Capsulotomy for Treatment of Compartment Syndrome in Patients with Post Extracorporeal Shock Wave Lithotripsy Renal Hematomas: Safe and Effective, But Also Advisable?

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Purpose: To examine whether surgical decompression of hematomas by capsulotomy can help to improve long-term renal function following extracorporeal shock wave lithotripsy (SWL).

Materials and Methods: This study retrospectively identified 7 patients who underwent capsulotomy for post SWL renal hematomas between 2008 and 2012. The control group comprised 8 conservatively treated patients. The median follow-up time was 22 months.

Results: The two groups were comparable in age, gender, body mass index, risk factors for developing hematomas (renal failure, urinary flow impairment, indwelling ureteral stent and diabetes mellitus) and the selected SWL modalities. Hematoma size was also similar. However, significantly more patients in the surgical group had purely intracapsular hematomas (85.7% vs. 37.5%) without a potentially pressure-relieving capsular rupture. There were no significant differences in the post-interventional drop in hemoglobin, rise in retention parameters or drop in glomerular filtration rate (GFR). No capsulotomy-related complications were observed, but surgery required a significantly longer hospital stay than conservative management (median, 9 days vs. 5 days). The two groups also showed comparable recovery of renal function at long-term follow-up (median change in GFR from baseline, 97.1% and 97.8%, respectively).

Conclusion: Since renal function did not differ between the two treatment groups, the conservative management remains the standard treatment for post-SWL renal hematoma.

Keywords: hematoma; etiology; therapy; lithotripsy; adverse effects; urolithiasis; decompression; surgical.

INTRODUCTION

Extracorporeal shock wave lithotripsy (SWL) is an effective noninvasive method for treating urolithiasis, particularly in the pelvicalyceal system and upper third of the ureter.[1,2] Generation of focused acoustic shock waves (electromechanical, electrohydraulic or piezoelectric) achieves stone fragmentation by the resulting tear and shear forces and cavitation.[3,4] This noninvasive technique has limited side effects. The intended stone disintegration and subsequent passage of stone fragments cause most of the complications (renal colic and ureteral obstruction). In rare cases, however, post-SWL renal and/or perirenal hematomas can also occur as more serious complications. The reported incidence of clinically significant post-SWL renal hematomas varies between 0.28 and 4.1%, depending on the publication.[5-8)]

Bleeding is thought to occur because the tear and shear forces and cavitation induced for stone disintegration not only impact the target concrement but also act on and arise from surrounding soft tissues and organs. This can already lead to damage at the cellular level with subsequent bleeding and hematomas. Morphological analyses of porcine kidneys after SWL therapy have shown that the applied energy causes damage particularly to the renal vessels from the cortical capillaries to the interlobular vessels or the arcuate arteries and veins.[8,9]

The following have been identified as risk factors for post-SWL hematomas: advanced age ($\geq$ 70 years), arterial hypertension, clotting disorders, oral anticoagulant therapy [particularly with acetylsalicylic acid (Aspirin)], diabetes mellitus, overweight [body mass index (BMI) $\geq$ 30 kg/m^2], oral corticosteroid therapy, arteriosclerosis, impaired renal function and urinary obstruction at the time of intervention.[5,8,10] Bleeding usually manifests clinically as flank pain and orthostatic symptoms. Ultrasonography (US) and computed tomography (CT) scan are now most commonly used to identify and evaluate post-SWL renal hematomas.[6]

The literature primarily favors conservative treatment of post-SWL renal hematomas, particularly in hemodynamically stable patients and recommends surgery only in cases of uncontrollable bleeding with unstable hemodynamics.[6,8]

Capsulotomy is an alternative treatment approach for large hematomas that impair renal tissue perfusion. It involves incising Gerota's fascia, decompressing the hematoma, and inserting a drain.[11] In recent years, this surgical procedure has been performed in individual cases of subcapsular renal hematoma with compression of the renal parenchyma and relevant impairment of renal perfusion and function demonstrated in some cases with Tc99m-MAG3 (Mercaptoacetyltriglycine) scan. The idea behind this surgical intervention was to achieve early kidney decompression in cases of compression-induced functional impairment comparable to lower extremity compartment syndrome.

This case-control study evaluates the safety, effectiveness and potential benefit of capsulotomy in a defined number of patients. The intervention was performed in patients with significant hematoma-related impairment of renal perfusion and/or function on contrast-enhanced CT scan or MAG3 scans in the acute phase after SWL.

