry: a new tool for clinical classification and prediction model for percutaneous nephrolithotomy monotherapy. J Endourol 26: 6–14. <u>https://doi.org/ 10.1089/end.2011.0145</u> PMID: 22050495
- Mishra S, Sabnis RB, Desai MR (2012) Percutaneous nephrolithotomy monotherapy for staghorn: paradigm shift for 'staghorn morphometry' based clinical classification. Curr Opin Urol 22: 148–153. https:// doi.org/10.1097/MOU.0b013e32834fc306 PMID: 22223067
- Matlaga BR, Assimos DG (2002) Changing indications of open stone surgery. Urology 59: 490–493; discussion 493–494. PMID: 11927296
- 5. Assimos DG (2001) Anatrophic nephrolithotomy. Urology 57: 161–165. PMID: 11164167
- 6. Zhang FB, Lin W, Yang S, Hsu J, Chang H, Chen M, et al. (2017) Outcomes of percutaneous nephrolithotomy versus open stone surgery for patients with staghorn calculi. Urol Sci 28: 97–100.
- Al-Kohlany KM, Shokeir AA, Mosbah A, Mohsen T, Shoma AM, Eraky I, et al. (2005) Treatment of complete staghorn stones: a prospective randomized comparison of open surgery versus percutaneous nephrolithotomy. J Urol 173: 469–473. <u>https://doi.org/10.1097/01.ju.0000150519.49495.88</u> PMID: 15643212
- Aminsharifi A, Irani D, Masoumi M, Goshtasbi B, Aminsharifi A, Mohamadian R (2016) The management of large staghorn renal stones by percutaneous versus laparoscopic versus open nephrolithotomy: a comparative analysis of clinical efficacy and functional outcome. Urolithiasis 44: 551–557. https://doi.org/10.1007/s00240-016-0877-6 PMID: 27032961
- El-Nahas AR, Shokeir AA, Shoma AM, Eraky I, Sarhan OM, Hafez AT, et al. (2014) Percutaneous nephrolithotomy versus open surgery for treatment of staghorn stones in pediatric patients. Can Urol Assoc J 8: E906–909. https://doi.org/10.5489/cuaj.1994 PMID: 25553164
- Cao GZ, Su H, Zhu YP, Wu B, Sun YW, Zhu M, et al. (2008) Comparison between mini-invasive percutaneous nephrolithotomy combined with holmium laser and open surgery for renal staghorn calculi (in chinese). Chinese Journal of Modern Operative Surgery 12(3): 171–174.
- Zheng B, Zhan HJ, Chen Y(2011) Comparative analysis for treatment of renal staghorn calculi with percutaneous nephrolithotomy and open surgery (in chinese). China Journal of Endoscopy 17: 1060–1063 +1067.
- **12.** Yang X, He Y. (2014) Comparison on the Efficacy and Safety of Percutaneous Nephrolithotomy and Open Surgery in Treating Staghorn Calculi (in chinese). Medical Recapitulate 20: 3258–3259.
- Fei X, Song YS, Wu B(2012) A comparative study of percutaneous nephrolithotripsy and open operation for staghorn nephrolithiasis (in chinese). Modern Oncology 20(05): 994–996.

- Liang TS, Gao HJ, Lu SG, Luo XD, Tang Z(2010) Comparison of percutaneous nephrolithotomy and open surgery for management of renal staghorn calculi (in chinese). Chin J Endourology (Electronic Edition) 4: 462–465.
- Falahatkar S, Panahandeh Z, Sourati A, Akbarpour M, Khaki N, Allahkhah A(2009) Percutaneous Nephrolithotomy Versus Open Surgery for Patients with Renal Staghorn Stones. UroToday International Journal 2: 1944–5784.
- Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. (2009) The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 339: b2700. https://doi.org/10.1136/bmj.b2700 PMID: 19622552
- Phillips B, Ball C, Sackett D. Levels of evidence and grades of recommendation. Oxford Centre for Evidence-based Medicine Web site. http://www.cebm.net/index.aspx?o=1025. Accessed April 26,2012.
- Stang A (2010) Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. Eur J Epidemiol 25: 603–605. <u>https://doi.org/10.1007/ s10654-010-9491-z PMID: 20652370</u>
- Higgins JP, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. (2011) The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 343: d5928. https://doi.org/10.1136/ bmj.d5928 PMID: 22008217