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ORIGINAL PAPER

A low or high BMI is a risk factor for renal hematoma after extracorporeal shock wave lithotripsy for kidney stones

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Abstract The purpose of this study was to evaluate risk factors for renal hematoma after extracorporeal shock wave lithotripsy (SWL) for kidney stones in a matched case–control analysis of a subgroup of patients recruited from a prospective randomized cohort. Between 06/2010 and 03/2013, 418 patients underwent SWL with the MODULITH®-SLX-F2-lithotripter for kidney stones. In 39/418 patients (9 %), ultrasound at post-treatment day 1 revealed renal hematomas. For 37 of these patients, a matched group without hematoma could be selected according to the following matching criteria: age, gender, number and energy of shock waves, stone burden and localization. Risk factors for renal hematoma after SWL were compared between the two groups. The rates of diabetes, stopped anticoagulant/antiplatelet medications and arterial hypertension were not different between the two groups ($p > 0.2$). The skin–kidney distance was virtually the same in both groups ($p = 0.5$). In the hematoma group, significantly more patients had a high (>30: $n = 16$) as well as a low (<21.5: $n = 4$) BMI when compared to the control group ($n = 4$; $n = 0$; $p < 0.001$). Importantly, all patients with BMI <21.5 developed renal hematomas after SWL. Patients with a high (>30) or low (<21.5) BMI had a higher risk for renal damage after SWL. Therefore, alternative endoscopic treatment options should be considered in these patients.

Keywords BMI · Extracorporeal shock wave lithotripsy · Stones · Case–control analysis · Renal hematoma

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Introduction

Since Chaussy et al. [1] described extracorporeal shock wave lithotripsy (SWL) for kidney stones in the 1980s, this technique has improved greatly and is a standard treatment for kidney stones [2, 3]. Major complications after SWL are obstruction of the ureter from stone fragments in approximately 7 % of patients, potentially accompanied with colic and/or infection [4–6] and renal hematomas with the risk of blood transfusion, potential loss of renal function and possibility of renal-mediated hypertension [7, 8]. The detection rate of renal hematomas increases from 1 to 15 % if routine follow-up by CT scan or MRI is performed [9]. While hypertension [10–14] and obesity [13] are known risk factors, our previously published prospective randomized trial [15] indicated that also patients with a low BMI might be at increased risk for renal hematomas. The aim of the present study was to evaluate risk factors for renal hematomas in a matched case–control analysis of a subgroup of patients within this prospectively randomized cohort [15].

Methods

Patients, randomization and group matching

Between July 2010 and March 2013, 418 patients with solitary or multiple unilateral kidney stones requiring elective or emergency SWL with the MODULITH® SLX-F2 lithotripter were randomized for either ramping-up ($n = 213$) or fixed maximal energy ($n = 205$) [15]. The study protocol was approved by the Ethics Committee of Bern Canton, Switzerland (protocol number 089/10), and all patients provided informed written consent. In 39/418 patients (9 %), renal ultrasound at post-interventional day

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1 revealed renal hematomas. A patient-by-patient control group was selected of patients without hematoma ($n = 379$) according to the following matching criteria: age, gender, number and energy regimen of shock waves, stone burden and stone localization. All parameters were used for matching: gender, number and energy regimen of shock waves were required to be identical; age within a range of 5 years and stone burden within a range of 2 mm, respectively. For two patients, matching was not successful and they were excluded from further analysis.

SWL and follow-up

All SWL treatments were performed under general or peridural anesthesia to eliminate pain as a limiting factor and to keep respiratory movements regular as previously described [16]. The same technician, under supervision and guidance by a senior staff member and a specially trained resident, treated all patients. The coupling protocol for the MODULITH1 SLX-F2 lithotripter involved application of oil (provided by Storz Medical AG) on the treatment head and degassed water between the patient and the foil. Shock wave delivery was heartbeat-triggered. Based on our previous prospective randomized trial [15] we used two different treatment regimens that were equally balanced between the cases and controls (Table 1) . The focal size was the same in both groups (6–28 mm). In the group with fixed mode of energy application, 2500 SWs at level 9 were administered. In the other group, energy was ramped up during the SWL, starting a series of 500 SWs at level 7 (corresponding to 14 kV) followed by 1000 SWs at level 8 (16 kV) and 1000 SWs at level 9 (18 kV), respectively.

