Computational Technology for Effective Health Care: Immediate Steps and Strategic Directions

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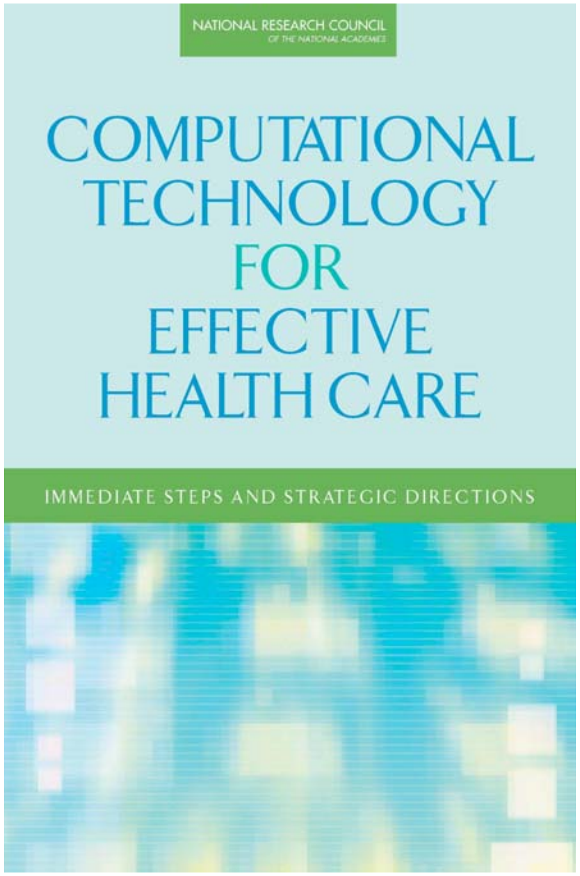

Sponsors

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Task

- Two challenges from sponsors
  - Identify how today's computer science-based methodologies and approaches might be applied more effectively to health care
  - Explicate how the limitations in these methodologies and approaches might be overcome through additional research and development.
- Engage the computer science research community in meeting these two challenges.

Evidentiary basis for study

- Site visits to acknowledged leaders in health care IT on the theory that many of the important innovations and achievements for health care IT will be found in such institutions.
- Previous work of the Institute of Medicine (IOM) on a vision for 21^{st} century health care—
- Work by IOM and National Academy of Engineering on a systems view of health care
- Selective literature review
- Committee member expertise

The central conclusion of the report

Current efforts aimed at the nationwide deployment of health care IT will not be sufficient to achieve the vision of 21st century health care, and may even set back the cause if these efforts continue wholly without change from their present course.

Success will require greater emphasis on providing cognitive support (i.e., computer-based tools and systems that offer clinicians and patients assistance for thinking about and solving problems related to specific instances of health care).

Health care in the U.S. today

- Fails to deliver the most effective care
- Suffers substantially from medical errors.
- Provides many unnecessary medical interventions.

- Why? The institution of health care is complex and not adequately structured to help clinicians avoid mistakes or to systematically improve their decision making and practice.

- The tasks and workflow of health care.
  - reasoning under uncertainty re the patient's medical state and the effectiveness of past and future treatments for the particular patient.
  - workflows often complex and non-transparent, characterized by many interruptions, inadequately defined roles and responsibilities, poorly kept and managed schedules, and little documentation of steps, expectations, and outcomes.
  - Complex care provided in a time- and resource-pressured environment because of cost containment.

- The institution and economics of health care.
  - large number of health care payers and coverage plans, each with their own rules for coverage, complicates administration.
  - distorted or perverse incentives for payment (e.g., more compensation for procedures than for communication, diagnosis or preventive care)
  - Navigation of confusing landscape of tertiary care centers, community hospitals, clinics, primary and specialist doctors and other providers, payers, health plans, and information sources.

Current implementations of health care IT

- monolithic implementations-hence, even small changes hard to introduce. Implementation time lines often measured in decades.
- designed to automate tasks or business processes, simply mimic existing paper-based forms; rarely well integrated into clinical practice.
- little support for the cognitive tasks of clinicians or for workflow of the people; rarely used to provide clinicians with evidence-based decision support and feedback.
- Rarely used to support data-driven process improvement, to link clinical care and research, to provide integrative view of patient data.
- Lack good human-computer interaction design, hence poor designs that increase the chance of error, workload, and frustrations
- Often used to document for regulatory compliance and for defending against lawsuits, rarely used to improve clinical care.

The IOM Vision and the connection to HCIT

IOM - health care should be safe, effective, patient-centered, timely, efficient, and equitable (*Crossing the Quality Chasm: A New Health System for the 21st Century*).

