Chen *et al. BMC Urology* (2024) 24:167
https://doi.org/10.1186/s12894-024-01555-z

BMC Urology

RESEARCH

Open Access

Clinical comparison of lateral supine position mini-percutaneous nephrolithotomy and anatrophic nephrolithotomy in the treatment of complete staghorn renal calculi

Bo Chen[1†], Min Wang[1], Zongping Chen[1*], Ningrui Pan[1], Xu He[1], Bengen Li[1†], Congcong Chen[1], Zidong Zhou[1†], Wei Cui[1], Peng Zhang[1], Qixu Ren[1†] and Youzhuang Zhong[1†]

Abstract

Background At present, the guidelines for urology recommend percutaneous nephrolithotomy (PCNL) as the preferred treatment for staghorn renal calculi (SRC). However, for complete SRC, it has been questioned by clinicians and patients due to high residual stone rate, complications, repeated hospitalizations and high treatment cost. Anatrophic nephrolithotomy (ANL) is a traditional and classic method for the treatment of SRC. Due to its high trauma and high technical requirements, it is difficult to carry out in primary hospitals, and gradually replaced by PCNL. The purpose of this study is to compare the efficacy of PCNL and ANL in the treatment of complete SRC.

Methods Overall, 238 patients with complete SRC were divided into mini-PCNL in lateral supine position group, ($n=190$) and ANL group ($n=94$) according to treatment for a retrospective cohort study. The calculi parameters, renal function index, comorbidities of calculi, surgical complications, length and frequency of hospitalization, treatment costs, results of postoperative satisfaction survey were compared between the two groups.

Results The risk of the residual stone rate after mini-PCNL in lateral supine position was 239 times (OR = 238.667, $P<0.0001$), the number of residual stone 1.3 times (OR = 1.326, $P<0.0001$), the amount of residual stone 2.2 times (OR = 2.224, $P<0.0001$) that of ANL. The risk of the cost of initial treatment after mini-PCNL in lateral supine position was 3.3 times (OR = 3.273, $P<0.0001$), the total cost of treatment 4 times (OR = 4.051, $P<0.0001$), the total length of hospital stays 1.4 times (OR = 1.44, $P<0.0001$) that of ANL, the incidence of postoperative renal atrophy was 2.2 times (OR = 2.171, $P=0.008$) higher in the ANL than in the mini-PCNL in lateral supine position. Glomerular filtration rate (GFR) reduction after ANL was 1.4 times (OR = 1.381, $P=0.037$) greater than that after mini-PCNL in lateral supine position at 24-month follow-up. The risk of the overall satisfaction of ANL was 58 times (OR = 57.857, $P<0.0001$) higher than that of mini-PCNL in lateral supine position, the number of branches of staghorn greater than 8 is a high risk factor for the occurrence of residual stone after mini-PCNL in lateral supine position (OR = 353.137, $P<0.0001$).

[†]Bo Chen, Zidong Zhou, Bengen Li, Qixu Ren and Youzhuang Zhong are co-first author.

*Correspondence:
Zongping Chen
2404259310@qq.com
Full list of author information is available at the end of the article

Conclusion Although the risk of renal atrophy and decreased GFR after ANL is higher than that of mini-PCNL in lateral supine position, the efficacy of traditional ANL in the treatment of complete SRC was generally superior to that of mini-PCNL in lateral supine position. Moreover, number of branches of staghorn greater than 8 are the preferred ANL for complete SRC.

Trial registration ChiCTR2100047462. The trial was registered in the Chinese Clinical Trial Registry; registration date: 19/06/2021.

Keywords Staghorn renal calculi, Percutaneous nephrolithotomy, Anatrophic nephrolithotomy, Curative effect evaluation

Background

Stones located in the renal pelvis and branching into the calyces are called staghorn renal calculi (SRC) [1]. Stones with branches occupying each calyx, or stones occupying more than 80% of the renal pelvis and calyx volume, are called complete SRC, and the rest are called partial SRC [1, 2]. SRC is a special type of kidney stone, which is complicated, usually compounded with urinary tract infection. Complete removal is difficult, combined with the fact that such stones are likely to re-form after surgery. As a result, it is still one of the difficulties in clinical treatment of urology. At present, the guidelines for urology recommend percutaneous nephrolithotomy (PCNL) as the preferred treatment for SRC [1, 2]. However, for complete SRC, it has been questioned by clinicians and patients due to high residual stone rate, complications, repeated hospitalizations and high treatment cost [3, 4].

Anatrophic nephrolithotomy (ANL) is a traditional and classic method for the treatment of SRC [5–7]. Due to its high trauma and high technical requirements, it is difficult to carry out in primary hospitals, and gradually replaced by PCNL [8–10]. Nonetheless, it is still widely used by some clinicians and medical institutions because of its low residual stone rate, low hospitalization frequency and low treatment cost [5–7].

Given a lack of systematic clinical evaluation of PCNL and ANL for the treatment of complete SRC, the optimal treatment for complete SRC is still under debate [11–15]. Therefore, the purpose of this study is to compare the efficacy of PCNL and ANL in the treatment of complete SRC.

Methods

Patients

The current study was a retrospective cohort study. A consecutive series of data covering 238 complete SRC patients from July 2012 to July 2022 was collected from the Affiliated Hospital of Zunyi Medical University in China. Inclusion criteria were as follows: (1) The initial treatment were PCNL and ANL in patients with complete SRC; (2) Clinical records of all complete SRC patients should be complete and accurate, the follow-up visits was more than 2 years; (3) Take a satisfaction survey. The exclusion criteria were as follows: (1) The initial treatment was in addition to PCNL and ANL in patients with complete SRC; (2) Incomplete clinical records; or (3) Willing termination of the treatment or refusal of follow-up visits.

The morphologic parameters of the patient's stone were detected by computed tomography 3D imaging technology. The standard Digital Imaging and Communications in Medicine viewing software [16] was used to establish accurate stone measurements. The parameters of residual stone rate, residual stone quantity, residual stone number were calculated by manual.

Experimental group and clinical data extraction

All 238 patients with complete SRC, including 192 unilateral cases and 46 bilateral cases, were treated 284 times. And they were assigned to the following two groups according to different treatment methods (see Fig. 1): mini-PCNL in lateral supine position group ($n=190$), referred to as PCNL group, and ANL group ($n=94$). The data we collected were shown in Fig. 1.

Diagnosis standards of the complete SRC

The stone branch that occupies each renal calyx (≥80% renal pelvis and calyceal volume) was defined as a complete SRC [1, 2].

Selection of the type of treatment and the key steps of treatment

ANL was based on the surgical method described by Boyce [17]. That is, the patient was selected lumbar incision. A rapid intravenous infusion of 250 ml of 20% mannitol was administered via the subclavian vein while exposing the kidney. Subsequently, the renal artery was blocked with an arterial clamp. After the renal artery was temporarily blocked, the renal parenchyma was quickly cooled with cold saline solution, and was immediately cut along the Brodel line of the kidney to the calyx and renal pelvis, then the calyx was cut radially, and the stone was extracted with the stone extractor.

