Optimizing Extracorporeal Shock Wave Lithotripsy

Ryan Flannigan
PGY4 Urology
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ESWL

History of ESWL

- ESWL 1st performed in 1980 by Dr. Christian Chaussy in Germany.
  - Using the Dornier HM1 Lithotripter.

- Dr. James Lingeman was the first to perform ESWL in North America.
  - Using the Dornier HM3 lithotripter.

- Uptake of ESWL increased due to being very effective with limited side effects.

- In past decade:
  - 55% increase in use for upper tract stones

- Limitations
  - Resistant stones
  - Anatomic abnormalities: calyceal diverticulum, acute infundibulopelvic angles, lower pole location
ESWL

• Shockwaves produced from one of three types of machines:
  • Electrohydraulic
  • Electromagnetic
  • Piezoelectric

• Stone fragmentation:
  • Stress waves
  • Cavitation

ESWL

• Indications
  – Location: Both Ureteric & Renal calculi
  – Size: Less than 2cm

• Contraindications
  – Pregnancy
  – Bleeding diatheses
  – Uncontrolled UTI’s
  – Severe skeletal malformations
  – Severe Obesity
  – Arterial Aneurysm near kidney
  – Anatomical obstruction distal to stone
Complications

- Steinstrasse 4-7%
- Re-growth of residual fragments 21-59%.
- Renal colic 2-4%
- Bacteriuria in non-infected stones 7.7%
- Sepsis 1%
- Symptomatic hematoma <1%
- Morbid cardiac events (case reports)
- Bowel Perforation (case reports)
- Liver, spleen hematomas (case reports)


Antimicrobial Prophylaxis

- Is it necessary?

Incidence of Infectious Complications after Extracorporeal Shock Wave Lithotripsy in Patients Without Associated Risk Factors

Alejandra Mira Moreno, María Dolores Montoya Lirola, Pedro J. García Tabar, Juan Francisco Galiano Baena, José Antonio Tenza Tenza and Juan José Lobato Encinas

- N = 366
  - 64 with JJ stent.
  - Mean stone size 1.3cm
- No Antibiotic prophylaxis given.
- Results
  - 20 (5.8%) positive urine culture post-ESWL
  - 4 (1.2%) symptomatic UTI
  - No urosepsis.

Antibiotic Prophylaxis for Shock Wave Lithotripsy in Patients with Sterile Urine Before Treatment May be Unnecessary: A Systematic Review and Meta-Analysis

Yang Lu, Fan Tianyong, Han Ping, Liu Liangren, Yuan Haichao and Wei Qiang

From the Department of Urology, West China Hospital, Sichuan University, Sichuan, China

- Meta-analysis
  - 9 Randomized Clinical Trials
    - 2 Double blind
    - 3 placebo controlled
  - N = 1364
  - *Only risk factors among these patients were ureteral stents
- Results:
  - No change in fever (RR 0.36, 95% CI 0.07-2.36, p=0.31)
  - No change +ve Ucx (RR 0.77, 95% CI 0.54-1.11, p=0.17)
  - No change UTI (RR 0.54, 95% CI 0.29-1.01, p=0.05)
Antimicrobial Prophylaxis

- **AUA**
  - Antibiotic prophylaxis only in patient with risk factors for infection prior to ESWL (updated in 2012)\(^1\).
  - 1\(^{st}\) Line: Quinolone or TMP-SMX.
  - 2\(^{nd}\) Line: Aminoglycoside +/- ampicillin; 1\(^{st}\)/2\(^{nd}\) generation cephalosporin; amoxicillin/clavulanate.

- **EUA**
  - Antibiotic prophylaxis only in patients with stents & drainage tubes\(^2\).

