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ORIGINAL PAPER

Is high diuresis an important prerequisite for successful SWL-disintegration of ureteral stones?

Hans-Göran Tiselius · Trine Aronsen · Stina Bohgard · Marita Fredriksson · Elsie-Marie Jonason · Monica Olsson · Kristina Sjöström

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Abstract A randomised comparison was made between high and normal diuresis during the primary session of extracorporeal shock wave lithotripsy (SWL) for removal of ureteral stones. High diuresis was accomplished by pressure infusion of approximately 1 L of Ringer acetate solution together with 20 mg of furosemide during the 30–40 min treatment session (*Group D*). These patients also had a bladder catheter. Patients in *Group 0* had a normal diuresis and no bladder catheter. The mean (SD) number of treatment sessions for the 65 patients in *Group D* were 1.26 (0.51) and for the 60 patients from *Group 0* 1.35 (0.84) [$p > 0.10$]. 51 (78%) and 46 (77%) patients in *Group D* and *Group 0*, respectively, required only one SWL session. Stones were located in the proximal, mid and distal ureter in 22, 9, and 29 of the patients in *Group D* and in 22, 5, and 38 in *Group 0*. No difference in treatment outcome was observed with regard to stone localisation. The stone treatment index (STI_{GR}) calculated for *Group D* and *Group 0* were 4.77 and 4.70, respectively. In conclusion there was no obvious advantage of using a forced diuresis during the primary SWL-session for treating patients with ureteral stones. Although a high diuresis and bladder catheter might be beneficial in certain complicated cases, in most situations it seems appropriate to omit this step.

Keywords SWL · Ureteral stones · Diuresis · Bladder catheter · Stone treatment index

Introduction

Extracorporeal shock wave lithotripsy (SWL) has been established as a standard, non-invasive or very low-invasive procedure for active removal of ureteral stones [1, 2]. We have previously shown that stone-free rates around 97% accordingly can be achieved with this technique. Similar results were recorded for the original Dornier HM3 lithothripter [3] and for the modern Storz lithotripters [2]. Almost all these patients were given a high diuresis during the SWL session and hence they also required a bladder catheter. Some studies provide support for such an auxiliary step [4, 5] and the theoretical basis for such a procedure has been to create a fluid space around the stone and thus getting a better transmission to and uptake of the shock wave energy into the stone [6, 7]. Although the early observation of haematuria in the bladder catheter, caused by stone disintegration, occasionally can be useful for decisions during the treatment, it is not clear whether the high urine flow in fact results in a better disintegration than just a normal urine flow with no need of a bladder catheter. The present randomised study therefore was carried out in order to compare the results of SWL for ureteral stones treated with and without a high diuresis.

Patients and methods

Patients with radio-opaque stones located in the ureter at the primary SWL treatment were randomised into two groups, if the patient decided to participate in the study

H.-G. Tiselius (✉) · T. Aronsen · S. Bohgard ·
M. Fredriksson · E.-M. Jonason · M. Olsson · K. Sjöström
Renal stone unit, Department of Urology,
Karolinska University Hospital, 141 86 Stockholm, Sweden
e-mail: hans.tiselius@karolinska.se

H.-G. Tiselius
Division of Urology, Department of Clinical Science,
Intervention and Technology, Karolinska Institutet,
141 86 Stockholm, Sweden

following appropriate explanation of its purpose. Patients with stents and percutaneous nephrostomy catheters were excluded and randomisation was not completed until the patient had been fully informed of the study, understood its meaning and given his/her consent. All patients with ureteral stones in whom active removal was considered necessary were in our stone unit treated with SWL and none of them was primarily referred to other methods of stone removal [2].

Patients in *Group D* were treated with a bladder catheter in place and with high-pressure infusion of approximately 1 L of Ringer acetate solution during the first SWL treatment session. A high-pressure infusion device was used to accomplish the intavenous infusion of that volume during the 30–40 min-duration of the SWL session. At the beginning of the treatment an intravenous dose of 20 mg of furosemide also was administered.

Group 0 patients were treated without the bladder catheter, without furosemide and only with passive intravenous infusion of much smaller volumes of Ringer acetate, usually in the range of 100–200 mL during the session. Otherwise all treatments followed a similar protocol. SWL treatments were carried out with the Storz Modulith classic or SLX F2 litotripters (Storz Medical AG, Tägerwilen, Switzerland) according to our routines with administration of small doses of alfentanyl and propofol as analgo-sedation [2]. The standard focus was used for treatments in the SLX F2 device and, with few exceptions, the frequency of shock wave administration was set to 90 per min. The energy level was selected by the operator and decided from the fluoroscopic appearance of disintegration. Stone-free rates were confirmed by follow-up with plain radiographs usually within a few weeks. There were 65 patients in *Group D* and 60 in *Group 0*.

