

# Patients, Pacemakers, and Implantable Defibrillators:

## Human Values and Security for Wireless Implantable Medical Devices

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Brian Gill<sup>2</sup>, Tadayoshi Kohno<sup>1</sup>, William H. Maisel<sup>3</sup>



**dub** design:  
use:  
build:  
university of washington

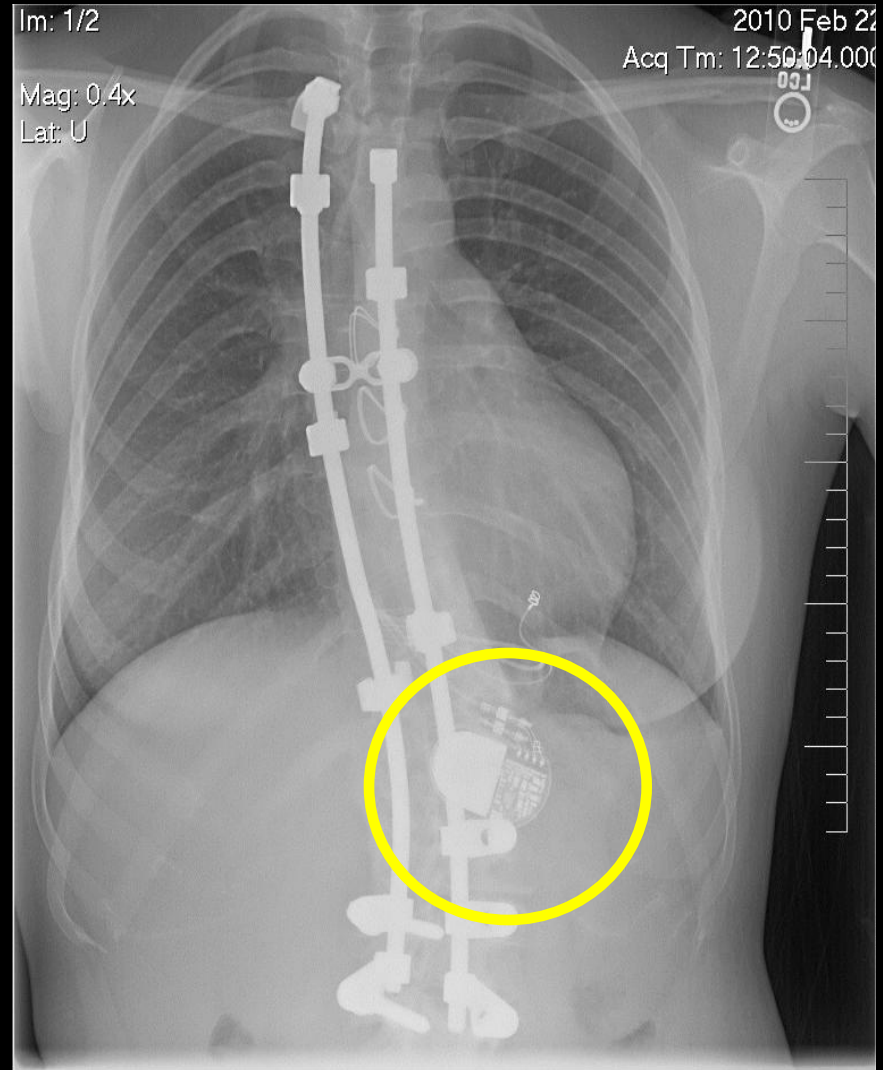


# Implantable Medical Devices

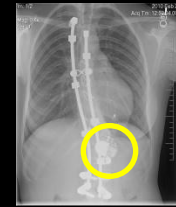
Over **25 million** US citizens depend upon them for **life critical functions** (2001)





Pacemakers, ICDs,  
Neurostimulators,  
Drug Pumps

Wireless

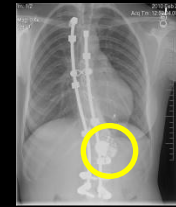


# Unique Characteristics



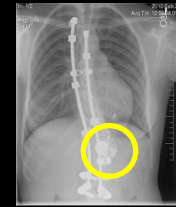
	 		
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<b>Opt-Out</b>	Yes – Turn it off	Yes – Leave the environment	No – Implanted in the body
<b>Usage</b>	At will	When present	Always – Even when unconscious





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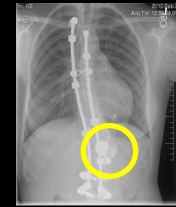
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# Access Control: System Goals

Authorized Clinical Access



Emergency Access



Security



Is security necessary?