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Antimicrobial Prophylaxis

- **Risk Factors for Infection?**\(^1\)
  - Positive urine culture
  - Pre-op UTI
  - Nephrostomy tube
  - Ureteric stent
  - Advanced age
  - Smoking
  - Chronic corticosteroid use
  - Colonized endogenous/exogenous material
  - Distant coexistent infection
  - Prolong hospitalization

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A Prospective Study Examining the Incidence of Bacteriuria and Urinary Tract Infection After Shock Wave Lithotripsy with Targeted Antibiotic Prophylaxis

R. John D’A. Honey,*† Michael Ordon,‡ Daniela Ghiculete,† Joshua D. Wiesenthal,§ Ronald Kodama‡ and Kenneth T. Pace¶

From the Division of Urology, St. Michael’s Hospital (RJDH, MO, DG, JDW, KTP) and Sunnybrook Health Science Centre (RK), University of Toronto, Toronto, Ontario, Canada

Prospective single cohort

• N = 526 patients
• Antibiotics used at surgeon’s discretion in 8 (1.2%) of patients

Results

• 11 (2.8%) Asymptomatic bacteriuria
• 1 (0.3%) UTI
• No urosepsis

Objectives

1. Patient factors effecting ESWL success.
2. Techniques to optimize treatment during ESWL.
3. Adjunctive therapy following ESWL.
Preoperative Nomograms for Predicting Stone-Free Rate After Extracorporeal Shock Wave Lithotripsy

Rent Kanao,* Jun Nakashima, Ken Nakagawa, Hirotaka Asakura, Akira Miyajima, Mototsugu Oya, Takashi Ohigashi and Masaru Murai

From the Department of Urology, Keio University School of Medicine, Tokyo, Japan

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### Table 3. Nomograms predicting stone-free rates 3 months after single ESWL®

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>5 or Less</th>
<th>6–10</th>
<th>11–15</th>
<th>16–20</th>
<th>21 or Greater</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stone</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Calix</strong></td>
<td>86.1 (68.7–96.2)</td>
<td></td>
<td>72.2 (60.8–81.6)</td>
<td></td>
<td>56.8 (40.6–70.2)</td>
</tr>
<tr>
<td><strong>Renal pelvis</strong></td>
<td>89.3 (97.7–73.6)</td>
<td></td>
<td>77.9 (64.1–88.5)</td>
<td></td>
<td>64.4 (48.4–77.0)</td>
</tr>
<tr>
<td><strong>Proximal ureter</strong></td>
<td>93.8 (88.0–98.3)</td>
<td></td>
<td>86.6 (80.9–91.3)</td>
<td></td>
<td>76.4 (65.2–84.5)</td>
</tr>
<tr>
<td><strong>Mid-distal ureter</strong></td>
<td>92.3 (80.7–98.2)</td>
<td></td>
<td>83.6 (78.5–78.8)</td>
<td></td>
<td>71.8 (59.1–82.2)</td>
</tr>
<tr>
<td><strong>Multiple stones</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Calix</strong></td>
<td>71.2 (51.4–90.1)</td>
<td></td>
<td>49.8 (36.1–62.4)</td>
<td></td>
<td>33.5 (21.2–46.0)</td>
</tr>
<tr>
<td><strong>Renal pelvis</strong></td>
<td>76.8 (54.7–92.4)</td>
<td></td>
<td>57.8 (42.6–77.8)</td>
<td></td>
<td>41.3 (26.5–52.3)</td>
</tr>
<tr>
<td><strong>Proximal ureter</strong></td>
<td>85.5 (85.0–95.3)</td>
<td></td>
<td>70.8 (56.5–82.5)</td>
<td></td>
<td>55.2 (38.3–71.3)</td>
</tr>
<tr>
<td><strong>Mid-distal ureter</strong></td>
<td>86.4 (86.3–94.3)</td>
<td></td>
<td>65.8 (52.3–77.6)</td>
<td></td>
<td>49.5 (35.4–63.2)</td>
</tr>
</tbody>
</table>

Parentheses show 95% confidence intervals (%).
Stone Location

- **Lower Pole Stones**
  - Low rates of success ~ 37%\(^1\)
- **Factors impeding clearance\(^2-4\):**
  - Infundibulopelvic angle < 70°
  - Infundibular length >3cm
  - Infundibular width <5mm
  - Singular minor calyx


Resistant Stones

Identifying Resistant Stones

- **Hounsfield Units (HU):**
  - Stones > 900HU are resistant to fragmentation¹

- **Resistant to Fragmentation²⁻⁴**
  - Brushite
  - Calcium Oxalate Monohydrate
  - Cysteine
    » Particularly homogenous appearing.

