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

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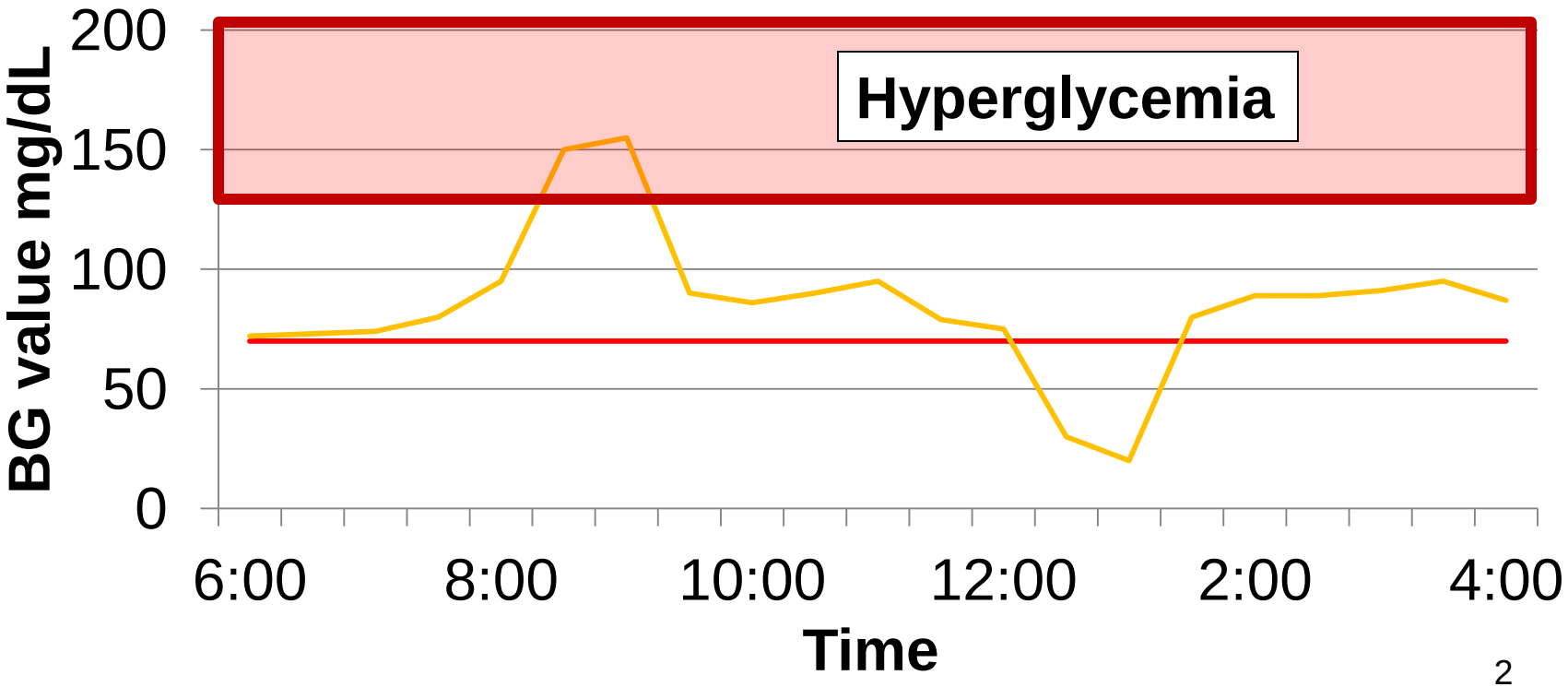
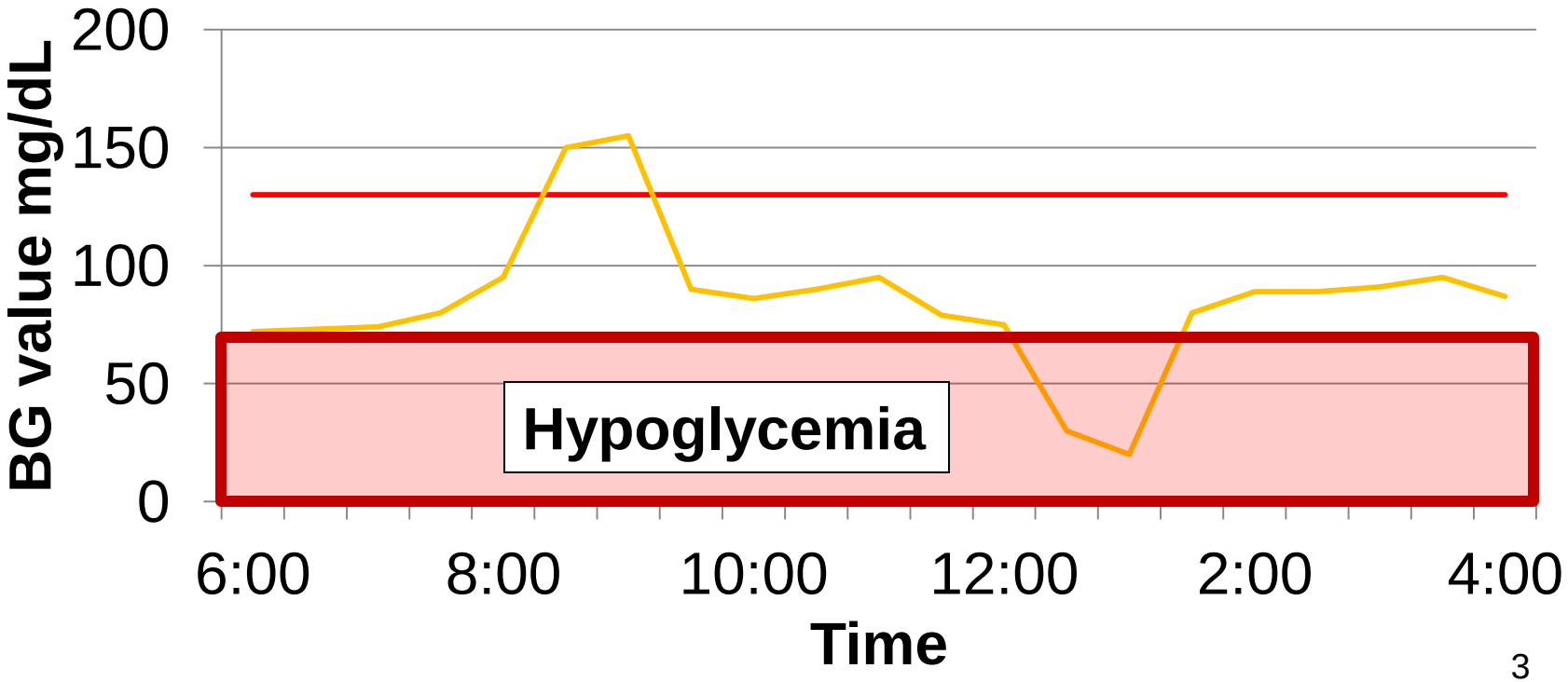
Diabetes

