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Original Article

Renal functional outcomes are not adversely affected by selective angioembolization following percutaneous nephrolithotomy

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Abstract *Objective:* Selective angioembolization (SAE) effectively diagnoses and treats iatrogenic vascular complications following percutaneous nephrolithotomy (PCNL).
Methods: We retrospectively reviewed 1329 consecutive PCNLs and identified patients who underwent SAE following PCNL with at least 12-month follow-up. Estimated glomerular filtration rate (eGFR) was calculated for all patients preoperatively, postoperatively and at last follow-up. A 1:2 matched cohort analysis was performed.
Results: Twenty-three patients underwent SAE and matched to 46 controls. There was no statistically significant difference in preoperative, postoperative, and follow-up eGFR when comparing patients who underwent SAE and those with an uneventful course.
Conclusion: Long-term eGFR is comparable in patients who undergo uncomplicated PCNL and those requiring SAE.

1. Introduction

Percutaneous nephrolithotomy (PCNL) was first described by Fernstrom and Johannson [1] in 1976 and is now the preferred approach for the management of large, complex renal stones. Despite its routine use in stone centers across the world, and the less invasive approach when compared to anotrophic nephrolithotomy, there remains a significant overall complication rate approaching 20% in contemporary cohorts [2,3]. Iatrogenic vascular injuries resulting in

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hemorrhage remain a serious complication with approximately 1%–11% of patients requiring transfusion of blood products [4–7]. While the majority of patients respond to conservative measures and recover without incident, 0.48%–2.6% will require selective angioembolization (SAE) for persistent hemorrhage or hemodynamic instability [8]. Although SAE is an effective procedure to control hemorrhage, embolization of a renal arteriole creates areas of ischemia and subsequent loss of functional parenchyma. Various authors have published their experience with vascular complications and attempted to identify potential risk factors, however the literature regarding the long-term effects on renal function in patients who underwent PCNL and required SAE for postoperative hemorrhage is limited. Furthermore, the studies available have not directly compared patients who underwent SAE to those who had a PCNL and did not necessitate SAE. The aim of this study was to investigate the renal functional outcomes in patients who underwent PCNL and required SAE, in comparison to patients who had an uneventful course.

2. Methods

After obtaining approval from the Feinstein Institute for Medical Research Institutional Review Board, we retrospectively reviewed 1329 consecutive PCNLs performed between 2008 and 2015. Patient demographics including age, gender, weight, body mass index (BMI), comorbidities, and medication history were identified. Laboratory evaluation included basic metabolic panel (BMP), complete blood count (CBC), International Normalized Ratio (INR), urinalysis, and urine culture. Patients were excluded from analysis if they did not have a serum creatinine measured at least 12 months postoperatively. Intraoperative and postoperative details including estimated blood loss (EBL), operating room time, number of punctures, number of dilations, blood product transfusion, and postoperative laboratory studies (CBC, BMP) were collected. All patients had cross sectional imaging available and images were reviewed to evaluate stone burden. Those patients who underwent SAE for postoperative hemorrhage were identified from our PCNL database. The indications for SAE included clinical signs of hemorrhagic shock, and failure to respond to conservative management (clamping nephrostomy tube, blood transfusion, intravenous fluid hydration, manual pressure, etc.). For those patients included in the final analysis estimated glomerular filtration rate (eGFR) was calculated using the Cockroft-Gault equation.

A 1:2 matched cohort analysis was performed between patients who underwent SAE for post PCNL hemorrhage and those with an uncomplicated postoperative course, adjusting for age, hypertension, and diabetes mellitus. Using SPSS® v23.0 (IBM Corporation, Armonk, New York, USA), a comparison between the two groups was performed using Chi-square test for categorical variables and Student's t-test for continuous variables. A $p < 0.05$ was used to determine statistical significance.

All SAEs were performed by interventional radiology at our institution. Direct puncture into the femoral artery was achieved under ultrasound guidance and a 5 Fr vascular sheath was advanced under fluoroscopic guidance to the abdominal aorta. A microcatheter was then directed into the renal artery and digital subtraction imaging was performed. Next a 2.8 Fr Progreat® microcatheter (Terumo Medical Corporation, Somerset, New Jersey, USA) was directed into the injured vessel of interest. A microwire was then used to direct the microcatheter to the vessel of interest and detachable coils are deployed. Postembolization angiography was performed in all patients and all patients were observed at least 24 h post procedure.

