Human Values and Security for Wireless Implantable Medical Devices:

Gathering Stakeholder Knowledge

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Outline

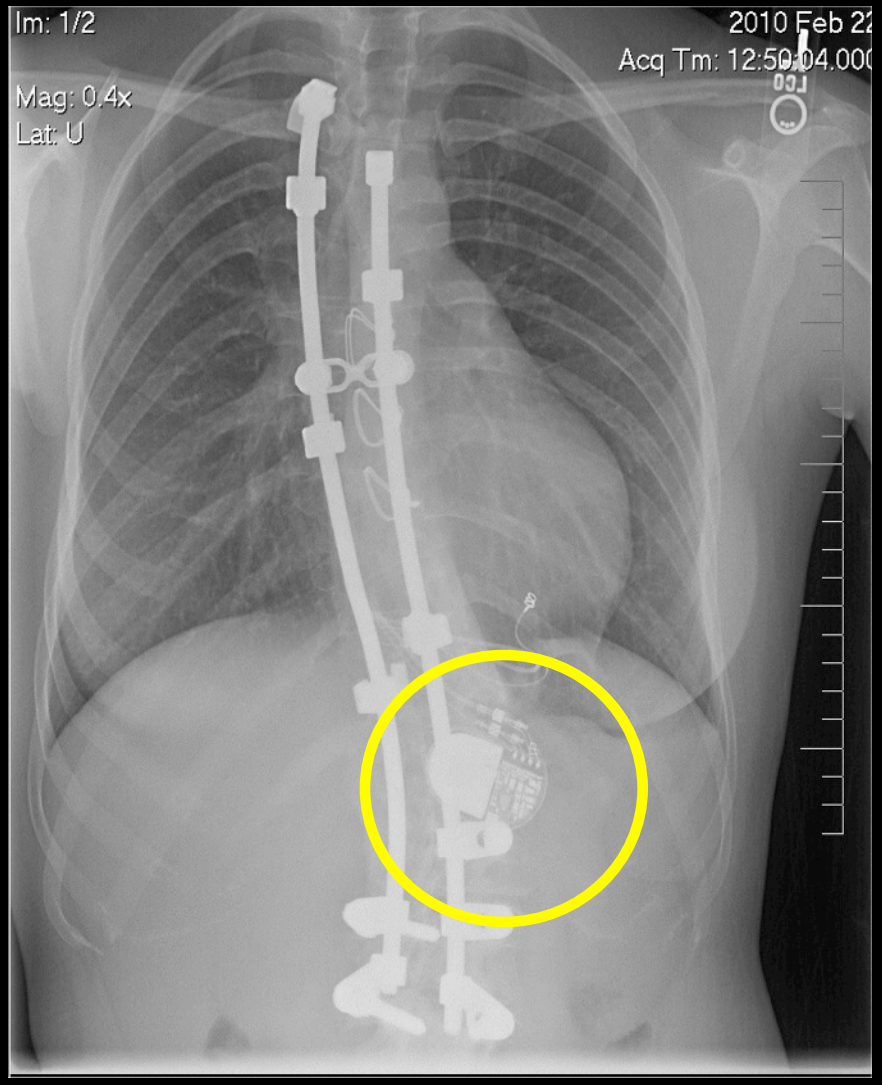
1. Background
2. Technical Security Options
3. The Broader Ecosystem: Patients
4. The Broader Ecosystem: Providers

Review

Why security is necessary

Some demonstrated compromises

Some possible defenses



Security Community's Interest

- Application is impactful
- Wireless
- Homecare and remote checkups
- Constrained resources
  - Battery
  - Storage
- Interesting domain

Access Control

Authorized Clinic Access

Security

Emergency Access

Some security solutions will negatively impact safety.

