**Core Content for the Subspecialty of Clinical Informatics**

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**Introduction**

*Definition and Description of the Subspecialty*

Clinical informaticians transform health care by analyzing, designing, implementing, and evaluating information and communication systems that enhance individual and population health outcomes, improve patient care, and strengthen the clinician-patient relationship.

Clinical informaticians use their knowledge of patient care combined with their understanding of informatics concepts, methods, and tools to:

- assess information and knowledge needs of health care professionals and patients;
- characterize, evaluate, and refine clinical processes;
- develop, implement, and refine clinical decision support systems; and
- lead or participate in the procurement, customization, development, implementation, management, evaluation, and continuous improvement of clinical information systems.

Physicians who are board-certified in clinical informatics collaborate with other health care and information technology professionals to promote patient care that is safe, efficient, effective, timely, patient-centered, and equitable.

As illustrated in Figure 1, clinical informatics encompasses three spheres of activity:

- clinical care (i.e., the provision of clinical services to an individual patient)
- the health system (i.e., the structures, processes, and incentives that shape the clinical care environment; this includes major health domains such as public health, population health, personal health, health professional education, and clinical research, in addition to clinical care)
- information and communications technology (i.e., the tools that enable the efficient capture, delivery, transmission, and use of data, information, and knowledge and the knowledge of how to apply those tools effectively)

Clinical informaticians work at the intersection of these three domains, and must demonstrate mastery of:

- medical knowledge;
- the field of informatics;
- the health care environment, including how business processes influence health care delivery and the flow of data among the major domains of the health system;
- how information systems and processes enhance or compromise the decision making and actions of health care team members;
- re-engineering health care processes;
- fundamental information system concepts, including the life cycle of information systems, the constantly evolving capabilities of information technology and health care, and the technical and non-technical issues surrounding system implementation;
- how clinical information systems impact users and patients, how to support clinician users, and how to promote clinician adoption of systems;
- monitoring and evaluation of information systems to provide feedback for system improvement;
- leading organizational change, fostering collaboration, communicating effectively, and managing large scale projects related to clinical information systems.

The core content for the subspecialty of clinical informatics comprises four major categories that must be mastered.

1. **Fundamentals:** The basic knowledge that provides clinical informaticians with a common vocabulary and understanding of the environment in which they function.

   Clinical informaticians draw from the broader field of biomedical and health informatics as they apply informatics methods, concepts, and tools to the practice of medicine. Thus, they must understand the culture, boundaries, and complexities of the field. Further, the stakeholders, structures, and processes that constitute the health system affect the information and knowledge needs of health care professionals and influence the selection and implementation of clinical information processes and systems. The flow of data, information, and knowledge among the various domains of the health system also creates important challenges for clinical informaticians as many of the data used in public health, personal health management, and clinical research originate in the clinical domain and reside in clinical information systems.

2. **Clinical Decision Making and Care Process Improvement:** The knowledge and skills that enable a clinical informatician to implement effective clinical decision making systems and participate in the development of clinical processes that support effective, efficient, safe, timely, and equitable patient-centered care.

A primary goal of clinical informaticians is to strengthen clinical decision making by health care professionals and patients and to support and improve clinical care processes. This goal depends on implementing systems that support clinical objectives and, when necessary, identifying changes needed in clinical processes to take full advantage of clinical information system capabilities.

A range of theoretical and practical issues must be addressed in the development and implementation of clinical decision support tools. The cognitive and scientific underpinnings of medical decision making must be understood to capitalize on information system capabilities in improving clinical processes. Design of robust clinical information systems and processes relies upon knowledge management principles in acquiring, generating, representing, modeling, and maintaining information to support clinical decision making. Further, to achieve the full benefits of information systems and processes, clinical informaticians must be able to conceptualize improvements in clinical processes and decision making and collaborate with their clinical colleagues as well as information technology professionals to implement changes in the information systems and clinical processes.


3. **Health Information Systems:** The knowledge and skills that enable a clinical informatician to participate in the development or selection of an information system for clinicians, prepare clinicians prior to implementation and support them during implementation and ongoing operation of a clinical information system, and evaluate the effectiveness of a system in meeting clinical needs.