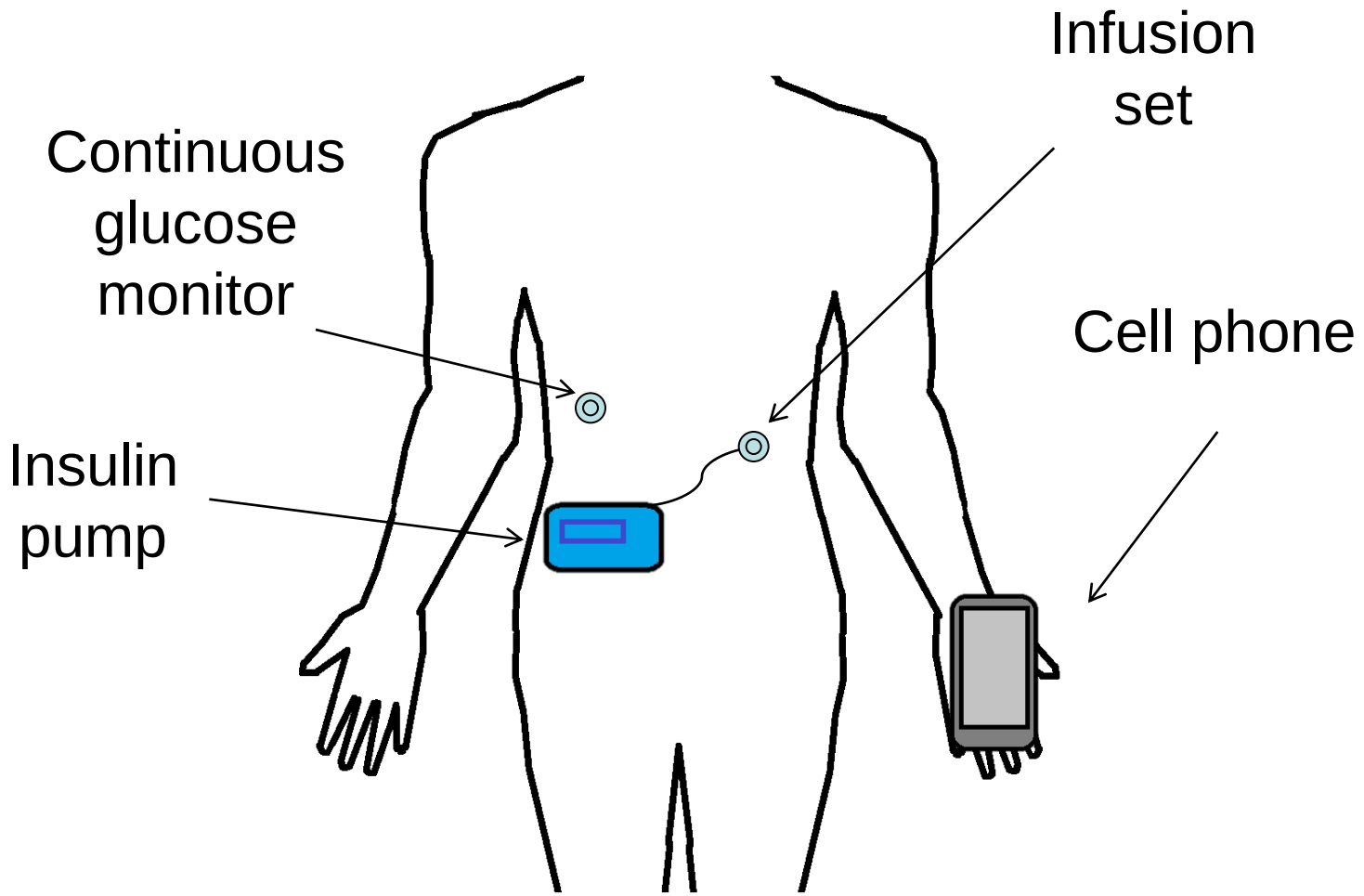
Hyperglycemia



Diabetes

- Hyperglycemia
- **Hypoglycemia**
- **Negative patient event**




Infusion set
Continuous glucose monitor
Cell phone
Insulin pump

Previous work

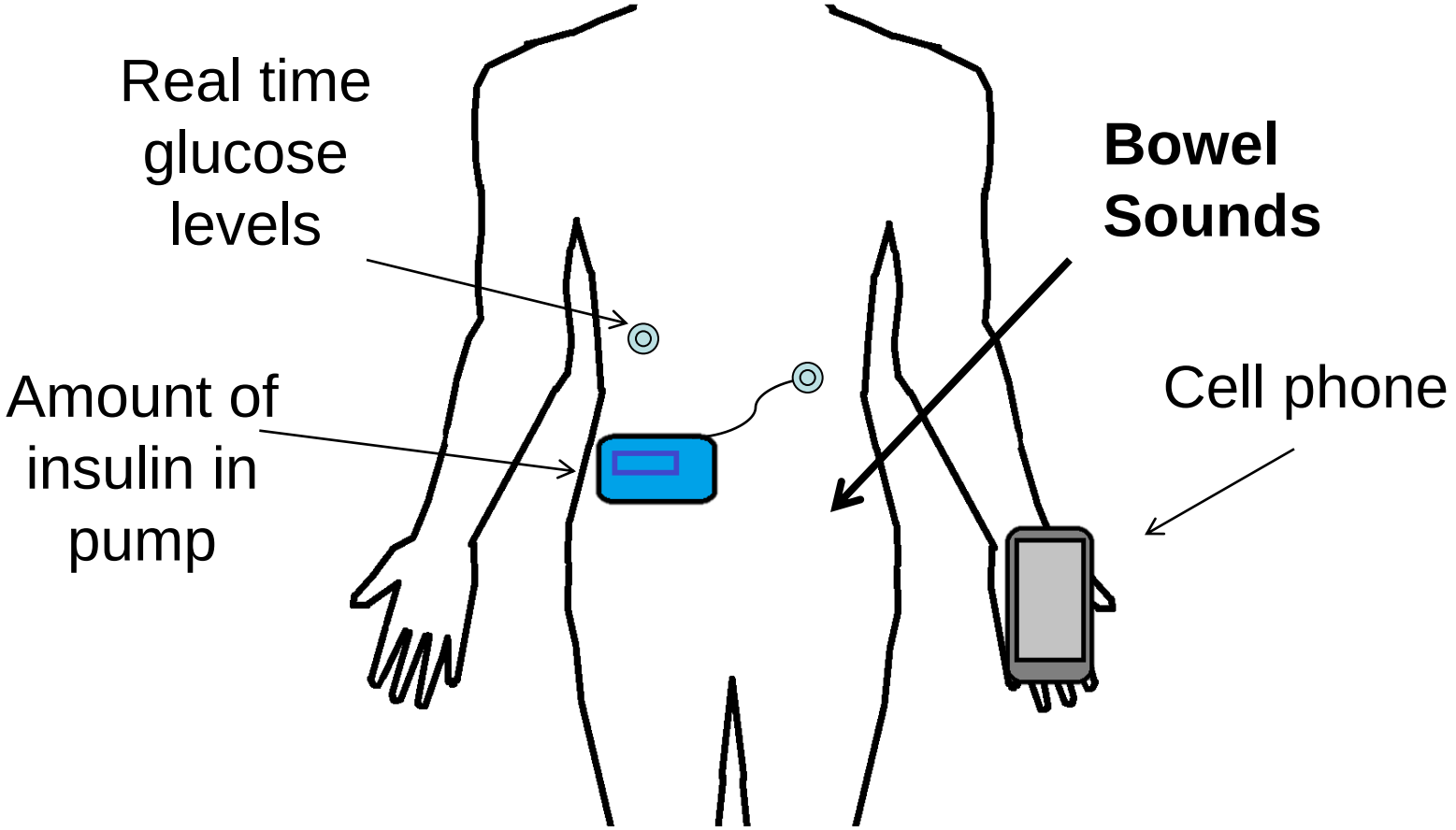
- Encrypted communications [Li 2012, Sorber 2012]
- Bolus anomaly detection [Hei 2013]
- Communication jamming [Gollakota 2011]

