Special Article

Minimally Invasive vs. Standard Percutaneous Nephrolithotomy vs. Retrograde Intrarenal Surgery: A Systematic Review and Meta-analysis

Sarayuth Viriyasiripong MD*, Sree Harsha Mandava MD**, Andrew Gabrielson MD**, James Liu MD**, Weil Lai MD**, Benjamin R Lee MD**

** Division of Urology, Department of Surgery, Srinakharinwirot University, Nakhon Nayok, Thailand*
*** Department of Urology, Tulane University, New Orleans, LA, USA*

Objective: *To review and perform a meta-analysis of the available literature on the minimally invasive percutaneous nephrolithotomy (PCNL) techniques in comparison with standard PCNL and retrograde intrarenal surgery (RIRS).*
Material and Method: *We systematically reviewed PubMed and Galileo in April 2016 to identify all relevant studies between 2010 to April 2016. The stone free rate, operative time, length of stay and blood loss were compared between standard PCNL, mini-PCNL, ultra-mini PCNL, micro-PCNL and RIRS to determine the best modalities for stone treatment.*
Results: *Included in analysis were 32 studies in a total of 4,586 total cases (316 standard PCNL cases, 2,581 mini PCNL cases, 185 ultra-mini PCNL cases, 316 micro PCNL cases and 739 RIRS cases). The meta-analysis results between standard PCNL vs. mini-PCNL vs. ultra-mini PCNL vs. micro-PCNL vs. RIRS are as follow: 1) mean stone sizes were 29.63, 30.38, 16.04, 13.83 and 14.4, respectively 2) stone free rates (%) were 75.63, 84.88, 86.13, 88.03 and 80.31, respectively 3) operative times (minutes) were 77.46, 57.28, 76.08, 56.53 and 64.39, respectively 4) length of hospital stays (hours) were 165.76, 101.54, 54.73, 45.28 and 32.59, respectively 5) hemoglobin decrease rates (g/L) were 12.87, 9.85, 7.35, 8.91 and 9.38, respectively.*
Conclusion: *Minimally invasive PCNL have higher stone free rates in comparison to standard PCNL and RIRS. Among the minimally invasive PCNL, mini-PCNL have the greatest flexibility in stone size ranges with comparable operative time, length of stay and blood loss to the others. For large stones (>2 cm), mini-PCNL are superior to standard PCNL in all variable outcomes. Future well designed multicenter randomized controlled trials are needed to support these findings.*

Keywords: *Percutaneous nephrolithotomy, Miniperc, Ultra-miniperc, Microperc, Retrograde intrarenal surgery, Flexible ureteroscope, Stone surgery, Systemic review, Meta-analysis*

J Med Assoc Thai 2017; 100 (Suppl. 8): S251-S263
Full text. e-Journal: *http://www.jmatonline.com*

The number of patients with renal stones who required treatment has increased worldwide in 10 years[1]. The goal of surgical stone treatment is complete stone clearance in short procedure time with minimum length of stay, minimum blood loss and minimum complications. Standard surgical kidney stone treatments are shock wave lithotripsy (SWL), retrograde intra-renal surgery (RIRS) and percutaneous nephrolithotomy (PCNL). PCNL has been developed since the 1980s and primarily utilized for management of large renal calculi[2]. PCNL is now the standard treatment for large stone >2 cm[3]. Historically, standard PCNL access sheaths are large (24 to 30 F), particularly for treatment of large renal stones, but have concerns around high risk of bleeding. So, smaller access sheaths and techniques have been developed, initially in pediatric urology[4] but with increasing use in adult patients, due to lower risk of complications[4,5]. Over time, with the use of laser for fragmentation of stones, access sheath has minimized from standard 30 F access down to mini PCNL, ultra-mini PCNL and now micro PCNL. All these are termed as 'Minimally invasive PCNL'. An alternative to the percutaneous approaches is utilized by flexible ureteroscopy, also referred to as retrograde intrarenal surgery (RIRS). Originally proposed in the treatment of a lower pole stone resistance to shockwave lithotripsy (SWL), some studies have shown its utility in the management of larger renal stones throughout the kidney[6].

Correspondence to:
Viriyasiripong S, Division of Urology, Department of Surgery, Faculty of Medicine, Srinakarinwirot University 62 Rungsit-Nakhon Nayok Road, Ongkarak, Nakorn Nayok 26120, Thailand.
Phone: +66-37-395085
E-mail: viriyasiripong@gmail.com

However, to our knowledge a meta-analysis has not been done to evaluate all these stone treatment modalities. Our goal of this study was to review and perform a meta-analysis of the available literature on the minimally invasive PCNL techniques in comparison with standard PCNL and RIRS.

Material and Method

Identification/search strategy

A systematic literature review was performed in April 2016. We searched the PubMed and Galileo electronic databases from 2010 to April 2016 to identify relevant studies. Searches were restricted to publications in English and in the adult population. Separate searches were done with the following search terms: percutaneous nephrolithotomy, retrograde intrarenal surgery, percutaneous lithotripsy, RIRS, miniPCNL, micropercutaneous nephrolithtomy, ultra-mini percutaneous nephrolithotomy and flexible ureteroscopy. Reference lists from retrieved documents were also searched. Computer searches were supplemented with a manual search. Two of us (SV, SHM) independently screened all citations and abstracts selected by the search strategy to identify potentially eligible studies based on Preferred Reporting Items for Systematic Reviews and Meta-analysis criteria (Fig. 1)[7].

Participant data sources

Study inclusion criteria were (1) patients with renal calculi, (2) one of the populations group undergoing minimally invasive PCNL (Mini-, Ultra-mini- or Micro-), (3) reporting at least one of the following outcomes (stone free rate, drop in hemoglobin, operative time, length of hospital stay).

Data extraction

Two investigators independently extracted data and reached consensus on all items. The analyzed outcomes were SFR, operative time, hospitalization time, drop in hemoglobin (Hb) levels. The level of evidence (LE) was rated for each included study according to the criteria provided by the Oxford Centre for Evidence-based Medicine[8].