3. Results

Twenty-three (1.7%) patients underwent SAE and were matched to 46 patients who had an uneventful postoperative course. There were no significant differences in demographic data, operating room time, number of punctures, and tract dilations (Tables 1 and 2). All included patients in the cohort were managed nonoperatively, and SAE was effective in controlling hemorrhage. The mean number of blood transfusions differed between the SAE group and the control group (3.3% *vs.* 0.1%, $p < 0.001$) as did the EBL (476 mL *vs.* 162 mL, $p < 0.001$) and hematocrit change from baseline to postoperation (−10% *vs.* −5.6%, $p < 0.001$). Patients who required postoperative SAE had a significantly longer length of stay in comparison to matched controls (9.4 days *vs.* 3.2 days, $p < 0.001$) (Table 2). The mean follow-up in the SAE group and the matched cohort was 25 months and 18 months, respectively (Table 1). There was no statistically significant difference in eGFR between the SAE group and the matched control group in regards to preoperative eGFR (86.1 *vs.* 96.1 mL/min/1.73 m^2, $p = 0.432$), postoperative eGFR (85.5 *vs.* 96.4 mL/min/1.73 m^2, $p = 0.424$), follow-up eGFR (88.2 *vs.* 97.6 mL/min/1.73 m^2, $p = 0.423$), and change in eGFR between preoperative and follow-up period (2.1 *vs.* 1.9 mL/min/1.73 m^2, $p = 0.983$) (Table 3).

4. Discussion

Vascular complications following PCNL remain a worrisome complication, but most cases can be managed conservatively. Vascular injuries are the result of renal artery branch laceration, which can occur during initial needle passage for access or tract dilation. In the postoperative period, patients can present with immediate clinical signs of hemorrhage including hemodynamic instability (hypotension, shock, tachycardia), anemia, flank pain, and hematuria. Furthermore, patients can present in a delayed fashion (>3 days postoperatively), with new onset gross hematuria and aforementioned signs of hemorrhage. For these patients who continue to show signs of hemorrhage refractory to conservative measures, SAE is an effective minimally invasive approach to subside post-PCNL hemorrhage. The benefits of SAE are well established as it is effective in treating post-PCNL hemorrhage in up to 88%–100% of patients with minimal complications secondary to embolization [5,8,9]. However, SAE effectively embolizes renal artery branches and thus creates areas of ischemia in renal parenchyma. Furthermore, the detrimental of effects of contrast-induced nephropathy must be considered as well. With the use of modern SAE techniques the area of

Table 1 Baseline patient and disease characteristics.

Characteristic	All	SAE group	Matched group	p value
Patients[a]	69 (100)	23 (33.33)	46 (66.67)	–
Age (year)[b]	59.9 ± 15.0	59.5 ± 16.3	60.2 ± 14.4	0.857
Gender[a]				0.862
Male	41 (59.42)	14 (60.87)	27 (58.70)	
Female	28 (40.58)	9 (39.13)	19 (41.30)	
BMI[b]	31.9 ± 8.5	29.6 ± 7.9	33.0 ± 8.6	0.115
Comorbidities[a]				
Hypertension	48 (69.57)	16 (69.57)	32 (69.57)	1.000
Diabetes mellitus	15 (21.74)	5 (21.74)	10 (21.74)	1.000
Hyperlipidemia	25 (36.23)	6 (26.09)	19 (41.30)	0.215
Coronary artery disease	8 (11.59)	2 (8.70)	6 (13.04)	0.595
Medications[a]				
Aspirin	16 (23.19)	4 (17.39)	12 (26.09)	0.245
Clopidogrel	2 (2.90)	1 (4.35)	1 (2.17)	0.701
Coumadin	5 (7.25)	3 (13.04)	2 (4.35)	0.889
Stone size[a]				0.008
<2 cm	31 (44.93)	5 (21.74)	26 (56.52)	
≥2 cm	38 (55.07)	18 (78.26)	20 (43.48)	
Full staghorn[a]	12 (17.39)	8 (34.78)	4 (8.70)	0.013
Follow-up (month)[c]	19 (16)	25 (31.5)	18 (14.75)	–

BMI, body mass index; IQR, interquartile range; SAE, selective angioembolization.
[a] Values are presented as n (%).
[b] Values are presented as mean ± SD.
[c] Values are presented as median (IQR).

Table 2 Perioperative characteristics and complications (mean ± SD).

	SAE group (n=23)	Matched group (n=46)	p value
Length of stay (day)	9.4 ± 6.9	3.2 ± 2.0	<0.001
Operative time (min)	76 ± 48	82 ± 30	0.589
Tract dilations (tract)	1.70 ± 1.02	1.38 ± 0.78	0.209
Punctures (time)	1.83 ± 1.07	1.44 ± 0.88	0.146
EBL (mL)	476 ± 480	162 ± 217	<0.001
Transfusions (PRBC unit)	3.30 ± 3.05	0.10 ± 0.38	<0.001
Change in hematocrit (%)	−10.1 ± 5.0	−5.6 ± 3.9	<0.001

EBL, estimated blood loss; SAE, selective angioembolization.

