# Does a Slower Treatment Rate Impact the Efficacy of Extracorporeal Shock Wave Lithotripsy for Solitary Kidney or Ureteral Stones?

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**Purpose:** We compared the efficacy of an SR (70 to 80 shocks per minute) and an FR (120 shocks per minute) for ESWL for solitary stones less than 2 cm located in the kidney or proximal ureter.

**Materials and Methods:** A total of 349 patients with a solitary, radiopaque kidney or ureteral stone underwent ESWL on a DoLi® 50 lithotriptor. Patients were grouped based on stone size, stone location and whether SR or FR treatment was performed. Of the 349 patients 135 had a renal stone between 1and 2 cm, 137 had a renal stone less than 1 cm and 77 had a proximal ureteral stone with a surface area of between 30 and 90 $mm^2$. SFRs were determined at approximately 1 month by plain x-ray of the kidneys, ureters and bladder.

**Results:** In comparison to the FR groups SR groups required fewer shocks and had significantly lower power indexes. Of patients with renal stones between 1 and 2 cm 24 of 52 (46%) in the FR group were stone-free compared to 56 of 83 (67%) in the SR group ($p < 0.05$). For stones with a surface area of 30 to 90 $mm^2$ located in the kidney or proximal ureter there was a trend toward an improved SFR in the SR group but differences between the SR and FR groups were not statistically significant.

**Conclusions:** For solitary renal stones between 1 and 2 cm an SR results in a better treatment outcome than an FR for ESWL. However, when stone size is less than 1 cm, SFR differences in the SR and FR treatment groups become less significant.

*Key Words: kidney, ureter, calculi, lithotripsy, treatment outcome*

Several factors determine the success of ESWL for kidney stones, including stone size, stone location in the collecting system, stone type, stone radiopacity or CT attenuation values, type of anesthesia and the ESWL machine used. It has been suggested that the ESWL treatment rate may also independently impact ESWL efficacy. To evaluate the independent effect of treatment rate on ESWL efficacy it is essential to control for the other confounding stone variables when assessing the outcome of lithotripsy.

In vitro studies using stone phantoms as well as retrieved human kidney stones have shown variable stone fragmentation rates based on treatment rates. Initial studies of Vallancien et al using the EDAP LT-01 lithotriptor (EDAP TMS S. A., Vaulx-en-Velin, France) suggested that the treatment rate for best stone fragmentation was 75 or 150 shocks per minute.[1] However, recent in vitro and animal studies using the electrohydraulic lithotriptors suggest that the most efficacious treatment rate is 30 or 60 shocks per minute.[2–4]

Limited clinical data are available to test whether the ESWL treatment rate impacts treatment efficacy. Robert et al reported improved ESWL outcomes using 240 vs 60 shocks per minute with the EDAP LT-02 lithotriptor for lower ureteral stones.[5] However, the total number of shocks given was not reported and no difference in treatment outcomes was noted for proximal ureteral stones at these 2 treatment rates. Recently Madbouly et al performed a prospective, randomized study in 156 patients assigned to treatment groups of 60 and 120 shocks per minute but the investigators did not specifically control for stone characteristics or the number of ESWL treatments.[6] On multivariate logistic regression analysis they reported a statistically significantly fewer number of shock waves, higher treatment time and higher SFR in the group of patients treated with 60 shocks per minute.

We examined the impact of treatment rate on the efficacy of ESWL for solitary stones less than 2 cm located in the kidney and stones in the proximal ureter with an SSA of between 30 and 90 $mm^2$, as calculated by the equation, stone length $\times$ stone width. In this retrospective study we controlled for confounding variables, including stone location, stone radiopacity, anesthesia type, stone size and machine type, to examine the potential independent effect of ESWL rate on treatment outcome. Kidney stones larger than 2 cm may best be treated with percutaneous nephrolithotomy and they were not a subject of this study.

## METHODS

From May 2002 to August 2004, 439 patients underwent ESWL with a DoLi® lithotriptor at our institution for a

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TABLE 1. *Patient and stone characteristics*

| | 1–2 Cm Renal Stones | | 30–90 Mm$^2$ Renal Stones | | 30–90 Mm$^2$ Ureteral Stones | |
|---|---|---|---|---|---|---|
| | Rapid Rate | Slow Rate | Rapid Rate | Slow Rate | Rapid Rate | Slow Rate |
| No. pts | 52 | 83 | 77 | 60 | 42 | 35 |
| No. stented (%) | 23 (44) | 20 (24) | 5 (7) | 4 (7) | 12 (29) | 14 (40) |
| No. men (%) | 30 (58) | 40 (48) | 52 (67) | 38 (63) | 30 (71) | 22 (63) |
| No. women (%) | 22 (42) | 43 (52) | 25 (33) | 22 (37) | 12 (29) | 13 (37) |
| Mean age ± SD | 50.7 ± 14.2 | 53.5 ± 12.9 | 49.1 ± 12.7 | 50.5 ± 12.9 | 50.2 ± 13.0 | 53.7 ± 11.2 |
| Mean length ± SD (mm) | 13.1 ± 2.7 | 12.3 ± 2.6* | 7.6 ± 1.1 | 8.0 ± 0.9* | 8.8 ± 1.8 | 8.7 ± 1.8 |
| Mean width ± SD (mm) | 8.4 ± 3.1 | 7.8 ± 2.4 | 6.0 ± 1.1 | 5.8 ± 1.3 | 6.0 ± 1.2 | 5.6 ± 1.2 |
| Mean surface area ± SD (mm$^2$) | 115 ± 61.6 | 99.4 ± 51.6 | 46.1 ± 12.8 | 46.5 ± 12.9 | 53.2 ± 16.8 | 49.0 ± 13.6 |
| No. lower pole stones (%) | 18 (35) | 36 (43) | 36 (47) | 35 (58) | | |
| No. nonlower pole stones (%) | 34 (65) | 47 (57) | 41 (53) | 25 (42) | | |