The degree of stone disintegration, dilatation of the collecting system (absent/present), colic pain (absent/present), and presence of a renal hematoma (perirenal or subcapsular liquid rim) were evaluated by kidney, ureter and bladder (KUB) X-ray and renal ultrasound after 1 day, and 3 months after SWL. CT scans were only used if deemed necessary, to reduce the exposure to ionizing radiation. No routine CT scans were performed in case of renal hematoma. Symptoms related to the hematoma such as pain and impaired bowel movement as well as the number of secondary interventions (including repeat SWL, JJ stent placement, percutaneous nephrolithotomy, and ureteroscopy) within 3 months of SWL was recorded.

Determination of the investigated parameters

For all patients of both groups, history of diabetes, anticoagulant/antiplatelet medications (all stopped at least 5 days before treatment), arterial hypertension in patients' history and BMI (<21.5/21.5–25/25.1–30/>30) were noted. Additionally, the distance from the skin to the capsule of the kidney within the SWL pathway was measured on pretreatment CT scan (skin–kidney distance). Furthermore, the extent of the kidney parenchyma within the SWL pathway was determined (parenchyma distance) (Fig. 1). In cases of multiple stones, the shortest skin–kidney distance was used for further analyses.

Statistical analysis

Parameters between the two groups were compared with nonparametric tests by using a two-sided Wilcoxon rank-sum test (for continuous data) and Fisher's exact test (for categorical data). For analysis between more groups, Kruskal–Wallis test was applied for continuous data. A significance level of 0.05 was used for all tests. Statistical analyses were conducted using R Software Package, version 3.0.3. Of all parameters used for matching, propensity scores of cases and controls were calculated using MatchIt package, version 2.4–21.

Results

Patient characteristics of the two groups

The baseline characteristics used for matching did not differ between the two groups (Table 1) and the propensity scores were virtually the same between cases (median 0.52, range 0.28) and controls (median 0.5, range 0.28).

Table 1 Baseline characteristics of the two groups used for matching

	Cases ($n = 37$)	Controls ($n = 37$)
Age (median, range); (years)	54 (24–79)	57 (23–75)
Female/male (n)	11/26	11/26
Shock wave number (median)	2500	2500
Mode of energy application (fix/ramping up) (n)	22/15	22/15
Stone size (median, range) (mm)	9 (3–31)	8 (4–31)
Secondary intervention (n)	1	3
Repeat SWL	1	2
JJ stent placement		1

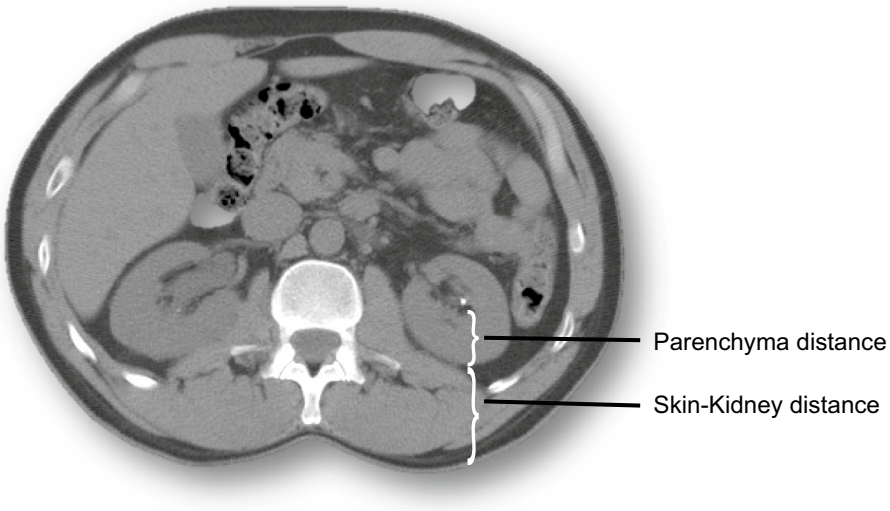

Fig. 1 Pretreatment CT scan on kidney level indicating the measurement of the anatomical assessed parameters. In all patients, the distance from the skin to the capsule of the kidney, within the SWL pathway, was measured (skin–kidney distance) and at the same localization, the distance of the kidney parenchyma was determined (parenchyma distance)

Table 2 Investigated parameters of patients with and without perirenal hematoma

	Cases ($n = 37$)	Controls ($n = 37$)	p
Diabetes mellitus (n)	6 (16 %)	2 (5 %)	0.3
Anticoagulant medications (n)	10 (27 %)	6 (16 %)	0.4
Hypertension (n)	14 (38 %)	8 (22 %)	0.2
Skin–kidney distance (median, range) (cm)	7.0 (3.2–14.0)	7.5 (4.7–11.6)	0.5
Parenchyma distance (median, range) (cm)	2.7 (1.6–5.5)	2.7 (0.8–6.4)	0.8