All require an operational change

Forensic Goals

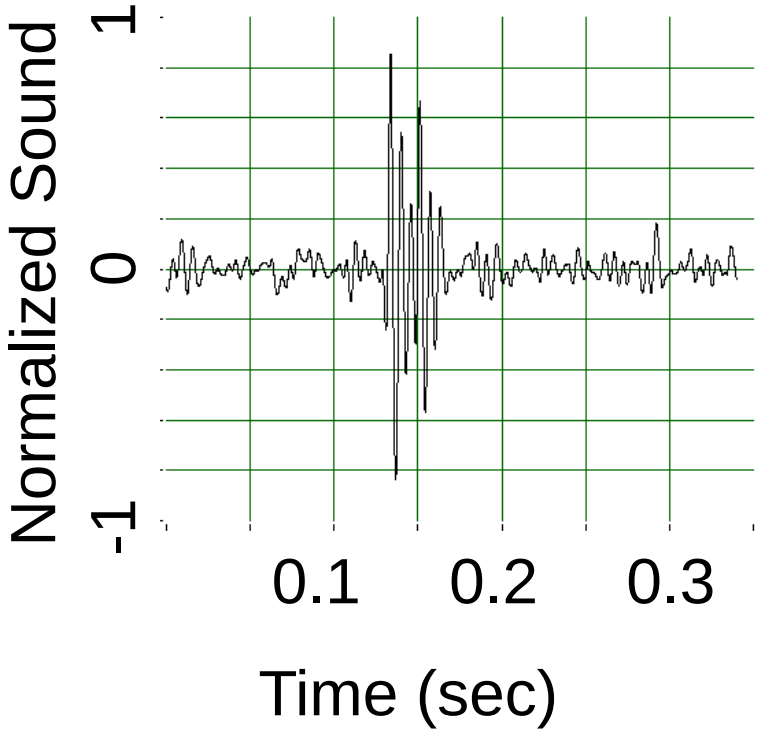
Given a hypoglycemic event, determine:

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

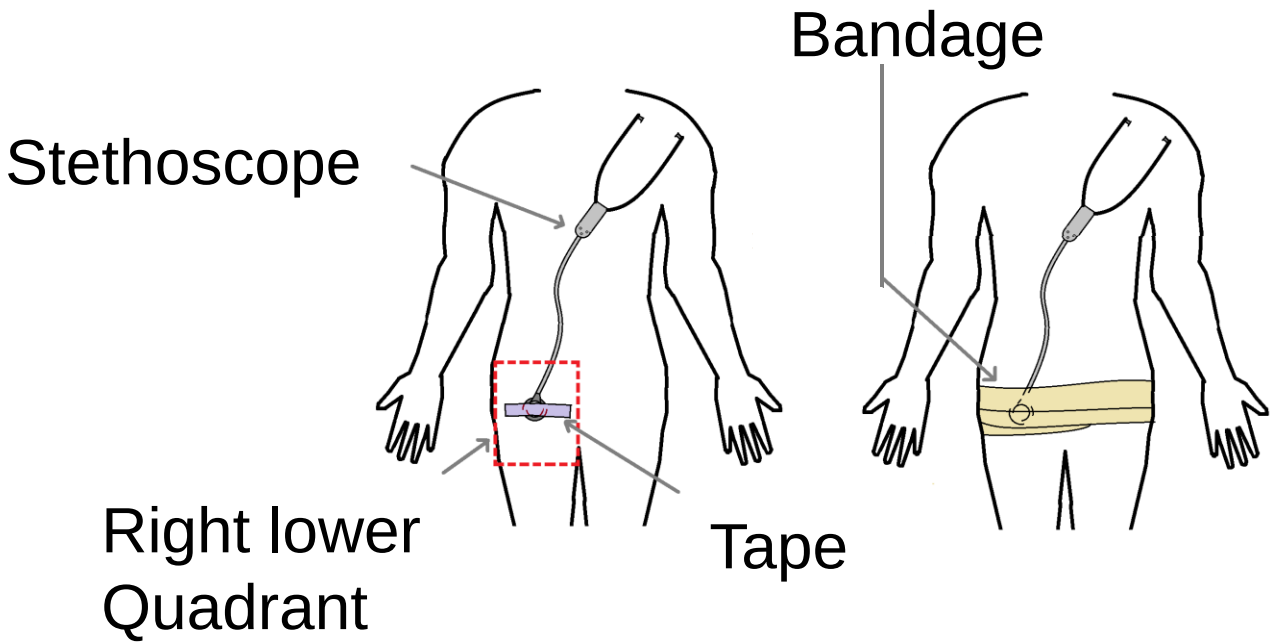
Bowel Sounds

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



Experiment setup

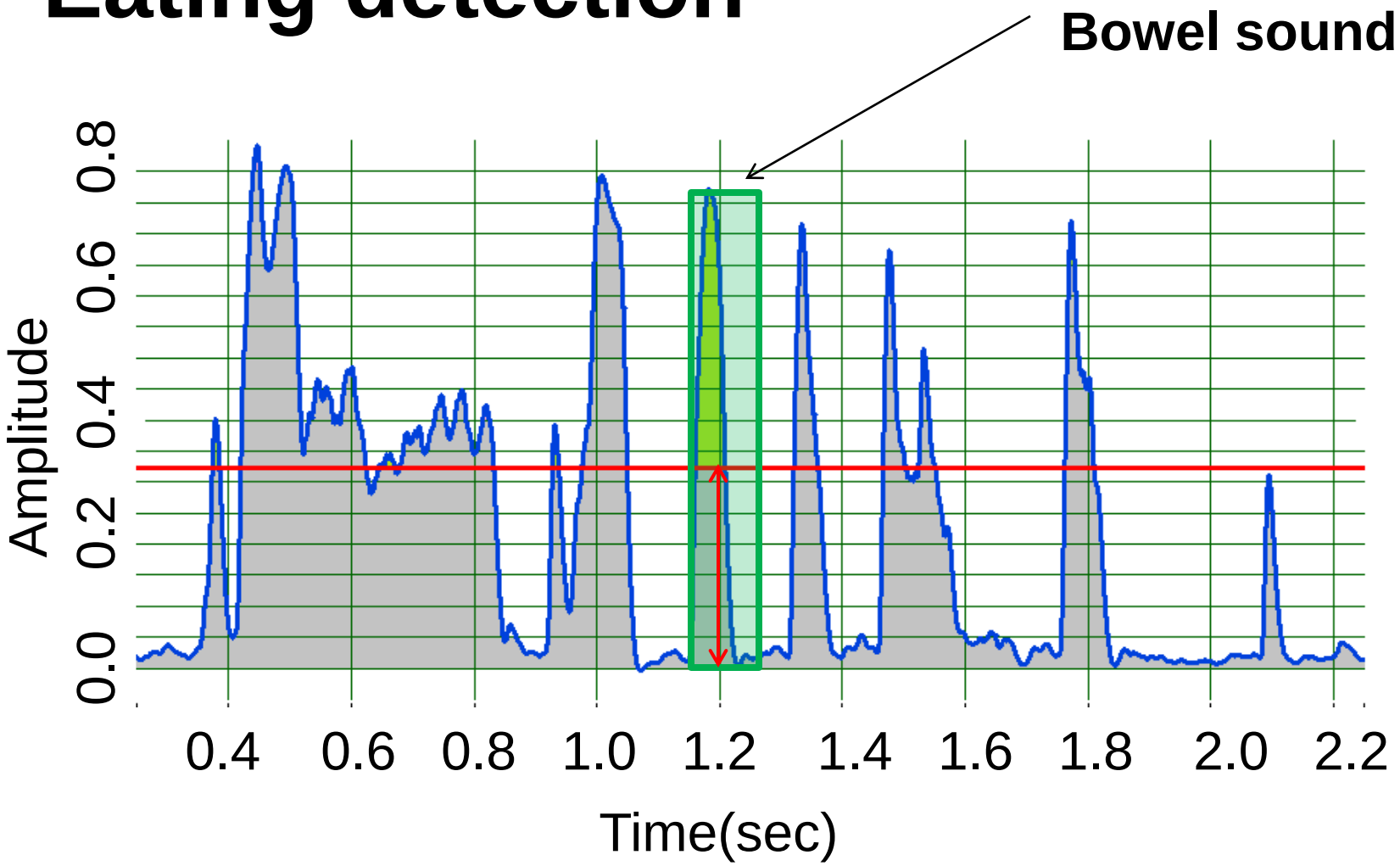
- **Electronic stethoscope** records bowel sounds
- Signal **processing** to find eating instances



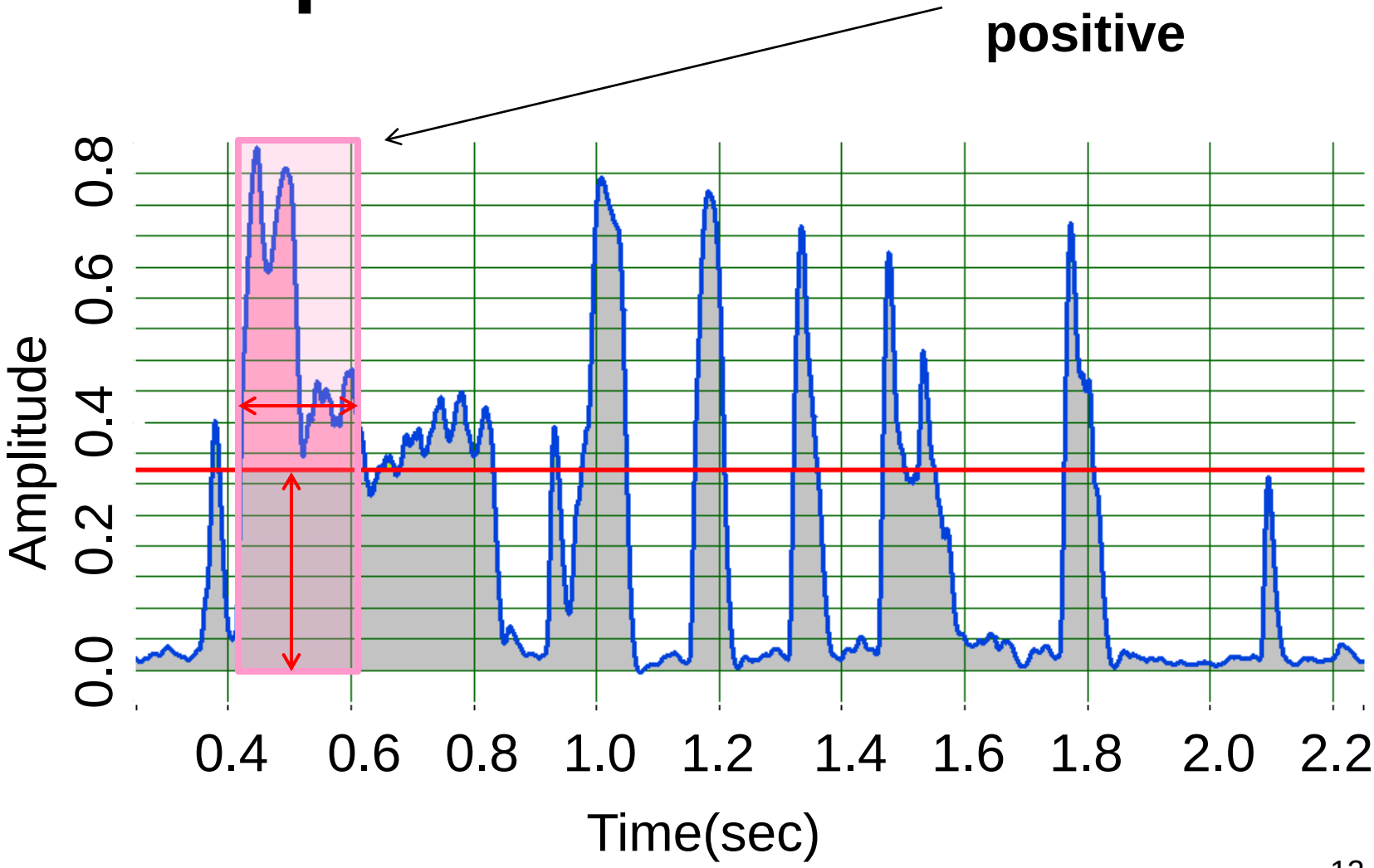
Experiment setup (cont'd)

