

Patients, Pacemakers, and Implantable Defibrillators:

Human Values and Security for Wireless Implantable Medical Devices

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Brian Gill², Tadayoshi Kohno¹, William H. Maisel³



dub
design:
use:
build:
university of washington

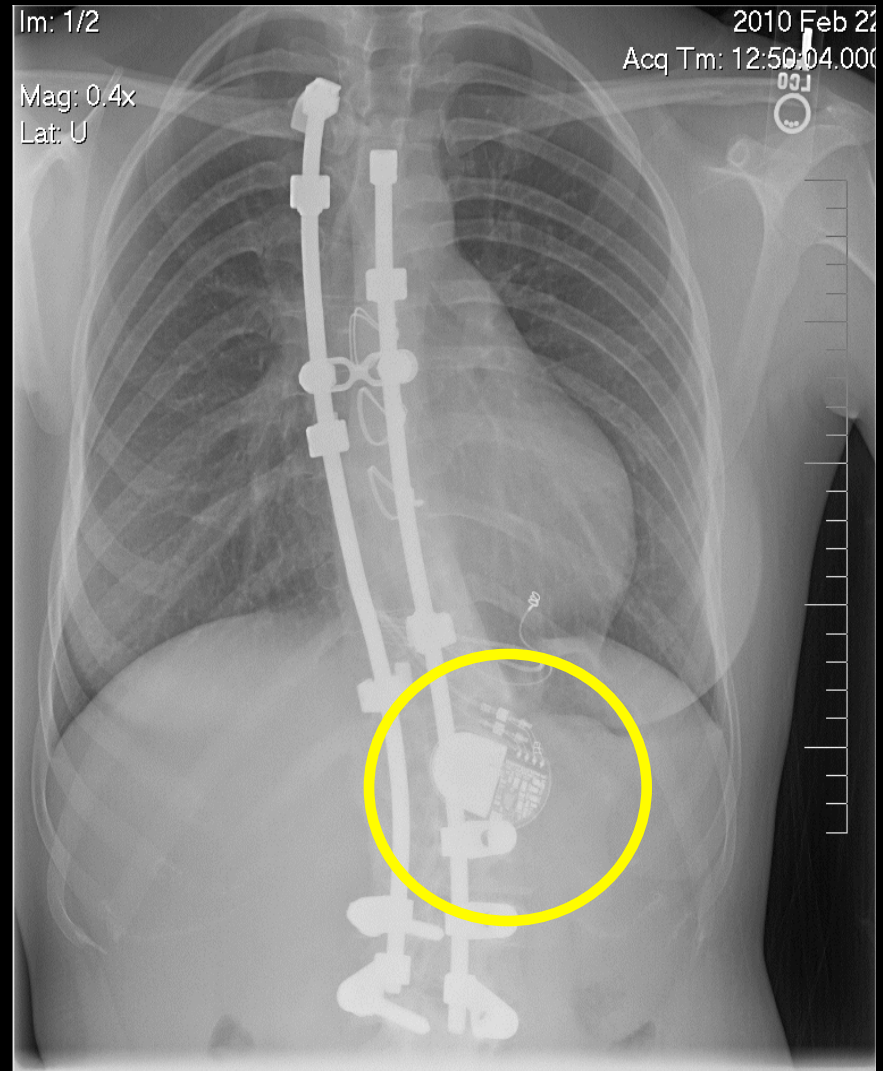


Implantable Medical Devices

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

Pacemakers, ICDs,
Neurostimulators,
Drug Pumps

Wireless



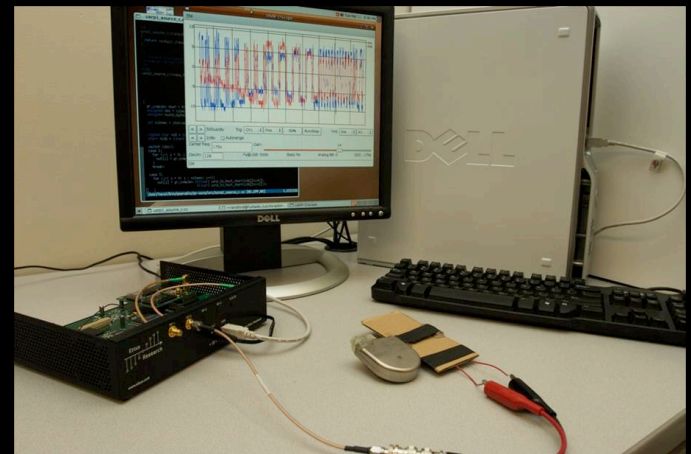
Is security necessary?