   Clinical informaticians need to assess the advantages and disadvantages of various technological approaches and determine the best fit for the clinical environment. They also need a common vocabulary and shared knowledge base to collaborate with information technology personnel. Since the quality of clinical data directly affects the effectiveness of information systems and clinical decision support tools as well as the reliability of clinical research that relies on those data, clinical informaticians work with interdisciplinary teams to ensure that the data used to make clinical decisions meet state-of-the-art standards.

   Information systems are not limited to hardware and software; they include people, processes, and policies that support the use of the technology. Thus, clinical informaticians must address these components as part of system analysis (planning) and implementation. System evaluation is required to determine whether a clinical information system is meeting its goals. Clinical informaticians need to understand the full range of issues related to evaluation so that they can determine the appropriate evaluative methods and provide feedback for successful information system implementation and use.

4.  **Leadership and Management of Change:** The knowledge and skills that enable clinical informaticians to lead and manage changes associated with the introduction and adoption of clinical information systems.

    Successful implementation of information systems requires behavioral, cultural, and social change within an organization. Thus, clinical informaticians require knowledge and skills in understanding and analyzing organizational culture, planning organizational change, building and working in effective multidisciplinary teams, and leading information system development and implementation. Clinical informaticians must be able to listen, understand needs, articulate plans, explain rationales, inform constituents, report results and foster collaboration. They must relate clinical information system needs and plans to larger organizational strategic goals and be proficient in project management to oversee the implementation of new systems and processes.

*Process Used to Identify Core Content of Clinical Informatics*

In March 2007, the Robert Wood Johnson Foundation awarded a grant to the American Medical Informatics Association (AMIA) to support the process of developing the Core Content and Training Requirements for clinical informatics. AMIA established the Core Content Team to develop this document; the Core Content Team members are listed in the Appendix. The team developed this outline for the core content of the field of clinical informatics during two meetings in 2007. The team began by identifying key tasks that clinical informaticians perform and then grouped them into major categories of activity. Each category was then expanded to capture all of the tasks performed by clinical informaticians.

The activity categories and corresponding tasks provided the basis for describing the field of clinical informatics and defining the role of clinical informaticians. The Core Content Team converted the tasks performed by clinical informaticians into knowledge and skills that must be mastered and subsequently organized the knowledge and skills into four major content categories.

There are myriad health information systems and these systems are constantly evolving. Thus, the Core Content team identified the common elements of health information systems used in different clinical settings and did not include an exhaustive list of clinical information systems as part of the Core Content.

AMIA invited its membership, health related federal agencies, and representatives of other clinical and informatics-focused organizations to review a draft of the Core Content in January 2008. Over 50 individuals from a wide variety of institutions provided comments during the review period. These individuals represented the perspectives of a broad range of health care disciplines and organizations. The Core Content Team reviewed each comment during its last meeting in January 2008. These comments

informed the team's deliberations and helped to shape the core content that appears in this document.

The field of clinical informatics is undergoing rapid evolution. Thus, the Core Content team anticipates that these core competencies will be modified as the field develops. For example, the current primary focus of clinical informaticians is in hospitals and other structured health care facilities and organizations. Over time, clinical informaticians may increasingly develop clinical information systems that are used to support less centralized and more disaggregated care (e.g., home care that is linked to a primary care provider).

## Core Content

1. **Fundamentals:** The basic knowledge that provides clinical informaticians with a common vocabulary and understanding of the environment in which they function.

   1.1. **Clinical Informatics**
      1.1.1. The discipline of informatics
         1.1.1.1. Definitions of informatics
         1.1.1.2. History of informatics (e.g., evolution of health records)
         1.1.1.3. Domains/subspecialties of informatics
         1.1.1.4. Careers in informatics
         1.1.1.5. Professional organizations
         1.1.1.6. Current and future challenges for informatics
      1.1.2. Key informatics concepts, models, and theories
      1.1.3. Clinical informatics literature
         1.1.3.1. Core literature
         1.1.3.2. Critical analysis of informatics literature
      1.1.4. International clinical informatics practices
      1.1.5. Ethics and professionalism
      1.1.6. Legal and regulatory issues

   1.2. **The Health System**
      1.2.1. Determinants of individual and population health
      1.2.2. Primary domains, organizational structures, cultures, and processes
         1.2.2.1. Health care delivery
         1.2.2.2. Public health
         1.2.2.3. Clinical research
         1.2.2.4. Health professionals education
         1.2.2.5. Personal health
      1.2.3. The flow of data, information, and knowledge within the health system
      1.2.4. Policy & regulatory framework
      1.2.5. Health economics and financing
      1.2.6. Forces shaping health care delivery
      1.2.7. Institute of Medicine quality components
         1.2.7.1. Safety
         1.2.7.2. Effectiveness
         1.2.7.3. Efficiency
         1.2.7.4. Patient-centeredness
         1.2.7.5. Timeliness
         1.2.7.6. Equity

**2. Clinical Decision Making and Care Process Improvement:** The knowledge and skills that enable a clinical informatician to implement effective clinical decision making systems and participate in the development of clinical processes that support effective, efficient, safe, timely, equitable, and patient-centered care.