The stone burden (SB) was calculated from the stone surface area (SA) derived from the stone length (l) and width (w) as measured on a plain film:

$$\mathrm{SA} = 0.25 \times l \times w \times \pi.$$

The hardness index (HI) was derived from information on chemical composition of delivered gravel [8]. When no stone material had been retrieved HI was set to 1.18 as a reasonable average estimate. The SB was subsequently obtained from the formula below [9]:

$$\mathrm{SB} = \mathrm{HI} \times \sqrt{\mathrm{SA}}.$$

A summary of the treatment efforts and results was expressed in terms of stone treatment index STI [9]:

$$\mathrm{STI} = \frac{N_{\mathrm{SF}}(\mathrm{SB} \times \mathrm{BMI}_{\mathrm{R}} \times \mathrm{Age}_{\mathrm{R}} \times (1 + \mathrm{ANA}))}{(N_{\mathrm{SESSION}} + N_{\mathrm{ANE}} + N_{\mathrm{AUX}} + N_{\mathrm{COMP}})}$$

where N_{SF} is the number of stone-free patients, $\mathrm{Age}_{\mathrm{R}}$ the age index expressed as the quotient Age/50 and $\mathrm{BMI}_{\mathrm{R}}$ as the quotient BMI/25. ANA is the presence of anatomical abnormities in the ureter. The number of sessions (N_{SESSION}), auxiliary procedures (N_{AUX}), complications (N_{COMP}) and procedures requiring anaesthesia (N_{ANE}) are used in the denominator. The means of SB, $\mathrm{Age}_{\mathrm{R}}$, $\mathrm{BMI}_{\mathrm{R}}$ and ANA are used in STI calculations for groups ($\mathrm{STI}_{\mathrm{GR}}$), whereas individual patient values are used for the individual STI calculations ($\mathrm{STI}_{\mathrm{IND}}$). For those few patients in whom information on BMI was missing BMI; was set to 1.0.

Statistical conclusions were drawn from Student's *t* test and χ^2 analysis.

The study was approved by the Karolinska University Hospital Ethical Committee and the study carried out between 2004 and 2006.

Results

Patients and stone characteristics are summarised in Table 1 and data on results and treatment evaluation in Table 2.

The mean (SD; range) of SWL sessions were 1.26 (0.51; 1–3) in *Group D* and 1.35 (0.84; 1–5) in *Group 0* ($p > 0.10$). Eight auxiliary procedures in each group were necessary after the primary treatment. While two minor complications were recorded in *Group 0*, there were no complications in *Group D*. Patients who required more than one SWL sessions were 15 in *Group D* and 13 in *Group 0* ($\chi^2 = 0.0007$). The small differences in terms of repeated treatments and session numbers might reflect the numerically slightly larger stone burden of 6.6 in *Group 0*, compared with 6.2 in *Group D* ($p > 0.10$). $\mathrm{STI}_{\mathrm{GR}}$ was almost identical in the two groups with a value of 4.77 in *Group D* and 4.70 in *Group 0*. The mean (SD) individual

Table 1 Patient and stone characteristics and in *Group D* and *Group 0*

	Group D	*Group 0*
Number of patients	65	60
Men	54	52
Women	11	8
Stone in left ureter	37	37
Stone in right ureter	28	23
$\mathrm{Age}_{\mathrm{R}}$ (mean)	1.06 [0.28]	1.03 [0.27]
$\mathrm{BMI}_{\mathrm{R}}$ (mean)	1.01 [0.11]	1.03 [0.10]
Stone length mm (mean[SD])	7.6 [2.1]	7.9 [2.3]
Stone width mm (mean[SD])	5.0 [1.6]	5.4 [1.5]
$\sqrt{\mathrm{SA}}$ (mean[SD])	5.24 [1.26]	5.62 [1.52]
HI (mean [])	1.18 [0.07]	1.20 [0.14]
ANA (mean)	0	0.02
SB (mean[SD])	6.2 [14,2]	6.6 [6, 13]

Table 2 Treatment efforts and result in *Group D* and *Group 0*

	Group D	*Group 0*	*p-value*
Stone-free after 1 session	50	47	$p > 0.10$
Mean [SD] sessions	1.26 (0.51)	1.35 (0.84)	$p > 0,10$
Number of shock waves at session one (mean[SD])	2,209 [683]	2,262 [655]	$p > 0.10$
	Range: 430–3,400	Range: 800–3,933	
Number of stone-free patients after all sessions	65 (100%)	59 (98%)	$p > 0.10$
STI_{GR} proximal ureter	5.37 ($n = 22$)	3.72 ($n = 21$)	–
STI_{GR} mid ureter	4.07 ($n = 5$)	5.22 ($n = 9$)	–
STI_{GR} distal ureter	4.57 ($n = 38$)	5.33 ($n = 29$)	–
STI_{IND} proximal ureter	6.12 [2,99]	4.86 [2,64]	$p > 0.10$
STI_{IND} mid ureter	4.36 [1,43]	5.37 [3.55]	$p > 0.10$
STI_{IND} distal ureter	5.36 [2.57]	5.92 [2.57]	$p > 0.10$
STI_{GR} left ureter	4.10	4.81	–
STI_{IND} left ureter (mean[SD])	4.77 [2.16]	5.53 [2.99]	$p > 0.10$
STI_{GR} right ureter	5.88	4.53	–
STI_{IND} right ureter (mean[SD])	6.56 [2.96]	5.72 [3.00]	$p > 0.10$
STI_{IND} all (mean[SD])	5.54 [2.67]	5.60 [2.62]	$p > 0.10$
STI_{GR} all	4.77	4.70	–

STI values for the two groups were 5.54 (2.67) and 5.60 (2.97), respectively ($p > 0.10$).