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Patient Positioning

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**Fig. 1.** Proposed treatment positions for ureteral calculi. (A) Schematic of coronal CT image showing that transverse processes of vertebra theoretically interfere with shockwave transmission when patient is in ordinary supine position. (B) Semilateral approach (rotated-supine position) should prevent such interference. (C) Use of Dornier U15/50 with patients in rotated-supine position. (D) In ordinary prone position, pelvic bone interferes with shockwave transmission. (E) Rotated-prone position reduces interference attributed to pelvic bone. (F) Extracorporeal lithotripsy with patients in rotated-prone position.
Efficacy of Extracorporeal Shockwave Lithotripsy with Patients Rotated Supine or Rotated Prone for Treating Ureteral Stones: A Case-Control Study

NOBORU HARA, M.D., Ph.D., HIROSHI KOIKE, M.D., VLADIMIR BILIM, M.D., Ph.D., KOTA TAKAHASHI, M.D., Ph.D., and TSUTOMU NISHIYAMA, M.D., Ph.D.

- Prospective trial
  - 734 patients.

- Ureteral Calculi
  - Proximal
    » Supine 1.74 sessions vs rotated supine 1.49 sessions
    p=0.02.
  - Mid
    » Prone 83.9% SF vs rotated prone 95% SF, p = 0.046
  - Distal
    » Prone 89.1% SF vs rotated prone 98% SF, p = 0.011

Skin to Stone Distance

Skin to Stone Distance

- Distance from skin to stone in path of lithotripter.
- Greater SSD predicts Failure
  - SSD >10-10.7cm$^{1,2}$.
  - Both fat and non-fat components independently predict failure.
  - Increased SSD decrease shock wave amplitude & symmetry of the focused wave$^{3}$.


Skin to Stone Distance Is an Independent Predictor of Stone-Free Status Following Shockwave Lithotripsy

Trushar Patel, M.D., Kristin Kozakowski, M.D., Greg Hruby, M.S., and Mantu Gupta, M.D.

- Retrospective single institution
- N = 1282 SWL procedures
- SSD was most significant Factor

Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Stone free</th>
<th>Residual fragments</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n)</td>
<td>51</td>
<td>32</td>
<td>n/a</td>
</tr>
<tr>
<td>Age</td>
<td>51.3</td>
<td>52.0</td>
<td>0.813</td>
</tr>
<tr>
<td>Laterality</td>
<td>Left 28</td>
<td>21</td>
<td>0.334</td>
</tr>
<tr>
<td></td>
<td>Right 23</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Stone location</td>
<td>Lower pole</td>
<td>32</td>
<td>0.106</td>
</tr>
<tr>
<td></td>
<td>Central region</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pelvis 5</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper pole 8</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Stone size (mm)</td>
<td>8.2</td>
<td>8.8</td>
<td>0.306</td>
</tr>
<tr>
<td>SSD (mm)</td>
<td>83.3</td>
<td>107.7</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>HU</td>
<td>787.7</td>
<td>803.2</td>
<td>0.410</td>
</tr>
<tr>
<td>Shock delivered</td>
<td>2342.7</td>
<td>2344.8</td>
<td>0.178</td>
</tr>
</tbody>
</table>

J Endo Urol 2009
Objectives

1. Patient factors effecting ESWL success.
2. Techniques to optimize treatment during ESWL.
3. Adjunctive therapy following ESWL.

Pre-ESWL Stenting?