MATERIALS AND METHODS

SWL was performed to treat urolithiasis in 1,344 patients at the Department of Urology, Ulm University Medical Center, between 2008 and 2012. The Siemens Lithoskop lithotripter (Siemens AG Healthcare, Erlangen, Germany) from 2007 was used in all cases. Retrospective analysis of all treatment cases identified seven patients who developed a significant hematoma and were treated by capsulotomy during this period. The reference group comprised eight patients with post-SWL hematomas that were treated conservatively during the same period.

To enable a comparison of the two groups (with and without capsulotomy), the following data were collected in patients with post-SWL hematomas: gender, age, BMI, comorbidities such as arterial hypertension, diabetes mellitus and urine transport disorders, pre- and post-SWL renal function, the number and strength of shock waves applied, the hematoma size and the hemoglobin drop recorded in the laboratory as well as the hospital stay after SWL treatment. In addition, patients were monitored by US for residual post-SWL renal hematomas at follow-up. The two groups were compared.

Statistical Analysis

Data presentation and analysis were done using the statistical package for the social science (SPSS Inc, Chicago, Illinois, USA) version 19.0. Data not normally distributed were given as median values; their distribution was de-

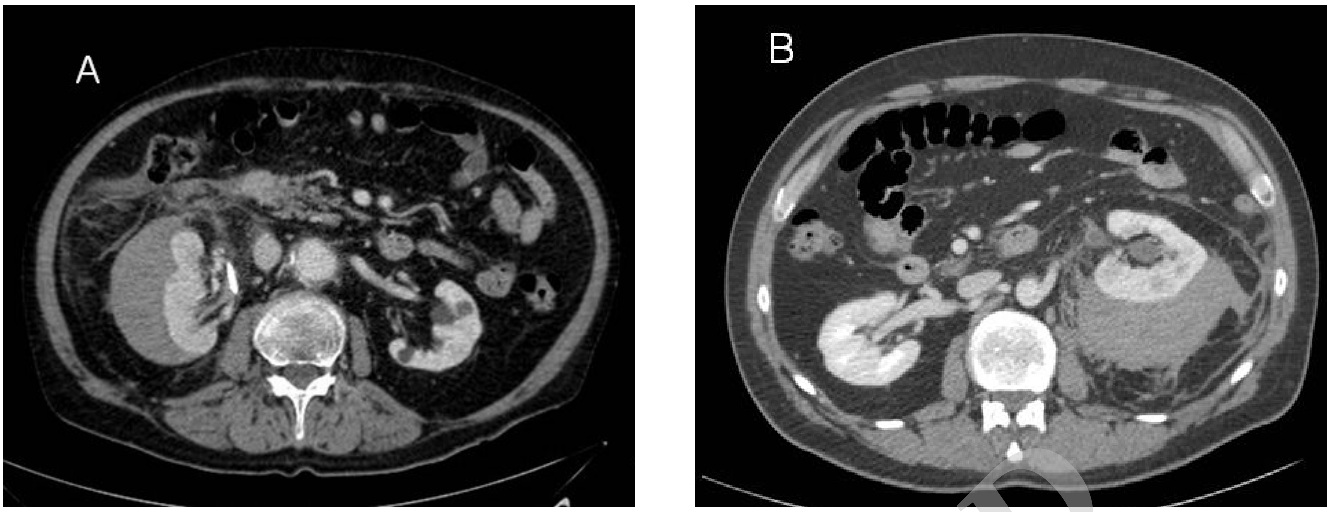

Figure 1. Examples of a purely intracapsular post- extracorporeal shock wave lithotripsy renal hematoma (A) with increased intrarenal pressure and reduced renal perfusion as well as a hematoma with partial capsular rupture (B).

scribed using "interquartile ranges" (IQR).

RESULTS

The median as well as the mean follow-up of the total patient population (n = 15) was 22 (IQR, 10-37) months and did not differ significantly between the patients who underwent capsulotomy and those who received conservative treatment (see Table).

Patient Population

The two groups (with and without capsulotomy) did not differ significantly in their risk of developing a hematoma: 71.4 and 75.0% were men; 14.3 and 12.5% had urinary obstruction at the time of SWL treatment; 28.6 and 25.0% showed renal failure prior to therapy (Table). Their median BMI was also comparable (28.1 and 28.2 kg/m^2). Patients submitted to capsulotomy had a somewhat higher median age (63 versus 52 years; P = .27, Mann-Whitney U test), already had an indwelling ureteral splint more often at the time of shock wave therapy (71.4 vs. 25.0%, P = .13, Fisher's exact test) and suffered significantly more often from arterial hypertension (57.1 vs. 0.0%; P = .03, Fisher's exact test) (Table).

SWL Treatment

Patients were treated with a median total dose of 3,000 shock waves; a total energy of 50 joules was applied and a maximum energy level of 3.0 was reached. Here too, no significant differences were found between the two treatment groups (also see Table).