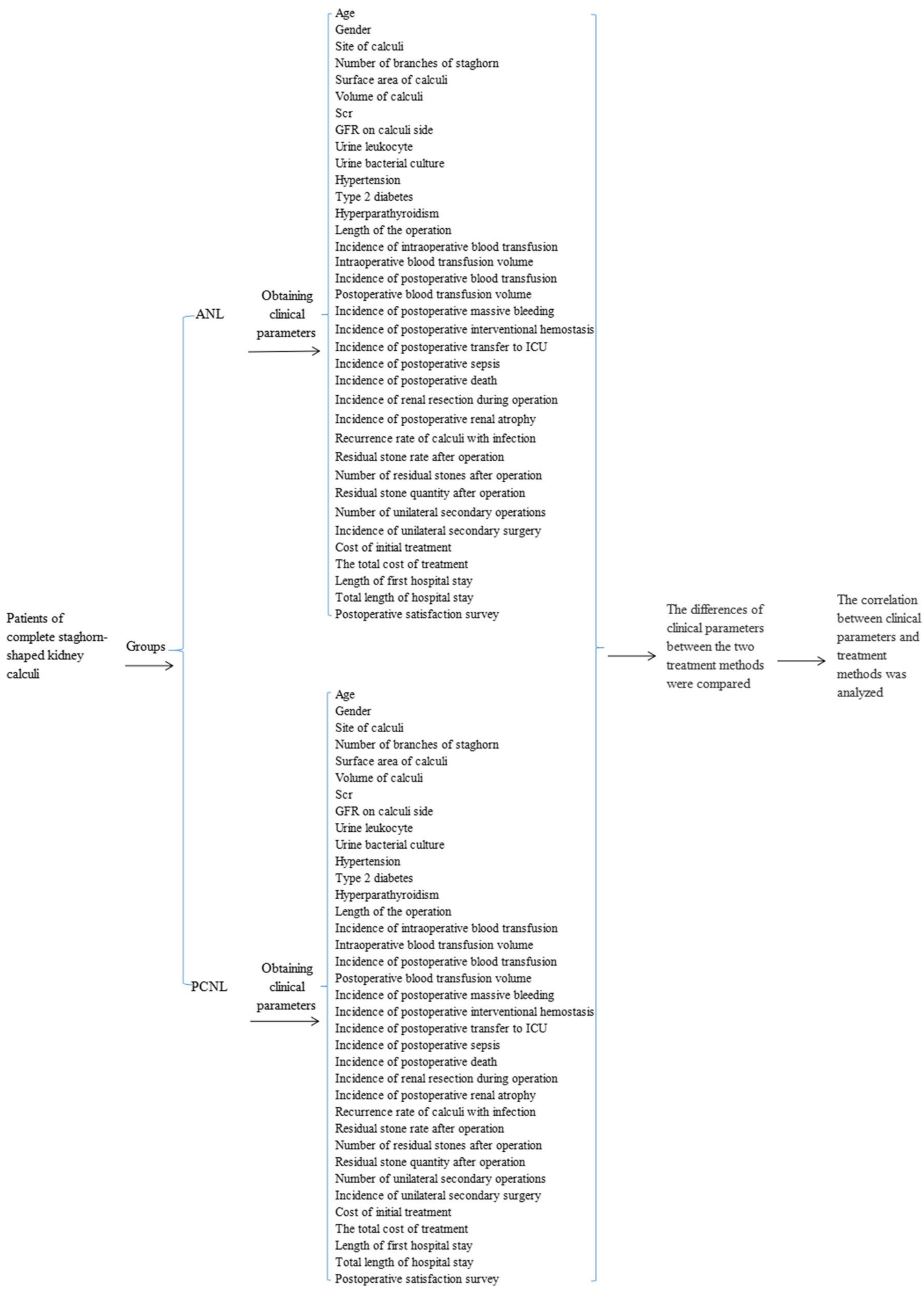

Fig. 1 Flow chart of the experimental design. Abbreviations: ANL, anatrophic nephrolithotomy; GFR, glomerular filtration rate; ICU, intensive care unit; PCNL, percutaneous nephrolithotomy; Scr, serum creatinine

In PCNL, the lithotomy position combined with lateral supine position was adopted, ultrasound localization was used to perform the puncture and a standard skin-kidney access tract for 22F was established. The calculi were removed by ultrasonic lithotripsy combined with pneumatic lithotripsy using a 18F nephroscope through 1–6 skin-kidney access tracts. In classification, it belongs to mini-PCNL in lateral supine position.

Both ANL and mini-PCNL in lateral supine position were performed by surgeons with senior professional titles who have been engaged in urologic surgery for more than 15 years and who are specialized in urolithiasis.

Definition and method of evaluation of stone free, residual stone

Two weeks to 4 weeks after surgery, plain film of the abdomen(KUB), urinary system color ultrasound or computed tomography examination, found that the stone is larger than 5 mm, called residual stone. If no stone was found on the above examination, or if the stone was found to be less than 4 mm in size, it was called stone free [1, 2].

Evaluate postoperative renal atrophy

According to literatures [18–20], normal renal size (long axis) ranged from 11 to 13.5 cm on the left (average 12.2 cm) and from 10.8 to 13 cm on the right (average 11.9 cm). It is generally believed that a difference of 1.5 cm in length (long axis) between the 2 kidneys (preoperative and postoperative) is of diagnostic significance. And renal atrophy was diagnosed if the renal length (long axis) was less than 1.5 cm after surgery. And renal atrophy was measured by ultrasound in this study.

An explanation for performing a second operation

Recurrent pain, uncontrolled infection, or obstruction due to residual stones after the first surgical procedure; When there is residual stone that requires surgical treatment after the first operation; And surgical intervention is needed when residual stone displacement occurs after the first operation. All of these cases are referred to as secondary surgery.

Evaluation of GFR of the involved kidney

Renal isotope scans using 99mTc DTPA were performed to measure the changes in selective function of the affected kidney (GFR%).

Calculate the initial cost and total cost

Initial cost refers to the cost of the first hospitalization for patients who choose PCNL or ANL treatment for the first time. The total cost refers to the initial cost plus the cost for subsequent secondary surgery for the initial choice of PCNL or ANL in one kidney with complete SRC.

Postoperative satisfaction survey

After each hospitalization, a postoperative satisfaction survey was conducted between 1 and 3 months after discharge.

Follow-up

The median follow-up time was 8.5 (range 2–10) years in each group. And the mean follow-up time was 6.5 years in the PCNL group and 6.8 years in the ANL group. All patients were followed up via telephone and regular outpatient visits.

Statistical analyses

Statistical analyses were performed using Statistical Package for the Social Sciences (IBM Corp., Armonk, NY, USA) version 29.0. Selected characteristics (including the clinical data parameters described above that was collected) were compared between treatment group cases using the chi-squared test for categorical variables and Mann–Whitney U test and one-way variance analysis for quantitative data. Numerical variables are presented as the mean ± standard deviation or as the median (minimum, maximum), and categorical variables are presented as percentages. Odds ratios (ORs) and 95% confidence intervals (CIs) were simultaneously estimated by univariate logistic regression analyses. $P < 0.05$ was considered significant.