Statistical analysis

Data analysis was performed using Graphpad Prism® 5.0 and Excelplot. For all eligible studies dichotomous data are presented as the relative risk and 95% CI. Meta-analysis was performed using fixed and random effects methods depending on the presence and absence, respectively, of significant heterogeneity. Statistical heterogeneity among trials was evaluated by the Chi-square test with the Yates correction with significance considered at $p<0.05$. In the absence of statistically significant heterogeneity, the Fisher exact test was used to combine results. Otherwise, the random effects method was used. Sensitivity analysis was also performed when low quality trials were included.

Results

Identification

The search protocol and its results are shown in (Fig. 1). At the end, 32 eligible studies including 4,586 total cases (316 standard PCNL cases, 2,581 mini-PCNL cases, 185 ultra-mini PCNL cases, 316 micro-PCNL cases and 739 RIRS cases) were included in the subsequent meta-analysis according to our predefined selection criteria (Table 1)[9-40].

Characteristics and quality

Thirty-two studies included seven RCTs (LE: 2b), seven prospective case-controls (LE: 3b), sixteen retrospective case-control studies (LE: 3b) and two match-pair analysis (LE: 3b) (Table 1). Multiple tracts were needed for stone removal in 2 studies[24,39]. Table 2 showed baseline characteristic and results of included studies.

Meta-analysis results

Baseline characteristic

Age did not differ significantly between each

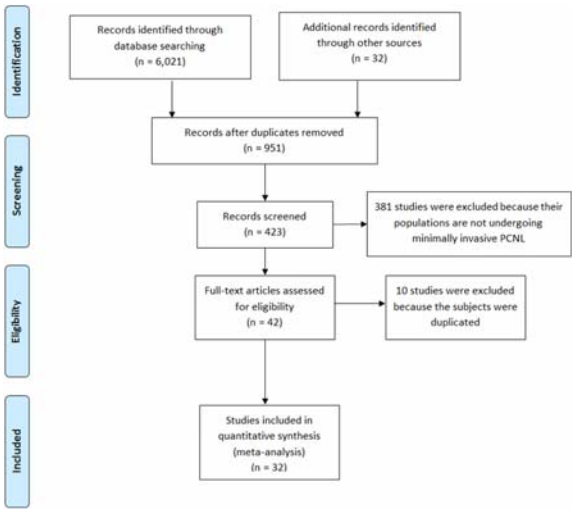

Fig. 1 PRISMA flow diagram outlining the systematic search strategy and study selection process[7].

Table 1. Summary of comparative studies

References	Country	Study period	Study design	LE	Inclusion criteria	Technique (n)				
						PCNL	Mini	Ultra	Micro	RIRS
Armagan et al. 2015[9]	Turkey	2012-2014	Retrospective case control	3b	Lower pole stone <2cm	-	-	-	68	59
Bagcloglu et al. 2015[10]	Turkey	2013-2015	Retrospective case control	3b	Stone 1-3cm	-	-	-	63	48
Desai et al. 2011[11]	India	2010	Prospective case control	3b	Stone <2.5cm	-	-	-	10	-
Ganpule et al. 2015[12]	India	2010-2014	Retrospective case control	3b	Stone <2.5cm	-	-	-	139	-
Karatag et al. 2015[13]	Turkey	2012-1014	Retrospective case control	3b	Failed SWL or stone >1cm	-	-	-	116	-
Oclucuoglu et al. 2015[14]	Turkey	2013	Retrospective case control	3b	Stone 1-2cm	-	-	-	20	-
Piskin et al. 2012[15]	Turkey	2012	Retrospective case control	3b	Stone <2cm	-	-	-	9	-
Tepeler et al. 2014[16]	Turkey	2012-2013	RCT	2b	Stone 1-3cm	10	-	-	10	-
Tok et al. 2015[17]	Turkey	2011-2014	Retrospective case control	3b	Lower pole stone 1-2cm	-	40	-	58	-
Hatipoglu et al. 2014[18]	Turkey	2011-2013	Retrospective case control	3b	Stone <2cm, SWL resistant	-	-	-	140	-
Bhattu et al. 2015[19]	India	2009-2013	Retrospective case control	3b	Stone <2.5cm	-	318	-	-	-
Cheng et al. 2010[20]	China	2004-2007	RCT	2b	Single tract procedure	115	72	-	-	-
Ganesamoni et al. 2013[21]	India	2011-2013	RCT	2b	Stone 1.5-2.5cm	-	60	-	-	-
Hu et al. 2015[22]	China	2007-2013	Retrospective case control	3b	Stone >2cm	-	1,368	-	-	-
Mishra et al. 2015[23]	India	2009-2010	Prospective case control	3b	Stone 1-2cm	28	27	-	-	-
Yuan Li et al. 2010[24]	China	2005-2008	Prospective case control	3b	Multiple tract included	79	98	-	-	-

LE level of evidence, *PCNL* standard percutaneous nephrolithotomy, *Mini*Mini PCNL, *Ultra* Ultra-mini PCNL, *Micro*Micro PCNL, *RIRS* retrograde intrarenal surgery, *RCT* randomized controlled trial

Table 1. Cont.

References	Country	Study period	Study design	LE	Inclusion criteria	Technique (n)				
						PCNL	Mini	Ultra	Micro	RIRS
Datta et al. 2016[25]	India	2013	Prospective case control	3b	Stone 0.9-3cm	-	-	94	-	-
Desai et al. 2013[26]	China	2012	Retrospective case control	3b	Stone <2cm	-	-	36	-	-
Schoenthaler et al. 2015[27]	Germany, England	2013-2014	Retrospective case control	3b	Stone 1-2cm	-	-	30	-	30
Wilhelm et al. 2015[28]	Germany	2013-2014	Match pair analysis	3b	Stone 1-3.5cm	-	-	25	-	25
Kirac et al. 2013[29]	Turkey	2009-2012	Retrospective case control	3b	Lower pole stone<1.5cm	-	37	-	-	36
Kiremit et al. 2015[30]	Turkey	2012-2014	Retrospective case control	3b	Stone 1-2cm	-	110	-	89	201
Kruck et al. 2013[31]	Germany	2001-2007	Retrospective case control	3b	Stone 0.5-5cm	-	172	-	-	108
Kumar et al. 2015[32]	India	2012-2013	RCT	2b	Lower pole stone 1-2cm	-	41	-	-	43
Lee et al. 2015[33]	Korea	2014-2015	RCT	2b	Stone >1cm	-	35	-	-	33
Pan et al. 2013[34]	China	2005-2011	Retrospective case control	3b	Single stone 2-3cm	-	59	-	-	56
Ramon et al. 2014[35]	Spain	2013	Prospective case control	3b	Stone 1-3cm	-	-	-	8	12
Sabnis et al. 2013[36]	India	2011-2012	RCT	2b	Stone <1.5cm	-	-	-	35	35
Zeng et al. 2014[37]	China	2012-2014	Match-pair analysis	3b	Solitary Kidney, Stone> 2cm	-	53	-	-	53
Knoll et al. 2010[38]	Germany	2009-2010	Prospective case control	3b	Single lower pole or renal pelvis	25	25	-	-	-
Zhong et al. 2011[39]	China	2008-2009	RCT	2b	Staghorn stone, multiple tract	25	29	-	-	-
Xu et al. 2014[40]	China	2011-2013	Prospective case control	3b	Stone >2cm	34	37	-	-	-