* Vs taped rate $p < 0.05$.

solitary kidney stone between 1 and 2 cm or for stones with an SSA of 30 to 90 mm$^2$ located in the kidney or proximal ureter. Stones in the mid or distal ureter were treated with ureteroscopy at our institution. Adequate followup was available on 349 patients (80%), of whom 135 had renal stones between 1and 2 cm, 137 had renal stones less than 1 cm (SSA between 30 and 90 mm$^2$) and 77 had a proximal ureteral stone with an SSA of between 30 and 90 mm$^2$. Treatment rates were 120 (FR) or between 70 and 80 shocks per minute (SR). The decision to treat at a FR or SR was made by the treating urologist.

Pretreatment imaging consisted of KUB, in addition to CT or excretory urogram. Most patients were evaluated with CT rather than excretory urogram. As such, determination of the caliceal location (lower pole vs mid calix) of a renal stone location was sometimes imprecise. KUB was done the day of treatment. Stone radiopacity on this KUB was compared to the radiopacity of the ipsilateral 12th rib. Patients who had stones with radiopacity less than that of the 12th rib were excluded. Ureteral stent use was determined by the referring urologist before ESWL or according to treating urologist discretion on the day of ESWL treatment.

Stone size was measured as the maximal linear length in mm and also as SSA in mm$^2$, as calculated by multiplying stone length by stone width. To eliminate small stones a minimum SSA of 30 mm$^2$ was necessary for the patient to be included in the study. A minimal SSA of 30 mm$^2$ also ensured that the minimal linear length of a small ureteral stone was at least 6 mm. Similarly an upper limit of 90 mm$^2$ was used to exclude large ureteral stones from analysis. Stone location was noted in all patients and a distinction was made between lower and nonlower pole stones. All treatments were performed with the patient under general anesthesia. The total shock number, power index, and fluoroscopy and treatment times were recorded in all patients. The power index for each treatment was calculated by adding the products of the number of shocks by the power level (range 1 to 6) at which the shocks were administered.

KUB was done approximately 1 month after ESWL. All patients were evaluated by the referring urologist and followup data were collected and analyzed at our institution. ESWL was considered a failure if any residual stone fragments were present after 1 month, or if secondary ESWL or an endourological procedure was required.

Chi-square analysis was used to determine the statistical significance of differences in SFRs between the FR and SR groups. The Student t test was used to compare differences in other indexes between the 2 groups.

## RESULTS

Table 1 lists patient characteristics. There were no significant differences between the FR and SR groups with respect to stent placement or patient age. Interestingly the male-to-female ratio for 1 to 2 cm renal stones was 1.08, whereas this ratio was 1.91 and 2.08 for smaller renal and ureteral stones, respectively.

Table 1 also lists stone characteristics. Although there were statistically significant differences in renal stone length in the SR and FR groups, SSA was similar in the 2 groups for all 3 stone categories. Of renal stones between 1 and 2 cm 40% were located in the lower pole. However, 52% of all smaller stones between 30 and 90 mm$^2$ were located in the lower pole. There were no statistical differences between the FR and SR groups with respect to stone location.

Table 2 shows treatment characteristics in the FR and SR groups for each stone category. The average number of shocks and power indexes in the FR group were significantly

TABLE 2. *ESWL treatment characteristics and outcomes*

| | 1–2 Cm Renal Stones | | 30–90 Mm$^2$ Renal Stones | | 30–90 Mm$^2$ Ureteral Stones | |
|---|---|---|---|---|---|---|
| | Rapid Rate | Slow Rate | Rapid Rate | Slow Rate* | Rapid Rate | Slow Rate |
| Mean no. shock waves ± SD | 2,785 ± 276 | 2,428 ± 445* | 2,625 ± 467 | 2,337 ± 291 | 3,020 ± 585 | 2,574 ± 326* |
| Mean power index × 1,000 ± SD | 11.1 ± 1.8 | 9.0 ± 2.4* | 10.1 ± 3.1 | 8.5 ± 2.0 | 12.5 ± 3.6 | 10.4 ± 2.2* |
| Mean fluoroscopy time ± SD (secs) | 108 ± 52 | 124 ± 63 | 109 ± 52 | 140 ± 78 | 130 ± 74 | 113 ± 51 |
| Mean treatment time ± SD (mins) | 34.1 ± 13.6 | 37.7 ± 11.6 | 29 ± 10.3 | 33 ± 5.3 | 34.6 ± 10.0 | 35.0 ± 5.1 |
| No. stone-free/total no. (%): | | | | | | |
| All | 24/52 (46) | 56/83 (67)* | 44/77 (57) | 39/60 (65) | 27/42 (64) | 27/35 (77) |
| Lower pole stones | 9/18 (50) | 25/36 (69) | 18/36 (50) | 24/35 (69) | | |
| Nonlower pole stones | 15/34 (44) | 31/47 (66) | 26/41 (63) | 15/25 (60) | | |

* Vs rapid rate $p < 0.05$.