- 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)

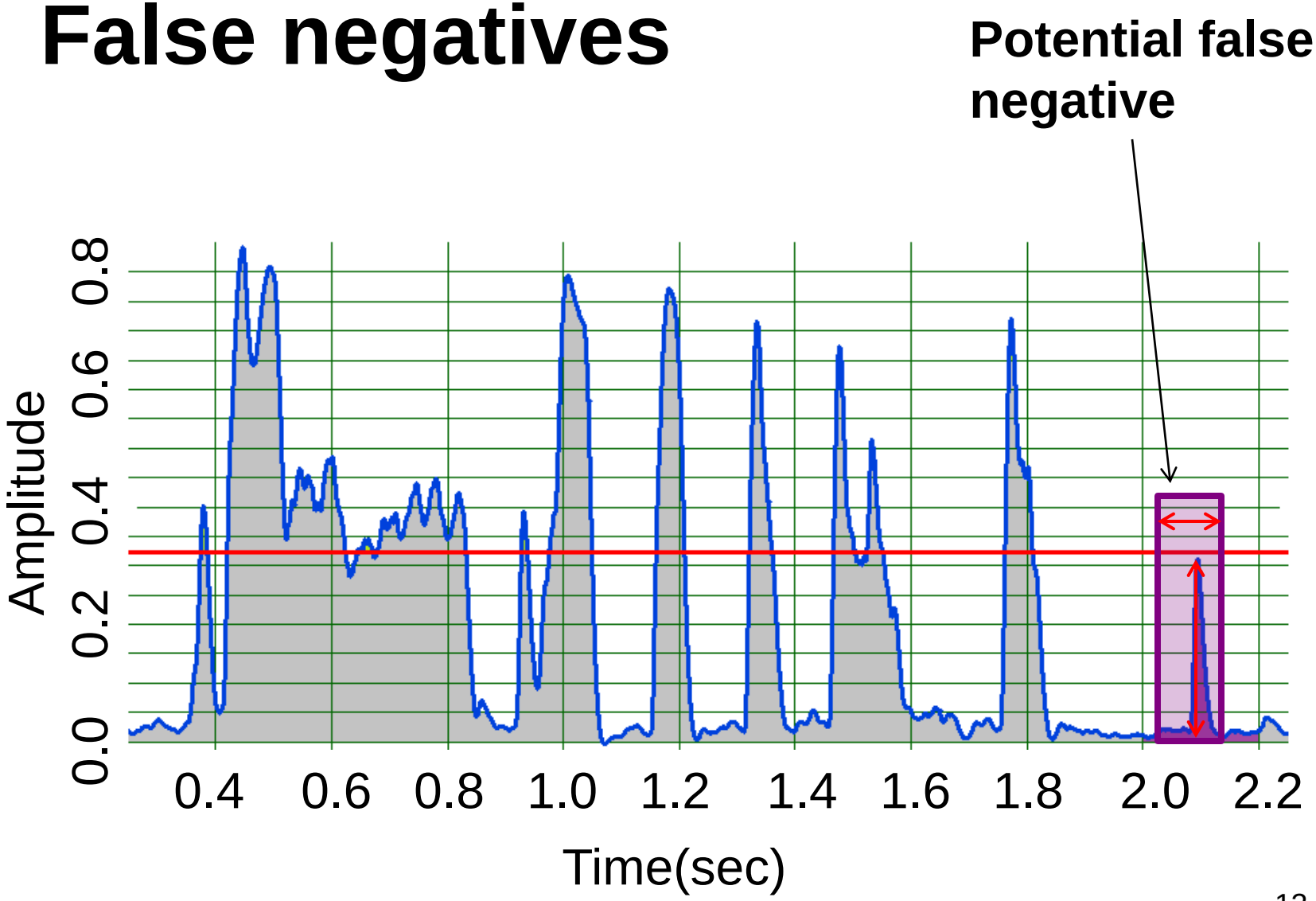
Eating detection



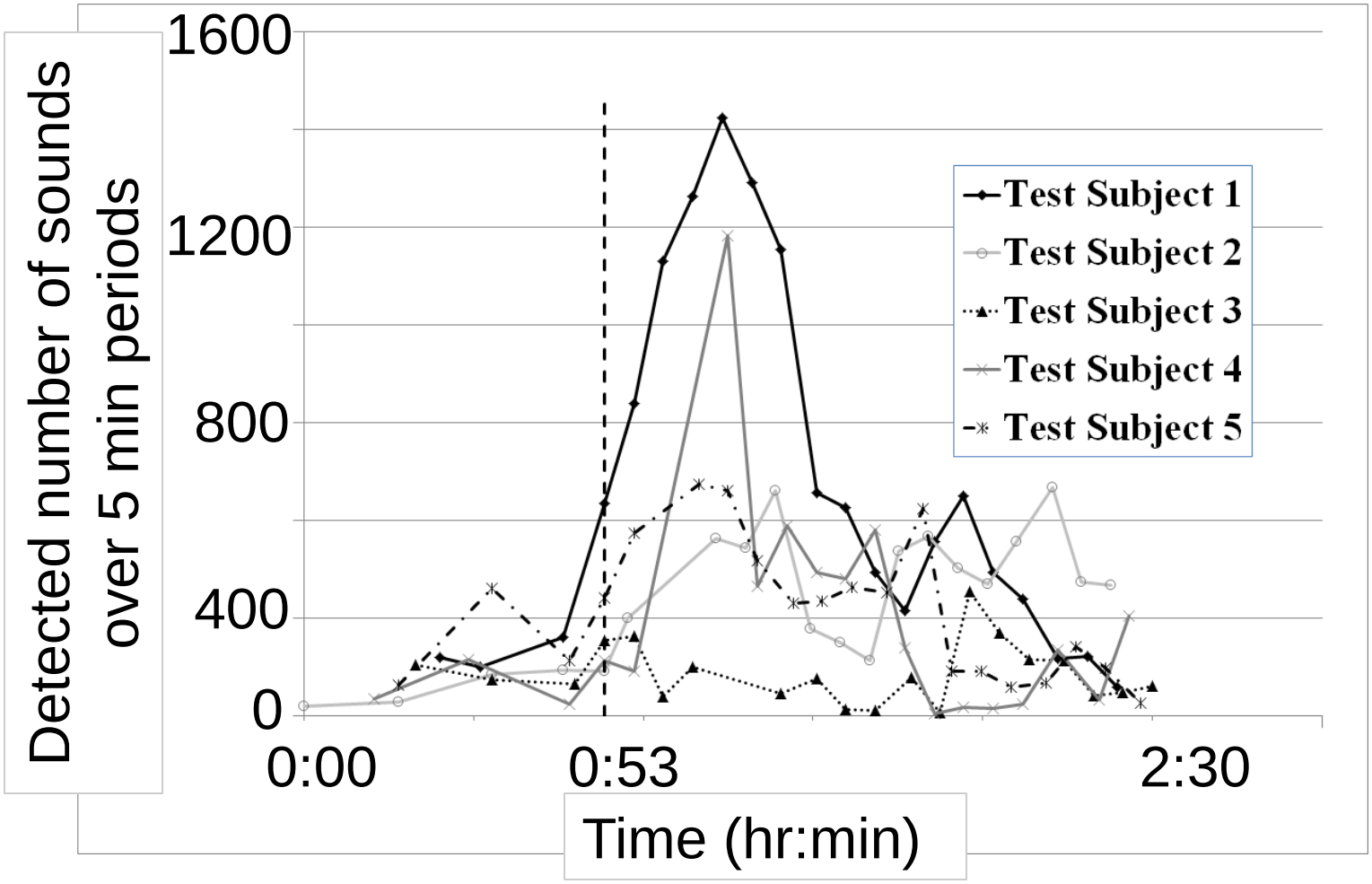
