

# Augmenting NLP Results by Leveraging SNOMED CT Relationships for Identification of Implantable Cardiac Device from Patient Notes

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# Agenda

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- Cardiac Implantable Electronic Devices (CIED)
- NLP framework at VUMC: Word Cloud
- Extending SNOMED concepts relevant to Implantable Cardiac Device
- Results

# Background

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*At some point in every person's life, you will need an assisted medical device – whether it's your glasses, your contacts, or as you age and you have a hip replacement or a pacemaker. The prosthetic generation is all around us. Aimee Mullins*

## Brief History of ICD

Year	Achievement
1947	First Human internal defibrillation
1956	First Human external defibrillation
1970	First implantable prototype
1980	First human implant @ John Hopkins
1985	ICD released to Market
1995	Pectoral ICD systems
1999	ICD & Atrial Defibrillation
2001	ICD & Resynchronization therapy



**Martin Mower**

**Michel Mirowski**

*Pioneers of Implantable Cardiac Device (ICD) "M & M"*

# CIED Indications

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- Treatment of bradycardia arrhythmia
- Prevention of sudden cardiac death
- Treatment of heart failure

# Pacemaker Implantation

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## Venous Access (technique)

Pneumothorax  
Hemothorax  
Injury to thoracic duct

## Lead Placement

Brady or tachy-arrhythmia  
Perforation of heart valve  
Damage to heart valve

# Complications

## Venous Access (insertion)

Air or foreign body embolism  
Perforation of the heart  
Inadvertent entry into artery

## Generator

Improper connection to the lead  
Pocket Hematoma  
Injury to thoracic duct

**Infection**

# ICD & Infection

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Causes for higher infection rates:  
(from 1.5% to 2.4% in US)

1. Increasing rate of ICD implantation
2. Increasing rate of Cardiac Resynchronization Therapy (CRT) device implanted
3. Increasing rate of ICD implantation in “higher risk” candidates (patients with diabetes, heart failure, and renal failure)
4. 57% increase in infection observed in CRT implantation

# Importance of early detection of infection in patients with CIED

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- Eradication of the infection is difficult and requires multiple antibiotics regimens
- Increased risk of acute complications such as pocket hematoma
- Extraction and reinsertion of a new device is costly
- Timely treatment can prevent local infection with a hospital mortality of 2-5% from progressing to a sepsis with 6-15% mortality

# Agenda

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- Cardiac Implantable Electronic Devices (CIED)
- NLP framework at VUMC: Word Cloud
- Augmenting NLP output
- Results



# Vanderbilt University Medical Center (VUMC) Word Cloud Project

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- **VUMC's Health Data Repository (HDR)**
- **EMR Vendor-neutral repository of all clinical data, since 1995**
- **Free-text documents, structured data, reports, images**
- **Stores all new clinical data into an infrastructure after deployment of a new EMR system**

# HDR Statistics

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- **Data for 3.4M patient**
- **1.03 billion documents**
- **Text data: 4.4TBytes**
- **Image data: 30TBytes**
- **~110,000 new text documents per weekday**



# NLP Concept Extraction

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- 1. Each document is processed in phases (regular expressions)**
- 2. Exclusion list is applied (“*ignore*” terms, such as “yellow fever shot”)**
- 3. Synonyms are applied**
- 4. All remaining concepts are extracted**

## Current set of concepts

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- **9,500 UMLS concepts**
  - 22,800 synonyms
  - 1,500 “ignore” expressions
- **Concepts organized in semantic groups**



# Approach

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- SNOMED CT concept coverage retrospective analysis:
  - 1,459 patients whose blood culture reported positive (August 2018 – March 2019)
  - Primary concepts of interest were suggested by 2 cardiologists:
    - Permanent Pacemaker
    - Implantable Cardioverter Defibrillator
  - Concepts relevant to Implantable Cardiac Device scattered through various nodes/hierarchies/axioms in SNOMED
    - Not all are relevant

# Discovering additional concepts

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- SNOMED CT vertical (*is-a*) and horizontal (attribute) relationships
  - *is-a* (n=29)
  - Attribute relationships ( n=23)
- Expanding on primary concepts
  1. Permanent Pacemaker
    - Permanent Pacemaker, device
  2. Implantable Cardioverter Defibrillator



