Clinical Modeling and the Future of Healthcare Computing

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Intermountain Healthcare
University of Utah
Please ask questions …
A Bit of Speculation

- **What are the Foundations of Medical Informatics**
  - Electronic Health Record
  - Computerized Decision Support
  - Access to Medical Knowledge
  - Access to Summarized Experience
- **If We Knew How to Do These---What’s Next?**
Grand Unified Theory of Medical Informatics

- **Models**
  - **Disease**: A Time-Based Clinical Trajectory
  - **Plan**: Point in Time Therapeutic Interventions
  - **Guideline**: Therapy over Time
  - **Model Health**

- **Solving Practical Problems**
  - **Diagnose Disease**
  - **Predict Disease Course**
  - **Plan Therapy**
  - **Recognize Co-morbidity**
  - **Manage Resources**
Start with the Medical Problem List

- A Well-Maintained Problem List Can Enhance Care
  - Provides the Most Concise Summary of the Patient’s Condition
  - Focuses Clinical Data Review, Order Entry, and Care Documentation

- Is Difficult to Maintain
  - Care is Given in Multiple Locations
  - Traditional Paper Problem List Reflects Fragmented Care

- Fails to Capture Dynamic Nature of Problems
Natural Language Processing System (SymText)

Proposed Problems (ScratchPad)

Problem List Management Program

Textual Documents

Clinical Database

Clinical Data

Famly Hx

Diabetes-Poorly Controlled

Pneumonia-Acute

Problem List

1) Myocardial Infarction
2) Renal Failure
causing: Hyperkalemia
Causing: Hypertension
3) Rheumatoid Arthritis

Infarction

Requires CPAP

Fever

of Sleep Apnea

Zocor

Myocardial Infarction

2) Renal Failure
    causing: Hyperkalemia
    Causing: Hypertension
3) Rheumatoid Arthritis
Medical NLP Systems

Local NLP Efforts

- SPRUS
- SymText
- MPLUS
- MedLee
- MMTX

**MRIUS**
- A First Effort in NLP Supported by Decision Tools
- Efforts to Modularize
- Some Object Oriented Properties
- Chest X-rays

**MedLee**

**SymText**
- From Carol Friedman-Columbia
  - A Complete System Mixing Syntactic Analysis with a Probabilistic Semantics
  - Used for Admitting Dx., Pulmonary Vascular Studies, and CT of the Brain

**MetaMap Transfer (MMTX)**
- From Carol Friedman-Columbia
  - Most Complete Coverage of Medicine
  - Component of the Unified Medical Language System

- National Library of Medicine
Parenchymal infiltrates are seen in both lungs particularly the right lower lobe, undoubtedly the result of pneumonia. Since previous studies, there has been a decrease in the size of the pleural effusions. Improvement of changes of congestive heart failure is noted.

**Findings**
- alveolar infiltrate
- effusion (fluid)

**Locations**
- both lung fields
- right lower lobe
- interpleural space

**Diseases**
- congestive heart failure
- pneumonia

**Associations**
- alveolar infiltrate - both lung fields
- alveolar infiltrate - right lower lobe
- effusion (fluid) - interpleural space

**Clinical Data Base**
1) Coded Radiology Findings
2) Natural Language Report
Extracting Problems from Medical Documents

NLU application:
To retrieve potential medical problems from free-text documents in the CPR.

Enhanced Problem List management application:
To allow addition of the potential medical problems to the Problem List.

Diagram:
- Free-text documents
- NLU
- Extracted concepts
- Proposed problems
- Addition by the user
- Problem List
  - Knowledge access
  - PCMS
  - Other...
A Computerize Problem List

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Maintained Manually
CHIEF COMPLAINT: "Shortness of breath."

HISTORY OF PRESENT ILLNESS: This 41-year-old female presents with severe shortness of breath and increasing fatigue. On 01/13/2004, the patient came to the emergency room complaining of fever and generalized malaise. She was treated with fluids and Loratadine and told to follow up if symptoms worsened.

The next night, she returned to the emergency room with a headache which was focused on her left side, and she had nasal drainage. She was treated for sinusitis and was sent home with Percocet and Benadryl 500 mg. She was rehydrated by IV and given 1 gram of Rocephin. The following day, she returned to the emergency room for a follow-up visit and felt much better.

The patient returned to the emergency room today stating she could not breathe. She had fett better yesterday, but today she has worsening dyspnea. The patient felt lightheaded and presented to the emergency room by phone and is not responsive. There is no history of pleuritic pain or hemoptysis. She denies any history of pulmonary embolism or leg pain or swelling.

