Short-term Alteration of Renal Function and Electrolytes after Percutaneous Nephrolithotomy

Subhabrata Mukherjee[1,4], Rajan Kumar Sinha[2,4]*, Tarun Jindal[3,4], Pramod Kumar Sharma[4], Soumendra Nath Mandal[4], Dilip Karmakar[4]

Purpose: To analyse the changes in renal function and serum electrolytes in the early post-operative period of percutaneous nephrolithotomy (PCNL).

Materials and Methods: A total of 110 patients with normal renal function, who underwent PCNL in our institute were evaluated prospectively. Haemoglobin percentage, packed cell volume, blood urea nitrogen, serum creatinine and serum electrolytes, namely sodium, potassium, chloride and ionized calcium were measured on the day before surgery and after 72 hours of the procedure. Renal function was assessed by Cockcroft-Gault formula and estimated glomerular filtration rate was calculated by modification of diet in renal disease formula.

Results: Serum creatinine increased significantly from a mean value of 0.89 ± 0.199 mg/dL to 0.96 ± 0.252 mg/dL ($P = 0.0002$) and both creatinine clearance and estimated glomerular filtration rate experienced a significant fall - from a median value (interquartile ranges) of 82.99 (72.37 to 96.88) mL/min to 75.38 (63.89 to 94.05) mL/min in case of creatinine clearance ($P = 0.0004$) and from a mean value of 95.18 ± 19.87 mL/min/1.73 m2 to 89.30 ± 23.14 mL/min/1.73 m^2 in case of estimated glomerular filtration rate ($P = 0.003$). Furthermore, there were significant drops in both haemoglobin percentage and packed cell volume. There were no significant alterations in serum electrolytes - sodium and potassium (mmol/L) [Median (IQR)] changed from a pre-operative figure of 137.5 (134.0 to 140.0) and 3.85 (3.60 to 4.10) to a post-operative value of 138 (135.0 to 140.0) and 3.85 (3.50 to 4.10) respectively.

Conclusion: Even though there is no significant variation in serum electrolytes, PCNL causes significant reduction in renal function in the early post-operative period.

Keywords: creatinine clearance; estimated glomerular filtration rate; percutaneous nephrolithotomy; serum creatinine; serum electrolytes

INTRODUCTION

Urinary stones have troubled humans since the earliest records of civilization[1]. Among the various surgical options for management of renal stone, percutaneous nephrolithotomy (PCNL), a minimally invasive endoscopic treatment, has emerged significantly over the last few decades. It is often the preferred treatment option especially for patients with large or complex renal stones, stones that are refractory to shock wave lithotripsy (SWL), residual stones after failed alternative modalities and so on[2-4]. It is an efficient and safe procedure for removal of renal calculi with low incidence of serious complications[5,6].

Interestingly, people have different views about the impact of PCNL on renal function in the early post-operative period. On the one hand, stone removal can improve renal function by relieving obstruction and eradicating underlying infection[7]. On the other hand, dilation and establishment of nephrostomy tract and associated stone removing procedure may negatively impact functional integrity[8-12]. To add on, some studies have also demonstrated that kidney function remains unchanged in the initial post-operative period[13-15]. Apart from that, usage of large amount of irrigation fluids during PCNL may also alter the serum electrolyte levels.

In this study attempts have been made to evaluate the changes in renal function in the form of creatinine clearance (CrCl) by Cockcroft-Gault formula (CGF) and estimated glomerular filtration rate (eGFR) by modification of diet in renal disease (MDRD) formula in the early post-operative period of PCNL along with estimation of changes in serum electrolytes at the same point of time (16,17). Knowledge in this field will help us managing post-operative cases of PCNL in a much better way, especially while making decisions regarding selection of drugs, or offering SWL or repeat PCNL.