2.1. **Clinical Decision Support**
    2.1.1. The nature and cognitive aspects of human decision making
        2.1.1.1. General
        2.1.1.2. Medical
    2.1.2. Decision science
        2.1.2.1. Decision analysis
        2.1.2.2. Probability theory
        2.1.2.3. Utility and preference assessment
        2.1.2.4. Cost effectiveness analysis
        2.1.2.5. Test characteristics (e.g., sensitivity, specificity, predictive value)
    2.1.3. Application of clinical decision support
        2.1.3.1. Types of decision support (e.g., alerts, reminders, prompts)
        2.1.3.2. Users of decision support (including clinicians and patients)
        2.1.3.3. Implementing, evaluating, and maintaining decision support tools
    2.1.4. Transformation of knowledge into clinical decision support tools
        2.1.4.1. Knowledge generation
        2.1.4.2. Knowledge acquisition
        2.1.4.3. Knowledge modeling
        2.1.4.4. Knowledge representation
        2.1.4.5. Knowledge management and maintenance
    2.1.5. Legal, ethical, and regulatory issues
    2.1.6. Quality and safety issues
    2.1.7. Supporting decisions for populations of patients

2.2. **Evidence-based Patient Care**
    2.2.1. Evidence sources
    2.2.2. Evidence grading
    2.2.3. Clinical guidelines
    2.2.4. Implementation of guidelines as clinical algorithms
    2.2.5. Information retrieval and analysis
        2.2.5.1. Search skills
        2.2.5.2. Critical analysis of biomedical literature

2.3. **Clinical Workflow Analysis, Process Redesign, and Quality Improvement**
    2.3.1. Methods of workflow analysis
    2.3.2. Principles of workflow re-engineering
    2.3.3. Quality improvement principles and practices

**3. Health Information Systems:** The knowledge and skills that enable a clinical informatician to participate in the development or selection of an information system for clinicians; prepare clinicians prior to implementation and support them during implementation and ongoing operation of a clinical information system; and evaluate the effectiveness of a system in meeting clinical needs.

3.1. **Information Technology Systems**
- 3.1.1. Computer Systems
  - 3.1.1.1. Programming
  - 3.1.1.2. Data and control structures
  - 3.1.1.3. Software development methods (e.g., agile, waterfall, spiral, rapid prototyping)
  - 3.1.1.4. System integration
  - 3.1.1.5. Quality
  - 3.1.1.6. Design (e.g., logical schema, normalization/denormalization, process modeling)
- 3.1.2. Architecture
  - 3.1.2.1. Systems (e.g., distributed, centralized, relational, object oriented, warehouses/data marts)
  - 3.1.2.2. Networks
  - 3.1.2.3. Data/database
- 3.1.3. Networks
  - 3.1.3.1. Topologies
  - 3.1.3.2. Telecommunications
- 3.1.4. Security
  - 3.1.4.1. The HIPAA Security Rule and other government regulations
  - 3.1.4.2. Firewalls
  - 3.1.4.3. Virtual private networks
  - 3.1.4.4. Encryption
- 3.1.5. Data
  - 3.1.5.1. Integrity
  - 3.1.5.2. Mapping
  - 3.1.5.3. Manipulation (e.g., querying, SQL, reporting)
  - 3.1.5.4. Representation and types
  - 3.1.5.5. Warehousing
  - 3.1.5.6. Data mining and knowledge discovery
- 3.1.6. Technical approaches that enable sharing data
  - 3.1.6.1. Integration versus interfacing
  - 3.1.6.2. Dealing with multiple identifiers
  - 3.1.6.3. Anonymization of data

