IPRO 308
Developing an Artificial Pancreas
Group Members

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Breakdown of Presentation

• Background
• Project Design
• Project Implementation
• Accomplishments
• Conclusions
Diabetes

- Body does not make or properly use insulin
- Insulin required for metabolism of sugars
- 20 million Americans
Types Of Diabetes

Type 1
- "Juvenile"
- The body produces little or no usable insulin

Type 2
- "Adult Onset"
- Insulin resistance causes insulin to be less useful
Adverse Effects of Diabetes

**Hyperglycemia**
- Greater than 200 mg/dl
- High blood glucose
- Effects develop slowly
- Include: ocular neuropathy, poor circulation, and heart problems

**Hypoglycemia**
- Less than 40 mg/dl
- Low blood glucose
- Medical emergency called ‘Insulin Shock’
- Results very quickly in slowed breathing, coma and even death
Monitoring and Delivering

- Blood glucose/insulin levels
- Venepuncture
- Painful and patient compliance suffers
- Non-Invasive techniques
Study Design – Project Goals

• Take ideas from last semester to lab settings
• Assessing the various components
  • Mechanical system
    • Vacuum pump
    • Ultrasound
    • Reverse Iontophoresis
  • Glucose measurement device
  • Vacuum trap for sweat/extracted sample
  • Microprocessor controller for insulin delivery
Past & Present

Fall ’06
• Primary ideas
• Interstitial fluid extraction
  • Ultrasound
  • Reverse Iontophoresis
• Glucose measurement
  • Electrical impedance

Spring ’07
• Ideas – lab settings/ pig skin
• IIT, Rush Medical college
• Glucose Measurement
  • Optical Absorbance and Electrical Impedance
  • Tested accuracy and limit of detection
Prototype Artificial Pancreas

Vacuum is applied along with ultrasound and an electrical gradient to increase interstitial fluid flow.
Division of Work

• Three main groups
  1) Research
  2) Prototype
    • ISF extraction
    • Glucose measurement
      • Electrical impedance
      • Optical absorbance spectroscopy
  3) Patents
Ultrasound & Reverse Iontophoresis

• Ultrasound
  • increase pore size
  • facilitate transdermal drug delivery
  • punches microscopic holes in skin

• Iontophoresis

• Reverse iontophoresis
Electrical Impedance - Background

- Ohm’s Law
- $Z$ is a function related to $R$
  - $Z_0 = \text{Magnitude}$
  - $\varphi = \text{phase shift}$
  - Current devices measure impedance through skin

$$R = \frac{E}{I}$$

$$Z = \frac{E(t)}{I(t)} = \frac{E_0 \cos(\omega t)}{I_0 \cos(\omega t - \varphi)} = Z_0 \frac{\cos(\omega t)}{\cos(\omega t - \varphi)}$$
Optical absorbance – Background

- Beer Lambert Law
- Optimum wavelength needed for measurement
- Consistent $\varepsilon$ allows glucose measurement
- Current devices measure through skin

Accomplishments

• Working ultrasound
• Extracted interstitial fluid
• Electrical impedance
• Optical readings
• Verification of Novel Idea
Prototype

• Theoretical Vacuum extraction
  • six hours
• Actual Vacuum extraction + ultrasound
  • six minutes at 26 mmHg
Electrical Impedance

- Glucose-D in Krebs Ringer solution tested
- Biophysics ECIS 1600 used to measure resistance of solutions
Optical Results

- Krebs Bicarbonate Buffer used to model interstitial fluid
- Glucose-D used

Absorbance vs. Krebs Ringer Glucose Concentration

\[ y = 0.0006x + 0.2804 \]

\[ R^2 = 0.8258 \]
Patent Research & Results


• Novel Points
  • Ultrasound + iontophoresis + vacuum simultaneously
  • Non-invasive insulin delivery transdermally
  • Automatic insulin calculation and delivery in a noninvasive device
IPRO 308 Team in Action

Also check out our website at:
http://www.iit.edu/~ipro308s07
In Closing…

• Progress

This being said…

» Ultrasound + vacuum - Good
» Reverse Iontophoresis + Vacuum

More work
Tasks for Next IPRO

1. Technical assessment of reverse iontophoresis
2. Optimization of iontophoresis
3. Develop embedded control
4. Assessment of safety of device
5. Exploration of device miniaturization
6. Establish optimum design for the device
Business Opportunity

- Millions of Americans use insulin.
- Top spot up for grabs
- Market: 44 billion - 100 billion of revenue each year.
Proposed Design
Proposed Design
Moral Benefits

• Everyone knows someone with diabetes

• Improved quality of life

• Plus, it feels good to help people…
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