# Expanding on primary concepts (graph query)

SNOMED	subject	predicate	object	
72506001	Implantable defibrillator	subClassOf	Biomedical device	<pre> PREFIX skos: &lt;http://www.w3.org/2004/02/skos/core#&gt; PREFIX rdfs: &lt;http://www.w3.org/2000/01/rdf-schema#&gt; PREFIX umls: &lt;http://bioportal.bioontology.org/ontologies/umls/&gt; PREFIX sct: &lt;http://purl.bioontology.org/ontology/SNOMEDCT/&gt; select ?id ?concept ?predicate ?object where {   ?subject skos:notation ?id;            skos:prefLabel ?concept;            ?predicate ?o.   ?o skos:prefLabel ?object.   filter (?id='72506001') }</pre>
72506001	Implantable defibrillator	subClassOf	Device	
72506001	Implantable defibrillator	subClassOf	Implant	
72506001	Implantable defibrillator	subClassOf	Cardiac implant	
72506001	Implantable defibrillator	subClassOf	Biomedical equipment	
72506001	Implantable defibrillator	subClassOf	Clinical equipment and/or device	
72506001	Implantable defibrillator	subClassOf	Defibrillator	
72506001	Implantable defibrillator	subClassOf	Automatic cardiac defibrillator	
72506001	Implantable defibrillator	subClassOf	Physical object	
72506001	Implantable defibrillator	subClassOf	Life support equipment	
72506001	Implantable defibrillator	subClassOf	Cardiovascular implant	
72506001	Implantable defibrillator	hasSTY	Medical Device	
72506001	Implantable defibrillator	associated_with	Implanted defibrillator electrode lead fracture	
72506001	Implantable defibrillator	associated_with	Disorder of implanted cardiac defibrillator electrode	
72506001	Implantable defibrillator	associated_with	Disorder of implanted defibrillator generator	
72506001	Implantable defibrillator	associated_with	Disorder of implantable defibrillator	
72506001	Implantable defibrillator	associated_with	Implanted defibrillator electrode infection	
72506001	Implantable defibrillator	associated_with	Implanted defibrillator electrode displacement	
72506001	Implantable defibrillator	associated_with	Implanted defibrillator electrode lead displacement	
72506001	Implantable defibrillator	associated_with	Implanted defibrillator generator infection	
72506001	Implantable defibrillator	associated_with	Implanted defibrillator generator failure	
72506001	Implantable defibrillator	associated_with	Disorder of defibrillator function	
72506001	Implantable defibrillator	associated_with	High threshold for implanted defibrillator	
72506001	Implantable defibrillator	associated_with	Inappropriate shocks from implanted defibrillator	
72506001	Implantable defibrillator	associated_with	Malfunction of biventricular automatic implantable cardioverter defibrillator generator	
72506001	Implantable defibrillator	associated_with	Mechanical malfunction of biventricular automatic implantable cardioverter defibrillator	
72506001	Implantable defibrillator	associated_with	Malfunction of biventricular automatic implantable cardioverter defibrillator	
72506001	Implantable defibrillator	associated_with	Malfunction of automatic implantable cardioverter defibrillator	
72506001	Implantable defibrillator	associated_with	Inappropriate implantable cardioverter shock	
72506001	Implantable defibrillator	associated_with	Implantable cardioverter battery end of life	
72506001	Implantable defibrillator	associated_with	Malfunction of implantable defibrillator ventricular lead	
72506001	Implantable defibrillator	direct_device_of	Insertion of dual chamber pulse generator and repositioning of cardioverter defibrillation pulse generator lead	
72506001	Implantable defibrillator	direct_device_of	Replacement of cardiac defibrillator using fluoroscopic guidance	
72506001	Implantable defibrillator	direct_device_of	Insertion of cardiac biventricular implantable cardioverter defibrillator (ICD) using fluoroscopic guidance	

# Permanent Pacemaker concept relationships

associated with	procedure device of	direct device of
Cardiac pacemaker myoinhibition	Cardiac pacemaker procedure	Creation of cardiac pacemaker pocket new site in subcutaneous tissue
Cardiac pacemaker sensitivity problem	Electronic analysis of dual-chamber internal pacemaker system with reprogramming	Emergency cardiac pacemaker
Cross-talk in dual chamber cardiac pacemaker	Electronic analysis of dual-chamber internal pacemaker system without reprogramming	Fixed-rate cardiac pacemaker
Infected pacemaker	Electronic analysis of internal pacemaker system	General maintenance of cardiac pacemaker
Infection of biventricular cardiac pacemaker	Electronic analysis of internal pacemaker system, complete	Implantation of biventricular cardiac pacemaker system
Malfunction of biventricular cardiac pacemaker	Fluoroscopy guided cardiac pacemaker procedure	Implantation of cardiac dual-chamber device, replacement
Malfunction of biventricular cardiac pacemaker battery	Implantation of emergency intravenous cardiac pacemaker	Implantation of cardiac pacemaker
Malfunction of cardiac pacemaker	Implantation of simple one wire intravenous cardiac pacemaker	Implantation of cardiac single-chamber device replacement, rate-responsive
Mechanical complication of cardiac pacemaker	Intraoperative cardiac pacemaker	Implantation of cardiac single-chamber device, replacement
Pacemaker re-entrant tachycardia	Maintenance of battery of cardiac pacemaker system	Implantation of rate-responsive cardiac single-chamber device
Runaway cardiac pacemaker	Maintenance of intravenous cardiac pacemaker system	Initial implantation of cardiac dual-chamber device
	Maintenance procedure for cardiac pacemaker system	Initial implantation of cardiac single-chamber device
	Management of permanent pacemaker	Insertion of pacemaker for control of atrial fibrillation
	Relocation of automatic implantable cardioverter/defibrillator	Insertion of programmable cardiac pacemaker
	Repair of cardiac pacemaker pocket in skin AND/OR subcutaneous tissue	Relocation of cardiac pacemaker pocket to new site in subcutaneous tissue
	Repositioning of cardiac pacemaker pocket	Renewal of intravenous cardiac pacemaker system
	Repositioning of cardioverter/defibrillator pulse	Repair of cardiac pacemaker
		Repair of pacemaker with replacement of pulse generator
		Replacement of cardiac pacemaker
		Replacement of cardiac pacemaker device with dual-chamber device
		Replacement of pacemaker device with single-chamber device, not specified as rate-responsive
		Reprogramming of cardiac pacemaker