Treatment Results and Long-Term Complications

The median size of renal hematomas did not differ (71 and 68 mm; Table). Similarly, both groups had a comparable drop in the hemoglobin level. The median level of hemoglobin at diagnosis of the hematoma was 86.9 and 87.1% of the baseline level. However, far more patients in the surgical group had purely intracapsular hematomas without evidence of capsular rupture (85.7 vs. 37.5%; Figure 1).

Renal function before SWL treatment did not differ between the two groups. The median serum creatinine level was initially 89 µmol/L (IQR, 78-101 µmol/L) in the patients who later underwent capsulotomy and also 89 µmol/L (IQR, 83-95 µmol/L) in those who received conservative treatment. Accordingly, baseline glomerular filtration rate (GFR) values were similar.

After developing the post-SWL renal hematoma, the GFR showed a similar median decrease in both groups, dropping to 69.5% of baseline (IQR 59.5-83.7%) in the capsulotomized group and to 80.6% of baseline (IQR 62.3-93.6%) in the conservatively treated group (P = .49, Mann-Whitney U test). No difference in renal function was found between the two groups after a median follow-up of 22 months; the GFR was 97.1% (IQR 94.8-136.8%) and 97.8% (IQR 92.0-106.8%) of the baseline value (P = 1.00, Mann-Whitney U

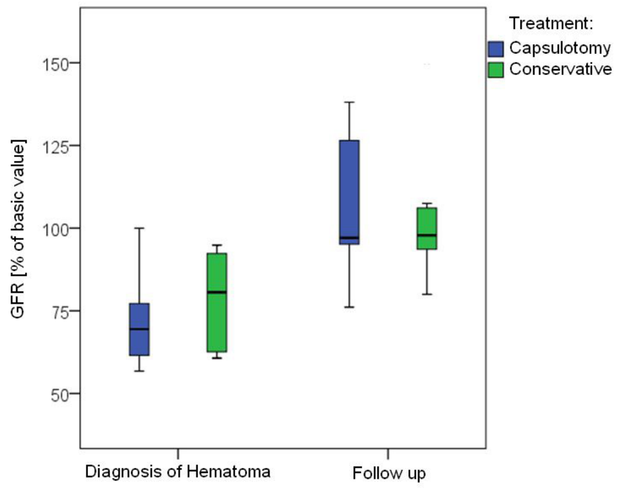

Figure 2. Overall kidney function (glomerular filtration rate, GFR) relative to pre- extracorporeal shock wave lithotripsy renal function in the acute phase of the hematoma and in the interval after a median follow-up of 22 months.

test; Figure 2). The median hospital stay after SWL differed significantly between the two groups; 9 (6-14) days for the surgically and 5 (2-7) days for the conservatively treated group (P = .003; Fisher's exact test).

DISCUSSION

The current literature favors conservative management for post-SWL renal bleeding in hemodynamically stable patients. An active approach in terms of a surgical intervention is only recommended in cases of uncontrollable bleeding and unstable hemodynamics.[6,8,9] Various studies have shown that conservative treatment of renal hematomas is usually not associated with any marked long-term defects like impaired renal function.[9,12] It has also been reported that most renal hematomas dissolve over a period of two years with no long-term functional or morphological sequelae.[8,9,12] On the other hand, reductions in renal function have also been described during the long-term follow-up after (repeated) SWL therapy.[13-16]

Surgical decompression by capsulotomy is an invasive experimental treatment option for post-SWL renal subcapsular hematomas. The idea behind this approach is early kidney decompression as a strategy for managing compartment syndrome, which is associated with short- and possibly long-term parenchymal damage (page kidney).[11] The aim was to avoid acute but particularly also persistent impairment of renal function and sequelae such as arterial hypertension, renal failure and shortened life expectancy.

The indication for capsulotomy in the retrospectively investigated patient population was based on the following: the patient's symptoms, the CT scan morphology of hematoma extension (including compression of the renal parenchyma), significant reduction of renal perfusion and, if available, the detection of impaired renal function on MAG3 scans in the acute phase. The primary aim was ideally to achieve fast and complete recovery of renal function by early surgical decompression of the kidney.

This retrospective analysis was performed to determine the long-term benefit or harm of capsulotomy, since it is still considered an experimental treatment. Seven patients identified as having undergone capsulotomy between 2008 and 2012 were compared with a control group who received conservative treatment.