Table 3 Perioperative and long-term renal function outcomes (mean ± SD).

	SAE group (n=23)	Matched group (n=46)	p value
Preoperative renal function			
Creatine (mg/L)	11.4 ± 4.5	12.8 ± 6.9	0.409
eGFR (mL/min/1.73 m^2)	86.1 ± 36.6	96.1 ± 56.8	0.432
Postoperative renal function			
Creatine (mg/L)	12.9 ± 8.1	12.8 ± 6.6	0.918
eGFR (mL/min/1.73 m^2)	85.5 ± 40.8	96.4 ± 57.8	0.424
Long-term renal function			
Creatine (mg/L)	11.7 ± 5.4	12.3 ± 7.9	0.748
eGFR (mL/min/1.73 m^2)	88.2 ± 42.8	97.6 ± 46.8	0.423
Long-term change in renal function			
Creatine (mg/L)	0.2 ± 2.7	−0.2 ± 4.8	0.653
eGFR (mL/min/1.73 m^2)	2.1 ± 22.5	1.9 ± 24.0	0.983

eGFR, estimated glomerular filtration rate; SAE, selective angioembolization.

infarction to the renal parenchyma can be minimized, but the effects on long-term renal function remain unclear.

In our study we found no significant difference in the eGFR between patients who underwent SAE postoperatively and controls with an uneventful postoperative course. This association was maintained from the preoperative period, postoperatively, and up to the last follow-up. Most reports investigating the effects of SAE on long-term renal function were composed of a heterogeneous study population including patients with renal hemorrhage secondary to trauma, renal biopsy, and partial nephrectomy. Mohsen et al. [10] investigated the long-term functional and morphological effects of SAE by evaluating serum creatinine, renal ultrasound, intravenous urography and radionucleotide studies (MAG3 and DMSA scan). After a mean follow-up of 4.6 years they found that 64% of patients had solitary photopenic areas on DMSA scan, while 22% had multiple photopenic areas at 3 months. More importantly, 14% had no evidence of scarring and this number increased to 21% of the population at last follow-up. Furthermore, MAG3 scans performed at 3 months and at last follow-up showed an improvement in GFR from 26 mL/min to 32 mL/min, respectively. Finally, the group found that SAE was most detrimental for those patients with a solitary kidney, where four of the nine patients demonstrated an average increase in creatinine of 3.25 mmol/L. The same group performed a similar study focusing specifically on patients undergoing PCNL. Thirty patients in the cohort had long-term follow-up ranging between 1.9 and 9.2 years [9]. When comparing DMSA scans at 3 months and at last follow-up, patients with single photopenic areas decreased from 64% to 57% and those with no detectable photopenic areas increased from 13% to 20%. Similar to their previous study, patients with a solitary kidney demonstrated the most pronounced deleterious effects to renal function. Similar to their prior study, they concluded that renal function and morphology improves in patients requiring SAE. Our study differs in that we compared patients who underwent SAE to a control group with an uneventful postoperative course, as opposed to observing the effects on renal function with intervention without a comparable control group. Both of our study's cohorts began with comparative renal function and showed no statistically significant difference in follow-up. This information becomes important when counseling patients about the complications of PCNL. Although patients should be made aware that they may undergo a second procedure, ultimately their postoperative renal function and long-term renal function is comparable to those never suffering a vascular complication. Based on our results SAE remains an important tool in managing vascular complications secondary to PCNL.

There are several limitations to this study including the retrospective nature of the study, small sample size, and relatively short follow-up. Furthermore, we did not investigate morphological changes in the kidney following SAE and did not include stone volume as part of our calculation. Details regarding the development of hypertension also would be important in assessing the SAE group in the future. We believe that the strengths of our study lie in homogeneity of the study population in regards to demographics, numbers of tract dilations and preoperative renal function. Furthermore we controlled for age, and history of diabetes or hypertension so that any change in renal function would be a result of the intervention rather than predisposing factors. Finally our analysis used the Cockroft-Gault equation to calculate eGFR, rather than relying on radionucleotide studies as was done in prior studies.

5. Conclusion

SAE is an effective tool in controlling bleeding secondary to a vascular injury sustained during PCNL. Long-term eGFR is comparable in patients who undergo uncomplicated PCNL and those that require SAE to control hemorrhage.

Conflicts of interest

The authors declare no conflict of interest.

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