Symptoms, treatment and outcome of patients with renal hematoma

A third of the patients was asymptomatic (11/39, 28 %). The remaining 28 patients had non-colic flank and 2/28 (7 %) patients presented impaired bowel peristalsis. A third of the patients did not require treatment (13/39, 33 %). The remaining patients received analgesics (26/39, 66 %) and the two patients with impaired bowel peristalsis received prokinetic drugs. At 3 months after SWL, the majority of the patients were asymptomatic and showed no signs of residual hematoma (37/39, 95 %). Two patients showed a residual renal hematoma in ultrasound without symptoms. The size of the hematoma was not related to symptoms or treatment. None of the patients required a surgical intervention or blood transfusion. One patient required secondary intervention and was treated by repeat SWL after the hematoma was resolved.

Investigated parameters of patients with and without perirenal hematoma

In both groups, the rate of diabetes and stopped anticoagulant/antiplatelet medications was effectively the same ($p > 0.2$, Table 2). Although statistically not significant, more patients in the hematoma group had a history of hypertension (14/37, 38 %) compared to the control group (8/37, 22 %; $p = 0.2$). The skin–kidney and the parenchyma distance did not differ between the two groups ($p > 0.5$).

Distribution of BMI between the two groups was different. In the hematoma group, significantly more patients had a high (>30) as well as a low (<21.5) BMI ($p < 0.001$, Fig. 2). Importantly, all patients with BMI <21.5 ($n = 4$) had renal hematomas.

Analyses of anatomical measurements and patient characteristics

The skin–kidney and parenchyma distances were analyzed between patients with different BMI (Fig. 3). The parenchyma distance was effectively the same between different BMI ($p = 0.65$). Whereas, in regards to skin–kidney distance, patients with BMI <21.5 had a shorter distance and those with BMI >30 a longer distance when compared to patients with BMI 21.5–30 ($p < 0.001$).

Discussion

According to the AUA guidelines, SWL is the standard treatment for kidney stones <1 cm [17]. Still, SWL is not without biological effects when the shock waves

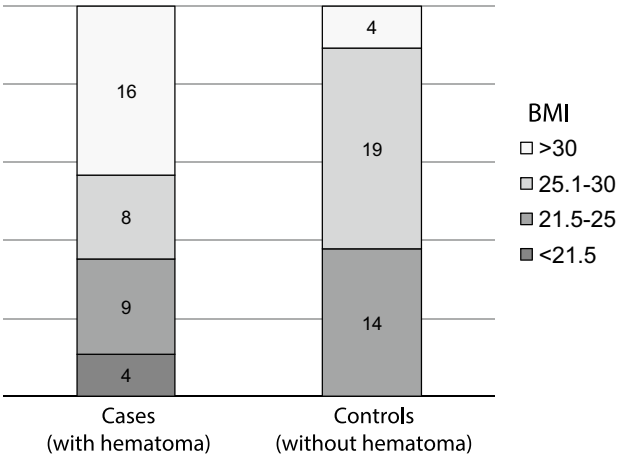

Fig. 2 *Bar plots* indicating the distribution of BMI between both groups. In the group with hematomas, significantly more patients had a low (<21.5) and a high (>30) BMI, respectively, when compared to the control group ($p = 0.001$)

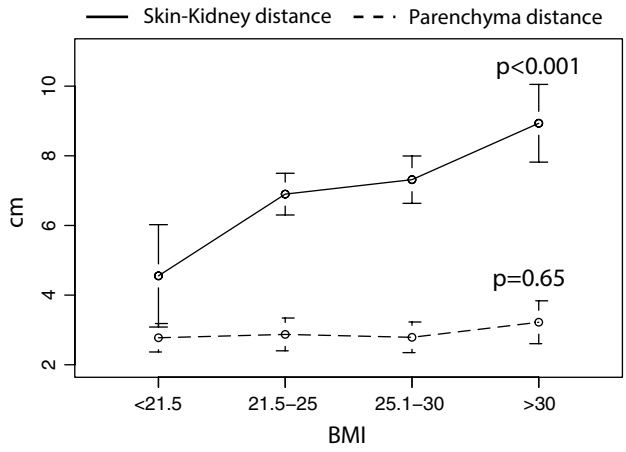

Fig. 3 *Line plot* indicating the skin–kidney distance (*solid line*) and parenchyma distance (*dashed line*) in dependence of BMI. While the parenchyma distance was virtually the same between different BMI ($p = 0.65$), the skin–kidney distance depends on the BMI. *Error bars* indicate the 95 % confidence intervals