**Indications?**

- **Absolute**
  - Obstructive pyelonephritis
  - Renal failure
  - Solitary kidney
- **Relative**
  - Stone size > 1.5cm
  - Pain management
  - Hydronephrosis
  - Long travel distance to stone centre
  - Steroid therapy, diabetic, advanced age

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**Extracorporeal shock wave lithotripsy for large renal calculi: the role of ureteral stents. A randomized trial.**

Riekers AF, Hendriks AJ, Lemmens VA, Debruyne FM

- **N = 64**
  - Randomized to ESWL +/- ureteric stent
  - Stone burden > 2cm
  - 3 month postop treatment result and post-ESWL morbidity analyzed

<table>
<thead>
<tr>
<th>Results</th>
<th>No stent (n=23)</th>
<th>Stent (n=41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fever/pyelonephritis</td>
<td>4 (17%)</td>
<td>8 (20%)</td>
</tr>
<tr>
<td>Steinstrasse</td>
<td>3 (13%)</td>
<td>6 (15%)</td>
</tr>
<tr>
<td>Stent calcification</td>
<td></td>
<td>7 (17%)</td>
</tr>
<tr>
<td>Stent migration</td>
<td></td>
<td>10 (24%)</td>
</tr>
<tr>
<td>Stone free rate</td>
<td>8 (35%)</td>
<td>18 (44%)</td>
</tr>
</tbody>
</table>

- **Conclusion:**
  - Ureteral stents do not reduce post-ESWL complications; have associated morbidity; do not markedly improve stone passage.
Use of Ureteral Stent in Extracorporeal Shock Wave Lithotripsy for Upper Urinary Calculi: A Systematic Review and Meta-Analysis

Shen Pengfei, Jiang Min, Yang Jie, Li Xiong, Li Yutao, Wei Wuran, Dai Yi, Zeng Hao* and Wong Jia*

- 8 randomized clinical trials
  - 876 pts; stented (n=453); stentless (n=423)
  - Subgroups (renal, ureteral, renal or ureteral)

Results:
- Stone free rate (all 8 trials)
  - Stented – 78% vs stentless – 83%
  - NO difference
- Steinstrasse (5 of 8 trials)
  - All but 1 trial had no significant difference in incidence
  - Stone size >20mm is risk for steinstrasse
- LUTS (3 of 8 trials)
  - RR 4.1 (CI 2.21-7.61) among stented patients!
  - Auxillary treatment (6 of 8 trials)
  - No statistical difference

Conclusion:
- Pre-stenting ESWL remains controversial
- No difference in stone-free rate, auxillary treatment
- Increased LUTS

Ureteric stents compromise stone clearance after shockwave lithotripsy for ureteric stones: results of a matched-pair analysis

Athanasios N. Argyropoulos and David A. Tolley
The Scottish Lithotripter Centre, Western General Hospital, Edinburgh, Scotland, UK

- Prospective Analysis
  - Sept 2004 – March 2006
  - Inclusion Criteria: solitary, radiopaque, previously untreated ureteric calculi matched by gender, side, location in ureter and size (+/- 1-2mm)
  - 45 pts with ureteric stent matched

- Stone-free rate
  - Stented – 71%
  - Unstented – 93%

- Conclusion
  - Stenting has LOWER stone free rate for ESWL in ureteric calculi
Pre-ESWL Imaging

- Plain KUB’s often performed to ensure stone can be seen on fluoroscopy.
- FLUOR.O
  - Algorithm created to predict ability to visualize stone under fluoroscopy base upon CT Characteristics:
    » Stone Size.
    » Stone to Anterior Abdominal Wall distance.
    » Mid ureter location.
    » HU
    » Abdominal wall fat thickness

- **Equation** = \( \frac{e^{0.203 + 0.304 \times \text{Stone size (in mm)} + 0.005 \times \text{HU} + 3.087 \times \text{Mid-ureteral stone (if yes=1, if no=0)}}}{1 + e^{0.203 + 0.304 \times \text{Stone size (in mm)} + 0.005 \times \text{HU} + 3.087 \times \text{Mid-ureteral stone (if yes=1, if no=0)}}} \) - [0.029*Stone to skin distance (in mm)] - [0.078*Fat thickness of the anterior abdominal wall (in mm)].
the FLUO.R.O. calculator

Hadassah University Hospital, the Hebrew University, Jerusalem, Israel

Calculate the probability of a renal stone to be radiopaque on SWL fluoroscopy
Please enter the appropriate values in the following empty brackets and press calculate

Distance between stone and anterior abdominal wall (values in mm)
(red arrow on the image)

Fat thickness of the anterior abdominal wall (values in mm)
(blue arrow on the image)

Is this a mid-ureteral stone? (If yes, enter 1. If no, enter 0.)