MATERIALS AND METHODS

Study Population

This prospective observational study was carried out at

[1]Department of Urology, Northwick Park Hospital, London North West University Healthcare NHS Trust, Harrow, UK.
[2]Department of Urology, Kidney Stone and Urology Clinic, Bhagalpur, India.
[3]Department of Urology, Tata Medical Centre, Kolkata, India.
[4]Department of Urology, Calcutta National Medical College and Hospital, Kolkata, India.
*Correspondence: Department of Urology, Kidney Stone and Urology Clinic, Bhagalpur, India.
Tel: +91-9007205371. E-mail: rajan_rims@yahoo.co.in.
Received April 2018 & Accepted May 2019

Table 1. Demographic data of the study population along with operative details

Parameters	Data
No. of patients	110
Age (years) [Mean ± SD]	40.27 ± 11.525
Sex [No. (Percentage)]	
Male	70 (63.64%)
Female	40 (36.36%)
Body weight (kg) [Mean ± SD]	57.09 ± 10.656
Laterality of stones [No. (Percentage)]	
Left	53 (48.18%)
Right	57 (51.82%)
No. of access [No. (Percentage)]	
One	103 (93.64%)
Two	7 (6.36%)
Type of access [No. (Percentage)]	
Infracostal	100 (90.91%)
Supracostal	8 (7.27%)
Combined	2 (1.82%)
Total procedure time (min) [Mean ± SD]	80.05 ± 20.782
Scope time (min) [Median (IQR)]	45 (30 to 55)
Irrigation fluids (L) [Mean ± SD]	13.44 ± 6.147
Stone clearance [No. (Percentage)]	
Complete	78 (70.91%)
Incomplete	32 (29.09%)

Calcutta National Medical College and Hospital, Kolkata over a period of one and half year. Ethical clearance was obtained from the institutional ethical committee when our first author requested for it as a part of his dissertation at the beginning of the study.

Inclusion and exclusion criteria

Patients with renal stone who were planned for PCNL (size >2 cm for non-lower pole stones, size > 1 cm for lower pole stones and stones of any size that were SWL resistant or within a calyceal diverticulum) and gave consent for the study were included. Whereas, patients with age < 18 years; radiolucent stones; preoperative impaired renal function (serum creatinine > 1.4 mg/dL or eGFR by MDRD equation < 60 mL/min/1.73 m^2); poorly functioning contralateral kidney on intravenous urography (IVU); solitary kidney; history of previous renal surgery; history of SWL within 6 months; history of anticoagulant intake or uncontrolled coagulopathy; history of intraoperative or postoperative blood transfusion; patients who required repeat PCNL in same admission with nephrostomy tube in situ; and patients who did not give consent for the study were excluded. A total of 110 patients were ultimately selected following these criteria.

Procedures

All patients underwent thorough clinical evaluation before the procedure. Urinary infection, if present, was treated with the antibiotics as per culture and sensitivity report.

All patients received injection ceftriaxone (1g) and infusion levofloxacin (500mg/100mL) intravenously just before the procedure[18]. Standard prone PCNL were performed by the same surgical team using 0.9% normal saline as irrigation solution. All patients received 0.9% normal saline intra-operatively followed by 0.9% normal saline and 5% dextrose solution in 2:1 ratio in first 24 h after operation. Serial tract dilatation was done with Amplatz fascial dilators up to 26 Fr. Nephroscopy was performed with 24 Fr rigid nephroscope (Richard Wolf) and stone fragmentation was carried out using Swiss pneumatic lithoclast. At the end of the procedure,

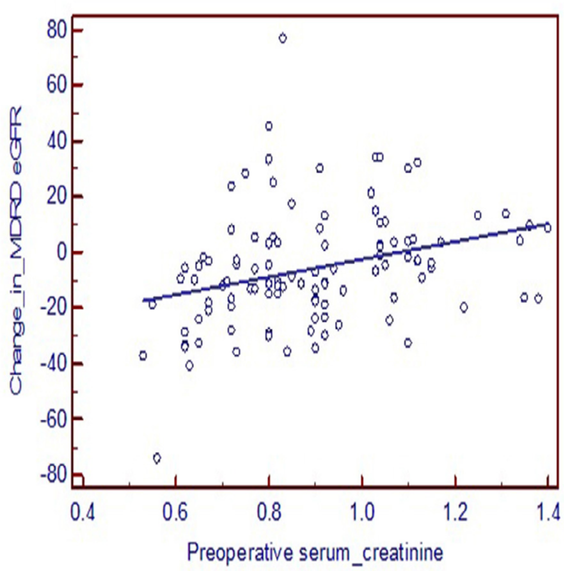

Figure 1. Scatter diagram and regression line showing significant positive correlation of preoperative serum creatinine with change in eGFR by MDRD formula measured 72 hours after PCNL (r= 0.31 , P = 0.001)