LE level of evidence, *PCNL* standard percutaneous nephrolithotomy, *Mini*Mini PCNL, *Ultra* Ultra-mini PCNL, *Micro*Micro PCNL, *RIRS* retrograde intrarenal surgery, *RCT* randomized controlled trial

Table 2. Summary of the literature results

Study	No. of patients	Ages* (yrs)	Stone size* (mm)	Operative time* (minutes)	Length of stay* (Hours)	Stone-free (%)	Imaging	Hct drop* (g/L)
Armagan et al.[9] 2015								
Micro	68	43.6	13.7	46.2	33.8	88.2	U/S 1month	12.9
RIRS	59	49.3	14.4	60.1	23	74.5	U/S 1month	6.8
Bagcloglu et al.[10] 2015								
Micro	63	41.53	17.7	98.5	65.28	80.9	CT 1month	9.1
RIRS	48	8.5	14.6	55.6	63.84	66.6	CT 1month	7.6
Desai et al.[11] 2011Micro	10	43.9	14.3	-	55.2	88.9	KUB 1month	14
Ganpule et al.[12] 2015Micro	139	38.9	12.78	50.15	56.64	91.53	U/S 1month	6.3
Karatag et al.[13] 2015Micro	116	38.72	12.37	49.5	33.91	92.18	CT 1month	10.1
Olcucuoglu et al.[14] 2015Micro	20	46.5	13	111	33.6	90	U/S 1month	12
Piskin et al.[15] 2012Micro	9	20.8	12.8	93.33	61.33	85	U/S 1month	-
Tepeler et al.[16] 2014								
Micro	10	47.2	19.9	36.5	26.4	80	CT 1month	6
PCNL	10	44.3	21.9	49	48	90	CT 1month	11.6
Tok et al.[17] 2015								
Micro	58	45.94	13.97	43.02	37.26	86.2	U/S 1month	6.5
Mini	40	3.08	16.13	52.25	3.12	82.5	U/S 1month	13.2
Hatipoglu et al.[18] 2014Micro	140	28.67	15.07	55.76	42.24	82.14	CT 1month	8.7
Bhattu et al.[19] 2015Mini	318	41.91	15.26	60	67.2	98.74	U/S 1month	10.4
Cheng et al.[20] 2010								
PCNL	115	40	31.01	95.98	180	80	U/S 1month	9.7
Mini	72	37.2	30.89	109.81	175.2	84.72	U/S 1month	5.3
Ganesamoni et al.[21] 2013Mini	60	39.9	17.5	58.95	-	95	U/S 1month	10.3
Hu et al.[22] 2015Mini	1,368	46	40.5	54	108	82	U/S 1month	-
Mishra et al.[23] 2015								
PCNL	28	48	12.21	31	115.2	100	KUB 1month	13
Mini	27	42.2	12.12	45.2	76.8	96	KUB 1month	8
Yuan Li et al.[24] 2010								
PCNL	79	49	30.4	64.5	158.4	63	CT 1month	16.3
Mini	98	51.5	28.6	87.6	151.2	78	CT 1 month	8.8
Datta et al.[25] 2016 Ultra	94	46.5	15.91	53.6	38.18	81	CT 1month	8.1
Desai et al.[26] 2013 Ultra	36	48.2	14.9	59.8	72	97.2	U/S 1month	5.4

*PCNL:*standard percutaneous nephrolithotomy, *Mini*: Mini PCNL, *Ultra*: Ultra-mini PCNL, *Micro:* Micro PCNL, *RIRS:* retrograde intrarenal surgery, *CT:*Computer tomography, *U/S:*Ultrasound, *KUB:*plain kidney ureter bladder x-ray, * Mean

Table 2. Cont.

Study	No. of patients	Ages* (yrs) (mm)	Stone size* (minutes)	Operative time* (Hours)	Length of stay*	Stone-free (%)	Imaging	Hct drop* (g/L)
Schoenthaler et al.[27] 2015								
RIRS	30	56.3	14.4	102	48	87	U/S 1 month	-
Ultra	30	54.3	15.1	121	55.2	84	U/S 1 month	-
Wilhelm et al.[28] 2015								
RIRS	25	51.36	19.2	98.52	67.2	96	CT 1 month	-
Ultra	25	51.56	19.28	130.12	91.52	92	CT 1 month	-
Kirac et al.[29] 2013								
RIRS	36	37.8	10.2	66.4	24.5	94.4	U/S 1 month	41
Mini	37	41.02	10.5	53.7	42.6	97.2	U/S 1 month	5.1
Kiremit et al.[30] 2015								
RIRS	201	44.3	14.15	89.6	-	86.1	KUB 1 month	-
Micro	89	40.1	13.37	46.3	-	88.8	U/S 1 month	-
Mini	110	25.05	16.81	55	-	83.6	KUB 1 month	-
SWL	535	44.43	14.44	-	-	77.2	KUB 1 month	-
Kruck et al.[31] 2013								
RIRS	108	50.0	6.8	-	55.2	77.8	-	-
Mini	172	53.3	12.6	-	108	79.7	-	-
SWL	202	50.9	7.5	-	52.8	58.4	-	-
Kumar et al.[32] 2015								
RIRS	43	33.4	13.1	47.5	31.2	86.1	CT 3 month	-
Mini	41	33.7	13.3	61.1	74.4	95.1	CT 3 month	-
SWL	42	33.1	13.2	43.6	-	73.8	CT 3 month	-
Lee et al.[33] 2015								
RIRS	33	55.8	28.9	99.6	36	97	CT 3 month	3.8
Mini	35	59.3	39.1	76.1	38.4	85.7	CT 3 month	6.9
Pan et al.[34] 2013								
RIRS	56	49.32	22.28	73.07	46.8	71.4	CT 1 month	4.9
Mini	59	49.37	22.37	62.39	107.28	96.6	CT 1 month	12.8
Ramon et al.[35] 2014								
RIRS	12	51.0	11.4	120	24	95	CT 3 month	-
Micro	8	53.5	13.78	120	36	96.9	CT 3 month	-
Sabnis et al.[36] 2013								
RIRS	35	43.7	10.4	47.1	49	94.3	KUB 3 month	5.6
Micro	35	38.6	11	51.6	57	97.1	KUB 3 month	9.6
Zeng et al.[37] 2015								
RIRS	53	48.47	18.22	55.38	48	43.4	KUB 3month	9.3
Mini	53	53.04	18.15	43.79	144	71.7	KUB 3month	10.8