Some information-intensive implications of the IOM's vision

- Cognitive support for health care professionals and patients to help integrate patient-specific data where possible and account for any uncertainties that remain;
- Cognitive support for health care professionals to help integrate evidence-based practice guidelines and research results into daily practice;
- Instruments and tools that allow clinicians to manage a portfolio of patients and to highlight problems as they arise both for an individual patient and within populations;
- Empowerment of patients and their families in effective management of health care decisions and their implementation, including personal health records, education about the individual's conditions and options, and support of timely and focused communication with professional health care providers.

Cognitive support for health care professionals and patients to help integrate patient-specific data where possible and account for any uncertainties that remain.

- A primary care clinician needs to monitor a patient's heart condition. Cardiac information is provided not as tables of numbers or individual EKG plots, but rather as an overlay on a visual animated structural model of the patient's heart (not a generic heart) derived from various imaging modalities. The system displays the relevant functional information in summary form and provides an image of the heart in operation driven by all of the data that have been collected about the patient over time. Different time scales are available for display, and the clinician can display an animated image of the patient's heart in operation as the patient is resting or exerting himself (i.e., in near-real time), or track how the structure of the heart has changed over the last 2 years using time-lapse-like sequences.

The clinical significance of an animated structural model is that it drastically reduces the cognitive effort needed for the clinician to visualize heart functioning in this particular patient, freeing her to use those cognitive resources for other related tasks. The model also helps the patient to understand the medical situation at hand and assists both clinician and patient in determining an appropriate course of action.

Cognitive support for health care professionals to help integrate evidence-based practice guidelines and research results into daily practice.

- A primary care clinician has a number of patients with various heart conditions. To stay current with recent medical literature, he subscribes to alerts and learns that a particular heart disease guideline has been updated to include a new drug that reportedly prevents a difficult and expensive complication. After comparing it to other guidelines that he believes to be trustworthy, he decides to incorporate this new guideline into his practice. By clicking on a link, the clinician can download the guideline to his system, which also searches for and constructs several potential action flowcharts to meet the guideline's goals, based on an internal computable model of clinic workflow and resources. He selects one and his disease management dashboards, order sets, and reminder systems are updated.

The clinical significance of the literature alert system is that it enables the clinician to keep current and to systematically translate new knowledge into his practice while enabling the clinician and the patient to decide on the appropriate course of treatment.

Instruments and tools that allow providers to manage a portfolio of patients and to highlight problems as they arise both within individual patients and populations.

- The computer of an outpatient care provider displays the summary health status (a “dashboard”) of her 300 diabetic patients with color-codes and carefully designed graphical displays for clinical measures of the disease (blood sugar levels, A1C counts, and so on) that provide rapid assessment, at a glance, of the status of all patients: those who are managing illnesses successfully, those requiring intervention, and those who are marginal cases. When a diabetic patient visits her, the system reviews applicable guidelines, customizes an order set to the patient’s state and insurance plan (e.g., picks the preferred drug from the drug class), and reminds the physician to discuss the selected drug with the patient. Feedback indicating success is provided when the provider sees that the display indicators of her patients show successful management.

The clinical significance of a summary health status display is that it gives the provider prompt feedback about where her attention is most needed in time to take corrective action.

Empowerment of patients and their families in effective management of health care decisions and execution and assistance in communicating with providers.

- The son of an elderly man hospitalized by a stroke needs to know about his father's medical condition. Rather than waiting for hours by his father's bedside to intercept a physician on rounds so that he can obtain authoritative information, he logs into a secure application that makes his father's electronic health record (EHR) available on the Internet. A data interpretation application examines the data in the EHR and provides in lay language a summary of the important aspects of a patient's medical condition, previously provided treatments, and treatment options under consideration and the reasoning underlying possible options. The son can also enter information based on his knowledge of his father's present state and medical history, providing caregivers with another source of information

The clinical significance of an automated EHR lay interpretation system is that the family can be kept in the decision-making loop, in a culturally sensitive way and on a more timely basis than is possible today. By providing relevant facts sooner (perhaps even days sooner, delays may be avoided if families need time to make decisions.

Four Domains of Information Technology in Health Care

- Automation-- the use of IT to perform tasks that can be repeated with little modification (e.g., bar code medication administration, invoices for payment).
- Connectivity (information exchange)
  - physical infrastructure—electronic connections between various physical facilities to transmit data (e.g., fiber, WiFi)
  - Data interfaces for mapping data between systems.
  - Connecting people to systems and to each other.
- Decision support—IT to provide information at a high conceptual level to clinicians to facilitate or improve decisions made about care. Includes:
  - rule-based alerts (e.g., drug interaction reminders)
  - informative information presentation
  - statistical and heuristic techniques that reflect an intelligent synthesis of information about the patient, care setting, biomedical knowledge
- Data mining—use of knowledge discovery techniques to analyze various similar or dissimilar datasets to recognize known or unknown relationships.
  - Datasets may include medical literature, multiple patient records, laboratory data (e.g., microarray data).