Results

Basic information of clinical data of complete SRC patients

As shown in Table 1, basic information of the 238 patients was males with a median age of 49 years and females with a median age of 51 years. And the median value was 15, 74, 23, 104, 32, 31, 3, 35 of number of branches of staghorn, surface area of calculi (cm^2), volume of calculi (ml), Scr (umol/l), GFR (ml/min) on calculi side of left, GFR (ml/min) on calculi side of right, number of access tract of mini-PCNL in lateral supine position, duration of renal artery occlusion (minutes) in ANL, respectively. The positive rate of urine leukocyte was 100%, but the positive rate of urine bacterial culture was 42%. 57 unilateral cases were treated with ANL, 9 bilateral cases were treated with both ANL, 135 unilateral cases were treated with mini-PCNL in lateral supine position, 18 bilateral cases were treated with bilateral mini-PCNL in lateral supine position, and 19 cases of bilateral calculi were treated with ANL on one side and mini-PCNL in lateral supine position on the other.

Table 1 Baseline characteristics of clinical data of complete staghorn renal calculi ($n = 238$)

Parameters	Number	Median (minimum, maximum)	Percentages (%)
Age (year)			
Male	123	49 (19, 77)	
Female	115	51 (27, 77)	
Gender			
Male	123		52
Female	115		48
Site			
Unilateral staghorn calculi	192		81
Left	99		42
Right	93		39
Bilateral staghorn calculi	46		19
Number of branches of staghorn	284	15 (5, 29)	
Surface area of calculi (cm^2)	284	74 (51, 157)	
Volume of calculi (ml)	284	23 (14, 67)	
Scr (umol/l)	238	104 (53, 479)	
GFR on calculi side			
Left (ml/min)	145	32 (16, 55)	
Right (ml/min)	139	31 (17, 55)	
Urine leukocyte			
Positive	238		100
Negative	0		0
Urine bacterial culture			
Positive	99		42
Negative	139		58
Hypertension			
Yes	57		24
No	181		76
Type 2 diabetes			
Yes	48		20
No	190		80
Hyperparathyroidism			
Yes	13		5.5
No	235		94.5
Surgical method selection			
Unilateral PCNL	135		56.7
Bilateral PCNL	18		7.6
Unilateral ANL	57		23.9
Bilateral ANL	9		3.8
PCNL on one side, ANL on the other	19		8.0
Number of established channels of PCNL	190	3 (1, 5)	
Duration of renal artery occlusion in ANL (min)	94	35 (15,70)	

Data are presented as percentage or as median (minimum, maximum)

Abbreviations: *ANL* anatrophic nephrolithotomy, *GFR* glomerular filtration rate, *ml* milliliter, *min* minute, *mol* mole, *cm^2* Square centimeter, *PCNL* Percutaneous nephrolithotomy; Scr, serum creatinine

To compare the clinical parameters of mini-PCNL in lateral supine position and ANL in treating complete SRC

As shown in Table 2, there was differences between the two treatments, and the residual stone rate, number of residual stones, residual stone quantity, the reoperation rate, the cost of treatment, the length of hospital stay, and the incidence of intraoperative and postoperative complications such as massive bleeding and infection

Table 2 To compare the efficacy of PCNL and ANL in treating complete staghorn renal calculi

Parameters	PCNL ($n=190$)	ANL ($n=94$)	*P*-value
Age (year)			
Male	48 (19, 70)	49 (27, 70)	0.587
Female	48 (27, 77)	47 (27, 77)	0.657
Gender			
Male	53.68% (102/190)	36.17% (34/94)	**< 0.001**
Female	46.32% (88/190)	63.83% (60/94)	**0.021**
Number of branches of staghorn	14 (5, 28)	15 (9, 29)	**0.001**
Surface area of calculi (cm^2)	64.66 (51.39, 157.49)	64.66 (52.37, 133.27)	0.738
Volume of calculi (ml)	18.19 (14.18, 67.23)	18.22 (14.98, 56.37)	0.526
Incidence of type 2 diabetes	19.47% (37/190)	26.60% (25/94)	0.165
Incidence of hypertension	22.63% (43/190)	24.47% (23/94)	0.713
Incidence of hyperparathyroidism	6.32% (12/190)	14.89% (14/94)	**0.003**
Residual stone rate after operation	94.21% (179/190)	6.38% (6/94)	**< 0.001**
Number of residual stones after operation	13 (0, 22)	0 (0, 2)	**< 0.001**
Residual stone quantity after operation (%)	28 (0, 61)	0 (0, 4)	**< 0.001**
Number of unilateral secondary operations			
< 6 months	2 (0, 4)	0 (0, 1)	**< 0.001**
7–12 months	0 (0, 2)	0 (0, 1)	**< 0.001**
13–24 months	0 (0, 3)	0 (0, 1)	**< 0.001**
Incidence of unilateral secondary surgery			
< 6 months	85.79% (163/190)	4.30% (4/93)	**< 0.001**
7–12 months	20.63% (39/189)	2.15% (2/93)	**< 0.001**
13–24 months	24.34% (46/189)	5.38% (5/93)	**< 0.001**
Scr (umol/l)			
preoperative	89 (55, 479)	85 (53, 186)	0.145
After 1 week	86 (45, 480)	85 (51, 195)	0.683
After one month	75 (53, 362)	68 (56, 88)	0.199
After 6 months	78 (56, 372)	78 (62, 96)	0.923
After 12 months	74 (49, 345)	74 (56, 96)	0.493
After 18 months	76 (47, 363)	76 (47, 96)	0.147
After 24 months	72 (61, 351)	72 (61, 102)	0.559
GFR at the surgical side			
Preoperative (ml/min)	28.65 (16.43, 55.42)[a]	29.46 (16.49, 47.23)[b]	0.52
After one month	28.77 (17.55, 55.68)	28.44 (15.22, 44.23)	0.143
After 6 months	27.56 (16.85, 51.21)	26.35 (14.36, 42.54)	0.077
After 12 months	27.56 (15.22, 52.01)[a]	25.88 (14.21, 41.56)[b]	**0.047**
After 18 months	26.56 (14.02, 50.23)[a]	25.43 (13.78, 41.89)[b]	**0.043**
After 24 months	26.72 (14.13, 50.12)[a]	24.32 (13.07, 40.89)[b]	**0.034**
Length of the operation (min)	110 (30, 210)	122 (45, 320)	0.435
Incidence of intraoperative blood transfusion	12.11% (23/190)	18.09% (17/94)	0.362
Intraoperative blood transfusion volume (IU)	0 (0, 6)	0 (0, 16)	**0.009**
Incidence of postoperative blood transfusion	11.05% (21/190)	5.32% (5/94)	**0.014**
Postoperative blood transfusion volume (IU)	0 (0, 6)	0 (0, 2)	**0.041**
Incidence of postoperative massive bleeding	8.42% (16/190)	1.06% (1/94)	**0.014**
Incidence of postoperative interventional hemostasis	8.42% (16/190)	1.06% (1/94)	**0.014**
Incidence of postoperative transfer to ICU	6.32% (12/190)	2.13% (2/94)	**0.047**
Incidence of postoperative sepsis	6.32% (12/190)	0	**0.047**
Incidence of postoperative death	0.53% (1/190)	0	0.669

Table 2 (continued)