stone clearance was checked on combined fluoroscopy and nephroscopy. Antegrade double - J stent (DJ stent) was inserted in all the cases. 24 Fr nephrostomy tube was placed in case of perforation of pelvicalyceal system, suspected residual fragments, incomplete stone clearance or bleeding from the tract. Intraoperative data like number of access, type of access, total procedure time (from cystoscopy to postoperative retrograde DJ stenting ± nephrostomy tube insertion), scope time (duration of nephroscopy) and amount of irrigation fluid (only during nephroscopy) were recorded in all the cases.

Nephrotoxic drugs like aminoglycosides and nonsteroidal anti-inflammatory drugs were avoided during this period[19,20]. X-ray of kidney, ureter and bladder (X-ray KUB) was performed after 48 hours and nephrostomy was removed before 72 hours unless there was no evidence of big residual fragments. PCNL procedure success was defined as no residual stone visible on X-ray KUB. Complications were also recorded.

Evaluations

Haemoglobin percentage (Hb), packed cell volume (PCV), blood urea nitrogen (BUN), serum creatinine (SeCr) and serum electrolytes, namely sodium (Na+), potassium (K+), chloride (Cl-) and ionized calcium (iCa++) were measured on the day before surgery and repeated after 72 hours. CrCl (by CGF) and eGFR (by MDRD formula) were calculated both pre and post procedure.

Statistical Analysis

Data were summarized by routine descriptive statistics namely mean and standard deviation (SD) for normally distributed numerical variables and count and percentage for categorical variables. Median values with interquartile ranges (IQR) have been presented for numerical variables with skewed distribution. Pre and post procedure values of numerical parameters have been

Table 2. Comparative preoperative and 72 hour postoperative data

Dataa	Preoperative	72 Hours Postoperative	*P*-value
Na+ (mmol/L) [Median (IQR)]	137.5 (134.0 to 140.0)	138 (135.0 to 140.0)	.1870
K+ (mmol/L) [Median (IQR)]	3.85 (3.60 to 4.10)	3.85 (3.50 to 4.10)	.9407
Cl- (mmol/L) [Mean ± SD]	100.94 ± 3.449	101.88 ± 3.534	.0704
iCa++ (mmol/L) [Median (IQR)]	1.12 (1.00 to 1.23)	1.15 (0.99 to 1.21)	.6391
BUN (mg/dL) [Mean ± SD]	9.34 ± 3.223	9.81 ± 3.887	.2749
Serum creatinine (mg/dL) [Mean ± SD]	0.89 ± 0.199	0.96 ± 0.252	.0002
Creatinine clearance (mL/min) [Median (IQR)]	82.99 (72.37 to 96.88)	75.38 (63.89 to 94.05)	.0004
MDRD eGFR (mL/min/1.73 m^2) [Mean ± SD]	95.18 ± 19.868	89.30 ± 23.143	.0036
Hb (gm/dL) [Mean ± SD]	13.78 ± 2.006	11.68 ± 1.742	< .0001
PCV (%) [Mean ± SD]	40.59 ± 5.847	34.6 ± 5.215	< .0001

compared by paired t test or Wilcoxon's matched pairs signed rank test as appropriate. Change in eGFR was compared between subgroups by student's unpaired t test. Association between change in eGFR and numerical variables were explored by calculating Pearson's correlation coefficient r or Spearman's rank correlation coefficient rho as appropriate. Scatter plots were constructed wherever relevant.

Analysis has been two tailed and *P* < .05 has been considered as statistically significant. MedCalc version 11.6 (Maria Kerke, Belgium; MedCalc software, 2011) was used for statistical analysis.

RESULTS

Demographic data of the study population along with operative details are presented in **Table 1**.