Stone maximum diameter (values in mm)

Stone attenuation (Hounsfield Units)

Calculate

https://www.dropbox.com/s/puhmmb8bgt6zsow/Fluoro.html

FLUO.R.O

Results:

• FLUO.R.O had better prediction of radiopaqueness during fluoroscopy than plain KUB p<0.001.

• ROC plots:
  » AUC for FLUO.R.O = 0.965 (CI: 0.894-0.994)
  » AUC for KUB = 0.727 (CI: 0.611-0.823)
Predictive Algorithms

- Logistic Regression
  - Uses variable inputs and their relationships to outcome to create a predictive model.

- Artificial Neural Networks
  - Software that requires training, recalls particular inputs and associated outcomes, creating weights among input variables for predicting the outcome.

Can we improve the prediction of stone-free status after extracorporeal shock wave lithotripsy for ureteral stones? A neural network or a statistical model?

Mohamed A. Gomha, Khaled Z. Sheir, Saeed Showky, Mohamed Abdel-Khalek, Alaa A. Mokhtar and Khaled Madbouly

From the Urology and Nephrology Center, Mansoura, Egypt

- Reviewed 984 patients

<table>
<thead>
<tr>
<th>Variables</th>
<th>No. Neurons</th>
<th>Categories</th>
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</thead>
<tbody>
<tr>
<td>Input neurons:</td>
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<td></td>
</tr>
<tr>
<td>Age</td>
<td>2</td>
<td>40 or Younger, older than 40</td>
</tr>
<tr>
<td>Sex</td>
<td>2</td>
<td>Male, female</td>
</tr>
<tr>
<td>Side</td>
<td>2</td>
<td>Rt, Lt</td>
</tr>
<tr>
<td>Stone location</td>
<td>4</td>
<td>PUJ, lumbar, iliac, pelvic</td>
</tr>
<tr>
<td>Renal anatomy</td>
<td>2</td>
<td>Normal, obstructed, pyelonephritic</td>
</tr>
<tr>
<td>Stone nature</td>
<td>2</td>
<td>De novo, recurrent</td>
</tr>
<tr>
<td>Stone No.</td>
<td>2</td>
<td>Single, multiple</td>
</tr>
<tr>
<td>Stone length</td>
<td>2</td>
<td>10 or Less, greater than 10 mm</td>
</tr>
<tr>
<td>Stone width</td>
<td>2</td>
<td>8 or Less, greater than 8 mm</td>
</tr>
<tr>
<td>Stent</td>
<td>2</td>
<td>No stent, ureteral catheter, Double-J stent</td>
</tr>
<tr>
<td>Output neuron:</td>
<td>1</td>
<td>0—Nonstone-free, 1—stone-free</td>
</tr>
</tbody>
</table>

- ANN
  - Sensitivity of 77.9%
  - Specificity of 77.9%
  - Positive Predictive Value 97.2%
  - Accuracy of 77.7%
Acoustic Coupling

• Coupling agent
  • Ideal media has minimal energy absorption & similar acoustic impedance to body tissue.
  • Classically Water
  • Newer Dry head lithotripters
    » Gel

http://www.medwow.com/articles/lithotripter/extracorporeal-shockwave-lithotripsy-defined/
Acoustic Coupling

- Low viscosity bubble free gel is most successful\(^1\).
- Air bubbles as little as 2% surface area reduce fragmentation by 20-40\(^\circ\)\(^2\).
- Optimal application of ultrasound gel directly to patient in a central mound rather than spreading along surface\(^3\).

![Image](image1.png)


Rate

- Shock wave rates of 60/min are better than 120/min\(^1\).
  - Improved stone fragmentation
  - Less renal tissue damage
- Mechanism\(^2\):
  - At increased rates, the cavitation bubble has not expired, thus an air interface is present for the following shock wave resulting in impaired fragmentation.
  - Loss of negative pressure portion of shockwave.

