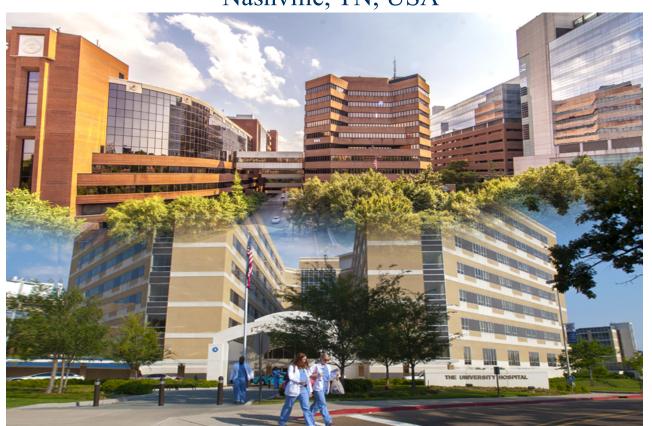
Augmenting NLP Results by Leveraging SNOMED CT Relationships for Identification of Implantable Cardiac Device from Patient Notes

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Agenda

Cardiac Implantable Electronic Devices (CIED)

NLP framework at VUMC: Word Cloud

 Extending SNOMED concepts relevant to Implantable Cardiac Device

Results

Background

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 prostatic generation is all around us. Aimee Mullins

Brief History of ICD

Year	Achievement
1947	First Human internal defibrillation
1956	First Human external defibrillation
1970	Fist 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

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

Pacemaker Implantation

Venous Access (technique)

Pneumothorax
Hemothorax
Injury to thoracic duct

Lead Placement

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

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

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

- 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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NLP framework at VUMC: Word Cloud

Augmenting NLP output

Results

Vanderbilt University Medical Center (VUMC) Word Cloud Project

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

Data for 3.4M patient

1.03 billion documents

Text data: 4.4TBytes

Image data: 30TBytes

~110,000 new text documents per weekday

What is going on with this patient?

