Effect of shockwave lithotripsy before percutaneous nephrolithotomy on the risk of renal arteriovenous fistula

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ABSTRACT

KEY MESSAGES

- PNCL after SWL can increase the risk of arteriovenous fistula.
- Arteriovenous fistulas can be successfully treated with angioembolization.

Introduction: This study aimed to assess the impact of shockwave lithotripsy (SWL) on the incidence of renal arteriovenous fistula (AVF) following percutaneous nephrolithotomy (PCNL).

Methods: We retrospectively analyzed data from patients who underwent PCNL and/or SWL for kidney stones, as well as angioembolization for renal AVF, between January 2000 and December 2024. Patients with inadequate followup or insufficient medical records were excluded. Patients were divided into two groups: The first group included those who did not undergo SWL before PCNL, while the second group included those who underwent SWL. Various patient factors, stone characteristics, and surgical features were compared between the groups.

Results: We reviewed data from 851 PCNL patients, 3043 SWL patients, and 31 patients who underwent angioembolization for renal AVF. Fourteen patients were excluded due to insufficient data. A total of seventeen patients (1.2%) developed renal AVF after PCNL, with 13 (76.5%) of them having undergone prior SWL at the same renal unit. In the group with a history of SWL

before PCNL, the odds ratio calculated for the occurrence of AVF was 190.4. (95% confidence interval 55.1–657.1, $p<0.001$).
Conclusions: AVF is a serious complication that occurs after vascular damage. Both SWL and PCNL are among the treatments that can cause this complication. Due to their additive effects, performing SWL and PCNL consecutively in a short period appears to increase the risk of developing AVF. Careful patient management is essential to minimize this risk.

INTRODUCTION

Nowadays, urinary stone prevalence varies from 1 to 15%, and this ratio depends on geographical regions.[1] Patients with urinary stones receive various therapeutic modalities based on the specific characteristics of the stone, including its location, composition, hardness, and radioopacity. Two of the well-known modalities employed for this purpose include percutaneous nephrolithotomy (PNL) and shockwave lithotripsy (SWL). Typically, we advocate SWL with dimensions below 20 mm, while we deem PNL more appropriate above 20 mm for kidney stones; however, in certain instances, we may employ a combination of these two methods.[2] Despite the successful application of these therapeutic modalities in numerous clinical settings globally, PNL and SWL are associated with certain complications is the development of renal arteriovenous fistula (AVF), which is a rare but potentially fatal outcome. The primary cause of hospital admission is typically macroscopic hematuria, often manifesting within a week following the procedural intervention. Upon confirmation of the diagnosis of renal AVF through Doppler ultrasonography and/or angiography, successful management can be achieved through selective embolization.[3]

This article aims to investigate the impact of SWL on the incidence of renal AVF following PNL.

METHODS

The data of patients who underwent PNL and/or SWL for kidney stones and angioembolization for renal AVF between January 2000 and December 2024 were retrospectively analyzed. The study included patients who underwent angioembolization to treat renal AVF that developed following PNL. The data from 851 patients who underwent PNL for renal stones, 3043 patients who underwent SWL for urinary stone disease, and 31 patients who underwent angioembolization for renal AVF were reviewed. Every patient with AVF underwent angioembolization, and no patient underwent conservative monitoring. Patients who had open renal surgery on the same renal unit in the past, had renal anomalies, or had problems with clotting were not included. Fourteen patients were excluded due to insufficient data about the patients. The study included 17 patients who developed renal AVF after PNL.

Ethics committee approval was obtained from the Research Ethics Committee of Baskent University (Protocol No: KA 24/81).

PNL procedure
After placing a cystoscopic ureteral catheter in the lithotomy position and using the Bull's Eye technique to access it, we operated on all patients in the prone position under general anesthesia. Following the insertion of the safety guidewire, the tract dilated up to 32/30 French (F) with Amplatz or balloon dilators. The stones were fragmented with a pneumatic or holmium laser lithotripter via a 22.2 F nephroscope, and the stone fragments were collected with forceps. According to the surgeon's preference, all procedures ended with a ureteral catheter or re-entry nephrostomy catheter.