Shock Wave Sequence

• Power ramping
  • Initial shocks are performed at lower voltage.
  • Voltage then escalated for majority of case.

• Advantages:
  • Patient can get accustomed to shockwaves.
  • Stone fragmentation is improved\(^1\).
  • Reduced renal injury in vitro\(^2-4\).

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Optimization of Treatment Strategy Used During Shockwave Lithotripsy to Maximize Stone Fragmentation Efficiency

Daniel Z. Yong, B.S.; Michael E. Lipkin, M.D.; W. Neal Simmons, Ph.D.; Georgy Sankin, Ph.D.; David M. Albala, M.D.; Pei Zhong, Ph.D.; and Glenn M. Preminger, M.D.

• In vitro experiment
  • 4 conditions:
    » Escalating voltage at 1Hz
    » Escalating voltage at 2Hz
    » Decreasing voltage at 1Hz
    » Decreasing voltage at 2Hz

• Results:
  • Escalating voltage at 1Hz had superior fragmentation

• Discussion:
  • Low voltage minimizes cavitation – allowing stress waves to cause fractures in the stone.
  • Higher voltage – emphasizes cavitation, working on the surface area of the stone.

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Prevention of Lithotripsy-Induced Renal Injury by Pretreating Kidneys with Low-Energy Shock Waves

Lynn R. Willis,* Andrew P. Evan,† Bret A. Connors,‡ Rajash K. Handa,*
Philip M. Blomgren,*, and James E. Lingeman†
Departments of *Pharmacology and Toxicology and †Anatomy and Cell Biology, Indiana University School of Medicine, and the ‡Methodist Hospital Institute for Kidney Stone Disease, Indianapolis, Indiana

Digitized serial-section images (coronal plane) of a kidney that had been treated first with 2000 shock waves (SW) at 24 kV to the lower pole (shock wave lithotripsy [SWL] 1) and immediately thereafter with the same “dose” (2000 SW at 24 kV) to the upper pole (SWL 2) showing renal injury as indicated by red-stained hemorrhage and hematomas.

Lesion sizes were 0.28% (first pole) in group 2 was 0.020% FRV; 0.33% (second pole) in group 2 was 0.01% FRV; 3.6% FRV with no pretreatment [NP]; 95% confidence interval [CI] 1.7 to 5.22% FRV in group 3 except 100 12-kV SW pretreatment. Mean lesion size for the protection may be 0.82% of functional renal volume (FRV; 95% CI 0.50 to 1.2) in group 4. It is concluded that the pretreatment protocol substantially limits the renal injury that normally is caused by SWL and occurs when the pretreatment and standard SW are applied to the same pole. The threshold power and smaller focal zones, ostensibly to enhance stone comminution and diminish injury to renal tissue. Ironically, the response occurred after pretreatment with low-energy SW, which cause minimal detectable damage to the renal parenchyma; the response was initiated by tissue injury or by the shock waves.

The studies described in this article aimed at confirming and characterizing this protective response and asked whether the response is initiated by tissue injury or by the shock waves. The experimental protocol used in this study was carried out in accordance with the institutional guidelines for the care and use of laboratory animals and was approved by the Institutional Review Board for the use of laboratory animals.
Prevention of Lithotripsy-Induced Renal Injury by Pretreating Kidneys with Low-Energy Shock Waves

Lynn R. Willis,* Andrew P. Evan,† Bret A. Connors,† Rajash K. Handa,* Philip M. Blomgren,* and James E. Lingeman†
Departments of *Pharmacology and Toxicology and †Anatomy and Cell Biology, Indiana University School of Medicine, and the ‡Methodist Hospital Institute for Kidney Stone Disease, Indianapolis, Indiana

Digitized images (mid-coronal plane) of three kidneys each from groups 3 (a) and 4 (b). The same pole of each kidney was treated with shock waves (SWs) at 12 kV (panel A), followed by a 3-min pause and then the standard dose of high-energy SWs (panel B), pretreatment with low-energy SWs (panel C), and pretreatment with high-energy SWs (panel D).
Focal Zone Size