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Technical Approaches

Password-Based	Proximity-Based Authentication
• Carrying Passwords • Tattooed Passwords • Centralized Database • Criticality-Aware Fail-Open	• Cryptographic Distance Bounding • Intra-Body Communication • Physiologically-Derived Keys • Mode Switch
External Hardware	**Notification/Forensics**
• Fail-Open Wristband • Jamming Wristband	• Break-Glass Systems

(Cherukuri *et al*. [2003], Denning *et al.* [2008], Denning *et al.* [2010], Ferreira *et al.* [2006], Gollakota *et al.* [2011], Gupta *et al*. [2006], Rasmussen *et al*. [2009], Schechter [2010], Xu *et al.* [2011])

Password-Based

- *Carrying Passwords*
- Tattooed Passwords
- Centralized Database
- Criticality-Aware Fail-Open

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Proximity-Based Authentication

- *Cryptographic Distance Bounding*
- Intra-Body Communication
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External Hardware

- *Fail-Open Wristband*
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External Hardware

- Fail-Open Wristband
- *Jamming Wristband*

Notification/Forensics

- *Break-Glass Systems*

Security systems…all about the tradeoffs.

Fitting the Solution to the Problem

Past works focused on technical properties of defenses, but we need to consider the broader ecosystem:

(1) Patients[1]

(2) Providers

Next part of talk: formative analyses toward understanding patient and provider concerns.

[1] Denning et al. Patients, Pacemakers, and Implantable Defibrillators: Human Values and Security for Wireless Implantable Medical Devices. CHI 2008.

http://www.flickr.com/photos/ellasdad/

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Patients

http://www.flickr.com/photos/dharmasphere/
http://www.flickr.com/photos/walkingthedeepfield/

Value Sensitive Design

(Friedman *et al.* [2006], Miller *et al.* [2007])

Methodology to incorporate ***human values*** into design

Values

Affordability

Autonomy

Sustainability

Solitude

Equality

Aesthetics

Methodologies

Value Dams and Flows

Semi-structured Interview

QUESTIONS

- Would you say that you like any of these systems?
- Would you say that you dislike any of these systems?
- If you were given a choice of systems, which system or system would you choose?
- Value questions (e.g., privacy, autonomy, safety, security, health)

DEMOGRAPHICS

13 interviews with pacemaker and ICD patients (+3 pilot interviews)

- 8 male, 5 female
- Age 67.9
- 9 pacemakers, 4 ICDs
- ~2nd device
- 7.8 years with IMD

System Mockups

Security Approach	**Mockup System**
Password & Body Modification	
Patient Behavior Change	
Patient-Passive	

Passwords + Body Modifications: Medical Alert Bracelet

Medical alert bracelet with engraved password – using password gives access to IMD

Passwords + Body Modifications: Tattoo

Tattoo with password as scannable 2D barcode – scanning barcode gives access to IMD

Passwords + Body Modifications: UV-Visible Tattoo

(Schechter [2010])

Tattoo with password as scannable 2D barcode, tattooed with ink that is only visible under a UV light – scanning barcode password gives access to IMD

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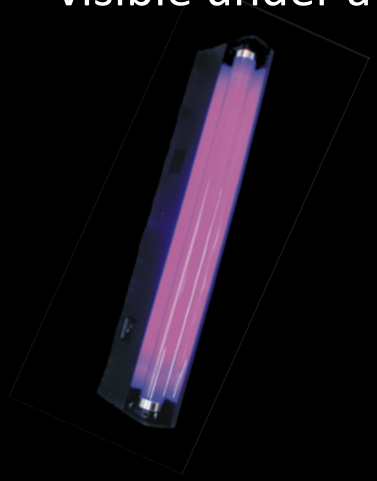