3.2. **Human Factors Engineering**
- 3.2.1. Models, theories, and practices of human-computer (machine) interaction (HCI)
- 3.2.2. HCI Evaluation, usability testing, study design and methods
- 3.2.3. Interface design standards and design principles

3.2.4.  Usability engineering

### 3.3. Health Information Systems and Applications
3.3.1.  Types of functions offered by systems
3.3.2.  Types of settings where systems are used
3.3.3.  Electronic health/medical records systems as the foundational tool
3.3.4.  Telemedicine

### 3.4. Clinical Data Standards
3.4.1.  Standards development history and current process
3.4.2.  Data standards and data sharing
3.4.3.  Transaction standards
3.4.4.  Messaging standards
3.4.5.  Nomenclatures, vocabularies, and terminologies
3.4.6.  Ontologies and taxonomies
3.4.7.  Interoperability standards

### 3.5. Information System Lifecycle
3.5.1.  Institutional governance of clinical information systems
3.5.2.  Clinical information needs analysis and system selection
    3.5.2.1.  Methods for identifying clinician information system needs
    3.5.2.2.  Assessment of clinical process changes that will be required
    3.5.2.3.  Elements of a system requirements specification document (e.g., technical specifications, intellectual property, patents, copyright, licensing, contracting, confidentiality, specific organizational needs such as user training and support)
    3.5.2.4.  Risk analysis and mitigation
    3.5.2.5.  The costs of health information and communications technologies
3.5.3.  Clinical information system implementation
    3.5.3.1.  Elements of a system implementation plan
    3.5.3.2.  Models of user training and support processes that can meet clinician needs
    3.5.3.3.  Processes and mechanisms that obtain and respond to clinician feedback
3.5.4.  Clinical information system testing, before, during and after implementation
3.5.5.  Clinical information system maintenance
    3.5.5.1.  Disaster recovery and downtime
    3.5.5.2.  Clinical information system transitions and decommissioning of systems
3.5.6.  Clinical information system evaluation
    3.5.6.1.  Outcomes relevant to the clinical goals and quality measures
    3.5.6.2.  Qualitative and quantitative methods for evaluating clinical information systems
    3.5.6.3.  Evaluation plan design

4. **Leading and Managing Change:** The knowledge and skills that enable clinical informaticians to lead and manage changes associated with implementing clinical information systems and promoting adoption by health professionals.

   4.1. **Leadership Models, Processes, and Practices**
      4.1.1. Dimensions of effective leadership
      4.1.2. Governance (e.g., processes; responsibility versus authority)
      4.1.3. Negotiation
      4.1.4. Conflict management
      4.1.5. Collaboration
      4.1.6. Motivation
      4.1.7. Decision making

   4.2. **Effective Interdisciplinary Teams**
      4.2.1. Human resources management (e.g., hiring, performance reviews and feedback, professional development, termination)
      4.2.2. Team productivity and effectiveness (e.g., articulating team goals, defining rules of operation, clarifying individual roles)
      4.2.3. Group management processes (e.g., nominal group, consensus mapping, Delphi method)
      4.2.4. Managing meetings
      4.2.5. Managing group deliberations

   4.3. **Effective Communications**
      4.3.1. Effective presentations to groups
      4.3.2. Effective one-on-one communication
      4.3.3. Writing effectively for various audiences and goals
      4.3.4. Developing effective communications program to support system implementation

   4.4. **Project Management**
      4.4.1. Basic principles
      4.4.2. Identifying resources
      4.4.3. Resource allocation
      4.4.4. Project management tools (non-software specific)
      4.4.5. Informatics project challenges
         4.4.5.1. Scope creep
         4.4.5.2. Managing expectations
         4.4.5.3. Balancing competing priorities

   4.5. **Strategic and Financial Planning for Clinical Information Systems**
      4.5.1. Establishing mission and objectives
      4.5.2. Environmental scanning
      4.5.3. Strategy formulation
      4.5.4. Action planning and strategy implementation

4.5.5. Capital and operating budgeting

4.5.6. Principles of managerial accounting

4.5.7. Evaluation of planning process

4.6. **Change Management**

4.6.1. Assessment of organizational culture and behavior.

4.6.2. Change theories (e.g., precede-proceed, social influence theories, complex adaptive systems)

4.6.3. Change management strategies

4.6.4. Strategies for promoting adoption and effective use of clinical information systems

**Appendix**
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Figure 1. Domains of Clinical Informatics