pass through the tissue. Various post-treatment laboratory changes may indicate these effects in the liver [11], skeletal muscle [11] and pancreas [18]. In the kidney itself, a rare but potentially significant complication is renal hematoma [7, 8, 11]. Various studies investigated patients' BMI as a possible predisposing factor for this complication [7, 13, 14]. While Lee et al. [13] identified a high BMI as a significant risk factor for renal hematomas, the others did not [7, 14]. In this matched prospective case–control analysis, SWL was performed according to a standardized protocol (focal size, energy level and number of shock waves), irrespective of patients' BMI. We were able to show that obese patients (BMI >30) had a higher risk for renal hematomas after SWL for kidney stones. This relationship is still not fully understood. Lee et al. [13] argued that the skin–stone distance in obese patients might exceed the focal length of the lithotripter, which might result in more surrounding tissue damage [19]. In our study, the skin–kidney distance but not the parenchyma within the SWL pathway was increased in obese patients. However, the sum of both did not exceed the lithotripter's focal length. Consequently, Lee's [13] argumentation might not be valid for our findings. On the other hand, obesity (high BMI) is part of the metabolic syndrome which again seems to be associated with altered coagulative and fibrinolytic proteins [20] and increased vascular vulnerability due to endothelial dysfunction [21]. This might increase the risk of vascular damage during SWL treatment. However, this is purely speculation and the reason for a higher rate of renal hematomas in obese patients remains unclear. Taken together, SWL is less effective in obese patients [22, 23] and they are at higher risk for renal hematomas. Therefore, energy and number of shock waves should not be increased without limit in obese patients.

Interestingly, all four patients with BMI <21.5 had renal hematomas. While SWL is less effective due to stronger damping of shock waves in obese patients [23], in slim patients the energy levels of the shock waves are still high when passing the kidney. This might result in increased parenchyma damage and thus a higher risk for renal hematomas. Another possible explanation is that patients with a low BMI tend to be malnourished, which again influences coagulation properties [24]. Even if the low number of patients with BMI <21.5 does not allow for definitive judgment, reduction of number and energy of shock waves in SWL for kidney stones should be considered in slim patients.

Hypertension has been discussed as risk factor for renal hematomas after SWL for kidney stones [7, 10–14, 25]. In the Cleveland series [7], hypertension was not a significant risk factor while others [10–14, 25] found a relation between hypertension and renal hematomas. Our data are in line with the latter findings; more patients with renal hematomas had hypertension when compared to the control group. However, this trend was not significant, most likely due to a too small cohort scale. Therefore, the present data and previous findings of others [7, 10–14, 25], do not allow for a definitive conclusion.

Besides the low number of patients, a major drawback might be the imaging technique we used to evaluate renal hematomas. Ultrasound is less accurate than CT scan or MRI [9] most of all because of its lower resolution and its investigator dependency. However, we do not think that this had a great impact on our results. Our incidence of perirenal hematomas of 9 % is in the same range with the 15 %

after CT scan or MRI [9] and much higher than the reported 1 % in other series [7, 8, 11]. This is most likely due to the fact that renal hematomas were systematically searched for post-SWL and that specially trained doctors performed the ultrasound. Furthermore, the clinical relevance of very small hematomas not seen by ultrasound remains questionable. Additionally, limitations in comparing series that evaluate risk factors for renal hematomas are variabilities in cohort selection, scale, study design and type of lithotripter. Although, the patients for this subgroup analysis were selected from a prospective randomized study [15], various restrictions prevent generalizations of our data.

In conclusion, patients with a high (>30) or low (<21.5) BMI are at increased risk for renal damage post-SWL. Therefore, alternative endoscopic treatment options should be considered in these patients.

Compliance with ethical standards

All authors confirm that all work was designed and conducted by all the authors; the manuscript has been written, read, and approved by all the authors; the manuscript, or parts of it, have not been and will not be submitted elsewhere for publication; and there are no conflicts of interest by any of the authors.
In this study, human participants are involved. The study protocol was approved by the ethics committee of Bern Canton, Switzerland (Protocol Number 089/10), and all patients provided informed written consent.

Conflict of interest There are no conflicts of interest by any of the authors.