Parameters	PCNL (*n* = 190)	ANL (*n* = 94)	*P*-value
Incidence of renal resection during operation	0	1.064% (1/94)	0.331
Incidence of postoperative renal atrophy	17.99% (34/189)	32.26% (30/93)	**0.007**
Positive rate of urine bacterial culture	47.37% (90/190)	56.38% (53/94)	0.256
Recurrence rate of calculi with infection			
After 6 months	8.47% (16/189)	6.45% (6/93)	0.555
After 12 months	21.69% (41/189)	15.05% (14/93)	0.187
After 24 months	24.34% (46/189)	18.28% (17/93)	0.252
Cost of initial treatment (￥,RMB)	4.78 (1.59, 14.21)	2.5 (1.43, 8.25)	**< 0.001**
The total cost of treatment (￥,RMB)	11.09 (2.35, 31.24)	2.51 (1.43, 8.66)	**< 0.001**
Length of first hospital stay (day)	16 (11, 26)	16 (14, 22)	**0.019**
Total length of hospital stay (day)	35 (11, 53)	17 (14, 31)	**< 0.001**
Postoperative satisfaction survey			**< 0.001**
Satisfactory	15.26% (29/190)	95.74% (90/94)	
Acceptable	37.89% (72/190)	4.26% (4/94)	
Dissatisfactory	46.85% (89/190)	0	

Data are presented as percentage or as median (minimum, maximum)

P-values were calculated using the Mann–Whitney U for quantitative data, and using the Chi-square test for counting data

The boldface represents statistical significance

Abbreviations: *ANL* anatrophic nephrolithotomy, *GFR* glomerular filtration rate, *ICU* intensive care unit, *IU* International unit, *l* litre, *ml* milliliter, *min* minute, *mol* mole, cm^2 Square centimeter, *PCNL* Percutaneous nephrolithotomy, *Scr* serum creatinine

[a] Represents the statistically significant difference between preoperative GFR and postoperative follow-up GFR at 12 months, 18 months, and 24 months in PCNL group, and the *P* values are 0.015, 0.003 and less than 0.001, respectively

[b] Represents the statistically significant difference between preoperative GFR and postoperative follow-up GFR at 6 months, 12 months, 18 months, and 24 months in ANL group, and the *P* values are 0.021, 0.001, less than 0.001 and less than 0.001, respectively

all were high; the incidence of postoperative renal atrophy were low; the postoperative satisfaction is sad, in the mini-PCNL in lateral supine position group compared to the ANL group (all $P < 0.05$). In addition, there was a difference in the GFR of the surgical side between the mini-PCNL in lateral supine position group and the ANL group at 12 months, 18 months, and 24 months after surgery (all $P < 0.05$). The decrease in GFR at 12 months, 18 months and 24 months after surgery was also different from the preoperative GFR comparison within the mini-PCNL in lateral supine position group (all $P < 0.05$). The decrease in GFR at 6 months, 12 months, 18 months, and 24 months after surgery was also different from the preoperative GFR comparison within the ANL group (all $P < 0.05$).

Logistic regression analysis of different clinical parameters in patients with complete SRC treated with mini-PCNL in lateral supine position and ANL

According to the Logistic regression analysis, as shown in Table 3, there was a significant correlation between treatment and residual stone rate, residual stone number, residual stone quantity, satisfaction, hospitalization times, length of hospital stay, hospitalization costs, postoperative renal atrophy, the decrease in GFR on the surgical side and gender selection. And women were twice as likely as men to choose ANL treatment (OR = 2.045, 95%CI:1.23–3.4, $P = 0.006$). The residual stone rate after mini-PCNL in lateral supine position was 239 times (OR = 238.667, 95%CI:85.468–666.47, $P < 0.0001$), the number of residual stone was 1.3 times (OR = 1.326, 95%CI:1.229–1.43, $P < 0.0001$), and the amount of residual stone was 2.2 times (OR = 2.224, 95%CI:1.737–2.848, $P < 0.0001$) that of ANL. The cost of initial treatment after mini-PCNL in lateral supine position was 3.3 times (OR = 3.273, 95%CI:2.075–5.161, $P < 0.0001$), the total cost of treatment 4 times (OR = 4.051, 95%CI:2.677–6.13, $P < 0.0001$), the length of first hospital stays 0.6 time (OR = 0.614, 95%CI:0.504–0.747, $P < 0.0001$), the total length of hospital stay 1.4 times (OR = 1.44, 95%CI:1.302–1.592, $P < 0.0001$) that of ANL. The incidence of postoperative renal atrophy was 2.2 times (OR = 2.171, 95%CI:1.226–3.845, $P = 0.008$) higher in the ANL group than in the mini-PCNL in lateral supine position group. A high preoperative GFR was associated with a lower probability of choosing mini-PCNL in lateral supine position (OR = 0.767, 95%CI:0.691–0.851, $P < 0.0001$) than ANL. GFR reduction after ANL was 1.4 times (OR = 1.381,

Table 3 Logistic regression analysis of different clinical parameters in patients with complete staghorn renal calculi treated with PCNL and ANL

Parameters	B	S.E	Wald	*P*-value	OR	95%CI
Gender						
PCNL ([a]*n* = 102, [b]*n* = 88)						
ANL ([a]*n* = 34, [b]*n* = 60)	0.716	0.259	7.616	**0.006**	2.045	1.23–3.4
Number of branches of staghorn						
PCNL (*n* = 190)						
ANL (*n* = 94)	0.096	0.03	10.277	**0.001**	1.101	1.038–1.168
Surface area of calculi (cm^2)						
PCNL (*n* = 190)						
ANL (*n* = 94)	-0.014	0.022	0.434	0.51	0.986	0.945–1.029
Volume of calculi (ml)						
PCNL (*n* = 190)						
ANL (*n* = 94)	0.017	0.046	0.14	0.709	1.017	0.93–1.113
Residual stone rate after operation						
PCNL (*n* = 189)	5.475	0.524	109.193	**< 0.0001**	238.667	85.468–666.47
ANL (*n* = 93)						
Number of residual stones after operation						
PCNL (*n* = 189)	0.282	0.394	53.526	**< 0.0001**	1.326	1.229–1.43
ANL (*n* = 93)						
Residual stone quantity after operation						
PCNL (*n* = 189)	0.799	0.126	40.189	**< 0.0001**	2.224	1.737–2.848
ANL (*n* = 93)						
Incidence of unilateral secondary surgery						
< 6 months						
PCNL (*n* = 189)	0.639	0.898	0.506	0.477	1.895	0.326–11.013
ANL (*n* = 93)						
7–12 months						
PCNL (*n* = 189)	1.831	1.016	3.249	0.071	6.24	0.852–45.683
ANL (*n* = 93)						
13–24 months						
PCNL (*n* = 189)	-0.23	1.011	0.052	0.82	0.794	0.109–5.766
ANL (*n* = 93)						
GFR at the surgical side (ml/min)						
Preoperative						
PCNL (*n* = 190)	-0.265	0.053	24.77	**< 0.0001**	0.767	0.691–0.851
ANL (*n* = 94)						
After one month						
PCNL (*n* = 189)	-0.096	0.128	0.561	0.454	0.909	0.708–1.167
ANL (*n* = 93)						
After 6 months						
PCNL (*n* = 189)	0.069	0.13	0.277	0.598	1.071	0.83–1.382
ANL (*n* = 93)						
After 12 months						
PCNL (*n* = 189)	-0.26	0.154	2.863	0.091	0.771	0.57–1.042
ANL (*n* = 93)						
After 18 months						
PCNL (*n* = 189)	0.269	0.186	2.088	0.148	1.309	0.909–1.885
ANL						
After 24 months						

