Quantifying the Force Needed for Ureteral Stent Removal:

Initial evaluation of a magnetic stent removal device on benchtop and porcine models

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Stent–X Magnetic Ureteral Stent Removal Device

Magnetic bead and stent are installed in initial pyeloplasty

3-5 weeks later, a surgeon pulls on the bead with an electromagnet, removing both the bead and stent in a 8 minute procedure

1st Prize – 2015 Rice Annual Showcase / Grand Prize – 2015 DMD Student Showcase
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Study Objective

- Little is known about the forces required to remove indwelling ureteral stents

Initial Objective

- To characterize and quantify the required forces for stent removal for testing of future prototypes
Lazarus 3D Benchtop Model
Modified Porcine Model

- Midline suprapubic incision
- Distal ureter transected for antegrade stent placement
- Urethra dissected distally from the bladder
- Urethral transection close to the urogenital sinus
- Urethra sutured to the inferior portion of the skin incision
  - cutaneous urethrostomy
Methods - Force Measurements

- HF-10 digital force gauge by M&A Instruments
  - Quantified force required to remove different stents
- External magnets versus catheter tip magnets
  - Quantified magnetic force
  - Measured success with various magnetic beads
### Results – Force Measurements

#### Table 1: Force to remove ureteral stent on benchtop and porcine model

<table>
<thead>
<tr>
<th>Bead type/Stent size</th>
<th>BENCHTOP - Max Retrieval Force in N</th>
<th>PIG - Max Retrieval Force in N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bladder</td>
<td>Ureter</td>
</tr>
<tr>
<td>5Fr x 14cm double-J Stent</td>
<td>0.793 ± 0.216</td>
<td>4.734 ± 0.620</td>
</tr>
<tr>
<td>5Fr x 14cm double-J Stent with 3.2x3.2mm cylindrical, hollow bead</td>
<td>0.993 ± 0.137</td>
<td>4.055 ± 0.564</td>
</tr>
<tr>
<td>5Fr x 14cm double-J Stent with 4.8x4.8mm cylindrical, hollow bead</td>
<td>1.685 ± 0.154</td>
<td>3.920 ± 0.624</td>
</tr>
<tr>
<td>3.2x3.2mm cylindrical, hollow bead</td>
<td>0.198 ± 0.044</td>
<td></td>
</tr>
<tr>
<td>4.8x4.8mm cylindrical, hollow bead</td>
<td>1.893 ± 0.186</td>
<td></td>
</tr>
<tr>
<td>5Fr x 14cm equivalent straight stent</td>
<td>0.293 ± 0.148</td>
<td>4.284 ± 0.584</td>
</tr>
<tr>
<td>Stent unfurling only</td>
<td>0.793 ± 0.216</td>
<td></td>
</tr>
</tbody>
</table>
Results – Magnetic Force Requirements

• Based on the measurements, a goal force of 1 N would be required to definitively remove the stent.
• For the external magnet design, this force needed to be present at a distance of 4-5 cm, correlating to urethral length.

*Figure 3. Distance vs force plots using the a) EM at 3A current and b) 2"x1" cylindrical permanent magnet.*
Design Change → Magnetic Tip Catheter

- Filled bladder appears to reduce friction and allow for easier passage
  - Allows for better results with smaller magnet
Conclusions

- The ureteral stent removal force is < 1N on the porcine model.

- However, external magnets could not generate sufficient force due to the inverse square relationship with urethral length.

- Alternatively, the catheter tip magnet model appears to overcome the limitation of distance.

- Further studies are needed to define the optimal combination of catheter tip magnet size and stent magnetic bead size.
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