*PCNL:*standard percutaneous nephrolithotomy, *Mini*: Mini PCNL, *Ultra*: Ultra-mini PCNL, *Micro:* Micro PCNL, *RIRS:* retrograde intrarenal surgery, *CT:*Computer tomography, *U/S:*Ultrasound, *KUB:*plain kidney ureter bladder x-ray, * Mean

Table 2. Conte. Summary of the literature results

Study	No. of patients	Ages* (yrs)	Stone size* (mm)	Operative time* (minutes)	Length of stay* (Hours)	Stone-free (%)	Imaging	Hct drop* (g/L)
Knoll et al.[38] 2010								
PCN	25	48	22	49	165.6	92	U/S 1 day	-
LMini	25	52	18	59	91.2	96	U/S 1 day	-
Zhong et al.[39] 2011								
Mini	29	41	34.2	116	235.2	89.7	KUB 1 day	10.6
PCNL	25	38	32.8	103	170.4	68	KUB 1 day	11.6
Xu et al.[40] 2014								
PCNL	34	45.3	41.4	121.1	223.2	79.4	U/S 1 day	9.6
Mini	37	50.3	33.4	126.4	235.2	78.4	U/S 1 day	7.4

*PCNL:*standard percutaneous nephrolithotomy, *Mini*: Mini PCNL, *Ultra*: Ultra-mini PCNL, *Micro:* Micro PCNL, *RIRS:* retrograde intrarenal surgery, *CT:*Computer tomography, *U/S:*Ultrasound, *KUB:*plain kidney ureter bladder x-ray, * Mean

Table 3. Summary of the meta-analysis results

Techniques	No. of patients	Ages	Mean stone size(mm)	Operative time (mins)	LOS (hours)	Stone free (%)	Hb drop (g/L)
PCNL	388	45	29.63	77.46	165.76	75.03	12.87
Mini	2,674	45.2	30.38	57.28	101.54	84.88	9.85
Ultra-mini	185	48.8	16.04	76.08	54.73	86.13	7.35
Micro	765	38.6	13.83	56.52	45.28	88.03	8.91
RIRS	739	46.2	14.4	64.39	32.59	80.31	9.38

*PCNL:*standard percutaneous nephrolithotomy, *Mini*: Mini PCNL, *Ultra*: Ultra-mini PCNL, *Micro*: Micro PCNL, *RIRS*: retrograde intrarenal surgery, *LOS:*Length of stay, *Hb:*hemoglobin drop

technique. The mean stone size (mm) between standard PCNL, mini-PCNL, ultra-mini PCNL, micro-PCNL and RIRS were 29.63, 30.38, 16.04, 13.83 and 14.4, respectively (Table 3, Fig. 2).

Stone free rate

The stone free rates between standard PCNL, mini-PCNL, ultra-mini PCNL, micro-PCNL and RIRS were 75.03, 84.88, 86.13, 88.03 and 80.31, respectively. Stone free rates among minimally invasive techniques were significantly higher statistically compared to PCNL and RIRS, $p<0.05$. However minimally invasive techniques did not differ statistically among themselves, $p>0.61$ (Table 3, Fig. 3).

Operative time

Operative time is not statistically significant between each technique. The operative times (minutes) between standard PCNL, mini-PCNL, ultra-mini PCNL, micro-PCNL and RIRS were 77.46, 57.28, 76.08, 56.52 and 64.39 respectively (Table 3, Fig. 4).

Length of hospital stay

Length of hospital stay is not statistically significant between each technique. The length of hospital stay (hours) between standard PCNL, mini-PCNL, ultra-mini PCNL, micro-PCNL and RIRS were 165.76, 101.54, 54.73, 45.28 and 32.59, respectively (Table 3, Fig. 5).

Blood loss (hemoglobin decrease)

Blood loss is not statistically significant between each technique. Hemoglobin decreases (g/L) among standard PCNL, mini-PCNL, ultra-mini PCNL,

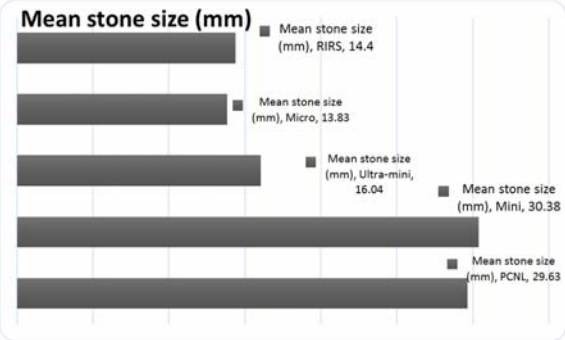

Fig. 2 Mean stone size comparison.