Table 3 (continued)

Parameters	B	S.E	Wald	*P*-value	OR	95%CI
PCNL (*n* = 189)						
ANL (*n* = 93)	0.323	0.154	4.371	**0.037**	1.381	1.02–1.869
Intraoperative blood transfusion volume (IU)						
PCNL (*n* = 190)	2.213	1.037	4.552	**0.033**	9.139	1.197–69.755
ANL (*n* = 94)						
Incidence of postoperative blood transfusion						
PCNL (*n* = 190)	2.146	1.039	4.269	**0.039**	8.552	1.117–65.5
ANL (*n* = 94)						
Postoperative blood transfusion volume (IU)						
PCNL (*n* = 190)	20.57	11,147.524	0	0.999	8.58E + 08	0–0.000
ANL (*n* = 94)						
Incidence of postoperative massive bleeding						
PCNL (*n* = 190)	1.217	0.77	2.498	0.114	3.379	0.746–15.292
ANL (*n* = 94)						
Incidence of postoperative interventional hemostasis						
PCNL (*n* = 190)	20.504	40,192.97	0	1	8.04E + 08	0–0.000
ANL (*n* = 94)						
Incidence of postoperative transfer to ICU						
PCNL (*n* = 190)	-21.857	28,420.722	0	0.999	0	0–0.000
ANL (*n* = 94)						
Incidence of postoperative sepsis						
PCNL (*n* = 190)	42.406	30,697.888	0	0.999	2.61E + 18	0–0.000
ANL (*n* = 94)						
Incidence of postoperative renal atrophy						
PCNL (*n* = 189)						
ANL (*n* = 93)	0.775	0.292	7.063	**0.008**	2.171	1.226–3.845
Preoperative GFR	-0.004	0.05	0.005	0.943	0.996	0.904–1.099
GFR at 1 month after surgery	-0.069	0.132	0.275	0.6	0.933	0.721–1.208
GFR at 6 months after surgery	-0.096	0.133	0.522	0.47	0.908	0.699–1.179
GFR at 12 months after surgery	0.093	0.158	0.35	0.554	1.098	0.806–1.496
GFR at 18 months after surgery	0.054	0.177	0.095	0.758	1.056	0.747–1.493
GFR at 24 months after surgery	-0.016	0.139	0.014	0.907	0.984	0.75–1.291
Incidence of hyperparathyroidism						
PCNL (*n* = 190)						
ANL (*n* = 94)	0.954	0.416	5.263	**0.022**	2.596	1.149–5.864
Cost of initial treatment (￥,RMB)						
PCNL (*n* = 190)	1.186	0.232	26.017	**< 0.0001**	3.273	2.075–5.161
ANL (*n* = 94)						
The total cost of treatment (￥,RMB)						
PCNL (*n* = 190)	1.399	0.211	43.824	**< 0.0001**	4.051	2.677–6.13
ANL (*n* = 94)						
Length of first hospital stay (day)						
PCNL (*n* = 190)						
ANL (*n* = 94)	0.488	0.1	23.806	**< 0.0001**	1.63	1.339–1.983
Total length of hospital stay (day)						
PCNL (*n* = 190)	0.364	0.051	50.204	**< 0.0001**	1.44	1.302–1.592
ANL (*n* = 94)						
Postoperative satisfaction survey						
Satisfactory						

Table 3 (continued)

Parameters	B	S.E	Wald	*P*-value	OR	95%CI
PCNL (*n* = 29)						
ANL (*n* = 90)	4.058	0.557	52.998	**< 0.0001**	57.857	19.404–172.517
Acceptable						
PCNL (*n* = 72)	22.37	4236.711	0	0.996	0	0–0.000
ANL (*n* = 4)						
Dissatisfactory						
PCNL (*n* = 89)	2.322	0.777	8.925	**0.003**	10.196	2.223–46.777
ANL (*n* = 0)						

P-values were calculated using the univariate Logistic regression analysis

The boldface represents statistical significance($P < 0.05$)

Abbreviation: *ANL* anatrophic nephrolithotomy, *CI* confidence interval, *ICU* intensive care unit, *IU* International unit, *l* litre, *ml* milliliter, *min* minute, *mol* mole, cm^2 Square centimeter, *GFR* glomerular filtration rate, *OR* odds ratio, *PCNL* Percutaneous nephrolithotomy

[a] Is the number of male

[b] Is the number of female

95%CI:1.02–1.869, $P = 0.037$) greater than that after mini-PCNL in lateral supine position at 24-month follow-up. And the overall satisfaction of ANL was 58 times (OR = 57.857, 95%CI:19.404–172.517, $P < 0.0001$) higher than that of mini-PCNL in lateral supine position. However, there was no significant correlation between postoperative renal atrophy and postoperative GFR reduction (all $P > 0.05$).

The occurrence of postoperative residual stone was analyzed by logistic regression for stone surface area, stone volume, number of branches of staghorn and surgical method

According to the logistic regression analysis, as shown in Table 4, there was a significant correlation between the occurrence of residual stone and the number of branches of staghorn (OR = 1.267, 95%CI:1.118–1.438, $P < 0.0001$) and the surgical method (OR = 0.001, 95%CI:0–0.003, $P < 0.0001$). Moreover, the number of branches of staghorn greater than 8 is a high risk factor for the occurrence of residual stone after mini-PCNL in lateral supine position (OR = 353.137, 95%CI:34.297–3636.076, $P < 0.0001$) when the number of branches of staghorn is divided into groups ≤ 8 and ≥ 9. However, the occurrence of residual stone after surgery was not significantly correlated with stone surface area (OR = 1.127, 95%CI:0.981–1.294, $P = 0.091$) or stone volume (OR = 0.797, 95%CI:0.593–1.072, $P = 0.134$).