SWL procedure
The SWL was performed under sedoanalgesia with fluoroscopy or ultrasonography guidance. The energy levels gradually increased up to the desired level, and the SWL session terminated with confirmation of stone fragmentation or reaching the safe shockwave number. During the follow-ups, we planned the number of SWL sessions, but we did not apply SWL to more than three sessions. Our SWL device is a third-generation electromagnetic lithotripter with enhanced shock wave parameters and an endoscopic treatment table. The penetration depth has been increased to 14 cm, and a new shock wave head has been used. The traditional spark gap in the device's electrical circuit has been replaced with a semiconductor switch. It has an elliptical focal area of 5x80 mm and a peak energy level of 101 mJ.

The diagnosis of renal AVF
The renal AVF was suspected due to the persistent macroscopic or gross hematuria or decreasing hemoglobin (Hb) levels. Renal angiography confirms the diagnosis.

The arteriovenous angioembolization technique
Interventional radiologists performed the embolization procedure. The Seldinger technique allowed access through the common femoral artery.[4] Renal angiography images were obtained using a hydrophilic guide wire. The images revealed an AVF. Subsequently, for the catheterization of the renal artery, a renal guiding catheter and a 0.018-inch guide wire were used. The segmental branch of the renal artery connected to the AVF was catheterized using a microcatheter. Subsequently, glue or coils were employed for vessel embolization in Figure 1-3.

Data interpretation
The first group included those who did not undergo SWL before PNL, while the second group included those who underwent SWL. Various factors pertaining to patients (such as age, gender, presence of accompanying systemic diseases like diabetes mellitus (DM) and hypertension (HT), history of open renal surgery or PNL for the same renal unit, presence of renal anomalies and coagulation disorders, and Hb levels), stone characteristics (size, side, location in the kidney, stone type), and surgical features (entry route and tract selection for accessing the stone, number of tracts, method for tract dilation, and type of catheter placement post-procedure) were compared.

Statistical analysis

The statistical tests were performed using the statistical package SPSS (Version 26.0, SPSS Inc., Chicago, IL, USA). Histograms and the Kolmogorov-Smirnov and Shapiro-Wilk tests were both used to determine the normality of each continuous variable. The categorical variables between the groups were analyzed using the chi-square test or Fisher's exact test. The risk of outcome measurements was calculated using the odds ratio. Values of $p < 0.05$ were considered statistically significant.

RESULTS

Patient-related data, such as gender and age distribution, the history of diseases causing vasculopathy like HT and DM, blood transfusion requirements, and stone-related data like stone compositions and measurements, which kidney the stone is in, and in which calyx of that kidney the stone is located, are given in Table 1.

While the stone was reached with a single access in 10 patients, a second access was needed in 7 patients. Intercostal access was required in only 2 patients. We used balloon dilatation in 10 patients and Amplatz dilatation in 7 patients for tract dilation. At the end of the surgery, a re-entry nephrostomy catheter was placed in 14 patients, and a ureteral catheter was placed in 3 patients. In terms of the risk of renal AVF development, there was no statistically significant difference between the groups with respect to access site, number of accesses, dilatation method, and catheter preference after PNL. We achieved stone-free status in 9 patients; however, 4 patients had <4 mm and 4 patients had ≥4 mm of residual fragments.

A total of 17 patients (1.2%) who developed renal AVF after PNL were included in the study, with 13 (76.5%) of them having undergone SWL at the same renal unit prior to the PNL procedure. All these 13 patients (SWL group) had unsuccessful 3 SWL sessions with a median of 10,750 (9000–13000) shocks. The median time between the last SWL session and PNL was 11 weeks (5-21). In the group with a history of SWL before PNL, the odds ratio calculated for the occurrence of AVF was 190.4. (95% CI: 55.1–657.1) ($p < 0.001$).

DISCUSSION

DM and HT are some of the well-known vasculopathy causes worldwide. AVF refers to abnormal connections between an artery and a vein, which can sometimes occur due to surgical traumas.[5] Therefore, this kind of illness affecting vascular systems may increase complication rates after surgery. We found no statistically significant difference between the two groups; however, the small number of patients in our study may have contributed to this finding. In contrast to our study, Irani et al. identified DM as a contributing factor ($p = 0.004$), while HT did not show a significant association ($p = 0.332$).[6] Nouralizadeh A et al.[7] also found HT and DM statistically insignificant for bleeding after PNL; however, the number of patients in this study is quite small as well. Additional studies with larger patient cohorts are necessary to better understand the role these conditions may play in the development of renal AVF, with a focus on examining the effects of acute and chronic vascular alterations.