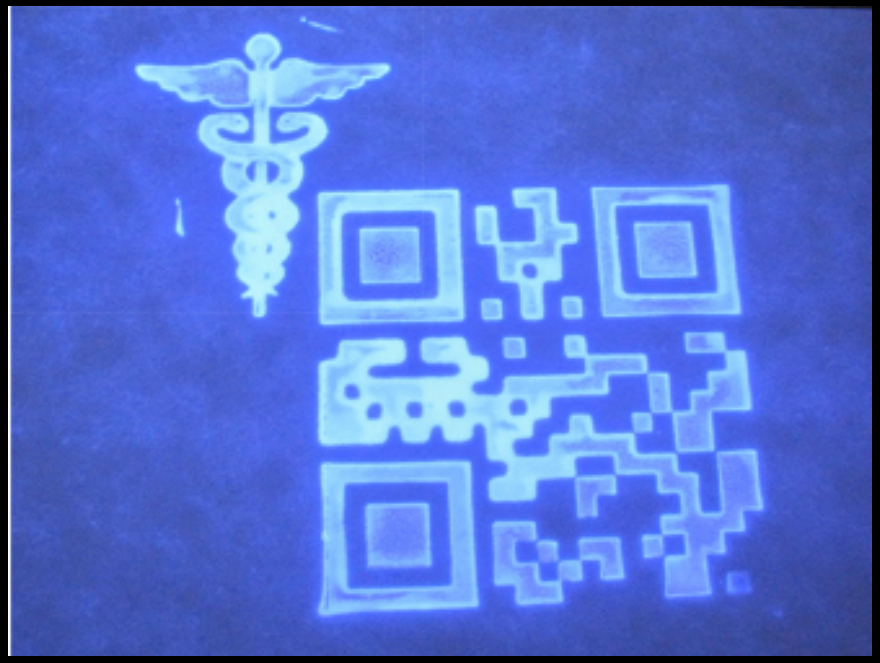

Patient Behavior Change: Wristbands

(Denning *et al.* [2008])

Wristband acts as access control – remove wristband for emergency access

Regular	Emergency and Warning	Patient-Specified Functionality

Passive with Respect to the Patient: Criticality-Aware IMD

(Gupta *et al.* [2006])

IMD auto-detects emergency situations (GPS location; patient position, e.g. prone; pulse rate) and allows access in emergencies

Passive with Respect to the Patient: Proximity-Based Authentication

(Cherukuri *et al.* [2003], Rasmussen *et al*. [2009])

Equipment carried by medical personnel (in ambulances and emergency rooms) is placed on patient to gain access

Values that Were Important to Patients

- Security
- Safety
- Privacy
- Aesthetics
- Psychological Welfare
- Convenience
- Cultural and Historical Associations
- Self-Image and Public Persona
- Autonomy and Notification

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"I don't like the idea of wearing the wristband...I already have a defibrillator. Why do I have to wear something on my hand...to show that I have-, that I have a defibrillator, that there's something wrong with me. No."

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"It would make me feel like an invalid...That I had this thing, like the Scarlet Letter or [laughs]."

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"Well, I mean for-, because I'm Jewish it-, I'm not-, a tattoo on the arm to me means a concentration camp. So right away that's the immediate horror."

Mockup Evaluation: Results

Security Approach	Mockup System	Liked (n=11)	Disliked (n=11)	Would choose (n=11)
Password & Body Modification	Medical Alert Bracelet	0%	27%	0%
	Visible Tattoo	9%	55%	9%
	UV-Visible Tattoo	18%	27%	18%
Patient Behavior Change	Regular	0%	36%	0%
	Emergency and Warning	45%	27%	27%
	Patient-Selected Functionality	0%	36%	9%
Patient-Passive	Criticality-Aware IMD	27%	18%	27%
	Proximity-Based Authentication	27%	0%	27%

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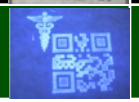
	UV-Visible Tattoo 	18%	27%	18%
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Achieving Coverage: 3 Systems

The Least Disliked: Proximity-Based Authentication

The Most Liked: Emergency and Warning Wristband

Satisfying the Stragglers: UV-Visible Tattoo

Multiple System Options: Revisiting the Idea

- Decreased Usability Means Decreased Safety
- Cost of FDA Approval
- Burden of Training
- Expense of Providing, Acquiring, and Maintaining Equipment
- Mental Stress and Complications of Choice

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Providers

Focus Groups

DEMOGRAPHICS

3 workshops (Seattle, Boston)

- 24 medical providers
- Cardiology/Electrophysiology, Emergency Room, Anesthesiology, Venture Capitalist, Medical Informatics, Device Sales Representative
- Nurses, Fellows, Residents, Physicians