Table 4 Logistic regression analysis of postoperative residual stone occurrence with surface area, volume, number of branches of staghorn and treatment of complete staghorn renal calculi

	Residual stone(*n* = 185)	Non-residual stone(*n* = 99)	Z/χ^2	[1]*P*-vable	OR	95%CI	[2]*P*-vable
Surface area of calculi (cm^2)	74.56 (51.39, 133.27)	72.48 (51.39, 157.49)	0.515	0.474	1.127	0.981–1.294	0.091
Volume of calculi (ml)	23.16 (14.98, 56.37)	22.88 (14.18, 67.23)	0.041	0.84	1.173	1.044–1.391	0.013
Number of branches of staghorn	15 (9, 28)	16 (5, 29)	5.008	**0.026**	1.267	1.118–1.438	**< 0.001**
Number of branches of staghorn(%)	185 (100)	99 (100)					
≥ 9	181 (97.64)	89 (89.90)	8.883	**0.003**	353.137	34.297–3636.076	**< 0.001**
≤ 8	4 (2.16)	10 (10.10)					
Treatments(%)	185 (100)	99 (100)					
PCNL	179 (96.76)	11 (11.11)	856.036	**< 0.001**	0.001	0–0.003	**0.001**
ANL	6 (3.24)	88 (88.89)					

Data are presented as percentage or as median (minimum, maximum)

The boldface represents statistical significance

Abbreviations: *ANL* anatrophic nephrolithotomy, *ml* milliliter, cm^2 Square centimeter, *OR* odds ratio, *PCNL* Percutaneous nephrolithotomy

[1] *P*-values were calculated using the One-way analysis of variance

[2] *P*-values were calculated using the univariate Logistic regression analysis

Discussion

In this study, the results showed that the residual stone rate of mini-PCNL in lateral supine position in the treatment of complete SRC was as high as 94.21%, and the residual stone shape was shown in Fig. 2. However, the residual stone rate of ANL treatment was quite low, accounting for only 6.38%, as shown in Fig. 3. Previous literature reported that the stone free rate of PCNL treatment for SRC (there is no clear distinction between complete and partial SRC) was in the range of 49% to 78%, which means that the residual stone rate is in the range of 22% to 51% [8, 10, 21–23]. In the previous literature, the residual stone rate of complete SRC, whether ANL or PCNL, was rarely reported. Because there is no clear distinction between complete and partial SRC, this may mislead the reader, it seems that the stone free rate of PCNL in the treatment of complete SRC is surprising [8, 10, 21–23]. In this study, we also evaluated the amount and number of residual stones, both of which were higher after PCNL treatment than after ANL treatment.

In the evaluation of reoperation due to residual stone, PCNL treatment has a higher reoperation rate, and longer hospital stay and higher treatment cost than ANL treatment. Similarly, our results showed that the incidence of intraoperative major bleeding, postoperative major bleeding, and sepsis was higher in PCNL than in ANL. However, the occurrence of late renal atrophy was more in ANL than in PCNL at 12 to 24 months after operation. ANL has higher satisfaction than PCNL. Through logistic regression analysis, we found that residual stone rate, residual stone amount, residual stone number, treatment cost, length of hospital stay, frequency of hospital stay, and satisfaction was all correlated with the treatment choice. And, these risks were positively correlated with PCNL, but the risk of renal atrophy was positively correlated with ANL. However, there was no significant correlation between ANL and PCNL in intraoperative hemorrhage, postoperative hemorrhage, and postoperative sepsis. At the same time, this study found that there was no significant correlation between renal atrophy and postoperative GFR reduction. Based on the above analysis, we believe that the cost performance of ANL treatment for complete SRC was significantly higher than that of PCNL treatment [5–13, 24–28].

Residual stones after mini-PCNL in lateral supine position in this study were 94%. This is very high in comparison with previous reports all over the world. We analyzed that the reason for the low residual stone rate reported worldwide in PCNL is that they do not clearly distinguish complete SRC and take the effect of treatment of partial SRC into account. The incidence of massive postoperative bleeding is 8% in this study. The reported incidence of massive bleeding in the world is also 5%-8% in PCNL. We analyzed the cause of massive bleeding can be related to the excessive pursuit of stone-free operation, the puncture site and the establishment of the channel are not reasonable, and the unskilled, brute-force operation. Moreover, these operations that excessively pursues the stone-free rate in PCNL can not really bring the effect of stone-free rate. We consider that the limitation of PCNL itself in the treatment of complete SRC can be the reason for the poor surgical effect and many complications [29, 30].

Guidelines for urology recommend PCNL as the first choice for the treatment of complex stones, which is to consider the impact of ANL surgery on renal function

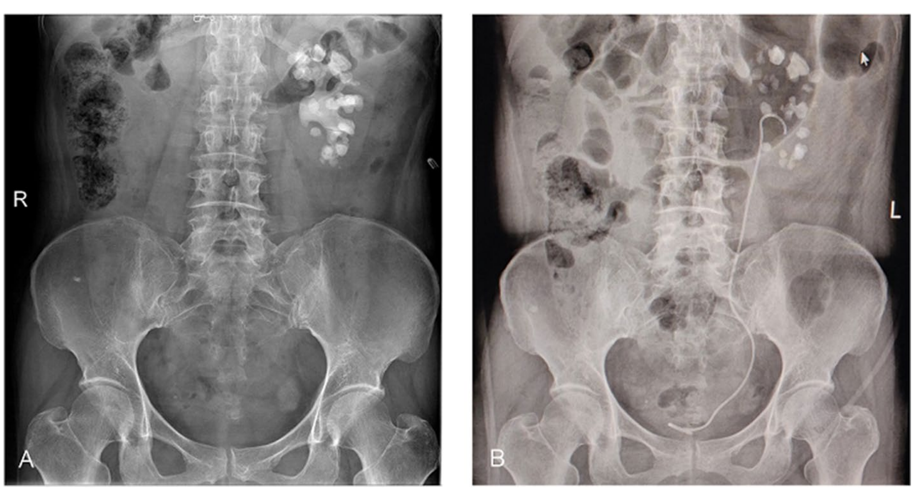

Fig. 2 The preoperative shape of complete staghorn renal calculi and the residual stone after PCNL is shown on KUB. Abbreviations: KUB, kidney ureter bladder; PCNL, percutaneous nephrolithotomy. **A** Complete staghorn renal calculi is located in the left; **B** The residual stone of complete staghorn renal calculi in the left kidney after PCNL

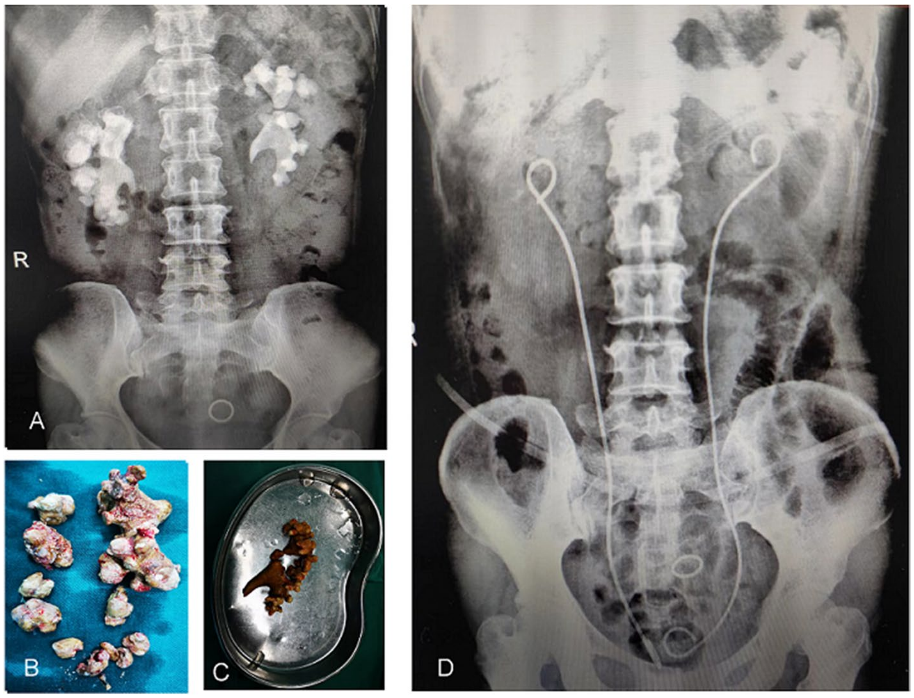

Fig. 3 Preoperative morphology of bilateral complete staghorn renal calculi and stone specimens completely removed by ANL surgery and postoperative KUB without stone imaging. Abbreviations: ANL, anatrophic nephrolithotomy; KUB, kidney ureter bladder. **A** Complete staghorn calculi are located in both of the left and right kidneys; **B** The stone removed by ANL was located in the right complete staghorn renal calculi; **C** The stone removed by ANL was located in the left complete staghorn renal calculi; **D** Bilateral complete staghorn renal calculi was completely removed by ANL surgery