Hematuria, arguably the most significant symptom signaling the onset of post-operative AVF, is also regarded as one of the severe complications requiring intervention that happens in less than 2% of patients.[8] Although post-PCNL hemorrhage due to AVF formation seems to be a rare phenomenon, it can be lethal if not diagnosed and treated in a well-timed manner.[9] In the literature, post-PNL hemorrhage-related hemoglobin drops have been significant.[10-12] We found that there was no statistical difference in blood loss between the groups with and without SWL before PNL. In cases of pronounced postoperative hematuria, substantial decreases in hemoglobin levels, or hemodynamic instability, angiography with selective angioembolization represents the established approach for managing these vascular complications.[13] Our series shows a higher incidence of arterial complications requiring angioembolization than the literature reports. We do not prefer a conservative approach in cases of persistent hematuria after PNL unless there is another underlying cause of bleeding diathesis.

Our study did not identify a significant correlation between stone types and the risk of developing renal AVF. Numerous studies have not evaluated the relationship between stone type and hemorrhage after PNL. We also found the stone type unrelated to postoperative bleeding, like Irani et al. However, it should not be forgotten that stones resistant to fragmentation both reduce the success of SWL and may require more manipulation during lithotripsy in PNL, thereby increasing the risk of vascular damage.[6]

Except for patient-related factors, the characteristics of PNL, like unsuccessful accesses, repeated puncture attempts, and upper or mid-pole access causing AVF, are also a topic of discussion in the literature. Turna et al.[14] found that AVF complications happened more often after PNL in patients who had staghorn stones or who needed more than one puncture during PNL surgery. Multiple punctures and operative time were introduced as predictive factors for severe postoperative bleeding. The cutoff point of mean operative time as a potential risk factor for postoperative blood transfusion was 58, 90, and 119 min in the reports by Akman, Wang, and Keoghane,[15-17] respectively. In addition, during tract dilation in PNL, the risk of AVF development may increase due to the size of the dilation. Yamaguchi et al.[18] found that patients who underwent PNL with a larger sheath size experienced postoperative AVF more frequently. There are studies indicating an increased risk of AVF when surgery is completed tubeless after PNL.[7] In our study, we also did not observe any association between PNL-related factors and the development of renal AVF, probably due to the small number of patients. It is certain that extensive series of studies are needed to find more accurate results.

Some studies have shown that acute traumas like SWL can temporarily alter the renal resistive index (RI), but it remains unclear whether SWL has permanent effects on renal vessels.[19] However, there are studies stating that RI returns to its pre-SWL state within 3–4 days.[20] After SWL, even if the RI returns to its pre-SWL value, nothing can be definitively said about the likelihood of vascular structures returning to their former elasticity. In our study, the post-PNL renal AVF development risk in the first 12 weeks after SWL was higher. This may necessitate looking at other parameters to detect AVF risk. As a conclusion, the vascular injuries that likely occur after SWL, combined with the trauma from PNL surgery during the acute period, can be interpreted as increasing the risk of AVF. Although more studies need to be conducted to use clearer expressions, it seems wiser to wait for this acute period to pass in patients where we plan to perform PNL surgery after SWL.

Limitations

The study's limitations, including a small cohort size, a retrospective design with uncontrolled parameters, and high data heterogeneity, pose challenges to its interpretation and complicate comparisons.

CONCLUSIONS

Renal AVF, a rare but potentially serious complication of the PNL procedure, occurs after vascular damage. Both SWL and PNL are among the treatments that can cause this complication separately; however, the risk may be higher when patients have both procedures consecutively in a short period of time because of the additive effect. If PNL surgery is planned for patients after SWL, it would be more reasonable to wait for the acute period to pass to be aware of AVF.

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FIGURES AND TABLES

Figure 1. Post-percutaneous nephrolithotomy angiography. Renal arteriovenous fistula in the lower pole of the right kidney.

Figure 2. Selective angiography revealing an arteriovenous fistula.

Figure 3. Post-embolization control angiography demonstrating successful occlusion of the arteriovenous fistula with coils, with no residual shunt.