False positives



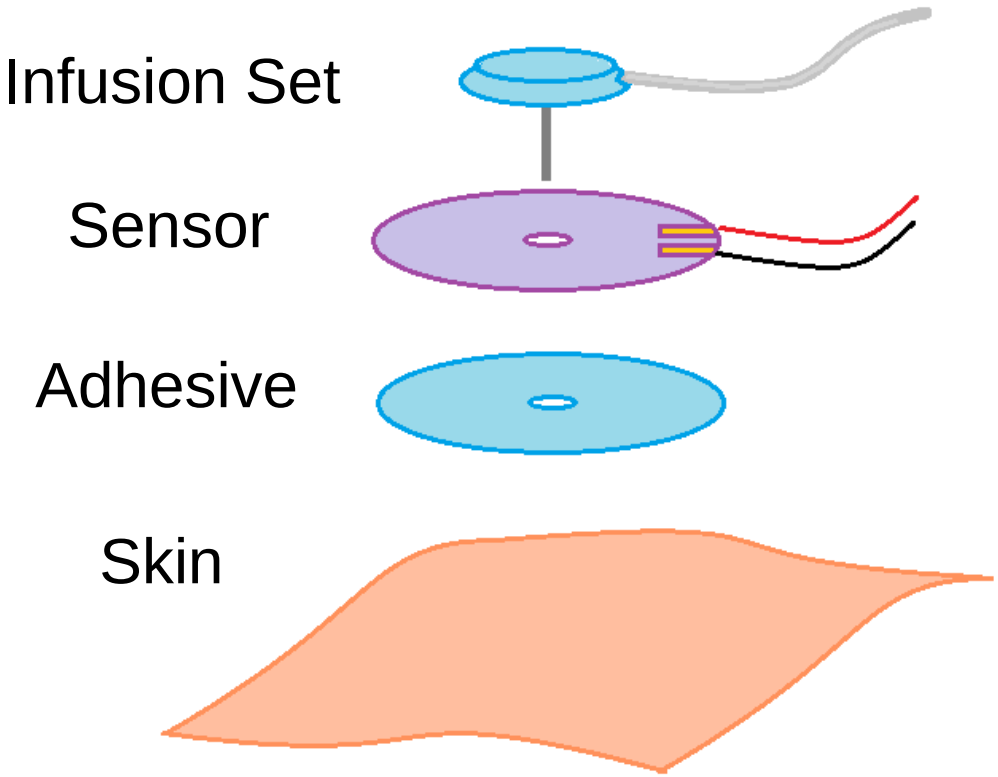
False negatives



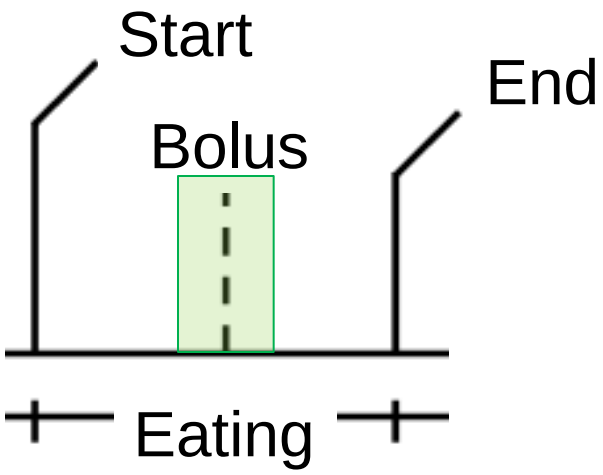
Test results



Integration



Forensic application.