References

1. Chaussy C, Schmiedt E, Jocham D, Brendel W, Forssmann B, Walther V (1982) First clinical experience with extracorporeally induced destruction of kidney stones by shock waves. J Urol 127:417–420
2. Pearle MS, Goldfarb DS, Assimos DG et al (2014) Medical management of kidney stones: AUA guideline. J Urol 192:316–324
3. Türk CKT, Petrik A, Sarica K, Skolarikos A, Straub M, Seitz C (2015) Guidelines on urolithiasis: European Association of Urology. http://www.uroweborg/guidelines
4. Sayed MA, El-Taher AM, Aboul-Ella HA, Shaker SE (2001) Steinstrasse after extracorporeal shockwave lithotripsy: aetiology, prevention and management. BJU Int 88:675–678
5. Skolarikos A, Alivizatos G, de la Rosette J (2006) Extracorporeal shock wave lithotripsy 25 years later: complications and their prevention. Eur Urol 50(5):981–990
6. Tan YM, Yip SK, Chong TW, Wong MY, Cheng C, Foo KT (2002) Clinical experience and results of ESWL treatment for 3,093 urinary calculi with the Storz Modulith SL 20 lithotripter at the Singapore general hospital. Scan J Urol Nephrol 36:363–367
7. Dhar NB, Thornton J, Karafa MT, Streem SB (2004) A multivariate analysis of risk factors associated with subcapsular hematoma formation following electromagnetic shock wave lithotripsy. J Urol 172:2271–2274
8. Wen CC, Nakada SY (2007) Treatment selection and outcomes: renal calculi. Urol Clin North Am 34:409–419
9. Martin Martinez JC, Diez Cordero JM, Duran Merino R et al (1995) Subcapsular renal hematoma following shock wave lithotripsy. Arch Esp Urol 48:179–184
10. Collado Serra A, Huguet Perez J, Monreal Garcia de Vicuna F, Rousaud Baron A, Izquierdo de la Torre F, Vicente Rodriguez J (1999) Renal hematoma as a complication of extracorporeal shock wave lithotripsy. Scan J Urol Nephrol 33:171–175
11. Knapp PM Jr, Konnak JW, McGuire EJ, Savastano JA (1987) Urodynamic evaluation of ileal conduit function. J Urol 137:929–932
12. Kostakopoulos A, Stavropoulos NJ, Macrychoritis C, Deliveliotis C, Antonopoulos KP, Picramenos D (1995) Subcapsular hematoma due to ESWL: risk factors. A study of 4,247 patients. Urol Int 55:21–24
13. Lee HY, Yang YH, Shen JT et al (2013) Risk factors survey for extracorporeal shockwave lithotripsy-induced renal hematoma. J Endourol 27:763–767
14. Razvi H, Fuller A, Nott L et al (2012) Risk factors for perinephric hematoma formation after shockwave lithotripsy: a matched case-control analysis. J Endourol 26:1478–1482
15. Skuginna V, Nguyen DP, Seiler R, Kiss B, Thalmann GN, Roth B (2016) Does stepwise voltage ramping protect the kidney from injury during extracorporeal shockwave lithotripsy? Results of a prospective randomized trial. Eur Urol 69:267–273
16. Zehnder P, Roth B, Birkhauser F et al (2011) A prospective randomised trial comparing the modified HM3 with the MODULITH(R) SLX-F2 lithotripter. Eur Urol 59:637–644
17. Preminger GM, Assimos DG, Lingeman JE, Nakada SY, Pearle MS, Wolf JS Jr. (2005) Chapter 1: AUA guideline on management of staghorn calculi: diagnosis and treatment recommendations. J Urol 173:1991–2000
18. Drach GW, Dretler S, Fair W et al (1986) Report of the United States cooperative study of extracorporeal shock wave lithotripsy. J Urol 135:1127–1133
19. Mezentsev VA (2005) Extracorporeal shock wave lithotripsy in the treatment of renal pelvicalyceal stones in morbidly obese patients. Int Braz J Urol 31:105–110
20. Alessi MC, Juhan-Vague I (2008) Metabolic syndrome, haemostasis and thrombosis. Thromb Haemost 99:995–1000
21. Kostapanos M, Florentin M, Elisaf MS, Mikhailidis DP (2013) Hemostatic factors and the metabolic syndrome. Curr Vasc Pharmacol 11:880–905
22. Hatiboglu G, Popeneciu V, Kurosch M et al (2011) Prognostic variables for shockwave lithotripsy (SWL) treatment success: no impact of body mass index (BMI) using a third generation lithotripter. BJU Int 108:1192–1197
23. Pareek G, Armenakas NA, Panagopoulos G, Bruno JJ, Fracchia JA (2005) Extracorporeal shock wave lithotripsy success based on body mass index and Hounsfield units. Urology 65:33–36
24. Miller GJ, Martin JC, Webster J et al (1986) Association between dietary fat intake and plasma factor VII coagulant activity—a predictor of cardiovascular mortality. Atherosclerosis 60:269–277
25. Newman LH, Saltzman B (1991) Identifying risk factors in development of clinically significant post-shock-wave lithotripsy subcapsular hematomas. Urology 38:35–38