All patients included in the study still exhibited residual SWL-induced defects and/or hematomas on follow-up US scans (after a median of 22 months). This finding contradicts reports in the literature describing complete "resolution" of hematomas within several months, two years at most.[12,17]

Our case-control study with a limited number of patients revealed no difference between the two treatment groups with regard to long-term impairment of renal function. Both surgically and conservatively treated patients regained median values of renal function nearly identical to the pre-SWL baseline values. The two groups only differed significantly in the length of hospital stay with a median of 9 days in the surgical and 5 days in the conservative group.

The results presented here do not support capsulotomy as a routine procedure for treating significant renal hematomas. Long-term results were similar after surgical and conservative treatment. Thus the invasive intervention cannot be recommended without a verifiable long-term benefit. However, this is a purely retrospective analysis involving very limited number of patients, and not all of them had preoperative or follow-up renal scans to assess split renal function. The specific symptoms of hematoma experienced by each individual (which may have influenced the decision to perform surgery) could no longer be clearly established retrospectively and

Table . Patient-specific characteristics, treatment and results.

Parameters	All Patients (*n* = 15)	Capsulotomy (*n* = 7)	Medical Management (*n* = 8)	*P*
Follow-up, median (days)	680 (30-1443)	680 (30-1443)	685 (141-1205)	.82*
Age[1], median (years)	54 (40-85)	63 (43-85)	52 (40-81)	.27*
BMI[1], median (kg/m^2)	28.2 (24.6-38.5)	28.1 (24.6-38.5)	28.2 (25.2-31.2)	.91*
Male gender[1]	11 (73.3%)	5 (71.4%)	6 (75.0%)	1.00**
Urinary obstruction[1]	2 (13.3%)	1 (14.3%)	1 (12.5%)	1.00**
Ureteral stent[1]	7 (46.7%)	5 (71.4%)	2 (25.0%)	.13**
Arterial hypertension[1]	4 (26.7%)	4 (57.1%)	0	.03**
Diabetes mellitus[1]	2 (13.3%)	2 (28.6%)	0	.20**
Preexisting renal failure[1]	4 (26.7%)	2 (28.6%)	2 (25.0%)	1.00**
Anticoagulants[1]	0.0	0.0	0.0	NA
Total energy applied, median (joules)	50 (14.4-81.1)	56.6 (27.9-78.3)	47.4 (14.4-81.1)	.20*
Number of shock waves, median	3000 (1500-3500)	3500 (2500-3500)	3000 (1500-3500)	.28*
Maximum energy level, median	3.0 (1.7-4.0)	3.5 (2.2-4.0)	2.9 (1.7-4.0)	.22*
Hematoma size, median (mm)	70 (30-100)	71 (47-100)	68 (30-99)	.36*
Purely intracapsular hematoma, no. (%)	9 (60.0)	6 (85.7)	3 (37.5)	.12**
Hb acute[2] (% of baseline value)	87.0 (62.0-100)	86.9 (62.0-100)	87.1 (70.3-97.5)	.95*
GFR acute[2] (% of baseline value)	70.7 (56.8-100)	69.5 (56.8-100)	80.6 (60.7-94.9)	.49*
GFR in the interval[3] (% of baseline value)	97.4 (76.1-150.7)	97.1 (76.1-138.1)	97.8 (80.0-150.7)	1.00*
Hospital stay (days)	6 (2-14)	9 (6-14)	5 (2-7)	.003*

Keys: Hb, hemoglobin; GFR, glomerular filtration rate; NA, not applicable; BMI, body mass index.
1= pre-SWL; 2 = at diagnosis of hematoma; 3 = in the interval relative to the individual lengths of follow-up prior to analysis.
* Mann-Whitney *U* test.
** Fisher's exact test.

thus could not be compared between the two groups. The localization of hematomas also differed between the groups. Six (85.7%) of the seven hematomas in the surgical group but only 3 (37.5%) of the eight in the conservative group had a purely intracapsular localization .Hematomas also showed extracapsular and retroperitoneal extension through capsular rupture in 1 (14.3%) and 5 (62.5%) patients. The latter cases could thus have been associated with lower intracapsular and intrarenal pressure and thus with potentially less long-term renal parenchymal damage. Complications due to postoperative bleeding, infections or renal failure did not occur in either group.

CONCLUSION

In conclusion, capsulotomy appears to be safe and effective, already achieving short-term results in cases of significant post-SWL renal hematomas compressing the parenchyma. Since long-term renal function did not differ from that in the conservatively treated reference group, however, a conservative approach remains the standard of care. Capsulotomy might only be considered in individual cases of purely intracapsular hematomas and significantly impaired renal perfusion and function.

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Andreas Al Ghazal and Thomas J. Schnoeller both contributed equally in this work.

CONFLICT OF INTEREST

None declared.

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