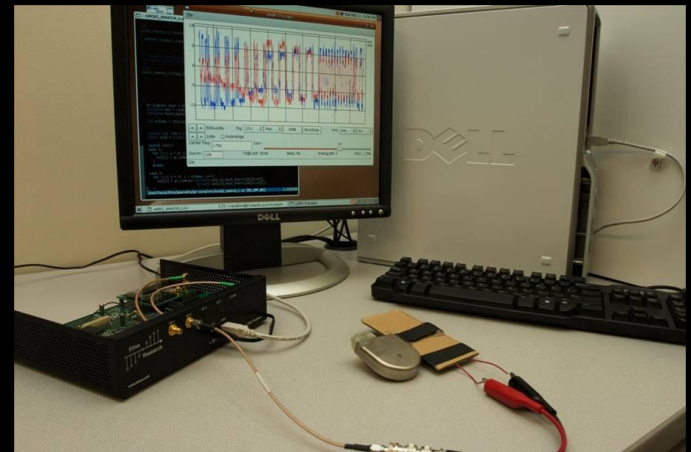


# Unauthorized Wireless Changes: Can Someone Do It?

(Halperin *et al.* [2008])

**Unauthorized wireless communications using custom hardware at short range (centimeters):**

- Obtain serial number, patient name, diagnosis
- Turn off therapies
- Induce cardiac fibrillation



(Risk to patients today is low)

# Unauthorized Wireless Changes: Would Someone Do It?

March 28, 2008

**WIRED**

## Hackers Assault Epilepsy Patients via Computer

“RyAnne Fultz, 33, says she suffered her worst epileptic attack in a year when she clicked on the wrong post at a forum run by the nonprofit Epilepsy Foundation.”



January 11, 2008

**The Register**<sup>®</sup>

## Polish teen derails tram after hacking train network: Turns city network into Hornby set

“He treated it like any other schoolboy might a giant train set, but it was lucky nobody was killed. Four trams were derailed, and others had to make emergency stops that left passengers hurt.”

# Technical Approaches

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

- Passwords
- Physical Tokens (e.g., key card)
- Fail-Open
- Proximity-Based Authentication
- Physiological Keying
- Criticality-Aware

How do we decide?

# The Human Factor

*Real people in their daily lives*



<http://www.flickr.com/photos/dharmasphere/>  
<http://www.flickr.com/photos/walkingthedeeppfield/>

# 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
- ~2<sup>nd</sup> 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

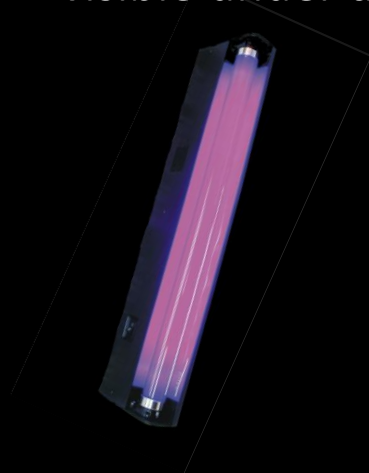
(Schechter [2010])

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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# 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

# Contributions

New HCI problem domain: Implantable Medical Devices

Interviews with implantable medical device patients

Qualitative suggestions for security systems for wireless cardiac implantable medical devices

Adaptation of value dams and flows method for choosing complementary systems to maximize patient satisfaction/minimize patient dissatisfaction

# Questions?