- Majority of today's HCIT is designed to support automation, with some connectivity, and little support for data mining or decision support. A “learning” health care system will require much more attention to connectivity, data mining and decision support.

Making progress in the near term--principles for evolutionary change

- Focus on improvements in care - technology is secondary.
- Seek incremental gain from incremental effort.
- Record available data so that today's biomedical knowledge can be used to interpret the data to drive care, process improvement, and research.
- Design for human and organizational factors so that social and institutional processes will not pose barriers to appropriately taking advantage of technology.
- Support the cognitive functions of all caregivers, including health professionals, patients, and their families."

…while preparing for the long term--principles for radical change

- Architect information and workflow systems to accommodate disruptive change.
- Archive data for subsequent re-interpretation, that is, in anticipation of future advances in biomedical knowledge that may change today's interpretation of data and advances in computer science that may provide new ways extracting meaningful and useful knowledge from existing data stores.
- Seek and develop technologies that identify and eliminate ineffective work processes.
- Seek and develop technologies that clarify the context of data.
- Encourage interdisciplinary research in three critical areas: (a) organizational systems-level research into the design of health care systems processes and workflow; (b) computable knowledge structures and models for medicine needed to make sense of available patient data including preferences, health behaviors, and so on; and (c) human-computer interaction in a clinical context.

Illustrative research challenges

- Patient-Centered Cognitive Support
- Modeling
- Automation
- Data sharing and collaboration
- Data management at scale
- Automated full capture of physician-patient interactions

Patient-centered cognitive support (1)

- The clinician interacts primarily with models and abstractions of the patient that place the raw data into context and synthesize them with medical knowledge in ways that make clinical sense for that patient. These virtual patient models are the computational counterparts of the clinician’s conceptual model of a patient.

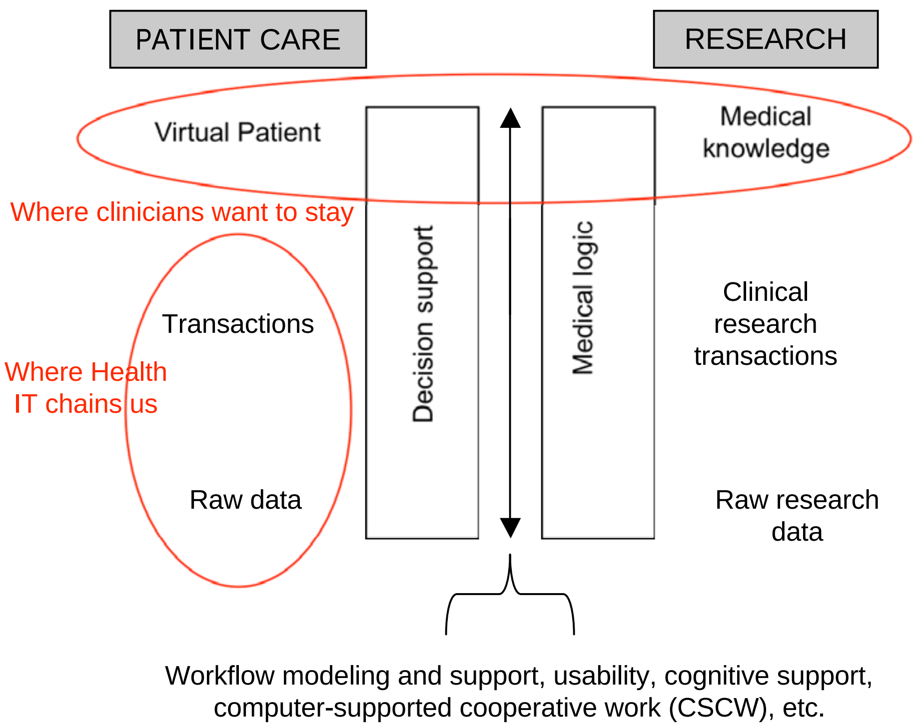
- They depict and simulate a theory about interactions going on in the patient and enable patient-specific parameterization and multicomponent alerts.

- They build on submodels of biological and physiological systems and also of epidemiology that take into account, for example, the local prevalence of diseases.

