Implantable Medical Devices – Cyber Risks and Mitigation Approaches

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Agenda

- Overview of IMDs
- Security Threats, Vulnerabilities and Risks
- Risk-Based Mitigation Approach
- Summary
- References

What is an IMD?

- **Implantable Medical Device (IMD)**
  - **Tiny computing platform with firmware**
  - **Runs on small batteries**
  - **Programmable**
  - **Implanted in human body**
  - **Monitors health status**
  - **Delivers medical therapy**

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IMD Examples

- **Pacemakers**
- **Implantable Cardiac Defibrillators (ICD)**
- **Cochlear Implants**
- **Insulin Pumps**
- **Neurostimulators**

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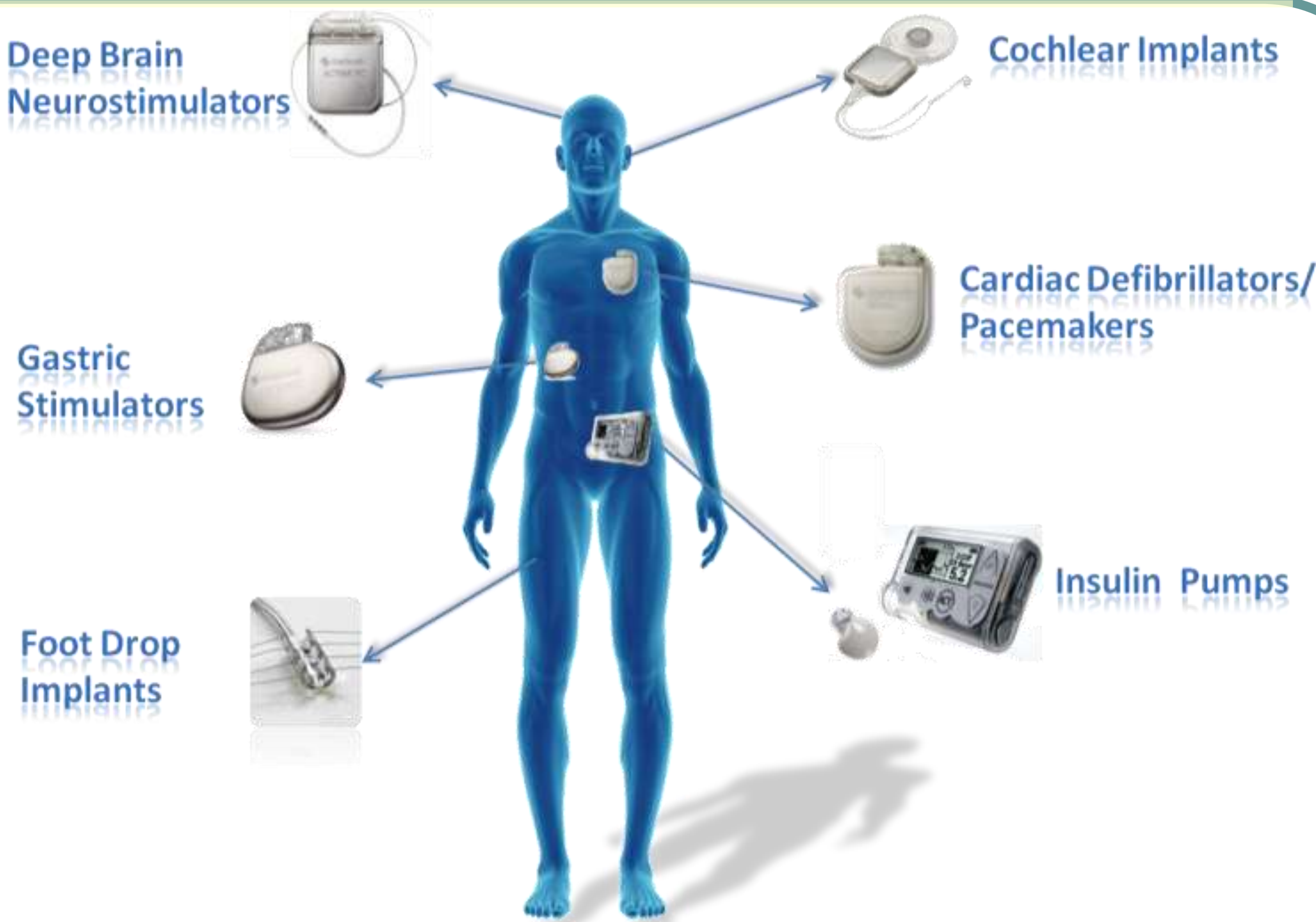
Wireless Implantable Medical Devices