and long-term adverse reactions of renal atrophy. Although our results showed that the rate of renal atrophy was higher in the ANL group (32.26%) than in the PCNL group (17.99%). Moreover, the risk of renal atrophy after ANL was higher than that after PCNL. However, the results of logistic regression analysis showed that there was no statistically significant correlation between the occurrence of postoperative renal atrophy and the decrease of postoperative GFR. In other words, it can be no significant correlation between GFR and long-term adverse reactions in the two surgical methods by logistic regression analysis of long-term follow-up results. Therefore, we believe that the occurrence of renal atrophy after complete SRC is more related to the compression of renal parenchyma by renal calculi itself and the combination of renal parenchyma infection, rather than the operation itself.

In this study, as well as in clinical practice, we have found that for complete SRC with more than 8 branches of staghorn, the occurrence of residual stone after treatment with PCNL was inevitable, even with multi-channel lithotomy. However, the incidence of residual stone after surgery was 0 when complete SRC with branches of staghorn less than or equal to 8 were treated with PCNL. However, in this study, all patients treated with ANL had more than 8 branches of staghorn for complete SRC, and the incidence of postoperative residual stone (6.38%) was very low (see in Tables 2 and 4). According to our analysis of the correlation to postoperative residual stone occurrence with stone surface area, stone volume, number of branches of staghorn and surgical methods of complete SRC (see in Table 4), we found that there was a significant correlation between the occurrence of residual stone and the number of branches of staghorn (OR = 1.267, 95%CI:1.118–1.438, $P < 0.0001$) and the surgical method (OR = 0.001, 95%CI:0–0.003, $P < 0.0001$). Moreover, the number of branches of staghorn greater than 8 is a high risk factor for the occurrence of residual stone after PCNL (OR = 353.137, 95%CI:34.297–3636.076, $P < 0.0001$) when the number of branches of staghorn is divided into groups ≤ 8 and ≥ 9. However, the occurrence of residual stone after surgery was not significantly correlated with stone surface area (OR = 1.127, 95%CI:0.981–1.294, $P = 0.091$) or stone volume (OR = 0.797, 95%CI:0.593–1.072, $P = 0.134$). Similarly, it can be seen from Table 4 that the stone-free rate of ANL is 88.89%, while the stone-free rate of PCNL is only 11.11%. Therefore, we suggest that the number of branches of staghorn greater than 8 is not appropriate for the treatment of PCNL, and treatment with ANL should be the preferred option for complete SRC.

Based on the above analysis, we advocate that SRC is clearly differentiated into complete SRC and partial SRC. For partial SRC, we are in favor of PCNL as the preferred treatment, and ANL for complete SRC. However, the present study had several limitations. This study was based on only single-center clinical data. Confounding factors, such as age, surgical operation time, surgical difficulty, puncture location method, aesthetic requirements of incision, patient and physician selection bias of surgical method. These limitations may have influenced the results and conclusions.

Conclusions

The results of the current study indicate that although the risk of renal atrophy and decreased GFR after ANL is higher than that of PCNL, the efficacy of traditional ANL in the treatment of complete SRC was generally superior to that of mini-PCNL in lateral supine position. Moreover, number of branches of staghorn greater than 8 are the preferred ANL for complete SRC.

Abbreviations

ANL Anatrophic nephrolithotomy
PCNL Percutaneous nephrolithotomy
SRC Staghorn renal calculi

Acknowledgements

In this study, Professor Yuanzhong Zhou from the School of Public Health Management of Zunyi Medical University gave us guidance in data statistics. Thanks Professor Zhou! We also wish to acknowledge the efforts of the participants and investigators of the study. In addition, the authors would like to thank Jichun Deng from New Oriental Education & Technology Group Inc. for proofreading.

Authors' contributions

Bo Chen, Congcong Chen, Wei Cui, Peng Zhang, Ningrui Pan, Min Wang, Xu He, Qixu Ren, and Youzhuang Zhong: Participated in the test and data collection; Bo Chen, Zidong Zhou and Bengen Li: Participated in summarizing the test data, data analysis and manuscript writing; Zongping Chen: Formed the project development, and writing—review & editing. All authors reviewed the manuscript.

Funding

Funding Statement were not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request
.Registration Registry used:Chinese Clinical Trial Registry
Unique Identifying number or registration ID:ChiCTR2100047462
Hyperlink to your specific registration: http://www.chictr.org.cn/showprojen.aspx?proj=64748

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Affiliated Hospital of Zunyi Medical University (the Ethics Approval number is KLLY-2021–169, and the date of ethics approval is 2021.12.31) and was complied with the Declaration of Helsinki. The consent was obtained from all of the participants was informed. This study does contain human participants.

Consent for publication

Our study does contain human subjects and written consent was obtained from all participants.

Competing interests

The authors declare no competing interests and have no relevant or non-financial interests to disclose.

Author details

[1]Department of Urology, Affiliated Hospital of Zunyi Medical University, Zunyi 563000, Guizhou, China.

