Team 11: 
Device to Monitor and Control IHD for Painful Stiff Shoulder Treatment

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Client, Advisor: Dr. Krystyna Gielo-Perczak
TA: Sarah Brittain
Background

- Adhesive Capsulitis (“Stiff Shoulder” or “Frozen Shoulder”): Painful chronic condition\(^1\)
  - Affects 3% of people at some point\(^2\)

- Symptoms
  - Reduced ROM
  - Pain (chronic & acute)

- Risk Factors
  - 20% have diabetes

- Common Treatments
  - Painkillers, steroids
  - Physical therapy
  - Surgical procedures
  - Very long recovery\(^1\)

\(^1\) [http://srisugam.com/Stiff_Shoulder.aspx](http://srisugam.com/Stiff_Shoulder.aspx)
Background

- Novel treatment: Intra-articular hydraulic distension (IHD)
  - Injection of fluid into articular capsule
  - Distends joint & increases ROM
  - Local anesthetic, steroids usually included

- Optimal conditions for treatment still unknown

Introduction

- **Project description from client:**
  - A device to monitor intra-articular pressure and control IHD in real-time, and record and analyze data to improve treatment and rehabilitation options

- **Specifications**
  - Control by PC
  - User interface
  - Portable
  - Procedure for use

- **Key Innovations**
  - Feedback control of pump system
  - Analysis of measurement errors
Project Design

**Patient subsystem:** Patient positioning, preparation, feedback
**Operator subsystem:** Operator functions, device interface, interactions with the patient
Fluid subsystem: Involves all parts of the mechanical system as the fluid is injected
**Project Design**

**Computational subsystem:** Involves the user interface, device control, feedback, and data acquisition and processing
NE-500 OEM

- Programmable
- LabVIEW compatible
- RS-232 pump-to-PC port w/ cable
- Power supply (120V A/C)

Error Analysis
- Data from manufacturer
- Future testing for analysis & calibration

http://www.syringepump.com/oem.php
PendoTECH Disposable Pressure Sensor

- Polycarbonate
- Reusable
- Fluid fittings: Luer-lock
- Wiring & specifications online
  - 4 analog pins: excitation voltage & signal voltage
- Error Analysis

NI USB-6008
- Analog & digital I/O (16 pins ea.)
- A/D conversion
- LabVIEW ready
- USB cable

Error analysis
- Design concern

http://www.ni.com/products/usb-6008/
Subunits: Syringe, Tubing, Adapters, Needles

- Terumo 30mL syringes (pump holds up to 60mL syringes)
- Tubing: 50’ bulk length, 1/16” inner diameter, vinyl
- Adaptors
  - Luer-lock w/ hose barb, male & female, polypropylene
  - 1-way check valves, SAN* w/ silicone diaphragm
- Needle
  - Need 22 gauge, 3.5” spinal needles to penetrate human glenohumeral capsule
- Error analysis
  - Leak-free
  - Effect of fittings

*Styrene-acrylonitrile resin
PC and User Interface

- LabVIEW driver
- Front Panel
  - User input/output
  - Real-time displays
  - Controls
- Background Operations
  - Negative feedback
  - Data processing
  - Data I/O
  - Pump communication

Complete System

Emergency Stop

Patient

Spinal Needle

1st Tubing

Pressure Sensor

Biohazard Waste Disposal

2nd Tubing

Syringe

Syringe Pump

Feedback Loop

Sanitization & Preparation

Ultrasound

Positioning

Operator

Patient Instruction

Data Display, User Interface

PC (LabVIEW)

DAQ

P vs. Curve

P vs. Volume Curve

Export Data
SolidWorks modeling for best design
  - Size, arrangement

Design concerns:
  - Safe for user
  - Communication between device and PC
  - Waterproof, spillproof
  - Components are secure & protected

Makes device more user-friendly
  - Portable
Patient Positioning System

- Device and/or procedure to stabilize the patient’s arm
  - Error associated with different patient positions
    - Intra-articular pressure changes with arm position\(^3\)
  - Identification of optimal position
    - Review of literature
- Risk Factors
  - Potential injury

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\(^3\) Inokuchi et al, “The relationship between the position of the glenohumeral joint and the intraarticular pressure: An experimental study,” J. Shoulder Elbow Surg. 6:2 1997, 144-149
Error Analysis

- Mathematical relationships between physical variables must be established
  - E.g., fluid subsystem: relationship between intra-articular pressure & pressure sensor reading depends on system

Bernoulli's Equation:

\[ P + \frac{1}{2} \rho V^2 + \rho gz = C \]

\[ P_2 = P_1 + \frac{16\rho \dot{V}^2}{2\pi^2} \left( \frac{1}{D^4} - \frac{1}{d^4} \right) - \rho g h \]
Safety Issues

- Patient security
  - Automatic
  - Manual
- Sanitation
- Electrical insulation
Device Impact

- Improved therapy and patient rehabilitation
- Optimized effectiveness of treatment
- Accurate measurements
  - Significant reduction of measurement error
- Increased understanding of technique
- Economic treatment option
## Budget

<table>
<thead>
<tr>
<th>Part</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Syringe Pump</td>
<td>$520.00</td>
</tr>
<tr>
<td>DAQ (NI USB-6008)</td>
<td>$169.73</td>
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<tr>
<td>Syringes</td>
<td>$7.45</td>
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<tr>
<td>Pressure Sensor, 1-way check valves</td>
<td>$35.21</td>
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<tr>
<td>Vinyl tubing, male &amp; female luer fittings with barb hose adaptors (1/16” inner diameter)</td>
<td>$37.52</td>
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<tr>
<td><strong>TOTAL COST</strong></td>
<td><strong>$777.77</strong></td>
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<tr>
<td><strong>REMAINING BUDGET</strong></td>
<td><strong>$222.23</strong></td>
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</tbody>
</table>
Design Conclusions: Fall 2012

- Preliminary programming of DAQ and syringe pump
  - Pump run via driver from NI website
  - DAQ set up using Signal Processing toolbox & readings obtained

- Early assembly of prototype
  - Fluid subsystem complete except for needle
  - Pump & syringe modeled in SolidWorks for later use
Future Direction

- Patient positioning system
- Implementation of feedback loop
  - Integration of pump & sensor
- Programming
  - Computations
  - Data processing & exporting
- Construction of case
- Vitro testing for error analysis purposes (porcine shoulders)
- Testing, error analysis, modification
Acknowledgements

- Client, Faculty Advisor: Dr. Krystyna Gielo-Perczak*
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Thank you!

Questions?