- **Focal zone** is the area which the shock waves are focused.
- **Acoustic output** ~ focal zone size & acoustic pressure
- **Older Lithotripters**
  - Wide Focal Zone (18-20mm) & 20mPa pressure.
- **Newer Lithotripters**
  - Narrow Focal Zone (3-6mm) & 60 to 160mPa pressure.
**Focal Zone Size**

- **Wider Focal zones:**
  - Superior stone fragmentation\(^1\).
  - Lower retreatment rates\(^2\).
  - Less complications\(^3\).
  - Less renal tissue injury\(^4\).

- **Reasons:**
  - More shocks within stone during respiration\(^5\).
  - Less energy focused acutely on parenchymal tissue.

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**Stone Tracking**

- **40-50% of shocks contact the stone during respiration\(^1\).**

- **Role for stone tracking systems\(^2\)?**
  - Combination of ultrasound and computer tracking algorithms.
    - Ultrasound & software track the stone in real time
    - The lithotripter then repositions with every shock based upon the ultrasound and software.
    - **RESULTS:** number of shocks used to fragment stones reduced by factor of 1.64

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Acoustic Feedback

- Functions to detect stone fragmentation
  - Allows user to stop additional unnecessary shocks with potential to damage tissue.
- In Vitro System\(^1\):
  - Broadband receiver monitors reverberations from the shock waves & stones.
  - Smaller fragments correspond to a higher frequency signal.
  - Discriminates between 1-2mm variance in size.


Serial shockwaves

- Tandem and Dual Head Lithotripters
Serial shockwaves

- Tandem and Dual Head Lithotripters
  - Uses two sources producing shock waves.

Results:
- Stone Fragmentation
  - 95.2% with tandem lithotripter vs 81.3% in original HM-3 lithotripter in vitro.
- Safety
  - Phantom vessel
    - HM-3 lithotripter ruptures in 30 shocks
    - Tandem lithotripter did not rupture after >200 shocks

Mechanism:
- Addition of second generator intensifies collapse of cavitation bubble enhancing fragmentation.
- The second generator limits size of the cavitation bubble that may be intraluminal and cause vascular injury.

Serial shockwaves

- Acoustic Bubble Removal

  - Cavitation bubbles last 1ms
  - Smaller cavitation nuclei may last up to 1 second!
  - Low-amplitude acoustic pulse aggregates the smaller nuclei to coalesce and collapse
  - Allows faster rate of shocking.

Acoustic Bubble Removal to Enhance SWL Efficacy at High Shock Rate: An In Vitro Study

Alexander P. Duryea, MSE; William W. Roberts, MD; Charles A. Cain, PhD; Hedieh A. Tamaddoni, MSE; and Timothy L. Hall, PhD

Medication Adjuncts

- Diuretics
- Mannitol
Effect of Diuretics on Ureteral Stone Therapy with Extracorporeal Shock Wave Lithotripsy

J. Goliavand, J. Samady and A. Zomorodi


- Randomized Trial
  - N = 87
  - ESWL: 3500 shocks
  - Standard care vs 40mg lasix during session

- Results
  - Stone clearance favored Lasix group by:
    » 28% Proximal ureter
    » 38% Mid ureter
    » 15.4% Distal ureter

Mannitol

- Mannitol has been shown to be renoprotective.

- Randomized trial:
  - Mannitol was associated with less of an increase in resistive indices compared to controls.
  - Mannitol was associated with decrease in Beta2-microglobulin excretion compared to controls
Objectives

1. Patient factors effecting ESWL success.
2. Techniques to optimize treatment during ESWL.
3. Adjunctive therapy following ESWL.