The comparative preoperative and 72 hours postoperative data are illustrated in **Table 2**. There were no statistically significant alterations in the values of serum electrolytes and BUN. However, SeCr was increased significantly from a mean value of 0.89 ± 0.199 mg/dL to 0.96 ± 0.252 mg/dL (*P* = .0002). Along with it, both CrCl and eGFR experienced a significant fall - from a median value (IQR) of 82.99 (72.37 to 96.88) mL/min to 75.38 (63.89 to 94.05) mL/min in case of CrCl (*P* = .0004) and from a mean value of 95.18 ± 19.87 mL/min/1.73 m^2 to 89.30 ± 23.14 mL/min/1.73 m^2 in case of eGFR (*P* = .003).

Furthermore, there were significant fall in both Hb and PCV. Preoperative mean values of Hb and PCV were 13.78 ± 2.01 gm/dL and 40.59 ± 5.85 percent respectively, and these declined to 11.68 ± 1.74 gm/dL and 34.6 ± 5.21 percent respectively in the postoperative period (*P* < .0001 in both the cases).

The relationship between the change in eGFR and different preoperative variables were analysed in detail and are summarised in **Table 3**. Sex, post-operative residual stone, age, body weight, total procedure time, scope time and amount of irrigation fluid did not have any significant association with eGFR change. Although the fall in eGFR was more in two-accesses group (a mean drop of 13.94 ± 16.35 mL/min/1.73 m^2) compared to one-access group (a mean drop of 5.33 ± 20.94 mL/min/1.73 m2), it did not achieve statistical significance (*P* = .29).

Preoperative SeCr had a significant positive correlation (r = 0.31, *P* = .001) (**Figure 1**) and preoperative CrCl and eGFR had a significant negative correlation (r = -0.21, *P* = .025 and r = -0.35, *P* = .0002 respectively) with the change in eGFR.

Similarly, the relationship between the change in Hb and different preoperative variables were analysed. Interestingly, men had significant drop in Hb (a mean decline of 2.46 ± 1.93 gm/dL) as compared to women (a mean decline of 1.48 ± 1.39 gm/dL). However, fall in Hb was comparable between one access and two accesses - both had an average decline of around 2 gm/dL. Only preoperative Hb had a significant negative

Table 3. Association between change in eGFR and different variables

A. Categorical Variables [No. (Percentage)][a]	**Change in eGFR(mL/min/1.73 m^2) [Mean ± SD]**	***P*-value**
Sex		
Male [70 (63.64%)]	-4.67 ± 18.328	.4219
Female [40 (36.36%)]	-7.99 ± 24.481	
No. of access		
One [103 (93.64%)]	-5.33 ± 20.944	.2895
Two [7 (6.36%)]	-13.94 ± 16.349	
Post-operative residual stone		
No (Complete clearance) [78 (70.91%)]	-7.5397 ± 18.872	.1898
Yes (Incomplete clearance) [32 (29.09%)]	-1.8172 ± 24.538	
B. Numerical Variables[b]	**r or rho Value**	***P*-value**
Age	-0.1543	.1076
Body weight	-0.02319	.8100
Total procedure time	-0.005153	.9574
Scope time	0.0416	.6661
Amount of irrigation fluid	-0.06213	.5190
Preoperative serum creatinine	0.3056	.0012
Preoperative creatinine clearance	-0.2131	.0254
Preoperative MDRD eGFR	-0.3506	.0002

[a] Change in eGFR was compared between subgroups by student's unpaired *t* test.

[b] Association between change in eGFR and numerical variables were explored by calculating Pearson's correlation coefficient r or Spearman's rank correlation coefficient rho as appropriate.