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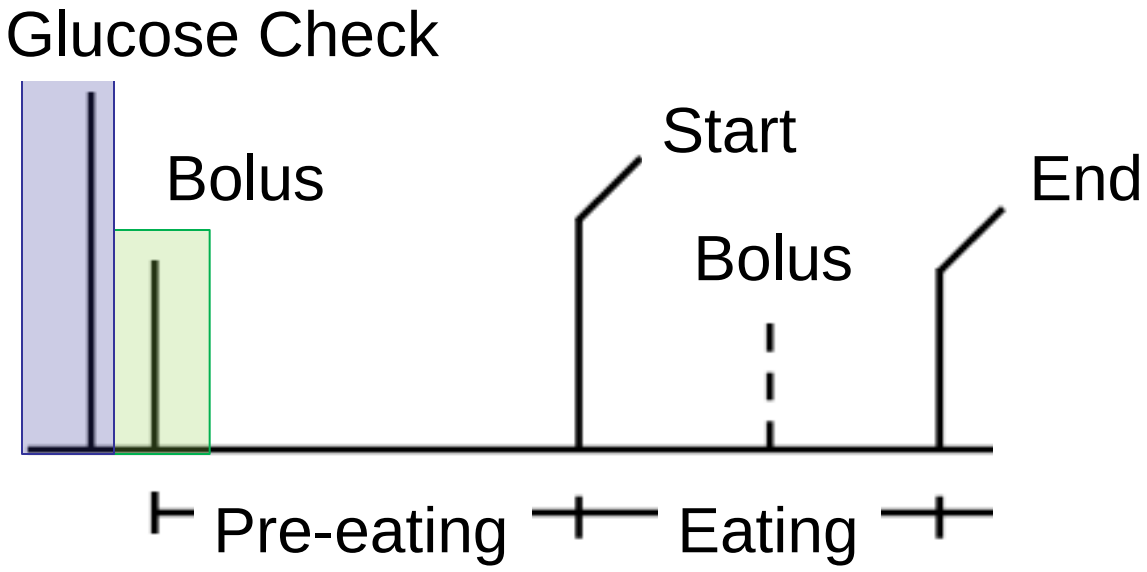
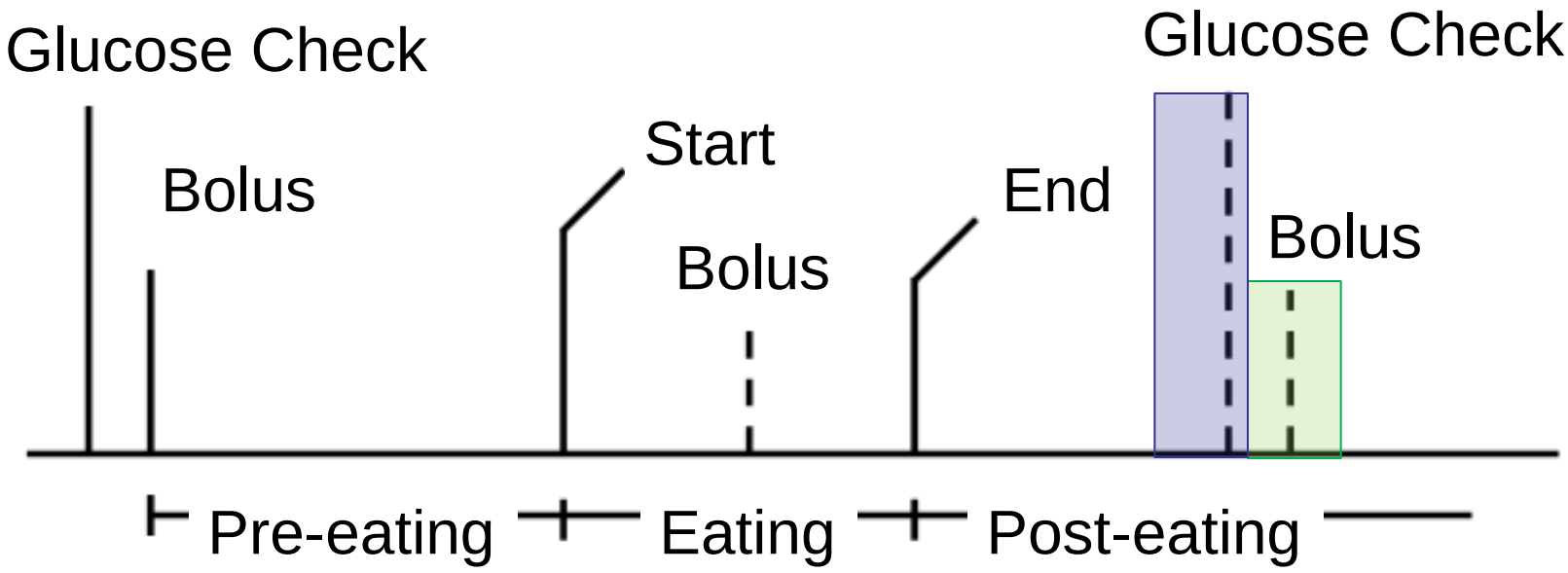
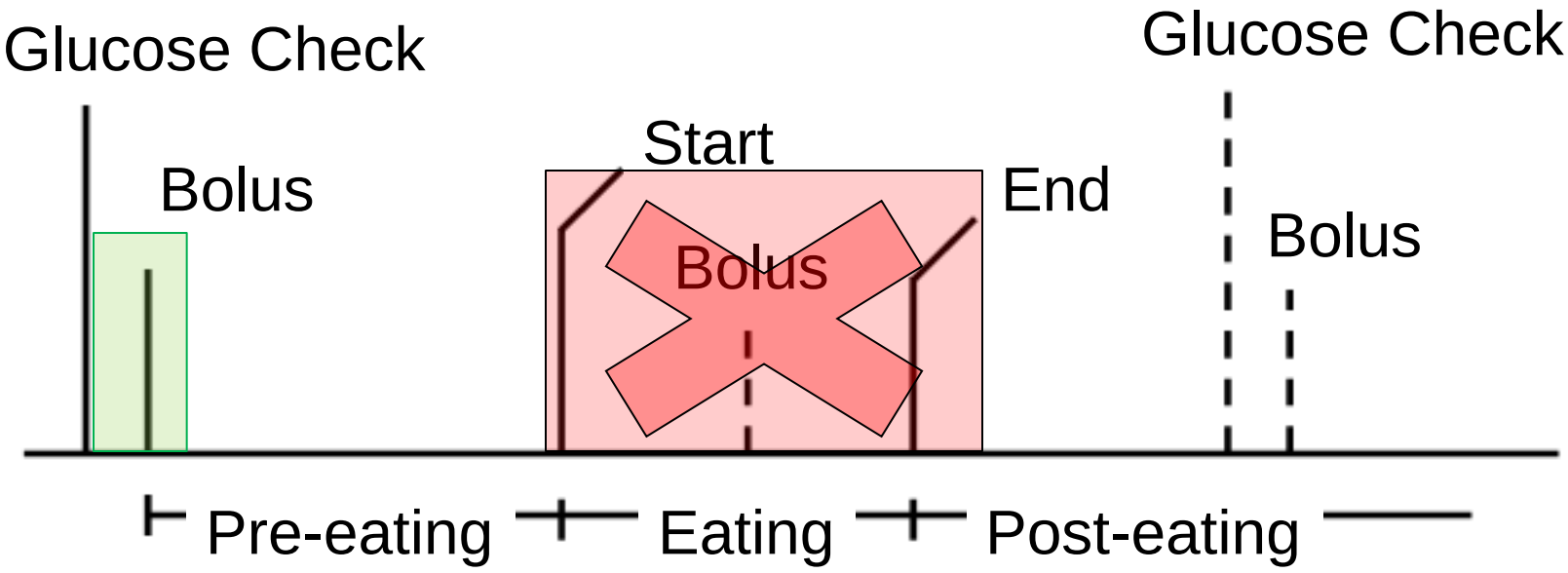


Forensic application.