Medical Expulsive Therapy

• Agents
  • Alpha Blockers
  • Calcium Channel Blockers
**α-Blockers to assist stone clearance after extracorporeal shock wave lithotripsy: a meta-analysis**

Yefang Zhu*, Diederick Duijvesz‡, Maroeska M. Rovers* and Tycho M. Lock**

*Department of Urology, Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, ‡Department of Urology, Central Military Hospital, Utrecht, and **Department of Urology, Erasmus Medical Center, Rotterdam, the Netherlands

- 7 trials meeting criteria.
  - 484 patients
  - Tamsulosin cleared 16% more stones (95% CI: 5-27%).
  - NNT = 6
  - Expulsion 8 days sooner
  - Less pain and analgesia use
  - Side effects in 3% being dizziness.

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**Adjuvant Tamsulosin or Nifedipine After Extracorporeal Shock Wave Lithotripsy for Renal Stones: a Double Blind, Randomized, Placebo-controlled Trial**

Fabio C. Vicentini, Eduardo Mazzucchi, Artur H. Brito, Elias A. Chedid Neto, Alexandre Danilovic, and Miguel Srougi

- Randomized controlled Trial
  - N = 136
  - Tamsulosin vs nifedipine vs placebo

- Results:
  - Primary outcome: stones <4mm at 30 days post ESWL
  - Tamsulosin 60.5%
  - Nifedipine 48.6%
  - Placebo 36.8%
  - Adverse events were higher in Nifedipine than placebo, no statistical difference among Nifedipine & Tamsulosin.
Pesky Lower Pole Stones

• Anything to help?

http://www.nature.com/nmsurjournal/v5/n6/images/nmsur51105-f1.jpg

Pesky Lower Pole Stones

• Percussion, Diuresis, Inversion (PDI) Therapy
  • Patients drink 500ml water 30 min prior to inversion and percussion therapy x 10 minutes.
  • Median of 4 sessions

• Results
  • 3 month stone free rates
    » Usual care 35.4%
    » PDI 62.5%

• Limitations:
  • Time & Convenience

Pesky Lower Pole Stones

- What if you could reposition them?
  - Not with a ureteroscope??

Focused Ultrasonic Propulsion of Kidney Stones: Review and Update of Preclinical Technology

Mathew D. Sorensen, MD, MS, Michael R. Bailey, PhD, Ryan S. Hsi, MD, Bryan W. Cunitz, MS, Julianna C. Simon, MS, Yak-Nam Wang, PhD, Barbrina L. Dunmire, MS, Marla Paun, BS, RDM, RVT, Frank Starr, BS, Wei Lu, PhD, Andrew P. Evan, PhD, and Jonathan D. Harper, MD

Feasibility of generating stone motion was first demonstrated in an animal model with an investigational ultrasound device. The initial testing of a prototype device using noninvasive ultrasound propulsion of kidney stones has been completed, and the results are promising.

- In a porcine model, ultrasound propulsion was able to move 11 mm kidney stones.
- The stones were moved without the need for additional surgical interventions.
- The technology has the potential to reduce the need for invasive procedures and improve patient outcomes.

The future of ultrasound propulsion technology includes further testing and clinical trials to validate its effectiveness and safety.

http://www.nature.com/nrm/journal/v15/n6/images/nrm3105-f1.jpg
Focused Ultrasonic Propulsion of Kidney Stones: Review and Update of Preclinical Technology

Mathew D. Sorensen, MD, MS,1,2 Michael R. Bailey, PhD,2 Ryan S. Hsi, MD,2 Bryan W. Cunlitz, MS,2 Julianna C. Simon, MS,2 Yak-Nam Wang, PhD,2 Barbrina L. Dunmire, MS,2 Marla Paun, BS, RDMS, RVT,2 Frank Starr, BS,2 Wei Lu, PhD,2 Andrew P. Evan, PhD,2 and Jonathan D. Harper, MD2

• Pre-Human Clinical Trials:
  • Successfully relocated stones from lower pole in porcine model 6/6 kidneys1.
  • Stone velocity 1cm/s1.
  • Duration less than 2 minutes1.
  • No detectable renal tissue damage when porcine kidneys exposed for 10 minutes1.
  • Commercial unit made; initiating human trials2.


Thank you

• Dr. Ben Chew
• Dr. Ryan Paterson