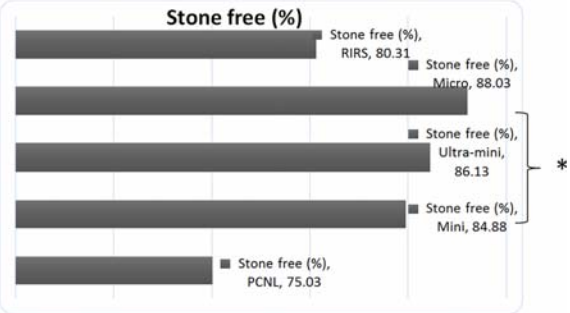

Fig. 3 Stone free rate comparison. Asterisk denotes statistical significance compared to un-bracketed techniques.

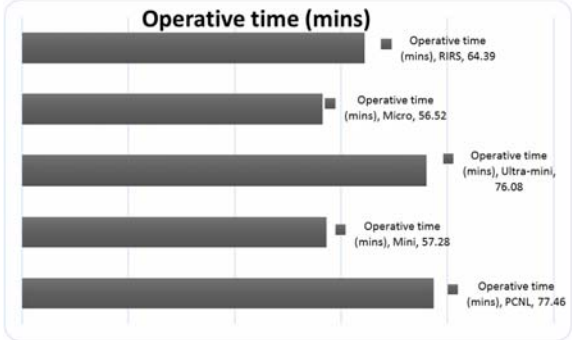

Fig. 4 Operative time comparison.

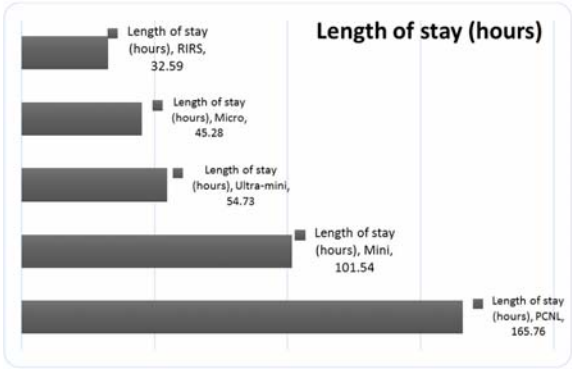

Fig. 5 Length of stay comparison.

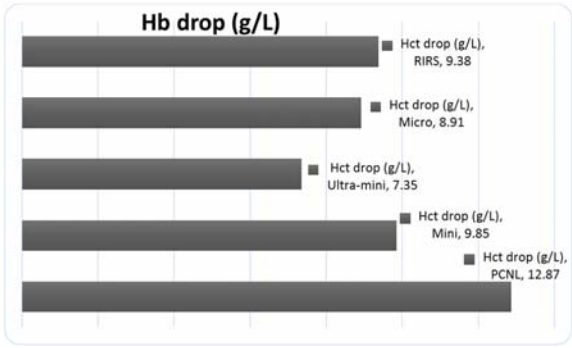

Fig. 6 Hemoglobin decrease comparison.

micro-PCNL and RIRS were 12.87, 9.85, 7.35, 8.91 and 9.38, respectively (Table 3, Fig. 6).

Discussion

This meta-analysis suggests that minimally invasive PCNL (mini-, ultra-mini-, micro-) are superior to standard PCNL and RIRS based on the findings that the stone free rate is higher in the minimally invasive PCNL (Fig. 3). Minimally invasive PCNL also has less blood loss and length of hospital stays than standard PCNL (Fig. 5, 6). Although the operative time definitions are variety in the studies, the operative time is comparable between minimally invasive PCNL, standard PCNL and RIRS (Fig. 4).

Among minimally invasive PCNL group, mini-PCNL is the best one with the greatest flexibility. From this present study, although their mean stone size is two fold larger than in another minimally invasive PCNL, their stone free rate is high comparable with another minimally invasive PCNL. Their operative time and blood loss are also not significantly different to another minimally invasive PCNL.

Both mini-PCNL and standard PCNL have very large mean stone sizes (29.63 vs. 30.38 mm). Compared with these two techniques for large stone sizes (>2 cm), mini-PCNLs have better outcomes in all aspects; stone free rates (88.03 vs. 75.03%), operative times (57.28 vs. 77.46 minutes), length of stays (101.54 vs. 165.76 hours) and blood loss (9.85 vs. 12.87 g/L).

The previous studies reported that the operative time in minimally invasive PCNL is longer than in standard PCNL[20,23,24]. Conversely, the present study results showed that the operative time in mini-

PCNL is shorter than in standard PCNL (Fig. 4).

PCNL is the kidney stone removal technique that has been in use since 1980s[2]. Standard PCNL (sheath size 24 to 30 Fr) has an indication to utilize in large stone (>2 cm)[3]. The advantages of standard PCNL are large working channel, good irrigation system and able to remove large stone fragment. The disadvantages are bleeding and high blood transfusion risk because the sheath size is large[41]. Due to this disadvantage of standard PCNL, in the 2000s, mini-PCNL (sheath size 16 to 20 Fr) was invented. Because the sheath size is less than 20Fr, the bleeding and complication rate of mini-PCNL are less than standard PCNL. Afterward, the smaller sheath size, ultra-mini PCNL (sheath size 11 to 14 Fr) and micro PCNL (4.8 Fr) was invented. The very small sheath size has both advantages and disadvantages. The advantages are less bleeding, less pain and less length of stay. The disadvantages are very small working channel, poor vision field due to limit irrigation system and unable to remove stone fragment. RIRS for stone treatment has been first utilized in the 1990s[42]. Due to the technological advances in the field of flexible ureteroscope, endoscopic basket devices and endoscopic lithotrites in the last decade, Many publications reported successful stone treatment in large stones[34]. The advantages of RIRS are insignificant blood loss and no external wound. Table 4 showed terminology, cost, advantages, limitations and fragmentation devices in comparison between each technique.

