History of Decision Support, Artificial Intelligence, and their Application in Medicine

Edward H. Shortliffe, MD, PhD
Professor and Senior Advisor, Arizona State University
Adjunct Professor, Columbia and Cornell Universities
Scholar in Residence, New York Academy of Medicine

Children's Hospital of Orange County
Anaheim, California
October 5, 2013

Decision Making vs Decision Support
Physicians and Information

• Among the most information-intensive fields
• Constant decision making
• Information may be specific to a case (patient data) or more generic (the knowledge we use to solve problems and make plans)
• Most physicians acknowledge that some “support” would be useful to them

1950’s

• Earliest recognition of statistical issues in diagnosis and the potential role of computers
1950’s

3 July 1959, Volume 130, Number 3366

Reasoning Foundations of Medical Diagnosis

Symbolic logic, probability, and value theory aid our understanding of how physicians reason.

Robert S. Ledley and Lee B. Lusted

Bayes’ Theorem

• Direct application in medical diagnosis and test interpretation
• Allows calculation of the likelihood of a disease given its prevalence in the population and characteristics of a test
• Requires knowing probability that a patient with the disease will have a positive test (sensitivity) and the likelihood that those without the disease will have a negative test (specificity)
Bayes’ Theorem

- Direct application in medical diagnosis and test interpretation
- Allows calculation of the likelihood of a patient with the disease will have a positive test (sensitivity) and the likelihood that those without the disease will have a negative test (specificity)

\[ PV^+ = \frac{(\text{sensitivity})(\text{prevalence})}{(\text{sensitivity})(\text{prevalence}) + (1-\text{specificity})(1-\text{prevalence})} \]

1960’s

- Bayesian diagnosis systems and statistical pattern recognition
  - Homer Warner’s work on congenital heart disease diagnosis
  - Gorry and Barnett: sequential diagnosis introduces notions of value in addition to probability (presaging decision analysis programs of early 1970’s)
1960's

Experience with a Model of Sequential Diagnosis*

G. Anthony Gobby
Sloan School of Management, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

AND

G. Octo Barnett
Laboratory of Computer Science, Massachusetts General Hospital, Boston, Massachusetts 02114

Received October 25, 1967

A physician must have available two different classes of information when

Classic Work of deDombal

- Extensive system used in emergency rooms throughout northern England
- Seven causes of acute abdominal pain: appendicitis, diverticulitis, perforated ulcer, cholecystitis, small bowel obstruction, pancreatitis, nonspecific abdominal pain
- Study at affiliated hospitals:
  - 304 patients with acute abdominal pain
  - Program accuracy 91.8% (and better than senior MD in 6 of 7 categories)
Frustrations with Computer Programs that Use Bayes’ Theorem for Diagnosis

- Inability to handle multiple coexisting diseases
- Makes a sometimes erroneous independence assumption
  - Simple Bayes assumes that relationships between findings and diseases are independent of one another

Causal Models

- Parathyroid Hormone (PTH)
  - Renal Resorption of Calcium
  - Bone Resorption of Calcium
- GI Absorption of Calcium
  - Serum Calcium
  - Neuromuscular Function
    - Muscle Strength
    - GI Motility
      - Constipation

Symptoms
Real-World Use of Bayes?

\[ P(V+) = \frac{\text{sensitivity} \times \text{prevalence}}{\text{sensitivity} \times \text{prevalence} + \text{specificity} \times (1 - \text{prevalence})} \]

Myths Regarding Decision-Support Systems

**Myth:**
Diagnosis is the dominant decision-making issue in medicine

Typical questions are not “What does this patient have?” but, rather, “What should I do for this patient?”
Myths Regarding Decision-Support Systems

Myth:
Clinicians will use knowledge-based systems if the programs can be shown to function at the level of experts

What do we know about “expertise” and the associated cognitive factors?

Cognitive Science and the Nature of Clinical Expertise

• Tremendous variation in practice, even among “experts”
• Need to understand better how experts use personal heuristics, experience, data, and knowledge to arrive at decisions
  • Improve clinical teaching
  • Improve decision-support systems
  • Better understand clinicians as computer users
1970’s

- Applications of flowcharting, logical diagrams, and complex algorithms
- Decision-analysis programs
- Mathematical modeling
- Emergence of applications of artificial intelligence in medicine (knowledge-based systems)

Artificial Intelligence (AI)

The study of ideas that enable computers to do the things that make human beings seem intelligent:

The ability to reason symbolically
The ability to acquire and apply knowledge
The ability to manipulate and communicate ideas
History of Decision Support, Artificial Intelligence, and their Application in Medicine

The Process of Patient Care

- **Patient presents with a problem**
  - Initial hypotheses
  - Ask questions
  - HPI, ID, CC

- **Patient is better; no further care required**
  - Observe results
  - Chronic Disease
  - Select most likely diagnosis

- **Patient dies**
  - More questions
  - PE
  - HPI, PMH, FH, Social, ROS

- **Treat patient accordingly**
- **Refine hypotheses**
  - EKG, etc.
  - Laboratory Tests
  - Radiologic Studies

Long-Term Memory
Short-Term Memory

Hypothesis Evocation
Internist-1 / QMR

Task: Diagnosis in internal medicine and neurology
- Scope: The entire field!
- Began in early 1970s
- Internist-1 was large-computer version of program, used to develop methods and to encode an extensive clinical knowledge base
- QMR later developed as PC version developed during 1980s
- iPad version under development at Vanderbilt Univ.