While in the emergency room, her oxygen saturations were in the 70’s but 99% on 12 liters non-rebreathing mask. Her blood pressure was 86/72. An EKG showed sinus tachycardia with ST elevation T3. A CT of the thorax with contrast was taken which showed large pulmonary emboli with multiple clot bilaterally, particularly in the upper lobes.

The patient was not a candidate for thrombolytic therapy due to recent surgery. She was given a 500 unit bolus of heparin and started on 1000 units per hour. The patient was then taken to have an angiographic pulmonary embolectomy done and a filter placed in the inferior vena cava.

MULTIMODEL TEXT ANALYSIS: Clinical Information System: The patient was a candidate for thrombolytic therapy due to recent surgery. She was given a 500 unit bolus of heparin and started on 1000 units per hour. The patient was then taken to have an angiographic pulmonary embolectomy done and a filter placed in the inferior vena cava.
An Enhanced Problem List

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Problems Proposed by the System

Current PL:
- Problems Proposed by the System
- Source: NLU System
  - Restless legs syndrome
  - Headache
  - Hypertension
  - Anxiety
CHIEF COMPLAINT: "Shortness of breath."

HISTORY OF PRESENT ILLNESS: This 41-year-old female presents with severe shortness of breath and increasing fatigue. On 01/13/2004, the patient came to the emergency room complaining of fever and generalized malaise. She was treated with fluids and Lortab and told to follow up if symptoms worsened.

The next night, she returned to the emergency room with a headache which was focused on her left side, and she had nasal drainage. She was treated for sinusitis and was sent home with Percocet and Biaxin 500 mg. She was rehydrated by IV and given 1 gram of Rocephin. The following day, she returned to the emergency room for a followup visit and felt much better.

The patient returned to the emergency room today stating she could not breathe. She had felt better yesterday, but today, she had worsening dyspnea. The patient felt lightheaded and presented to the emergency room plethoric and hypotensive. There is no history of pleuritic pain or hemoptysis. She denies any history of pulmonary embolism or leg pain or swelling.

While in the emergency room, her oxygen saturations were in the 70s but 99% on 12 liters nonbreathing mask. Her blood pressure was 95/72. An EKG showed sinus tachycardia with S1 Q3 inverted T3. A CT of the thorax with contrast was taken which showed large pulmonary emboli with multiple clots bilaterally, particularly in the lower lobes.

The patient was not a candidate for thrombolytic treatment due to recent surgery. She was given a 500 unit bolus of heparin and started on 1000 units per hour. The patient was then taken to have an angiographic pulmonary embolectomy done and a filter placed in the inferior vena cava.

MEDICATIONS: Tunalol, Percocet, Biaxin. The patient recently stopped prednisone.
Problem List
1) Myocardial Infarction
2) Renal Failure
causing: Hyperkalemia
Causing: Hypertension
3) Rheumatoid Arthritis

Proposed Problems
(Scratch Pad)

Expert System
(Bayesian Network)

Clinical Database

Natural Language Processing System
(SymText)

Textual Documents

Clinical Data

Problem List Management Program
Extracting Medical Knowledge From Clinical Data

Episodes of Care

Medical Information System

Modeling and Analysis

Clinical Models
Developed with a data set of 32,000 emergency department patients
Emergency Department

Clinical information system: HELP System

## Emergency department: Current patient list

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<th>LAB</th>
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Emergency Department

Pneumonia System:

Radiology Viewing Station
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Temporal course of probability

Involved variables

communication monitor
Results: Validation Study

Automatic Identification of Pneumonia Patients: Receiver Operating Characteristic Curve

Area under the ROC curve: 0.942 (0.927, 0.955)

ROC curve created with ROCKit using maximum likelihood estimation (Charles Metz/Ben Herman)
Beyond Problem Recognition

- **Problem Status**
  - Problems Change through Time
- **Predictive Models**
  - What will the Patient Look Like Tomorrow
- **Therapy and Transitions**
  - How will Treatment A Change Tomorrow's Status
- **Simulation**
- **Etc.**
Advanced Probabilistic Modeling Environments

- Bayesian Modeling
  - Bayesian Networks
  - Influence Diagrams
  - Dynamic (Temporal) Bayesian Networks
  - Partially observed Markov Decision Processes (POMDPs)
  - Limited Memory Influence Diagram (LIMID)
  - Etc.
Dynamic (Temporal) BN

- Capture Change over Time
- Related to Hidden Markov Models
- Can Support Multiple Functions
  - Diagnosis
  - Prediction (Prognosis)
  - Simulation
  - Explanation

Two Slices of MI
Questions???