The advantages of minimally invasive stone removal procedures (mini-PCNL, ultra mini-PCNL, micro-PCNL) over non-minimally invasive procedures (RIRS, standard PCNL) in regards to stone-free rates has been validated in several studies[10,20,24,29,32,34,36,39,43,37]. In 2010, two randomized prospective studies involving more than 380 patients demonstrated increased stone-free rates in patients receiving mini-PCNL when compared to standard PCNL[20,24]. More recently, two additional studies involving more than 230 patients have demonstrated a significant stone-free rate advantage in patients receiving micro-PCNL when compared to RIRS[10,43]. Lastly, three studies involving more than 500 patients demonstrated significantly increased stone-free rates in patients receiving mini-PCNL when compared to RIRS[31,34,37]. The patient populations represented in the aforementioned studies make up a large majority of the reported data comparing minimally invasive vs. non-minimally invasive stone removal procedures. When

Table 4. Comparison of standard, mini, ultra-mini, micro PCNL and RIRS technique

Technique	Sheath Size (Fr)	Cost ($)	Advantages	Limitations	Fragmentation device
Standard PCNL	24-30	12,395	Large working channel, Able to remove large fragment	Increased bleeding and transfusion risk	Pneumatic, Ultrasound or Laser
Mini PCNL	16-20	12,500	Reduced blood loss, decrease pain	Difficult to treat staghorn calculi	Pneumatic, Ultrasound or Laser
Ultra-mini PCNL	11-14	13,800	Reduced blood loss, decrease pain, small external wound	Able to remove only small stone fragment	Laser
Micro PCNL	4.8	13,600	Insignificant blood loss, nearly no external wound, no transfusion ('all seeing needle' and sheath)	Unable to remove stone fragment, Disposable cost	Laser
RIRS	-	15,300	Insignificant blood loss, no external wound, no transfusion	Limit eye vision, Disposable cost (sheath)	Laser

*PCNL*rcutaneousnephrolithotomy; *IRS*,retrograde intrarenal surgery

taken together with the rest of the studies analyzed in this meta-analysis, these studies lend support to the trend that minimally invasive stone removal procedures have greater efficacy in regards to stone-free rate.

In 2015 Lee et al reported the outcomes of a prospective randomized controlled trial in 68 patients comparing mini-PCNL and RIRS in the management of renal stones >10 mm, after 3 months of follow-up[33]. In this study, RIRS produced a higher stone-free rate (97% for RIRS vs. 86% for mini PCNL), but more immediate postoperative pain and higher analgesic requirement compared with mini-PCNL. The higher stone-free rate for RIRS in this study may be attributed to the fact that patients in the RIRS treatment arm had substantially smaller preoperative stone size and stone number. The RIRS treatment arm in this study also had significantly more patients with preoperative hydronephrosis compared to the mini-PCNL arm.

In addition to the increased functionality offered by the mini-PCNL technique, there is also a cost advantage. Although procedural costs can vary between institutions and healthcare systems, mini-PCNL carries a similar cost to standard PCNL with greater stone-free rates, and both are $1,300 to $2,800 cheaper than other stone removal modalities (Table 4).

There are some limitations to this present study. Most of the studies were nonrandomized comparisons. Among 32 studies in our meta-analysis, there were only seven RCTs available for inclusion. We did not include complication rates in this meta-analysis because the complications are different in severity from fever to death. In addition, heterogeneity among studies was found to be high for several parameters. This heterogeneity could be explained by the difference in study design, surgical practice, outcome definitions and medical settings. The imaging modalities and imaging time to determine the stone free rate were different between each studies. CT was used to determine the stone free rate in eleven studies. Other imaging modalities were U/S and plain KUB. There was also significant heterogeneity in protocol with regards to hospital stay between healthcare systems as well as geographic location. Finally, the sample sizes between each technique are not equal. Mini-PCNL has the largest sample size (2,674) and ultra-mini PCNL has the smallest sample size (185). The small sample size in some techniques might not achieve sufficient power to obtain valid results.

Conclusion

Our meta-analysis study demonstrated that minimally invasive PCNL has better outcome in comparison to standard PCNL and RIRS. Among the minimally invasive PCNL, mini-PCNL has the greatest flexibility in stone size ranges with comparable outcomes to the others. For large stones (>2 cm), mini-PCNL are superior to standard PCNL in all variable outcome. Future well designed multicenter randomized controlled trials are needed to be conducted to support our findings.

What is already known on this topic?

Standard PCNL and RIRS are known to be the standard treatment for kidney stone. Minimally invasive PCNL is the new modalities for renal stone treatment. However, there are no meta-analytical studies which compare minimally invasive PCNL with standard PCNL and RIRS.

What this study adds?

Minimally invasive PCNL has better outcome in comparison with standard PCNL and RIRS. Among the minimally invasive PCNL, mini-PCNL has the greatest flexibility in stone size range with comparable outcome to the others. For large stones (>2 cm), mini-PCNL are superior to standard PCNL in all variable outcome.

Potential conflicts of interest

None.

References

1. Heers H, Turney BW. Trends in urological stone disease: a 5-year update of hospital episode statistics. BJU Int 2016; 118: 785-9.
2. Patel SR, Nakada SY. The modern history and evolution of percutaneous nephrolithotomy. J Endourol 2015; 29: 153-7.
3. Bultitude M, Smith D, Thomas K. Contemporary management of stone disease: The new EAU urolithiasis guidelines for 2015. EurUrol 2016; 69: 483-4.
4. Jackman SV, Hedican SP, Peters CA, Docimo SG. Percutaneous nephrolithotomy in infants and preschool age children: experience with a new technique. Urology 1998; 52: 697-701.
5. Monga M, Oglevie S. Minipercutaneousne phrolithotomy. J Endourol 2000; 14: 419-21.
6. Inoue T, Murota T, Okada S, Hamamoto S, Muguruma K, Kinoshita H, et al. Influence of pelvicaliceal anatomy on stone clearance after flexible ureteroscopy and holmium laser lithotripsy