Table 4. Previous studies showing the effect of PCNL on renal function in the early post-operative period

Study	Parameter Measured	Time Point(s) After Preoperative Measurement	Change (Compared to Preoperative Value)
A. Animal Model			
1. Webb and Fitzpatrick (1985) [13]	CrCl	48 h	Nil
		6 wk	Nil
2. Handa et al (2006) [8]	GFR by inulin clearance	1.5 h	Drop*
		4.5 h	Drop*
3. Handa et al (2009) [9]	GFR by inulin clearance	Single tract	
		1.5 h	Drop*
		4.5 h	Drop*
		Multiple tract	
		1.5 h	Drop*
		4.5 h	Drop*
4. Handa et al (2010) [10]	GFR by inulin clearance	1 h	Drop*
		72 h	Nil
B. Human Model			
1. Saxby (1997) [14]	Urinary CrCl	24 h	Nil
	Urinary prostaglandin F2α	2 wk	Nil
		24 h	Rise
		2 wk	Nil
2. Handa et al (2006) [8]	SeCr	24 h	Rise*
3. Hegarty and Desai (2006) [15]	CrCl (CGF)	Single tract	
		Post op	Nil
		Multiple tract	
		Post op	Drop*
4. Handa et al (2009) [9]	CrCl (CGF)	Single tract	
		24 h	Drop*
		48 h	Drop*
		Multiple tract	
		24 h	Drop*
		48 h	Drop*
5. Nouralizadeh et al (2011) [11]	CrCl (by CGF)	6 h	Drop
		24 h	Drop*
		48 h	Drop*
		72 h	Drop
6. Bayrak et al (2012) [7]	CrCl (by CGF)	72 - 96 h	Rise*
7. Tabibi et al (2014) [12]	CrCl (by CGF)	6 h	Drop
		24 h	Drop*
		48 h	Drop*
		72 h	Drop
		Discharge	Nil

* = statistically significant change

correlation with change in Hb (r = -0.59, P = < .0001). Rest of the parameters did not have any significant correlation with Hb change.

DISCUSSION

PCNL is one of the most commonly performed surgical intervention for management of renal stone disease with minimum morbidity[2-6]. Most of the clinical studies have almost uniformly established that PCNL does not have any significant effect on long term renal function and even, at times, it may ameliorate renal performance [21-23]. However, the literature is inadequate and even contradictory regarding the consequence of PCNL on early renal function (**Table 4**).

According to Webb and Fitzpatrick, who worked in a canine model, CrCl were similar at baseline, 48 hours, or 6 weeks after the procedure[13]. Saxby measured urinary CrCl and urinary prostaglandin F2α immediately before and at 24 hours and 2 weeks after PCNL.[14] There was no difference in CrCl values. Although urinary prostaglandin level was increased at 24 hours, it returned to preoperative levels at 2 weeks. Additionally, in the study by Hegarty and Desai, CrCl was unchanged in single tract PCNL in the early post-operative period [15].

In contrast, there are some literatures suggesting a decline in renal function in the early period after PCNL. Handa and colleagues demonstrated a statistically significant fall in GFR in their consecutive animal studies at 1h, 1.5 h and 4.5 h after operation which returned to baseline at 72 hours[8,10]. This group also performed a retrospective analysis of 196 patients undergoing single-stage unilateral PCNL and detected an overall significant increase in SeCr concentration (0.14 ± 0.02 mg/dL; P < .001) 24 hours after the procedure[8].

Nouralizadeh and co-workers prospectively evaluated 94 patients who underwent unilateral PCNL and CrCl was estimated by CGF preoperatively and at 6, 24, 48 and 72 hours after operation[11]. The mean ± SD of preoperative CrCl was 87.5 ± 32.2 mL/min, which decreased to 85.5 ± 29.4 mL/min 6 hours after operation. Continuous decrease in CrCl was observed up to 48 hours after operation (75.9 ± 25.0 mL/min), and then, a slight increase in CrCl level was noted at 72 h after operation (81.9 ± 26.4 mL/min) although it was quite low compared to the pre-operative value. The drops in CrCl at 24 and 48 hours after PCNL were statistically significant relative to their preoperative values (P < .05). Tabibi and associates retrospectively assessed 486 cases that underwent PCNL and CrCl was measured by CGF preoperatively and at 6, 24, 48 and 72 hours after operation and on the day of discharge[12]. Their findings in the initial post-operative days were almost similar to the study by Nouralizadeh and colleagues. CrCl returned to baseline level at the time of discharge from hospital. Interestingly, a study by Bayrak and co-workers has