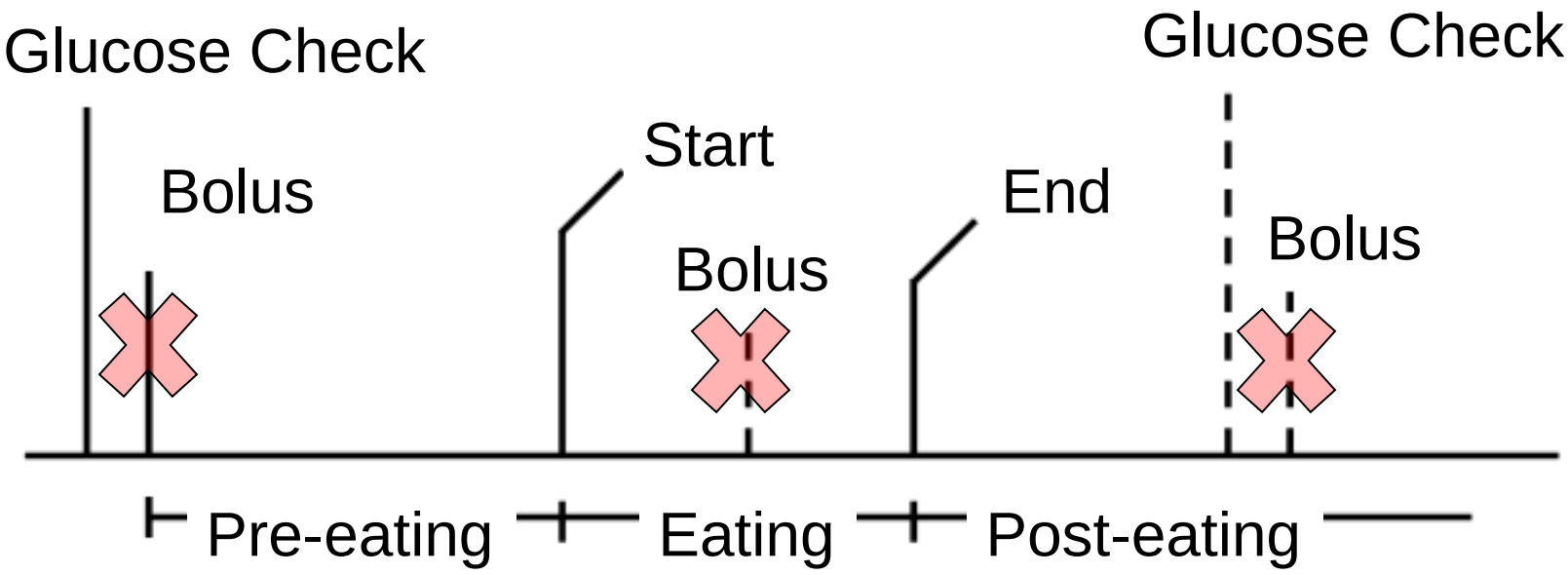
Rule 1: A bolus without a meal

An insulin bolus without a corresponding meal → possible **Hypoglycemia**



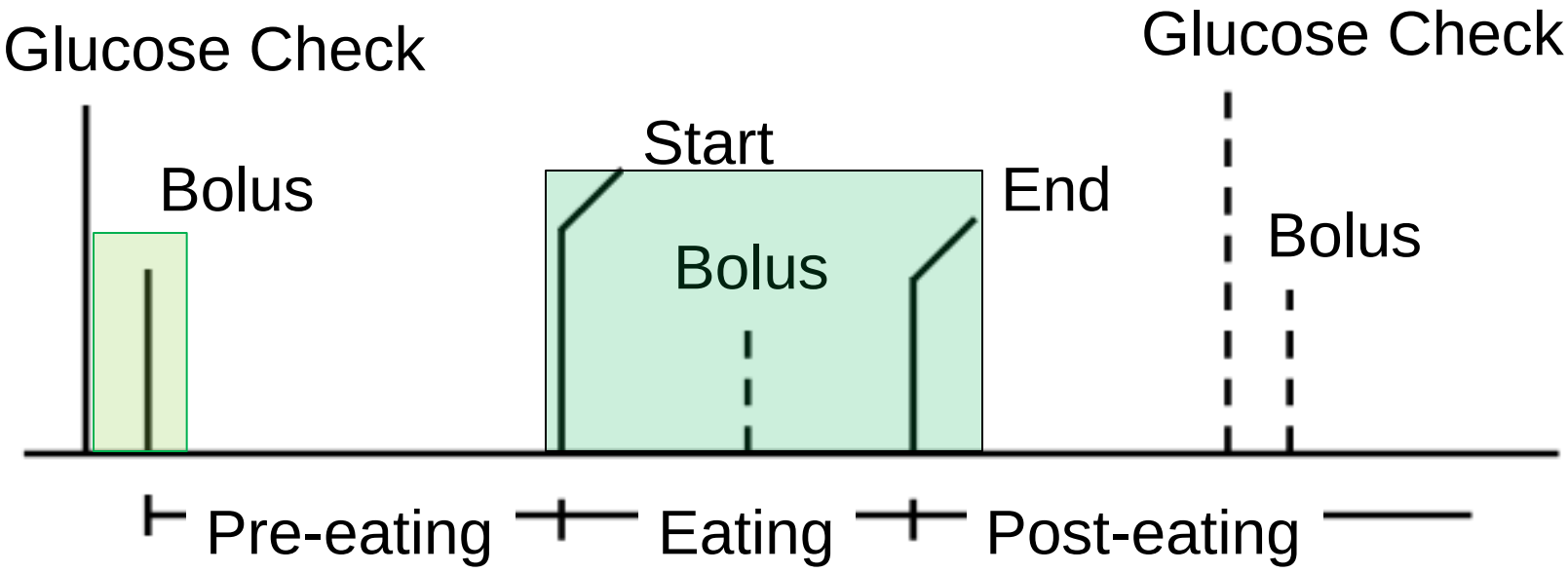
Rule 2: Eating without a bolus

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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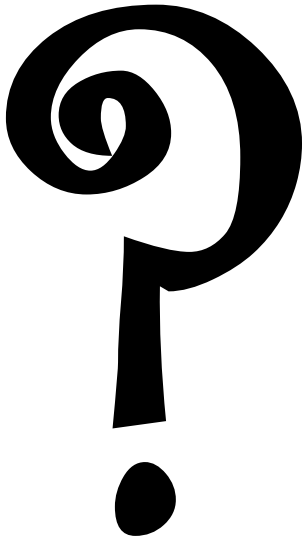

SHARPS