# Relationships discovery for extension

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- A graph version of SNOMED CT was generated by converting UMLS RRF subset format (umls2rdf.py)
  - subClassOf
  - ~~hasSTY~~
  - associated\_with
  - direct\_device\_of
  - indirect\_device\_of
  - ~~interprets~~
  - ~~has\_interpretation~~
  - procedure\_device\_of
  - device\_used\_by
  - ~~causative\_agent\_of~~

# Extending concepts beyond

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1. Permanent pacemaker
2. Permanent cardiac pacemaker, device
  - *Cardiac pacemaker (subClassOf)*
  - *Permanent cardiac pacemaker procedure (procedure device of)*
3. Implantable Cardioverter Defibrillator
  - *Automatic cardiac defibrillator (subClassOf)*
    - *Implantation of automatic cardiac defibrillator (direct device of)*
  - *Implantation of internal cardiac defibrillator (direct device of)*
    - *Implantation of automatic cardiac defibrillator (subClassOf)*
    - *Implantable defibrillator (has direct device)*
  - *Insertion of biventricular implantable cardioverter defibrillator (direct device of)*
    - *Implantation of internal cardiac defibrillator*
    - *Implantable defibrillator*

**Concept Details** 🕒 ⚙️

Summary | Details | Diagram | Expression | Refsets | Members | References Stated Inferred

**Implantation of internal cardiac defibrillator (procedure)** 📄 ⓘ

SCTID: 395218007, Primitive, Active

**United States of America English language reference set**

Term	Acceptability (US)
F ☆ Implantation of internal cardiac defibrillator (procedure)	Preferred ⓘ
S ★ Implantation of internal cardiac defibrillator	Preferred ⓘ

Type	Destination	Group	CharType
● Is a (attribute)	☰ Insertion of therapeutic device (procedure)	0	Inferred ⓘ
● Is a (attribute)	☰ Implantation of automatic cardiac defibrillator (procedure)	0	Inferred ⓘ
● Procedure site - Indirect (attribute)	● Heart structure (body structure)	1	Inferred ⓘ
● Direct device (attribute) ←	● Implantable defibrillator, device (physical object)	1	Inferred ⓘ
● Method (attribute)	● Insertion - action (qualifier value)	1	Inferred ⓘ

## Concept Details



Summary Details Diagram Expression Refsets Members References

Stated Inferred

### Implantable defibrillator, device (physical object)



SCTID: 72506001, Primitive, Active

#### United States of America English language reference set

Term	Acceptability (US)
F ☆ Implantable defibrillator, device (physical object)	Preferred
S ☆ Implantable defibrillator	Preferred
S ✓ Implantable defibrillator, device	Acceptable

Type	Destination	Group	CharType
● Is a (attribute)	● Cardiac implant (physical object)	0	Inferred
● Is a (attribute) ←	● Automatic cardiac defibrillator (physical object)	0	Inferred

# Examples of irrelevant associations

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Implantable defibrillator (associated\_with)

- *Disorder of implantable defibrillator*
- *Disorder of implanted cardiac defibrillator electrode*
- *Disorder of implanted defibrillator generator*
- *High threshold for implanted defibrillator*
- *Implantable cardioverter battery end of life*

# Iterative reconciliation with SMEs

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- 411 concepts from original extension
- Reduced to 160, 110, and 52 after multiple review sessions with cardiologists

Attribute relationship



subClassOf	29
direct_device_of	10
has_direct_device	10
uses_device	1
has_procedure_device	1
procedure_device_of	1



# NLP Results

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- Total cardiac device related concepts picked up by NLP  
38,779
  - Original 3 SNOMED concepts: 66.5%
  - Additional SNOMED concepts: 33.5%
    - initial addition: 25.8%
    - secondary addition: 5.7%
    - last extension: 2%



# Questions?

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I am proud of my heart.  
It's been played,  
Stabbed,  
Burned and Broken but somehow still works

PACEMAKERS *saving hearts, one thud after another*



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