demonstrated an improvement in renal function in the early post-operative period[7]. They prospectively evaluated 80 patients who underwent unilateral PCNL and measured CrCl by CGF preoperatively and between 72 to 96 hours after operation. The result was a statistically significant increase (104.30 ± 37.30 ml/min preoperative and 112.38 ± 40.1 ml/min postoperative) in CrCl.
In our study, we prospectively evaluated 110 patients with normal SeCr and found a statistically significant reduction in both CrCl and eGFR at 72 hours after unilateral PCNL. The results are in accordance with the outcome of other previous studies that reported a fall in CrCl in the early post-operative period[8,11,12].
Alike other studies sex, age, body weight, total procedure time, scope time and amount of irrigation fluid did not have any significant association with eGFR change [7,11,12].
In this study, we observed that even though the fall in eGFR was more in two-accesses group compared to single-access group, it was not statistically significant (P = .29). Handa and colleagues also compared single tract and multiple tracts PCNL in animal and human model and found significant decrease in renal function in both the groups, at 1.5 hours and 4.5 hours in animal study and at 24 and 48 hours in human study, without any significant difference between them[9]. Similarly, Nouralizadeh and co-workers and Bayrak and co-workers did not find any significant difference in fall of renal function between the patients with multiple accesses (usually two) and single access[7,11]. On the contrary, in the study by Hegarty and Desai comparing 40 patients with single tract versus multiple tract PCNL (2 to 6 tracts), a significant decrease in CrCl was observed in only multiple tract group, whereas there was no change in single tract cohort[15]. Limited study population and more than two accesses might be the cause of this single divergent result.
Although in the study by Saxby, a fall in serum potassium, sodium and calcium were noted 24 hours after PCNL, majority of other studies including ours did not find any change in electrolytes in the early post-operative period[7,14,,24,25]. In the study by Sichani and groups serum sodium slightly decreased from preoperative value of 140.3 ± 2.8 mEq/l to 140.1 ± 3.6, 139.1 ± 3.4 ($p < 0.01$) and 139.3 ± 2.7 ($p < 0.05$) at 6, 24 and 48 h after the operation, respectively[26]. It was probably due to the use of hyponatremic solution in postoperative period.
One of the limitations of this study is measurement of serum creatinine and electrolytes only 72 hours after operation. It would have been interesting to get some longer term data to determine long term effects. Also, the implementation of these wide exclusion criteria may compromise the generalizability of results. In addition, the degree of statistically significant drop in renal function may arguably not be clinically significant in this group of normal creatinine level patients. Finally, if the patients were compared with a controlled group that was given anaesthesia and did not perform kidney surgery other factors could have been excluded which may affect the results.

CONCLUSIONS

The results of this study show that significant impairment of renal function persists even at 72 hours after PCNL. No alteration in serum electrolytes has been observed during this period. Also, no significant difference has been noticed in drop in renal function between the patients with multiple accesses (usually two) and single access. One should keep these factors in mind when planning for PCNL and try to avoid factors which may further impair renal function in the early post-operative period like nephrotoxic drugs, contrast agents, ESWL or redo-PCNL.

CONFLICT ON INTEREST

No competing financial interest exist.