Courtesy of http://groups.csail.mit.edu/netmit/IMDShield/

Pacemaker

- Consists of battery, computerized generator, and wires with sensors at tips (pacing leads)
  - Wires connect generator to the heart

- Records heart's electrical activity and rhythm
  - Recordings used to adjust pacemaker therapy
- On abnormal heart rhythm
  - Generator sends electrical pulses to heart

- Can monitor blood temperature, breathing etc.
  - Can adjust heart rate to changes in your activity
- Wireless communication with Programmer
  - Read battery status and heart rhythms
  - Send instructions to change therapy

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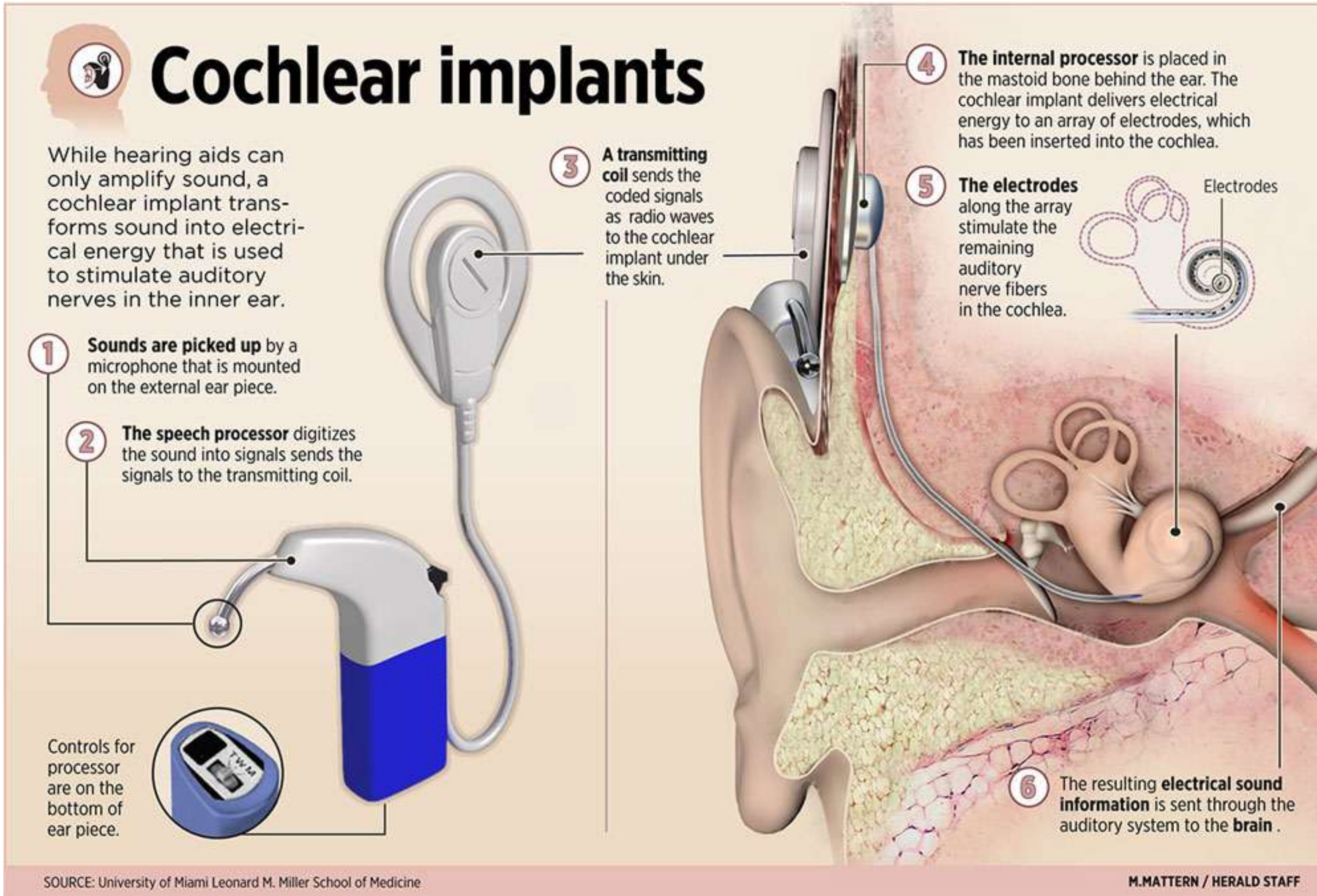
Wireless Insulin Pump