- Age: 28 – 64
- Gender: 11 F, 13 M
- Experience: 2 – 28 years

Focus Groups

QUESTIONS

1. Metaphors
2. Critiques
3. System Comments
4. Freeform Discussion

Quantitative Results

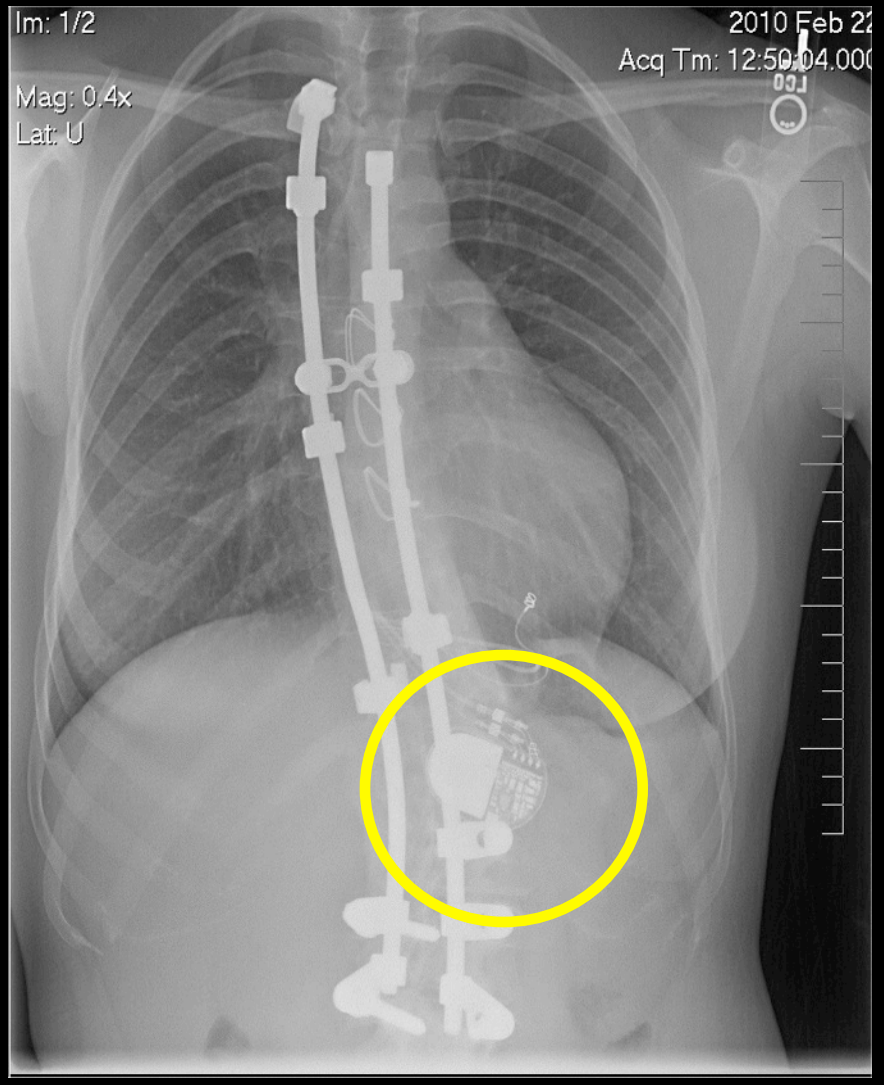
System	Like	Dislike	Recommend	Recommend Against
Medical Alert Bracelet	29%	46%	21%	33%
Centralized Database	38%	21%	25%	25%
UV-Visible Tattoo	17%	54%	13%	50%
Emergency-Warning Wristband	58%	17%	46%	13%
Proximity Bootstrap	38%	25%	38%	21%
Criticality-Aware IMD	38%	42%	33%	38%

Qualitative Results

Still under analysis!

Inter-Community Dialogue

Computer security: many trade-offs

Past works: significant focus on technical directions

This talk: critical to consider patients and providers too