REFERENCES

1. Stoller ML. Urinary Stone Disease. In: Tanagho EA, editor. Smith's general urology, 17th ed. New York: The McGraw-Hill Companies; 2008. p. 246-77.
2. Wolf JS Jr, Clayman RV. Percutaneous nephrolithotomy: What is its role in 1997? Urol Clin North Am. 1997;24:43-58.
3. Preminger GM, Assimos DG, Lingeman JE, et al. AUA guideline on management of staghorn calculi: diagnosis and treatment recommendations. J Urol. 2005;173:1991-2000.
4. Probst CE, Denstedt JD, Razvi H. Preoperative indications for percutaneous nephrolithotripsy in 2009. J Endourol. 2009;23:1557-61.
5. Rudnick DM, Stoller ML. Complications of Percutaneous nephrolithotomy. Can J Urol. 1999;6:872-75.
6. Michel MS, Trojan L, Rassweiler JJ. Complications in Percutaneous nephrolithotomy. Eur Urol. 2007;51:899-906.
7. Bayrak O, Seckiner I, Erturhan SM, Mizrak S, Erbagci A. Analysis of changes in the glomerular filtration rate as measured by the cockroft-gault formula in the early period after percutaneous nephrolithotomy. Korean J Urol. 2012; 53: 552–5
8. Handa RK, Matlaga BR, Connors BA, et al. Acute effects of percutaneous tract dilation on renal function and structure. J Endourol. 2006;20:1030-40.
9. Handa RK, Evan AP, Willis LR, et al. Renal functional effects of multiple tract percutaneous access. J Endourol. 2009;23:1951-6.
10. Handa RK, Willis LR, Connors BA, et al. Timecourse for recovery of renal function after unilateral (single-tract) percutaneous access in the pig. J Endourol. 2010;24:283-8.
11. Nouralizadeh A, Sichani MM, Kashi AH. Impacts of percutaneous nephrolithotomy on the estimated glomerular filtration rate during the first few days after surgery. Urol Res. 2011;39:129-33.
12. Tabibi A, Khazaeli M, Modir A, Abedi A, Nabavizadeh P, Soltani MH. Early effects of percutaneous nephrolithotomy on glomerular filtration rate and determining the potential risk factors responsible for acute postoperative renal function impairment. Novel Biomed

2014;2:95-101.

13. Webb DR, Fitzpatrick JM. Percutaneous nephrolithotripsy: a functional and morphological study. J Urol. 1985;134:587-91.
14. Saxby MF. Effects of percutaneous nephrolithotomy and extracorporeal shock wave lithotripsy on renal function and prostaglandin excretion. Scand J Urol Nephrol. 1997;31:141-4.
15. Hegarty NJ, Desai MM. Percutaneous nephrolithotomy requiring multiple tracts: comparison of morbidity with single-tract procedures. J Endourol. 2006;20:753-60.
16. Cockcroft DW, Gault MH: Prediction of creatinine clearance from serum creatinine. Nephron.1976;16:31-41.
17. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D: A more accurate method to estimate glomerular filtration rate from serum creatinine: A new prediction equation. Modification of Diet in Renal Disease Study Group. Ann Intern Med. 1999;130:461-70.
18. Lai WS, Assimos D. The Role of Antibiotic Prophylaxis in Percutaneous Nephrolithotomy. Reviews in Urology 2016;18:10-14.
19. Walker R. J., Duggin G. G. Drug nephrotoxicity. Annu Rev Pharmacol Toxicol. 2008;28:331-45.
20. Stillman MT, Schlesinger PA. Nonsteroidal anti-inflammatory drug nephrotoxicity. Should we be concerned? Arch Intern Med. 1990;150:268-70.
21. Al-Kohlany KM, Shokeir AA, Mosbah A, et al. Treatment of complete staghorn stones: a prospective randomized comparison of open surgery versus percutaneous nephrolithotomy. J Urol. 2005;173:469-73.
22. Moskovitz B, Halachmi S, Sopov V, et al. Effect of percutaneous nephrolithotripsy on renal function: assessment with quantitative SPECT of (99m)Tc-DMSA renal scintigraphy. J Endourol, 2006;20:102-6.
23. Ünsal A, Koca G, Res¸orlu B, Bayindir M, Korkmaz M. Effect of percutaneous nephrolithotomy and tract dilatation methods on renal function: assessment by quantitative single-photon emission computed tomography of technetium-99m-dimercaptosuccinic acid uptake by the kidneys. J Endourol. 2010;24:1497-502.
24. Khoshrang H, Falahatkar S, Ilat S, et al. Comparative study of hemodynamics electrolyte and metabolic changes during prone and complete supine percutaneous nephrolithotomy. Nephrourol Mon. 2012;4:622-8.
25. Xu S, Shi H, Zhu J, et al. A prospective comparative study of haemodynamic, electrolyte, and metabolic changes during percutaneous nephrolithotomy and minimally invasive percutaneous nephrolithotomy. World J Urol. 2014;32:1275-80.
26. Sichani MM, Kashi AH, Al-Mousawi S, Tabibi A. An assessment of serum sodium within 48 h after percutaneous nephrolithotomy with half-strength saline solution. Urol Res. 2010;38:413-6.