- Supports blood sugar monitoring & insulin delivery
- Wireless integration of Monitor and Pump
- Pump pre-set with user-specific information
- Monitor transmits glucose value to pump via wireless
- Pump calculates and delivers proper insulin dosage
- Pump “remembers” dosage history
- PC “dongle” can connect to Pump to read data or update settings

Medtronic Paradigm 512 Insulin Pump with Wireless Blood Sugar Meter

Cochlear Implants



IMD Data

- **IMD holds various Data Types**
  - **Static Data**
    - **Device make**
    - **Model #**
  - **Semi-static Data**
    - **Physician & Health Center Identification**
    - **Patient Name and DOB**
    - **Medical condition**
    - **Therapy configuration**
  - **Dynamic Data**
    - **Patient health status history**
    - **Therapy and dosage history**
    - **Audit logs**

IMD Accessibility

- "Programmer" Device communicates with IMD
  - Through wireless channels
  - Using radio frequency transmission
- PC communicates with IMD
  - Through USB-port "dongles" using radio frequencies
  - PC may also be connected to Internet
- IMD functions accessed remotely
  - Read data on health status & therapy history
  - Emergency extraction of patient health history
  - Emergency reset of IMD configuration
  - Therapy programming/reprogramming
  - Firmware updates

Regulation of IMDs

- **In US, IMDs are regulated by**
  - **Food and Drug Administration (FDA) Center for Devices and Radiological Health (CDRH)**
- **Testing focus**
  - **Safe and effective functioning**
  - **Different environmental conditions**
- **Absence of focus**
  - **Resistance/Resilience to cyber attacks**

Are IMDs Vulnerable?

- **A resounding YES!**
- **Current devices are engineered without considering threat of a potential hacker**
- **Current methods to prevent unauthorized access to IMDs include**
  - **Use of proprietary protocols**
  - **Controlled access to "Programmers" devices**
  - **Essentially, *security by obscurity!***

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Black Hat security conference – Aug 2011

- "Security researcher Jerome Radcliffe has detailed how our use of SCADA insulin pumps, pacemakers, and implanted defibrillators could lead to **untraceable, lethal attacks from half a mile away**"

- "He managed to **intercept the wireless control signals, reverse them, inject some fake data**, and then send it back to the [insulin] pump."

- "He could increase the amount of insulin injected by the pump, or reduce it"

http://www.extremetech.com/extreme/92054-black-hat-hacker-details-wireless-attack-on-insulin-pumps

IEEE Symposium on Security and Privacy - 2008

- Halperin et al, "Pacemakers and Implantable Cardiac Defibrillators: Software Radio Attacks and Zero-Power Defenses"
- "… an implantable cardioverter defibrillator (1) is potentially **susceptible to malicious attacks that violate the privacy** of patient information and medical telemetry, and (2) may experience **malicious alteration to the integrity of information or state**, including patient data and therapy settings for when and how shocks are administered."

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Threats

- Patient Data Extraction
- Patient Data Tampering
- Device Re-programming
- Repeated Access Attempts
- Device Shut-Off
- Therapy Update
- Malicious Inputs
- Data Flooding

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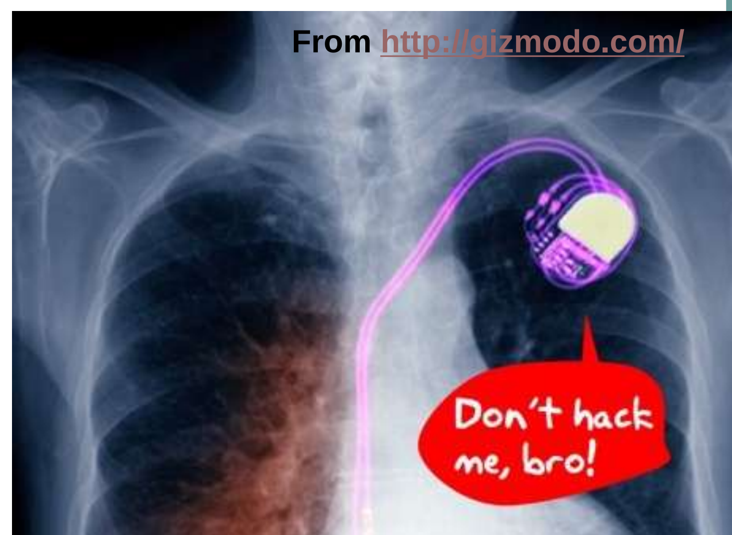
Vulnerabilities

- **Unsecured Communication Channels**
- **Inadequate Authentication Mechanisms**
- **Inadequate Access Controls**
- **Software Vulnerabilities**
- **Weak Audit Mechanisms**
- **Meager Storage**
- **Insufficient Alerts**