Word Cloud View





iron deficiency anemia

```
edema.
                                            alopecia
                                                            histoplasmosis
         lower back pain
                                            coronary artery disease
   pituitary tumor malabsorption
                                                        mucocele knee pain
                                     constipation
                             tricuspid valve regurgitation
                                                         streptococcal pharyngitis
               neck pain
    depression shortness of breath
                                                  vomiting skin nodule
                                  thyroid ablation lymphadenopathy
      heart failure
                                          cardiomyopathy
                                influenza
      chest pain syncope
                                                    pregnancy
pharyngitis tonsillitis
                                   back pain
                              hyperthyroidism
                                                   anemia
                                                           palpitations
                                                                     arrhythmia
 premature infant nodule
                                                     acute kidney injury
                                fever rubella
                                               dizziness
                                                           right upper quadrant pain
    bronchitis migraine iud
                              heartburn breast feeding
                                                      sinus arrhythmia
                                     laceration
 weight loss graves' disease
                                  lung
                                                           tonsillectomy
        congenital heart disease
                                                            vaginal bleeding
      congestive heart failure hiv
                                                             thyrotoxicosis
     cold intolerance abdominal pain dysphagia
                                                             headache
                                                         sinus bradycardia
          postpartum leukocytosis overweight urticaria
                  myocardial infarction diarrhea scoliosis
                                                          left ventricular dysfunction
        gestational hypertension hip pain
       hemorrhage celiac disease
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NLP Concept Extraction

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

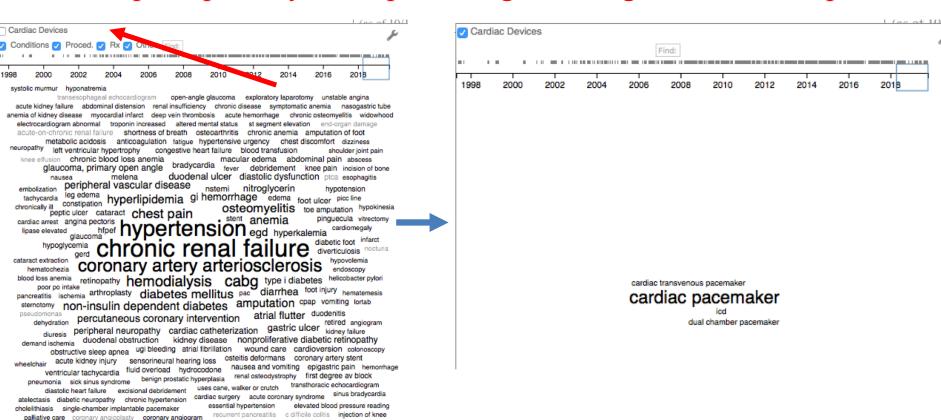
4. All remaining concepts are extracted

Current set of concepts

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

Objective

- 1. Identify primary SNOMED concept(s) relevant to CIED, captured by Word Cloud NLP
- 2. Expand primary concepts through ontological relationships



Approach

- 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

- 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)

NOMED	subject	predicate	object		
72506001	Implantable defibrillator	subClassOf	Biomedical device	PREFIX skos: http://www.w3.org/2004/02/skos/core#>	
72506001	Implantable defibrillator	subClassOf	Device	PREFIX rdfs: PREFIX umls: http://bioportal.bioontology.org/ontology/SNOMEDCT/> PREFIX sct: http://purl.bioontology.org/ontology/SNOMEDCT/> select ?id ?concept ?predicate ?object where {	
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	<pre>- ?predicate ?o ?o skos:prefLabel ?object.</pre>	
72506001	Implantable defibrillator	subClassOf	Physical object	filter (?id='72506001') }	
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			

Permanent Pacemaker concept relationships

associated with

Cardiac pacemaker myoinhibition

Cardiac pacemaker sensitivity problem

Cross-talk in dual chamber cardiac pacemaker

Infected pacemaker

Infection of biventricular cardiac pacemaker

Malfunction of biventricular cardiac pacemaker

Malfunction of biventricular cardiac pacemaker battery

Malfunction of cardiac pacemaker

Mechanical complication of cardiac pacemaker

Pacemaker re-entrant tachycardia

Runaway cardiac pacemaker

device used by