As shown in Table 2, STI both expressed as group parameters and as individual variables did not disclose any significant difference between the two methods for stones at different levels of the ureter.

The overall results show that the treatment outcome of SWL for ureteral stones essentially was unrelated to a high diuresis. The benefit of using the appearance of haematuria as a treatment determinant was not specifically analysed in this study, but even in that regard the absence of a bladder catheter did not demonstrate a significantly inferior outcome. The stone-free rates after one single session were almost identical with 50 (77%) patients in *Group D* and 47 (78%) in *Group 0*.

Discussion

The great advantages of SWL for active removal of ureteral stones are the non-invasive and non-anaesthesia requiring character of the treatment [1, 10, 11]. In this regard SWL thus is superior to other methods for active stone removal that are more invasive and usually necessary to complete with general or regional anaesthesia [2, 11]. The non-invasiveness of SWL has, however, slightly been notched by our routine to insert a bladder catheter in order to cope with a high urine production during the SWL session. Not unexpectedly a majority of patients found that step to be the most uncomfortable part of the whole treatment procedure.

For more than two decades we have used forced diuresis during the SWL session with the aim of increasing the fluid space around stones and in that way improve the uptake of shock wave energy and thus get a better and faster stone fragmentation [6, 7]. Moreover, a high urine flow might facilitate the elimination of fragments from the stone surface and allow a deeper penetration of the shock wave. It also was found in a previous study [4] that a high urine flow markedly improved the results of SWL for distal ureteral stones. Another recent report showed a better fragmentation and stone clearance with diuretics than without [5]. In addition, it has been suggested that the saline infusion via a ureteral catheter also might be helpful for the stone disintegration by providing a fluid layer between the stone and the ureteral wall [12]. The use of a ureteral catheter as a routine primary measure during SWL of ureteral stones was, however, found to be unnecessary and abandoned many years ago [3].

The results obtained from the randomised study reported here clearly indicate that there is no obvious benefit with a high diuresis as part of the primary SWL for removal of ureteral stones. Although a majority of the stones in our patients were located in the distal ureter at the time of treatment, a stratified analysis of stones at different levels of the ureter did not show any differences in the treatment outcome or efforts between the groups.

We are well aware of the usefulness of notifying early appearing haematuria as a reflection of stone disintegration, but it is likely that the high diuresis and bladder catheter can be omitted at the primary treatment, at least if the stone can be clearly identified. For stones not sufficiently disintegrated at the first SWL session, high diuresis might be considered as a helpful auxiliary procedure and such a routine was accordingly applied for all our re-treated patients. Here, we cannot draw any conclusions on the possible benefit of the high diuresis for the final outcome after repeated treatments.

When we separately analysed the stone situation in those four patients in *Group 0* and two patients in *Group D* who were treated with more than *two* SWL sessions the need of repeated sessions in *Group 0* seemed to be at least partly related to the larger stone burden, which was 10.4 and 6.6 in *Groups 0* and *D*, respectively. These numbers should be compared with the average stone burdens of 6.6 and 6.2 in the two groups. Due to the lack of a clear-cut definition of the degree of stone impaction and insufficient data in this respect, an impaction factor was not included in our analysis. In view of the high percentage of patients who were satisfactorily treated with only one SWL session (77 and 78% for *Groups D* and *0*) such a factor seems to be less important for the treatment outcome. The STI_{GR} for the two groups also were almost identical and so were the mean (SD) STI_{IND} (Table 1). It needs to be emphasised that the use of bladder catheter and high diuresis was *not* included as an auxiliary procedure in the STI calculations, if so the STI for *Group D* would have been much lower than for *Group 0*.

It should be added that a high diuresis and a bladder catheter in occasional cases might be helpful in order to use the appearance of haematuria as an observation tool for deciding whether the stone has been correctly identified or adequately disintegrated. But as a general measure in SWL of ureteral stones it appears both possible and reasonable to omit such a step. We are aware of the fact that numerous SWL centres do not apply a high diuretic regimen as part of the treatment procedure, but also that the results with SWL for ureteral stones vary considerably [1, 11].

In conclusion, the possibility to avoid a bladder catheter and high diuresis during the primary SWL treatment of stones located in the ureter is a further improvement of a so far very successful and low-invasive stone removing procedure [2, 10] and despite the current enthusiasm for invasive procedures [13], the non-invasive SWL can maintain its attraction as a first line treatment modality for the majority of patients with ureteral stones.

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