From http://gizmodo.com/

Risks

- **Patient Health Safety**
  - **Firmware Malfunction**
  - **Malicious Therapy Update**
  - **Malicious Inputs to Device**
- **Patient Privacy Loss**
  - **Data Leakage from Device**
- **Inappropriate Medical Follow-up**
  - **Tampering of Patient Readings**
- **Device Unavailability**
  - **Battery Power Depletion**
  - **Device Flooding**

Risk-Based Mitigation Approach

- **Develop IMD Security Impact Matrix**
- **Develop IMD Access Requirements Matrix**
- **Select Appropriate Security Mechanisms**
- **Tailor Security Mechanisms**
  - **Accommodate IMD Environment Constraints**
  - **Add Compensating Mechanisms (as needed)**

FIPS 199-based Impact Analysis

- **Identify IMD Data Types**
  - **E.g., Firmware, Device Identification, Patient Identification, Provider Identification, Health Condition, Therapy Configuration, Patient Readings, Audit Logs**
- **Identify IMD Health Delivery Commands**
  - **E.g., Emergency reset**
- **Analyze Impact of Compromise**
  - **For each Data Type, estimate impact**
    - **Loss of Confidentiality, Integrity and Availability**
  - **For each Command Type, estimate impact**
    - **Loss of Availability**
  - **Assign Impact as [LOW, MODERATE, HIGH]**
- **Tabulate in IMD Security Impact Matrix**

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IMD Security Impact Matrix (IMD-SIM)

Security Function / Data, Command	Emergency Reset Command	Patient ID Data	Therapy Data	Patient Heath Data
Confidentiality	N/A	MOD	LOW	MOD
Integrity	N/A	MOD	HIGH	HIGH
Availability	HIGH	LOW	MOD	MOD

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Determine IMD Access Requirements

- **Develop Matrix**
  - **By Data Type and Health Delivery Command**
  - **By Role of Individual Accessing IMD and**
    - **By Access Channels (e.g., wired, wireless)**
- **Add Required Access Privileges**
  - **Per Basic IMD Functionality**
  - **By Need for Emergency Access**
  - **By Utility and Quality of Life Factors**
- **Tabulate as IMD Access Requirements Matrix (IMD-ARM)**

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IMD Access Requirements Matrix (IMD-ARM)

ROLE-CHANNEL / Command, Data	Emergency Reset Cmd	Patient ID Data	Therapy Data	Patient Heath Data
Patient-Wireless				
Prescribing Physician-Wired		Read Write	Read Write	Read
Maintenance Physician-Wireless		Read	Read	Read
Emergency Tech-Wireless	Invoke			

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Select Needed Security Mechanisms

- Overlay IMD-IAM and IMD-ARM
- Select Security Mechanisms to Protect IMD Data/Commands
  - Channel Protection Mechanisms
    - Crypto-protected channel
    - None (Proprietary Protocols)
  - Authentication Mechanisms
    - Password
    - Device-to-device handshake
    - Cryptographic authentication
  - Audit Mechanisms
    - Auditable Events
    - Management of Audit Space Depletion
  - Alert/Alarm Mechanisms
    - Audible Alarms
    - Automatic Device Reset to Safe Mode

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Tailor Security Mechanisms

- **IMDs subject to many constraints**
  - **Device Size**
  - **Cost**
  - **Power**
  - **Computational Capability**
  - **Storage**
- **Adjust security mechanisms to accommodate constraints**
  - **E.g., Add Alarm if authentication can't be strengthened for certain Data Types**

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Special Challenges in Securing IMDs

- **Battery and Power Limitations**
  - **Power usage must be minimized to extend battery life**
  - **Battery depletion has devastating health consequences**
- **Use of Cryptographic Techniques**
  - **Highly Constrained Environment (cost, power, storage)**
  - **Compatible Crypto Suites/Protocols Needed**
    - **Crypto for Sensor Networks**
- **Audit Mechanisms**
  - **Limited Storage Area on Device**
    - **Attacks may generate deluge of audit entries**
  - **Managing Audit Space Depletion**
    - **Selective Overwriting; Alarms (Audible or to Remote Monitor)**

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Summary – IMDs and Security

- **IMDs – Essential in Current Healthcare Environment**
- **Wireless Access**
  - **Promotes Usability and Utility**
  - **Poses Significant Security and Privacy Concerns**
- **Risk-based Mitigation Approach**
  - **Determine Security Impact for Data Types**
  - **Implement Adequate Security Mechanisms**
  - **Balance Security/Privacy with Safety/Usability**
- **Further Work**
  - **Models for IMD security and privacy**
  - **Crypto-suites for IMD environments**

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Questions and Contact Information

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