Internist-1 → QMR

QMR (Quick Medical Reference) is the powerful diagnostic decision support knowledge base designed for integration into your healthcare environment. Developed to provide physicians with assistance in diagnosing and refining differential diagnoses, the QMR knowledge base includes a comprehensive list of over 750 disease profiles and the clinical manifestations reliably reported to be associated with them, including 5,000+ related symptoms, signs and labs.

With QMR you can:
- Formulate differentials
- View the most common findings for a particular disease
- Generate the best labs to order or questions to ask for ruling in or ruling out a diagnosis
- Generate case analyses
- And more...

QMR Toolkit: This new application programming interface (API) captures the power of the QMR knowledge base and makes integration into your electronic medical record (EMR) system, Windows®, UNIX® (but"Solaris"), and MAC™ Server versions available.

QMR Net: An intranet solution that gives you the power of the QMR knowledge base with the potential and flexibility of an intranet. Perfect for a group practice, hospital setting or educational institution.

QMR for Windows: Stand-alone software to help you make diagnostic decisions. Single user or network versions.

www.firstdatabank.com
800-633-3453
Design Considerations

- Reliability
  - Hardware, software, knowledge, advice
- Human engineering
  - Accessibility, speed, mode of interaction
- Explanation/justification
  - Representation of knowledge and reasoning processes
- Responding to questions
  - Language, speech, and graphics/pictures
- Congeniality
  - Understanding the psychology of the user

The Clinical Problem

A life-threatening staph* infection?
Culture results tomorrow.
Which antibiotic tonight?

Initial therapy: A delay in susceptibility studies may cost up to 48 hours. If your patient presents with a high fever and toxic shock syndrome, begin empiric therapy immediately. If the organism is not immediately available, use broad-spectrum initial therapy to control symptoms and avoid the need for additional treatment. Once the organism is identified, narrow the spectrum of therapy to a more specific antibiotic. In many cases, however, the peptide is not available. In those cases, use empirical therapy until the organism is identified.

*On oral or intravenous therapy.

Parenteral administration.

For patients who present within 48 hours after admission, high concentrations of sodium and ethyl alcohol may result if the organism is not identified. Randomization for 24 hours.

Intravenous administration of a single dose of sodium nafcillin is a helpful tool in the management of such patients. For more information, consult the manufacturer’s instructions for use. The manufacturer recommends a dose of 10,000 mg intravenously every 6 hours for 24 hours.

The manufacturer recommends a dose of 10,000 mg intravenously every 6 hours for 24 hours.

Important information on next page.
The MYCIN System

Major design themes:

• The program should give excellent advice
• The program should provide useful explanations of its reasoning about a case
• The program should be able to acquire and incorporate new knowledge

Explosive Interest in AI

• Expert systems heavily covered in lay press, with medical examples prominent
  • Cover stories in both Time and Newsweek
• Investment by companies in learning about AI and its potential application in their businesses
### 1980’s

- “Overselling” of artificial intelligence
- Resurgence of interest in Bayesian approaches
- Major changes due to new hardware and software technologies
  - Personal computers
  - Graphical interfaces
  - Networking
- “Greek oracle” model falls into disfavor

---

### Myths Regarding Decision-Support Systems

**Myth:** Clinicians will use stand-alone decision-support tools

The death of the “Greek Oracle” model

→ Integrated decision support in the context of routine workflow
1990’s

- Integration and networking become central issues
  - World Wide Web revolutionizes our thinking about distributed information access
  - Integration of decision-support features with clinical records systems arrives in some commercial products
- Standards emerge as a major issue
  - terminology, representation of decision logic
  - crucial to promote sharing and collaboration

Event Monitoring = Clinical Alerting (Pre-EHR)
2000-2010

- Integration of decision support with workflow viewed as a central requirement
- Patient safety and error reduction major motivators
- Increasing incorporation of decision-support functionalities in commercial products
  - CPOE
  - EMR Systems

2000-2010

- New issues regarding relationships between vendors and hospital IT staffs
  - Locally built systems give way to vendor-supplied electronic health records
  - Challenges in the incorporation of decision support and knowledge-management tools
  - Institutional barriers (beyond technology) that limit the ability to share rules and guidelines between hospitals and health systems
Conclusions

- Integration with routine workflow is the key
- Transparency helps to assure acceptance
- The Internet is a great facilitator of integration
  - Does not avoid the need for standardized terminologies and data-sharing protocols
- We are experiencing new challenges in providing locally-derived decision support through collaborations with vendors of EHR systems

Thank You!

ted@shortliffe.net