Using Bowel Sounds to Create a Forensically-aware Insulin Pump System

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Diabetes

Hyperglycemia

![Graph showing BG values and hyperglycemia time period]
Diabetes

- Hyperglycemia
- Hypoglycemia
- Negative patient event
Previous work

• Encrypted communications [Li 2012, Sorber 2012]
• Bolus anomaly detection [Hei 2013]
• Communication jamming [Gollakota 2011]

All require an operational change
Forensic Goals

Given a hypoglycemic event, determine:
1. what steps led to hypoglycemia
2. the cause of the hypoglycemia
3. what type of negative patient event
   – whether safety or security event
Real time glucose levels

Amount of insulin in pump

Bowel Sounds

Cell phone
Bowel Sounds

- Amount of Bowel sounds increase after a meal [Craine 1999]
- This increase can indicate a meal
Experiment setup

- **Electronic stethoscope** records bowel sounds
- **Signal processing** to find eating instances
Experiment setup (cont’d)

• 5 subjects gave consent and were tested
• Bowel sounds were recorded before, during, and after meal
• Subjects fasted before experiment (no food for at least 2 hours)
Eating detection

Bowel sound

Time(sec) 0.4 0.6 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2
Amplitude 0.0 0.2 0.4 0.6 0.8
False positives

Rejected false positive
False negatives

Potential false negative

Amplitude

Time (sec)
Test results

Detected number of sounds over 5 min periods

Time (hr:min)

Test Subject 1
Test Subject 2
Test Subject 3
Test Subject 4
Test Subject 5
Integration

Infusion Set

Sensor

Adhesive

Skin
Forensic application.
Forensic application.

Glucose Check

- Pre-eating
- Eating
  - Start
  - Bolus
  - End
Forensic application.

Glucose Check
- Bolus

Pre-eating  Eating  Post-eating

Start Bolus End

Bolus
Rule 1: A bolus without a meal

An insulin bolus without a corresponding meal $\rightarrow$ possible Hypoglycemia
Rule 2: Eating without a bolus

If a bolus is not detected in conjunction with a meal → possible Hyperglycemia
Rule 3: Normal eating

• Bolus appropriately taken with food
• Forensic investigator can ignore this case
Contributions

• Proof-of-concept forensics approach for electronic diabetes therapy system
• Bolus/eating forensic rules
• Seamless integration with current and future insulin pump systems/artificial pancreas
Questions?
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