Transesophageal cardiac pacing procedure

Transthoracic cardiac pacing procedure

procedure device of

Cardiac pacemaker procedure

Electronic analysis of dual-chamber internal pacemaker system with reprogramming Electronic analysis of dual-chamber internal

pacemaker system without reprogramming

Electronic analysis of internal pacemaker system

Electronic analysis of internal pacemaker system, complete

Fluoroscopy guided cardiac pacemaker procedure

Implantation of emergency intravenous cardiac pacemaker

Implantation of simple one wire intravenous cardiac pacemaker

Intraoperative cardiac pacemaker

Maintenance of battery of cardiac pacemaker system

Maintenance of intravenous cardiac pacemaker system

Maintenance procedure for cardiac pacemaker system

Management of permanent pacemaker Relocation of automatic implantable

cardioverter/defibrillator

Repair of cardiac pacemaker pocket in skin

AND/OR subcutaneous tissue

Reposition of cardiac pacemaker pocket

Repositioning of cardioverter/defibrillator pulse

direct device of

Creation of cardiac pacemaker pocket new site in subcutaneous tissue

Emergency cardiac pacemaker

Fixed-rate cardiac pacemaker

General maintenance of cardiac pacemaker

Implantation of biventricular cardiac pacemaker system

Implantation of cardiac dual-chamber device, replacement

Implantation of cardiac pacemaker

Implantation of cardiac single-chamber device replacement, rate-responsive

Implantation of cardiac single-chamber device, replacement

Implantation of rate-responsive cardiac single-chamber device

Initial implantation of cardiac dual-chamber device

Initial implantation of cardiac single-chamber device

Insertion of pacemaker for control of atrial fibrillation

Insertion of programmable cardiac pacemaker

Relocation of cardiac pacemaker pocket to new site in subcutaneous tissue

Renewal of intravenous cardiac pacemaker system

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

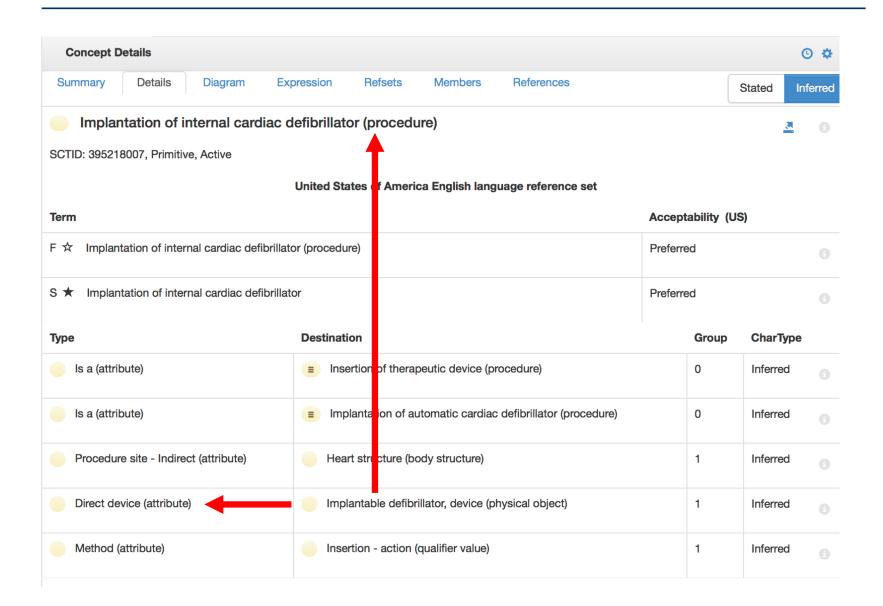
Reprogramming of cardiac pacemaker

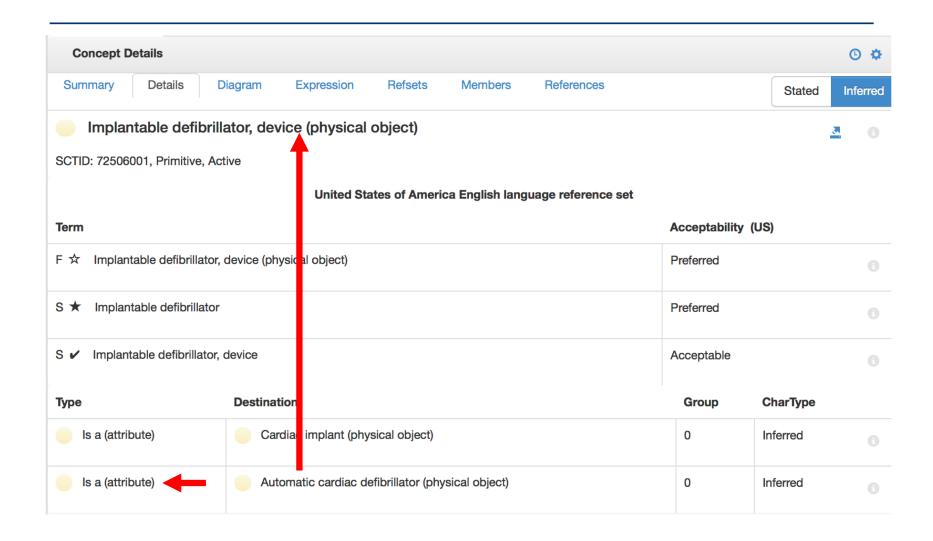
Relationships discovery for extension

- 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
 - <u>causative_agent_of</u>

Extending concepts beyond

- 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





Examples of irrelevant associations

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

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

Attribute relationship	$\left\{ \right.$
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subClassOf	29
direct_device_of	10
has_direct_device	10
uses_device	1
has_procedure_device	1
procedure_device_of	1

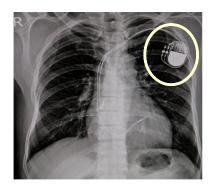
NLP Results

- 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%

Word Cloud Content Guided Alerts







Proactive Alerting in At Risk Patients

- Bacteremia + Cardiac implant = Increased risk of complications
- Word Cloud examines the patient's entire record
- Identifies if a patient has a cardiac implant
- Alerts Engine signals provider if Bacteremia + Cardiac implant
- First Alert 09/18/2019

liver dysfunction nasogastric tube deconditioning hemofiltration hemoperitoneum hypertension multiple organ failure continuous deficiency pneumothorax central venous catheter hypertension multiple trauma lower palliative care anemia kidney failure orif hematoma transplant crush injury esblar pseudoaneurysm uti debridement ostomy tibia repressure ulcer renal transplant crush injury esblar pseudoaneurysm uti debridement ostomy tibia repressure ulcer renal transplant crush injury esblar pseudoaneurysm uti debridement ostomy tibia repressure ulcer renal transplant crush injury esblar pseudoaneurysm uti debridement ostomy tibia repressure ulcer renal transplant crush injury esblar pseudoaneurysm uti debridement ostomy tibia repressure ulcer renal transplant crush injury esblar foot pair osteomyelitis chronic renal failure abscess ileus enteral nutrition tpn suprapubic cathete tachycardia proctectomy fracture exploratory laparotor revision of scar evacuation of hematoma colostomy ocystoscopy acute kidney injury respiratory failure respi



Questions?

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



Acknowledgement

Vanderbilt University Medical Center

Department of HealthIT

Dario Giuse, PhD Asli Weitkamp, PhD Michael McLemore