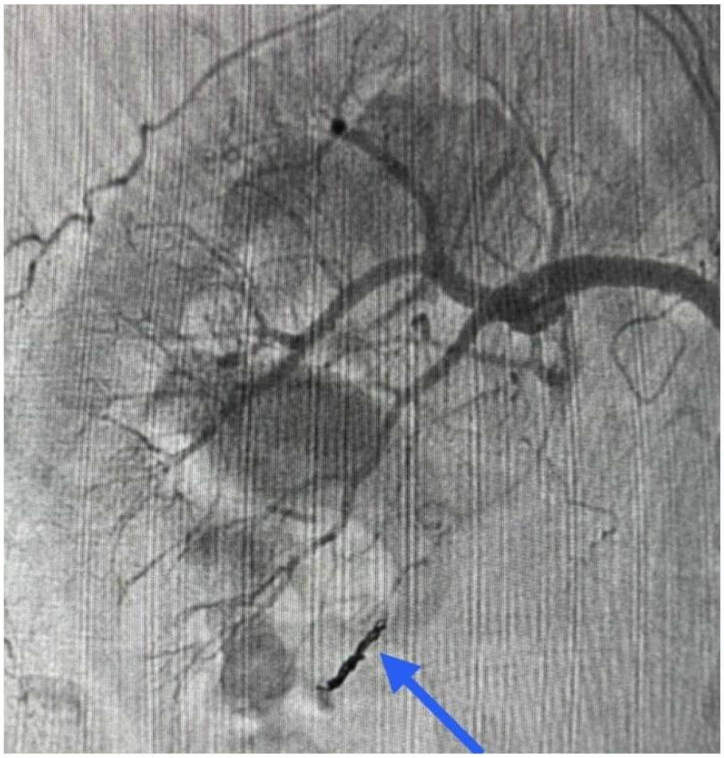

Table 1. Patient, stone, and percutaneous nephrolithotomy-related factors

Patients-related	**Non-SWL group**	**SWL group**	**Total**	**p**
n (%)	4 (23.5)	13 (76.5)	17 (100)	
Age (years)[a]	36.5 (25–49)	35 (18–61)	38.4 (18–62)	0.386
Gender (n, %)				
Male	2 (11.8)	9 (52.9)	11 (64.7)	0.584
Female	2 (11.8)	4 (23.5)	6 (35.3)	
Systemic disease (n, %)				
Hypertension	1 (5.9)	4 (23.5)	5 (29.4)	0.670
Diabetes mellitus	2 (11.8)	3 (17.6)	5 (29.4)	0.330
Hemoglobin (g/dL)[b]				
Preoperative	13.6±2.3	13.6±2.2	13.6±2.2	
Postoperative	12.5±1.6	11.7±1.5	11.8±1.5	0.293
Pre-angioembolization	9.5±1.5	9.2±1.3	9.3±1.3	
Stone-related				
Diameter (mm)[a]	18.5 (17–20)	22.3 (18–26)	20 (17–26)	0.507
Side (n, %)				
Left	3 (17.6)	6 (35.4)	9 (53.0)	0.603
Right	1 (5.9)	7 (41.2)	8 (47.0)	
Location (n, %)				
Upper pole	–	2 (11.8)	2 (11.8)	
Middle	1 (5.9)	5 (29.4)	6 (35.3)	0.740
Lower pole	1 (5.9)	2 (11.8)	3 (17.6)	
Pelvis	2 (11.8)	4 (23.5)	6 (35.3)	
Type (n, %)				
Calcium oxalate	3 (17.6)	10 (58.8)	13 (76.4)	
Uric acid	–	2 (11.8)	2 (11.8)	0.243
Carbonate apatite	–	1 (5.9)	1 (5.9)	
Brushite	1 (5.9)	–	1 (5.9)	
PNL-related				
Access route (n, %)				
Middle	2 (11.8)	7 (41.2)	9 (53.0)	0.744
Lower pole	2 (11.8)	6 (35.3)	8 (47.0)	
Second access (n, %)				
Middle	–	3 (17.6)	3 (17.6)	0.441

Upper pole	1 (5.9)	3 (17.6)	4 (23.5)	
Intercostal access (n, %)				
No	3 (17.6)	12 (70.6)	15 (88.2)	0.426
Yes	1 (5.9)	1 (5.9)	2 (11.8)	
Dilatation type (n, %)				
Amplatz	1 (5.9)	6 (35.3)	7 (41.2)	0.441
Baloon	3 (17.6)	7 (41.2)	10 (58.8)	
Tube type (n, %)				
Nephrostomy	4 (23.5)	10 (58.8)	14 (82.3)	0.421
Ureteral tube	–	3 (17.6)	3 (17.6)	

[a]Data presented as mean ± standard deviation. [b] Data presented as median (minimum-maximum). PNL: percutaneous nephrolithotomy SWL: shockwave lithotripsy.