Clinical Decision Support Historical Perspectives – 1

Component 11 / Unit 3

CDS: historical perspectives

- Early approaches focused on application of artificial intelligence and expert systems to improve medical diagnosis
- Diagnostic decision support was a major focus of the field in the early days, circa 1970s and 1980s
  - But computer-aided diagnosis proved difficult and it became apparent computers could better be used in more focused capacities to reduce errors and improve quality
  - Laid the intellectual groundwork for techniques used in modern CDS and shift of focus to therapeutic decision support
- With the availability of data in the modern electronic health record (EHR), the older approaches may yet be useful in the future

Let's define some terms

- Artificial intelligence (AI) – the area of computer science concerned with building computer programs that exhibit characteristics associated with human intelligence
- Expert system (ES) – a computer program that mimics human expertise
- Decision support system (DSS) – also mimics human expertise but acts in more of a supportive than independent role
  - Diagnostic decision support – focused on aiding in diagnosis of patients
  - Therapeutic decision support – focused on aiding in treatment of patients

Early efforts arose out of attempts to "quantify" medical diagnosis

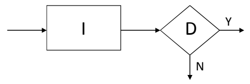
- Ledley and Lusted (1959, 1960) proposed mathematical model for diagnosis
  - Clinical findings based on set theory and symbolic logic, with diagnosis made using probabilities
- Warner (1961) developed a mathematical model for diagnosing congenital heart disease
  - Approach used contingency table with diagnoses as rows and symptoms as columns
  - System predicted diagnosis with the highest conditional probability given a set of symptoms

Approaches to diagnostic ESs

- Functions of systems tightly linked to methods for knowledge representation
- Four general approaches
  - Clinical algorithms
  - Bayesian statistics
  - Production rules
  - Scoring and heuristics
- Current approaches taken advantage of modern EHRs and other advances

Clinical algorithms

- Follow path through "flow chart"
- Elements in chart are nodes
  - Data is gathered at information nodes
  - Decisions are made at decision nodes



Clinical algorithms (cont.)

- Benefits
  - Knowledge is explicit
  - Knowledge is easy to encode
- Limitations
  - No accounting for prior results
  - Inability to pursue new etiologies, treatments, etc.
  - New knowledge difficult to generate
- Forerunner of modern clinical practice guidelines

Bayesian statistics

- Based on Bayes' theorem, which calculates probability based on prior probability and new information
- Assumptions of Bayes' theorem
  - Conditional independence of findings – no relationship between different findings for a given disease
  - Mutual exclusivity of conditions – more than one disease does not occur

Bayes' Theorem generalized form

- Probability of disease i in the face of evidence E, out of a set of possible j diseases is:

$$P(Di|E) = \frac{P(Di)\ P(E|Di)}{\Sigma\ P(Dj)\ P(E|Dj)}$$

- Translation of formula: the probability of a disease given one or more findings can be calculated from
  - The prior probability of the disease
  - The probability of findings occurring in the disease

Implementation and limitations of Bayesian approach

- Leeds Abdominal Pain System (de Dombal, 1975)
  - Most successful implementation, used in diagnosis of acute abdominal pain
  - Performed better than physicians – accuracy 92% vs. clinicians 65-80%, better in 6 of 7 disease categories
  - But difficult to use and not transportable to other locations (Berg, 1997)
- Limitations of Bayesian statistics
  - Findings in a disease are usually not conditionally independent
  - Diseases themselves may not be mutually exclusive
  - When multiple findings important in diagnosis, reaches high computational complexity quickly

Production rules

- Knowledge encoded as IF-THEN rules
- System combines evidence from different rules to arrive at a diagnosis
- Two types of rule-based ESs:
  - Backward chaining – System pursues goal and ask questions to reach goal
  - Forward chaining – Similar to clinical algorithms, with computer following proscribed path to reach answer
- Generic rule: IF test-X shows result-Y THEN conclude Z (with certainty p)

The first rule-based ES in medicine: MYCIN

- PhD dissertation of Shortliffe (1975) and one of the first applications in medical informatics
- Major features
  - Diagnosed the infectious diseases, meningitis and bacteremia
  - Used backward chaining approach
  - Asked questions (relentlessly!) in an attempt to reach diagnosis
- Evaluation of MYCIN (Yu, 1979)
  - 10 cases of meningitis assessed by physician experts and MYCIN; output judged by other physician experts
  - Recommendations of experienced physicians judged acceptable 43-63% of the time, compared with 65% of the time for MYCIN
  - In no cases did MYCIN fail to recommend an antibiotic that would cover the infection (even if it was not optimal choice)

Limitations of rule-based systems

- Depth-first searching could lead to focus in wrong area
- Rule bases were large and difficult to maintain
  - MYCIN had 400 rules covering two types of bacterial infection
  - Approach worked better in constrained domains, such as pulmonary function test interpretation
- Systems were slow and time-consuming to use
  - Rule-based goal seeking could take long time
  - System also developed prior to era of modern computers and graphical user interfaces