Received: 28 August 2023 Accepted: 26 July 2024
Published online: 07 August 2024

References

1. Zhong W, Osther P, Pearle M, et al. International Alliance of Urolithiasis (IAU) guideline on staghorn calculi management. World J Urol. 2024;42(1):189. https://doi.org/10.1007/s00345-024-04816-6. Published 2024 Mar 25.
2. EAU Guidelines. Edn. Presented at the EAU Annual Congress Amsterdam (2022) ISBN 978–94–92671–16–5. https://uroweb.org/guidelines/urolithiasis.
3. Sfoungaristos S, Gofrit ON, Pode D, Landau EH, Duvdevani M. Percutaneous nephrolithotomy for staghorn stones: which nomogram can better predict postoperative outcomes? World J Urol. 2016;34(8):1163–8. https://doi.org/10.1007/s00345-015-1743-9.
4. Huang J, Zhang S, Huang Y, Ozsoy M, Tiselius HG, Huang J, et al. Is multiple tract percutaneous nephrolithotomy a safe approach for staghorn calculi? World J Urol. 2021;39(6):2121–7. https://doi.org/10.1007/s00345-020-03420-8.
5. Assimos DG. Anatrophic nephrolithotomy. Urology. 2001;57(1):161–5. https://doi.org/10.1016/s0090-4295(00)00920-1.
6. Moslemi MK, Safari A. A huge left staghorn kidney, a case report of inevitable open surgery: a case report. Cases J. 2009;2:8234. https://doi.org/10.4076/1757-1626-2-8234.
7. Keshavamurthy R, Karthikeyan VS, Mallya A, Sreenivas J, Nelivigi GG, Kamath AJ. Anatrophic nephrolithotomy in the management of large staghorn calculi - a single centre experience. J Clin Diagn Res. 2017;11(5):PC01–4. https://doi.org/10.7860/JCDR/2017/24723.9837.
8. El-Nahas AR, Eraky I, Shokeir AA, et al. Percutaneous nephrolithotomy for treating staghorn stones: 10 years of experience of a tertiary-care centre. Arab J Urol. 2012;10(3):324–9. https://doi.org/10.1016/j.aju.2012.03.002.
9. Abreu Lde A, Camilo-Silva DG, Fiedler G, Corguinha GB, Paiva MM, Pereira-Correia JA, Muller VJ. Review on renal recovery after anatrophic nephrolithotomy: are we really healing our patients? World J Nephrol. 2015;4(1):105–10. https://doi.org/10.5527/wjn.v4.i1.105.
10. Soucy F, Ko R, Duvdevani M, Nott L, Denstedt JD, Razvi H. Percutaneous nephrolithotomy for staghorn calculi: a single center's experience over 15 years. J Endourol. 2009;23(10):1669–73. https://doi.org/10.1089/end.2009.1534.
11. Chen Y, Feng J, Duan H, Yue Y, Zhang C, Deng T, Zeng G. Percutaneous nephrolithotomy versus open surgery for surgical treatment of patients with staghorn stones: a systematic review and meta-analysis. PLoS ONE. 2019;14(1):e0206810. https://doi.org/10.1371/journal.pone.0206810.
12. Al-Kohlany KM, Shokeir AA, Mosbah A, Mohsen T, Shoma AM, Eraky I, El-Kenawy M, El-Kappany HA. Treatment of complete staghorn stones: a prospective randomized comparison of open surgery versus percutaneous nephrolithotomy. J Urol. 2005;173(2):469–73. https://doi.org/10.1097/01.ju.0000150519.49495.88.
13. Nourian SMA, Bahrami M. Open surgery versus percutaneous nephrolithotomy for management of staghorn calculi. Am J Clin Exp Urol. 2022;10(4):271–6 Published 2022 Aug 15. PMID: 36051615; PMCID: PMC9428571.

14. Hollowell CM, Patel RV, Bales GT, Gerber GS. Internet and postal survey of endourologic practice patterns among American urologists. J Urol. 2000;163(6):1779–82. PMID: 10799181.
15. Aminsharifi A, Irani D, Masoumi M, Goshtasbi B, Aminsharifi A, Mohamadian R. The management of large staghorn renal stones by percutaneous versus laparoscopic versus open nephrolithotomy: a comparative analysis of clinical efficacy and functional outcome. Urolithiasis. 2016;44(6):551–7. https://doi.org/10.1007/s00240-016-0877-6.
16 Talyshinskii A, Guliev B, Komyakov B, Galfano A. Patient counseling through the pelvicalyceal-shaped labyrinth: in search of an easy understanding of the upcoming stone removal: a pilot study. Urology. 2020;143:75–9. https://doi.org/10.1016/j.urology.2020.04.114.
17. Boyce WH. Re: anatrophic nephrolithotomy: experience with a simplification of the Smith and Boyce technique. J Urol. 1980;123(4):604. https://doi.org/10.1016/s0022-5347(17)56047-4. PMID: 7365912.
18. Xiangrui Y, Xiong W, Xi W, Yuanbing J, Shenqiang Q, Yu G. Clinical Assessment of Risk Factors for Renal Atrophy After Percutaneous Nephrolithotomy. Med Sci Monit. 2020;26:e919970. https://doi.org/10.12659/MSM.919970. Published 2020 Sep 28.
19. Hui P, Shuli Y, Zhangji D, et al. CT index of chronic renal disease with renal atrophy. Inner Mongolia Med J. 2015;47:667–6 [Google Scholar].
20. Wein AJ, Kavoussi LR, Novick AC, et al. Campbell-Walsh Urology Tenth Edition. 10th revised edition Saunders. Philadelphia: Elsevier/Saunders; 2011.
21. Choi SW, Bae WJ, Ha US, Hong SH, Lee JY, Kim SW, Cho HJ. Prediction of stone-free status and complication rates after tubeless percutaneous nephrolithotomy: a comparative and retrospective study using three stone-scoring systems and preoperative parameters. World J Urol. 2016;35(3):449–57. https://doi.org/10.1007/s00345-016-1891-6.
22. Choi SW, Bae WJ, Ha US, Hong SH, Lee JY, Kim SW, Cho HJ. Prognostic impact of stone-scoring systems after percutaneous Nephrolithotomy for staghorn calculi: a single Center's experience over 10 years. J Endourol. 2016;30(9):975–81. https://doi.org/10.1089/end.2016.0188.
23. Mishra S, Sabnis RB, Desai M. Staghorn morphometry: a new tool for clinical classification and prediction model for percutaneous nephrolithotomy monotherapy. J Endourol. 2012;26(1):6–14. https://doi.org/10.1089/end.2011.0145.
24. Ganpule AP, Desai M. Management of the staghorn calculus: multiple-tract versus single-tract percutaneous nephrolithotomy. Curr Opin Urol. 2008;18(2):220–3. https://doi.org/10.1097/MOU.0b013e3282f3e6e4.
25. Aron M, Yadav R, Goel R, et al. Multi-tract percutaneous nephrolithotomy for large complete staghorn calculi. Urol Int. 2005;75(4):327–32. https://doi.org/10.1159/000089168.
26. Blum KA, Parkhomenko E, Thai J, Tran T, Gupta M. A contemporary lower pole approach for complete staghorn calculi: outcomes and efficacy. World J Urol. 2018;36(9):1461–7. https://doi.org/10.1007/s00345-018-2284-9.
27. Xu G, Liang J, He Y, Li X, Yang W, Lai D, et al. Comparison of two different minimally invasive percutaneous nephrostomy sheaths for the treatment of staghorn stones. BJU Int. 2020;125(6):898–904. https://doi.org/10.1111/bju.15031.
28. Suntharasivam T, Mukherjee A, Luk A, Aboumarzouk O, Somani B, Rai BP. The role of robotic surgery in the management of renal tract calculi. Transl Androl Urol. 2019;8(Suppl 4):S457–60. https://doi.org/10.21037/tau.2019.04.06.
29. El-Nahas AR, Elsawy AA, Abdelhalim A, Elsaadany MM, Osman Y. Long-term effects of anatrophic nephrolithotomy on selective renal function. Urolithiasis. 2019;47(4):365–70. https://doi.org/10.1007/s00240-018-1058-6.
30. Garcia-Chairez LR, Franco-Gonzalez CD, Gonzalez-Guillermo CA, et al. Prognostic Factors for Residual Lithiasis in Patients With Staghorn Calculi Undergoing Percutaneous Nephrolithotomy in the Maya Region of Yucatan, Mexico: A Case-Control Study. Cureus. 2024;16(3):e57052 Published 2024 Mar 27.

Publisher's Note