Development of a Low-Cost, High-Fidelity Simulator for Ultrasound-Guided Percutaneous Nephrolithotomy (PCNL) Training

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Background

Ultrasound-guided percutaneous nephrolithotomy (US-PCNL) has emerged as an attractive alternative for renal access compared to fluoroscopic PCNL. Most simulation PCNL models are expensive and focus on mimicking fluoroscopic PCNL, with few existing models tailored to practice skills specific to US-PCNL. To address the need for an affordable and structurally comprehensive US-PCNL model, a novel simulator was designed. The model consists of a calyx system, kidney, soft tissues, anatomical landmarks, and a box (Figure 1).

The aim of this study is to report the cost and fidelity of this novel US-PCNL simulator and assess urologic trainees’ procedural confidence and learning curve using this model.

Methods

Resident Training (n=9)
- US-PCNL Didactic: 5-minute PowerPoint of US-PCNL procedure
- Practice on US-PCNL Model: 30 minutes of hands-on practice
- Skill Assessment: Demonstration of successful renal access, confirmed by the visualization of fluid drip within 5 minutes
- Procedural Confidence Survey: Pre- & post-training surveys
- Model Fidelity Survey: Comparison of model to US-PCNL on patient

Attending Training (n=8)
- Practice on US-PCNL Model: Minimum of one full access attempt
- Skill Assessment: Demonstration of successful renal access, confirmed by the visualization of fluid drip within 5 minutes
- Model Fidelity Survey: Comparison of model to US-PCNL on patient

Statistical Analysis:
- All statistical analysis was performed in STATA.
- Paired student’s t-tests were used to compare resident procedural confidence before and after the training with a p-value <0.05 considered statistically significant.
- Welch’s t-test was used to confirm that there were no significant differences between resident and attending model fidelity ratings with a significance level of 5%.

Results

<table>
<thead>
<tr>
<th>Procedure Fidelity Survey</th>
<th>Rating (Mean ± SD)</th>
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</thead>
<tbody>
<tr>
<td>Palpation and identification of rib cage landmarks</td>
<td>3.8 ± 0.8</td>
</tr>
<tr>
<td>Palpation and identification of paraspinous muscle landmarks</td>
<td>3.8 ± 1.0</td>
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<tr>
<td>Resistance of skin and soft tissue layers to the passing of a needle</td>
<td>4.0 ± 0.8</td>
</tr>
<tr>
<td>Feel of needle puncture through the renal capsule</td>
<td>3.6 ± 0.8</td>
</tr>
<tr>
<td>Confirmation of access via fluid drip</td>
<td>4.4 ± 0.9</td>
</tr>
</tbody>
</table>

Cost, High fidelity, structurally comprehensive, & educationally beneficial model
- Cost effective: $50 per model/1.5 hours labor
- Adaptable design: Varying stone shapes, amount of hydronephrosis, and thickness of soft tissue

Disadvantages of the US-PCNL Model:
- Storage: Must be sealed and refrigerated
- Shelf Life: 3 weeks

Limitations:
This study was limited by sample size and limited resident experience on real patients. Additional validity evidence is needed to support the findings of this study.

Benefits of the US-PCNL Model:
- High fidelity, structurally comprehensive, & educationally beneficial model

If you have any questions regarding this project, please contact:
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