IPRO 319: New Technology for Cardiac Arrest Victims

Presenters: Grant Austin and Jennifer John
Presentation Outline

- Introduction
- Goals
- Team Structure
- Timeline
- Results
- Obstacles
- Future Challenges
- Conclusion
Cardiac Arrest

- Disruption of heart activity

- In the US,
  - 265,000 cardiac arrests outside hospitals
  - 18% survival rate after discharge in hospitals
  - 95% of victims die before reaching hospital

- Induced hypothermia reduces neurological damage

- Z-axis oscillation along the spine, shown to be better than normal CPR
Previous Work

- Spring 2006: Oscillator for testing mice
- Fall 2006: Developed oscillation table for U of C
- Spring 2007: Basic cooling jacket model
- Spring 2008: Cooling jacket
- Fall 2008: Reduced oxygen breathing mask
- Spring 2009: Investigated chemical cooling and effects of oscillation
- Fall 2009: Designed and constructed oscillator and cooling bed prototypes
Project Goals

- Develop and investigate two devices:
  - rapid cooling bed/blanket
  - periodic z-axis accelerator
Mission Statement

- Develop and improve upon cooling and oscillation technologies
Team Structure

IPRO 319

Cooling

Oscillation

Ethics

Design

Testing

Design

Testing
Team Development and Performance

- Learning how to work together
  - Helping other subgroups in areas each individual member has expertise
- Continuously challenging one another
  - Weekly presentations of progress
  - Intense brainstorming and Q&A sessions
- Developing communication skills
# Timelines of Progress

## Estimated

<table>
<thead>
<tr>
<th>AUGUST</th>
<th>SEPTEMBER</th>
<th>OCTOBER</th>
<th>NOVEMBER</th>
<th>DEC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Week 1</td>
<td>Week 2</td>
<td>Week 3</td>
<td>Week 4</td>
</tr>
<tr>
<td></td>
<td>24 25 26</td>
<td>27 28</td>
<td>29 30</td>
<td>1 2</td>
</tr>
<tr>
<td></td>
<td>7 8 9 10</td>
<td>11 12</td>
<td>13 14</td>
<td>15 16</td>
</tr>
<tr>
<td><strong>TASKS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discuss Technologies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Prototype</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order Parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receive Parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction of Prototype</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing and Debugging</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modification of Prototype</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Actual

<table>
<thead>
<tr>
<th>AUGUST</th>
<th>SEPTEMBER</th>
<th>OCTOBER</th>
<th>NOVEMBER</th>
<th>DEC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Week 1</td>
<td>Week 2</td>
<td>Week 3</td>
<td>Week 4</td>
</tr>
<tr>
<td></td>
<td>24 25 26</td>
<td>27 28</td>
<td>29 30</td>
<td>1 2</td>
</tr>
<tr>
<td></td>
<td>7 8 9 10</td>
<td>11 12</td>
<td>13 14</td>
<td>15 16</td>
</tr>
<tr>
<td><strong>TASKS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discuss Technologies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design Prototype</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Order Parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Receive Parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction of Prototype</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Testing and Debugging</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modification of Prototype</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Shaking Table Design

- Force per wheel is:

  \[ \text{Flin} = \text{macrit} = (100 \text{kg}) \times (5.884 \text{m/s}^2) = 161.81 \text{N}. \]

- Thus, 4 wheels of radius 3 ½” with springs each with spring rating of 34.290 lbf-in.
Shaking Table Results

Linear Displacement vs. Time (sec)
Shaking Table Results

Auto (Power) Spectrum

\[ k_{\text{theoretical}} = 9771 \frac{N}{m} \]
\[ k_{\text{experimental}} = 8720 \frac{N}{m} \]
\[ \frac{8720}{9771} \frac{N}{m} = 89.2\% \]
Cooling Design

- Chemical Reaction vs. Phase Change
- Ammonium Nitrate and Water:

\[
\text{Ba(OH)}_2 \cdot 8\text{H}_2\text{O(s)} + 2\text{NH}_4\text{NO}_3(s) \rightarrow \text{Ba(NO}_3)_2(s) + 2\text{NH}_2\text{aq}) + 10\text{H}_2\text{O(l)}
\]

- Cooling Capacity: **197.4 kJ/kg**

- Phase Change: R125a
- Cooling Capacity (from EES software): **238.5 kJ/kg**
Cooling Design

- Found a suitable material
  - Manipulated via heat sealer

- Tube system to channel refrigerant throughout bed

- Developed pop-rivet/washer valve mechanism to simplify tube attachment

- Custom refrigerant holder optimized ease of use

- Testing the bed alone proved the cooling surface reached temps of -15 F
Cooling Results

Cooling Test - Warm Turkey

- Internal Temp in Ambient Air (Control)
- Internal Temp w/ Cooling
- External Temp w/ Cooling
Obstacles

- Designing devices that the average person would feel comfortable using
- Time & money
- Developing accurate mathematical models
- Constructing an accurate model prior to living subject testing
  - One-way valves?
  - Connecting the heart to system?
- Implementation of devices
Ethical Issues

- Testing on Humans
- Making a decision for a victim that could be physically damaging
  - Negative effects of shaking

Documents of Interest
- Universal Declaration of Human Rights
- Nuremberg Code
- Belmont Report
- International Ethical Guidelines for Biomedical research involving human subjects
- Public Act 096-078
Achievements

- Successfully created two working prototypes: one for cooling and one for oscillation

- Tested prototypes: cooling on a body-temperature turkey and acceleration with human weight

- Learned to manage tasks in parallel to contribute to more than one subgroup
Recommendations

- **Cooling:**
  - Thinner bed for better evaporation/skin interface
  - Gel conducting material
  - Better refrigerant containment system

- **Oscillation:**
  - Refine design of full-scale model
  - Animal and human testing
  - Increase stability of subject

- **Overall:**
  - Revising EMS protocol to adapt new technology
Questions?

Special thanks to Francisco Ruiz, Ray DeBoth and the IPRO Office