for large renal stones. J Endourol 2015; 29: 998-1005.
7. Moher D, Liberati A, Tetzlaff J, Altman DG. Reprint—preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Phys Ther 2009; 89: 873-80.
8. Phillips B, Ball C, Sackett D, Badenoch D, Straus S, Haynes B, et al. Centre for Evidence-Based Medicine. Oxford Centre for Evidence-based Medicine-levels of evidence (March 2009) [Internet]. 2016 [cited 2016 Feb 23]. Available from: http://www.cebm.net/index.aspx?o=1025.
9. Armagan A, Tepeler A, Silay MS, Ersoz C, Akcay M, Akman T, et al. Micropercutaneousnephrolitho tomy in the treatment of moderate-size renal calculi. J Endourol 2013; 27: 177-81.
10. Bagcioglu M, Demir A, Sulhan H, Karadag MA, Uslu M, Tekdogan UY. Comparison of flexible ureteroscopy and micropercutaneousnephrolitho tomy in terms of cost-effectiveness: analysis of 111 procedures. Urolithiasis 2016; 44: 339-44.
11. Desai MR, Sharma R, Mishra S, Sabnis RB, Stief C, Bader M. Single-step percutaneous nephrolitho tomy (microperc): the initial clinical report. J Urol 2011; 186: 140-5.
12. Ganpule A, Chhabra JS, Kore V, Mishra S, Sabnis R, Desai M. Factors predicting outcomes of micropercutaneous nephrolithotomy: results from a large single-centre experience. BJU Int 2016; 117: 478-83.
13. Karatag T, Tepeler A, Buldu I, Akcay M, Tosun M, Istanbulluoglu MO, et al. Is micro-percutaneous nephrolithotomy surgery technically feasible and efficient under spinal anesthesia? Urolithiasis 2015; 43: 249-54.
14. Olcuccoglu E, Kasap Y, Olcucuoglu E, Pirin ME, Gazel E, Tastemur S, et al. Micropercutaneousne phrolithotripsy: initial experience. WideochirInne Tech Maloinwazyjne 2015; 10: 368-72.
15. Piskin MM, Guven S, Kilinc M, Arslan M, Goger E, Ozturk A. Preliminary, favorable experience with microperc in kidney and bladder stones. J Endourol 2012; 26: 1443-7.
16. Tepeler A, Akman T, Silay MS, Akcay M, Ersoz C, Kalkan S, et al. Comparison of intrarenal pelvic pressure during micro-percutaneous nephrolithotomy and conventional percutaneous nephrolithotomy. Urolithiasis 2014; 42: 275-9.
17. Tok A, Akbulut F, Buldu I, Karatag T, Kucuktopcu O, Gurbuz G, et al. Comparison of microperc and mini-percutaneous nephrolithotomy for medium-sized lower calyx stones. Urolithiasis 2016; 44: 155-9.
18. Hatipoglu NK, Tepeler A, Buldu I, Atis G, Bodakci MN, Sancaktutar AA, et al. Initial experience of micro-percutaneous nephrolithotomy in the treatment of renal calculi in 140 renal units. Urolithiasis 2014; 42: 159-64.
19. Bhattu AS, Mishra S, Ganpule A, Jagtap J, Vijaykumar M, Sabnis RB, et al. Outcomes in a large series of minipercs: analysis of consecutive 318 patients. J Endourol 2015; 29: 283-7.
20. Cheng F, Yu W, Zhang X, Yang S, Xia Y, Ruan Y. Minimally invasive tract in percutaneous nephrolithotomy for renal stones. J Endourol 2010; 24: 1579-82.
21. Ganesamoni R, Sabnis RB, Mishra S, Parekh N, Ganpule A, Vyas JB, et al. Prospective randomized controlled trial comparing laser lithotripsy with pneumatic lithotripsy in miniperc for renal calculi. J Endourol 2013; 27: 1444-9.
22. Hu G, Guo Z, Liu H, Luo M, Liu M, Lai P, et al. A novel minimally invasive percutaneous nephrolithotomy technique: safety and efficacy report. Scand J Urol 2015; 49: 174-80.
23. Mishra S, Sharma R, Garg C, Kurien A, Sabnis R, Desai M. Prospective comparative study of miniperc and standard PNL for treatment of 1 to 2 cm size renal stone. BJU Int 2011; 108: 896-9.
24. Li LY, Gao X, Yang M, Li JF, Zhang HB, Xu WF, et al. Does a smaller tract in percutaneous nephrolithotomy contribute to less invasiveness? A prospective comparative study. Urology 2010; 75: 56-61.
25. Datta SN, Solanki R, Desai J. Prospective outcomes of ultra mini percutaneous nephrolithotomy: A consecutive cohort study. J Urol 2016; 195: 741-6.
26. Desai J, Solanki R. Ultra-mini percutaneous nephrolithotomy (UMP): one more armamentarium. BJU Int 2013; 112: 1046-9.
27. Schoenthaler M, Wilhelm K, Hein S, Adams F, Schlager D, Wetterauer U, et al. Ultra-mini PCNL versus flexible ureteroscopy: a matched analysis of treatment costs (endoscopes and disposables) in patients with renal stones 10-20 mm. World J Urol 2015; 33: 1601-5.
28. Wilhelm K, Hein S, Adams F, Schlager D, Miernik A, Schoenthaler M. Ultra-mini PCNL versus flexible ureteroscopy: a matched analysis of analgesic consumption and treatment-related patient satisfaction in patients with renal stones 10-35 mm. World J Urol 2015; 33: 2131-6.