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)

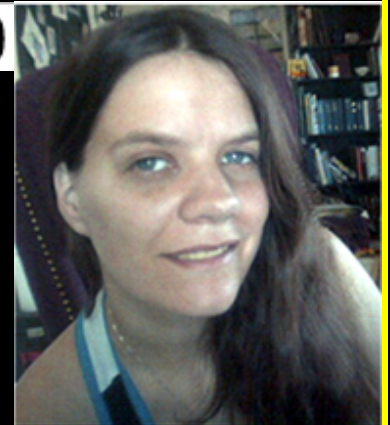
Unauthorized Wireless Changes: Would Someone Do It?

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[®]

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

What is the right solution?

The Human Factor

Real people in their daily lives



<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

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

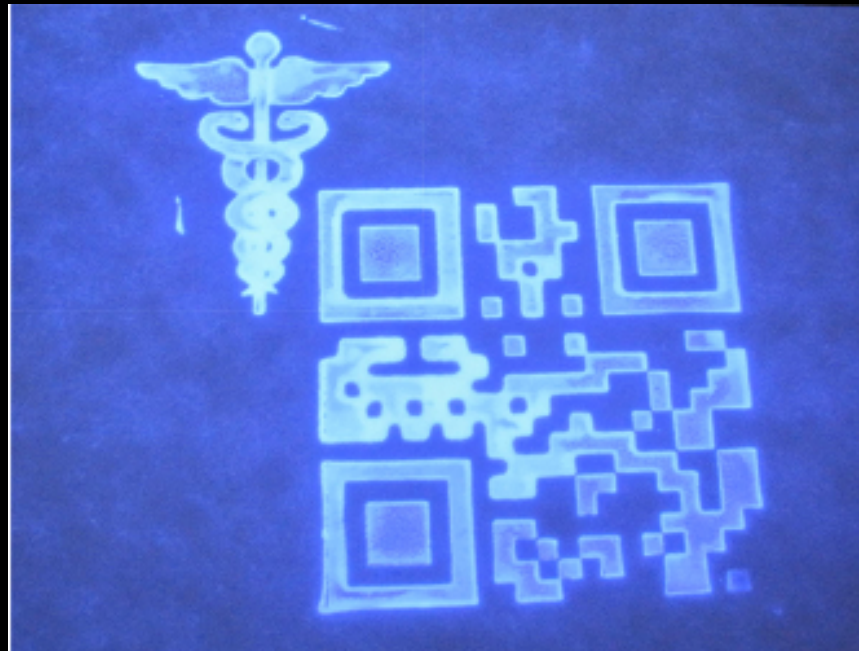
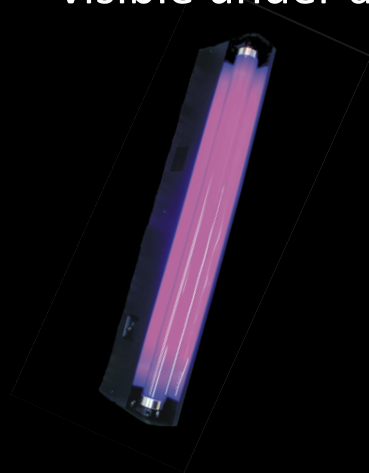
(Schechter [2010])

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

Passwords + Body Modifications: UV-Visible Tattoo

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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



Semi-structured Interview (with mockups)

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

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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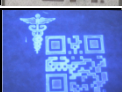



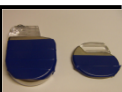

“It would make me feel like an invalid...That I had this thing, like the Scarlet Letter or [laughs].”

Values that Were Important to Patients



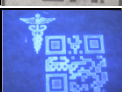





- Security
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“Well, I mean for-, because I’m Jewish it-, I’m not-, a tattoo on the arm to me means a concentration camp. So right away that’s the immediate horror.”



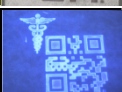



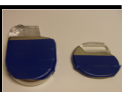

Mockup Evaluation: Results

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%



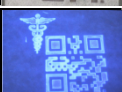





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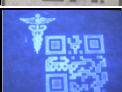



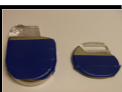

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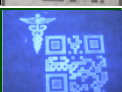



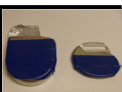

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Achieving Coverage: 3 Systems

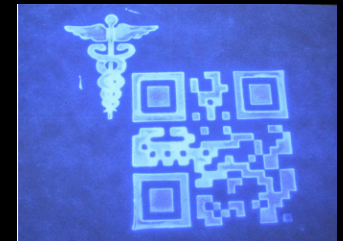
The Least Disliked: Proximity-Based Authentication



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

Questions?

