Heat generation from high power holmium laser lithotripsy: In-vivo assessment in a porcine model

William W. Roberts, MD
Professor of Urology and Biomedical Engineering
University of Michigan

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Disclosure

Unrelated to this presentation

• I am an inventor on patents licensed to HistoSonics.
• I hold stock in HistoSonics.

Further information:
http://www.engin.umich.edu/admin/adaa/disclosure
http://histosonics.com/
David Bloom, MD  Chairman of Urology UM
Background

- Kidney/ureteral stones increasing in frequency
- URS with LL now dominant modality for most stones
- Expanded laser parameter set with newer high power (120 W) holmium lasers.
Laser Power

- Definition: rate at which energy is transferred
- SI unit is the Watt = 1 Joule/sec
- Laser power = pulse energy x frequency
  
  Actual peak power is ~3 kilowatts for 1 J pulse

- Thermal effects are result of the time-averaged power
- i.e. 0.5J x 20Hz = 0.2J x 50 Hz = 10 W
Typical laser settings

- Fragmentation 0.8J at 10 Hz  8 W
- Dusting 0.3-0.5 J at 50 Hz  15-25 W
- Pop-dusting 0.5 J at 80 Hz  40 W
Thermal dose

• For in-vivo and in-vitro systems an exponential relationship exists between temperature and exposure time.

Sapareto and Dewey Int J Rad Onc Biol Phys 1984
Thermal dose

- Cell death occurs when tissue is maintained at 43°C for 120 minutes.
- $t_{43}$ equivalent minutes is a concept developed by Dewey and Sapareto.

$$t_{43} = \sum_{t=0}^{t=\text{final}} R^{(43-T)\Delta t}$$

- $t_{43} > 120$ minutes = cell death
Thermal dose

Threshold for tissue damage is 43°C for 120 minutes.

- Equivalent to 50°C for 56 seconds
- Equivalent to 56°C for 0.9 seconds
- In each of these cases the $t_{43} = 120$ minutes
In vitro studies

Molina...Kim et al J Endo 2015
Buttice...Traxer et al J Endo 2016
Sourial...Knudsen et al abstract EUS 2017
Aldoukhi...Roberts et al J Endo 2017
Wollin...Lipkin et al J Endo 2018
Temperature changes with different settings at flow rate of 14-15 mL/min

- No irrigation
- Laser deactivation with Irrigation
- 0.5 J x 10 Hz
- 0.5 J x 20 Hz
- 1.0 J x 20 Hz
- 1.0 J x 40 Hz
- Laser activation with Irrigation
- 0.5 J x 80 Hz
Temperature at different flow rates for laser setting of 1.0 J x 40 Hz
Simulation 40 W, 0 ml
Simulation 10W 5 ml
Simulation 40 W, 40 ml
Medium irrigation (100 cm H₂O gravity irrigation)
High irrigation (100 cm H₂O gravity + 150 mmHg)
Mean temperature change with 60 seconds of laser activation

- High flow
- Medium flow
- No flow
<table>
<thead>
<tr>
<th>Trial</th>
<th>Irrigation rate</th>
<th>Thermocouple type</th>
<th>Temperature after 10 seconds (°C)</th>
<th>Time to T43 120 min. (sec)</th>
<th>Peak temp (°C)</th>
<th>T43 equivalent minutes</th>
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</thead>
<tbody>
<tr>
<td>3</td>
<td>No</td>
<td>Needle</td>
<td>78.44</td>
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<td>93.54</td>
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<td>0.14</td>
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</table>
Conclusions

• High power laser lithotripsy expands the options and strategies for laser lithotripsy and increases treatment efficiency.

• High power laser settings, prolonged laser activation, and low irrigation can produce a thermal dose that is injurious to adjacent tissue.

• Further work to define the safety envelope within the laser lithotripsy parameter space is ongoing.

• Strategies and techniques are being studied to control and mitigate thermal effects during Holmium laser lithotripsy.
Thank you!
• Operator Duty Cycle
1 min continuous laser firing (starting at 20 sec)

- 0 mL/min (Needle)
- 0 mL/min (Wire)
- 7-8 mL/min (Needle)
- 7-8 mL/min (Wire)
- 14-15 mL/min (Needle)
- 14-15 mL/min (Wire)
Lasering was 5 sec on and 5 sec off (starting at 20 sec)
Lasering was 10 sec on and 10 sec off (starting at 20 sec)

- 0 mL/min (Needle)
- 0 mL/min (Wire)
- 7-8 mL/min (Needle)
- 7-8 mL/min (Wire)
- 14-15 mL/min (Needle)
- 14-15 mL/min (Wire)
It was calculated for the whole curve.

<table>
<thead>
<tr>
<th>Flow rate (thermocouple type)</th>
<th>1 min</th>
<th>5 on 5 off</th>
<th>10 on 10 off</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 mL/min (Needle)</td>
<td>2,328,827.32</td>
<td>672,635.80</td>
<td>515,716.33</td>
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<tr>
<td>0 mL/min (Wire)</td>
<td>14,587,782.00</td>
<td>294,156.48</td>
<td>1,512,717.17</td>
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<tr>
<td>7-8 mL/min (Needle)</td>
<td>5,942.97</td>
<td>302.75</td>
<td>1,978.30</td>
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<tr>
<td>7-8 mL/min (Wire)</td>
<td>25,901.07</td>
<td>93.01</td>
<td>288.17</td>
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<tr>
<td>14-15 mL/min (Needle)</td>
<td>61.87</td>
<td>4.76</td>
<td>8.34</td>
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<tr>
<td>14-15 mL/min (Wire)</td>
<td>137.83</td>
<td>1.64</td>
<td>6.39</td>
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