Patient-centered cognitive support (2)

- The use of these models to establish clinical context would free the clinician from having to make direct sense of raw data, and thus he or she would have a much easier time defining, testing, and exploring his/her own working theory.
- What links the raw data to the abstract models might be called medical logic—that is, computer-based tools that examine raw data relevant to a specific patient and suggest their clinical implications given the context of the models and abstractions.
- Computers can then provide decision support—that is, tools that help clinicians decide on a course of action in response to an understanding of the patient's status.
- Although clinicians can work with abstractions that keep them from being overwhelmed by data, they must also have the ability to access the raw data as needed if they wish to explore the presented interpretations and abstractions in greater depth.

The virtual patient



Other challenges

- Modeling - e.g., computational models of different organs, coupling models in a realistic manner
- Automation - e.g., integrating independently designed systems, managing trust issues
- Data sharing and collaboration - e.g., incremental data integration
- Data management at scale - e.g., annotation and metadata, linkage, and privacy.
- Automated full capture of physician-patient interactions - elimination/dramatic reduction of clinician effort in data entry (e.g., real-time transcription and interpretation of the dialog, summarization of physical interactions based on the interpretation of images recorded by various cameras)

Recommendations for…

- Government
- Computer Science Research Community
- Health Care Organizations

Government

- Incentivize clinical performance gains rather than acquisition of IT per se.
- Encourage initiatives to empower iterative process improvement and small-scale optimization.
- Encourage development of standards and measures of health care IT performance related to cognitive support for health professionals and patients, adaptability to support iterative process improvement, and effective use to improve quality.
- **Encourage interdisciplinary research in three critical areas: (a) organizational systems-level research into the design of health care systems processes and workflow; (b) computable knowledge structures and models for medicine needed to make sense of available patient data including preferences, health behaviors, and so on; and (c) human-computer interaction in a clinical context.**
- Encourage (or at least do not impede) efforts by health care institutions and communities to aggregate data about health care people, processes, and outcomes from all sources subject to appropriate protection of privacy and confidentiality.
- Support additional education and training efforts at the intersection of health care, computer science, and health/biomedical informatics.

Organizational systems-level research into the design of health care systems processes and workflow (research in systems engineering in HC context)

- Languages/systems to describe and visualize health care workflows
- Modeling health care workflow at scale while enabling explicit step by step escalation rules;
- Support for distributed, multi-player decision making among players with sometimes conflicting optimization functions;
- Rigorous analysis and documentation of the workflow demands of routine practice, and how computer technology could be used to facilitate and support the work flow support of the practitioner;
- Use of queuing theory to optimize organizational performance.

Computable knowledge structures and models to connect medical knowledge to patient data

- Computable guidelines and approaches for comparing, assessing, updating, and integrating them into a library of guidelines for a given patient
- Systems that can infer clinical conditions from raw data (e.g., inferring that "patient is feeling more pain" from the report of an upwards adjustment in the IV drip of a pain management drug).

Purpose: to provide needed abstractions for the health care provider and the clinician to help them understand what is going on with a given patient.

Human-computer interaction in a clinical context

- Development of systems for maximizing the capture, retrieval, and display of clinically relevant information and handling related uncertainties in ways that minimally distract from attention to the patient and situation yet provide information in a manner that is immediately understandable and interpretable. Uncertainties include
  - Patient data
  - Patient response to proposed treatment
  - Scientific uncertainties about the nature of a disease.

- Different human users with different needs--care givers, medical staff, insurance companies, patients/relatives.

- Primary task is information extraction for a particular user’s needs without disruption to caregiving while providing a comprehensive record.
- Also facilitates patient management--Information dashboards would allow rapid overview of multiple patients, calling attention to cases that require closer examination.

Computer science research community

- Engage as co-equal intellectual partners and collaborators with health care practitioners and experts in health/biomedical informatics and other relevant disciplines, such as industrial and process engineering and design, in an ongoing relationship to understand and solve problems of importance to health care.
- Develop institutional mechanisms within academia for rewarding work at the health care/computer science interface.
- Support educational and retraining efforts for computer science researchers who want to explore research opportunities in health care.

Health care organizations

- Organize incentives, roles, workflow, processes, and supporting infrastructure to encourage, support, and respond to opportunities for clinical performance gains.
- Balance the institution's IT portfolio among automation, connectivity, decision support, and data-mining capabilities.
- Develop the necessary data infrastructure for health care improvement by aggregating data regarding people, processes, and outcomes from all sources.
- Insist that vendors supply IT that permits the separation of data from applications and facilitates data transfers to and from other non-vendor applications in sharable and generally useful formats.
- Seek IT solutions that yield incremental gains from incremental efforts.

For more…

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www.cstb.org (report, summary, press release)