29. Kirac M, Bozkurt OF, Tunc L, Guneri C, Unsal A, Biri H. Comparison of retrograde intrarenal surgery and mini-percutaneous nephrolithotomy in management of lower-pole renal stones with a diameter of smaller than 15 mm. Urolithiasis 2013; 41: 241-6.
30. Kiremit MC, Guven S, Sarica K, Ozturk A, Buldu I, Kafkasli A, et al. Contemporary management of medium-sized (10-20 mm) renal stones: a retrospective multicenter observational study. J Endourol 2015; 29: 838-43.
31. Kruck S, Anastasiadis AG, Herrmann TR, Walcher U, Abdelhafez MF, Nicklas AP, et al. Minimally invasive percutaneous nephrolithotomy: an alternative to retrograde intrarenal surgery and shockwave lithotripsy. World J Urol 2013; 31: 1555-61.
32. Kumar A, Kumar N, Vasudeva P, Kumar JS, Kumar R, Singh H. A prospective, randomized comparison of shock wave lithotripsy, retrograde intrarenal surgery and miniperc for treatment of 1 to 2 cm radiolucent lower calyceal renal calculi: a single center experience. J Urol 2015; 193: 160-4.
33. Lee JW, Park J, Lee SB, Son H, Cho SY, Jeong H. Mini-percutaneous nephrolithotomy vs. retrograde intrarenal surgery for renal stones larger than 10 mm: A prospective randomized controlled trial. Urology 2015; 86: 873-7.
34. Pan J, Chen Q, Xue W, Chen Y, Xia L, Chen H, et al. RIRS versus mPCNL for single renal stone of 2-3 cm: clinical outcome and cost-effective analysis in Chinese medical setting. Urolithiasis 2013; 41: 73-8.
35. Ramon dF, Garcia-Tello A, Andres G, Redondo C, Meilan E, Gimbernat H, et al. Comparative study of retrograde intrarenal surgery and micropercutaneous nephrolithotomy in the treatment of intermediate-sized kidney stones. Actas Urol Esp 2014; 38: 576-83.
36. Sabnis RB, Ganesamoni R, Doshi A, Ganpule AP, Jagtap J, Desai MR. Micropercutaneous nephrolithotomy (microperc) vs. retrograde intrarenal surgery for the management of small renal calculi: a randomized controlled trial. BJU Int 2013; 112: 355-61.
37. Zeng G, Zhu W, Li J, Zhao Z, Zeng T, Liu C, et al. The comparison of minimally invasive percutaneous nephrolithotomy and retrograde intrarenal surgery for stones larger than 2 cm in patients with a solitary kidney: a matched-pair analysis. World J Urol 2015; 33: 1159-64.
38. Knoll T,Wezel F, Michel MS, Honeck P, Wendt-Nordahl G. Do patients benefit from miniaturized tubeless percutaneous nephrolithotomy? A comparative prospective study. J Endourol 2010; 24: 1075-9.
39. Zhong W, Zeng G, Wu W, Chen W, Wu K. Minimally invasive percutaneous nephrolithotomy with multiple mini tracts in a single session in treating staghorn calculi. Urol Res 2011; 39: 117-22.
40. Xu S, Shi H, Zhu J, Wang Y, Cao Y, Li K, et al. A prospective comparative study ofhaemodynamic, electrolyte, and metabolic changes during percutaneous nephrolithotomy and minimally invasive percutaneous nephrolithotomy. World J Urol 2014; 32: 1275-80.
41. Lee KL, Stoller ML. Minimizing and managing bleeding after percutaneous nephrolithotomy. Curr Opin Urol 2007; 17: 120-4.
42. Grasso M, Bagley D. A 7.5/8.2 F actively deflectable, flexible ureteroscope: a new device for both diagnostic and therapeutic upper urinary tract endoscopy. Urology 1994; 43: 435-41.
43. Armagan A, KaratagT, Buldu I, Tosun M, Basibuyuk I, Istanbulluoglu MO, et al. Comparison of flexible ureterorenoscopy and micropercutane ousnephrolithotomy in the treatment for moderately size lower-pole stones. World J Urol 2015; 33: 1827-31.

การศึกษาเปรียบเทียบ Systemic Review and Meta-Analysis ของการรักษานิ่วที่ไตโดยวิธีส่องกล้องผ่าตัดนิ่วแบบแผลขนาดเล็ก แผลขนาดมาตรฐานและการส่องกล้องผ่าตัดนิ่วผ่านท่อไต

ศรายุทธ วิริยะศิริพงศ์, ชรี ฮาซา แมนดาวา, แอนดรูว์ กาเบรียลสัน, เจมส์ ลิว, วีลไล, เบนจามิน ลี

ภูมิหลัง: เพื่อทำการศึกษาเปรียบเทียบผลการผ่าตัดนิ่วที่ไตแบบ meta-analysis ระหว่าง minimally invasive percutaneous nephrolithotomy (PCNL), standard PCNL และ retrograde intrarenal surgery (RIRS)

วัสดุและวิธีการ: ทำการทบทวนวรรณกรรมที่เกี่ยวข้องจากฐานข้อมูลของ PubMed และ Galileo ในเดือนเมษายน พ.ศ. 2559 ทำการวิเคราะห์ข้อมูลเปรียบเทียบใน stone free rate, ระยะเวลาของการผ่าตัด, ระยะเวลาในการนอน โรงพยาบาลและการเสียเลือดระหว่างการผ่าตัดแบบ standard PCNL, mini-PCNL, ultra-mini PCNL, micro-PCNL และ RIRS เพื่อค้นหาวิธีการผ่าตัดรักษานิ่วที่ดีที่สุด

ผลการศึกษา: พบว่ามีการศึกษาทั้งหมด 32 การศึกษาที่เกี่ยวข้อง รวมทั้งหมด 4,586 ราย โดยแบ่งเป็น standard PCNL 316 คน, mini PCNL 2,581 คน, ultra-mini PCNL 185 คน, micro PCNL 316 คน และ RIRS 739 คน ผลการศึกษา meta-analysis ของ standard PCNL vs. mini-PCNL vs. ultra-mini PCNL vs. micro-PCNL vs. RIRS เป็นดังต่อไปนี้ 1) ขนาดของก้อนนิ่วโดยเฉลี่ย: 29.63 vs. 30.38 vs. 16.04 vs. 13.83 vs. 14.4 2) stone free rate (%): 75.63 vs. 84.88 vs. 86.13 vs. 88.03 vs. 80.31 3) ระยะเวลาการผ่าตัด (นาที) 77.46 vs. 57.28 vs. 76.08 vs. 56.53 vs. 64.39 4) ระยะเวลาการนอนโรงพยาบาล (ชั่วโมง) 165.76 vs. 101.54 vs. 54.73 vs. 45.28 vs. 32.59 5) hemoglobin decrease (g/L): 12.87 vs. 9.85 vs. 7.35 vs. 8.91 vs. 9.38

สรุป: การผ่าตัดแบบ minimally invasive technique มี stone free rate สูงกว่า standard technique ในกลุ่มที่เป็น minimally invasive technique การผ่าตัด mini-PCNL มีความยืดหยุ่นสูงที่สุดในเรื่องขนาดของนิ่ว ส่วนระยะเวลาการผ่าตัด ระยะเวลานอนโรงพยาบาล การเสียเลือดมีความใกล้เคียงกัน ในนิ่วที่มีขนาดใหญ่ (>2 cm) mini-PCNL มีผลการศึกษาที่ดีกว่าในทุกอย่างเมื่อเทียบกับ standard PCNL ในอนาคตควรจะมีการศึกษาแบบ multicenter randomized controlled trial เพื่อยืนยันผลการศึกษานี้