Chapter 16
Clinical Informatics Subspecialty Certification and Training

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Clinical Informatics History and Background

The term "Clinical Informatics" was used first in an article entitled "*Clinical specialty systems as an introduction to* ***Clinical Informatics"*** in 1983 [1]. In 1984, the authors published a second article; "***Clinical Informatics***: *a strategy for the use of information in the clinical setting"* [2]. While the designation "Clinical Informatics" might have been novel, the field of Clinical Informatics was not, as it had been evolving for at least a century. Florence Nightingale may have been the first clinical informatician, when she introduced, during the Crimean War in 1854, "the first model for the systematic collection of hospital data using a uniform classification of

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diseases and operations that was to form the basis of the ICD code used today" [3]. Another early clinical informatician Herman Hollerith developed an electromechanical punched card tabulator used to assist in the 1890 US census [4].

Early Clinical Informatics efforts include a 1959 key paper by Ledley and Lusted on computerized medical reasoning in the journal *Science* entitled "Reasoning foundations of medical diagnosis; symbolic logic, probability, and value theory aid our understanding of how physicians reason" [5]. In the 1960s, medical investigators leveraged computers to improve the practice of medicine in the US. Warner [6, 7] and colleagues at LDS Hospital in Salt Lake City created a clinical decision support system called HELP [8]. Lindberg developed the first automated clinical laboratory system in the 1960s [9] and Collen created automated multiphasic screening at Kaiser-Permanente in northern California in 1964 [10]. In 1966, Barnett [11], Greenes [12], Pappalardo [13], and colleagues developed the computer programming language MUMPS (**M**assachusetts General Hospital **U**tility **M**ulti-**P**rogramming **S**ystem) still used in health care today and in 1968 used mini-computers to develop the Computer Stored Ambulatory Record (COSTAR) patient care system.

In 1966, Slack developed a computer-based history taking system [14] and his colleague Bleich developed methods for interpreting and recommending treatment for acid–base disorders in 1968 [15]. Slack and Bleich went on to develop multiple hospital-wide clinical computing systems at Boston's Beth-Israel Hospital and the Brigham and Women's hospital.

The 1970s saw the development of a large number of clinical systems. Simborg added another medical history taking system [16]. El Camino Hospital in California developed automated medical records [17]. Stead and Hammond created TMR (The Medical Record) at Duke University [18] and Shortliffe developed a computer-based infectious disease consulting system named MYCIN at Stanford University [19]. McDonald used protocol-based computer reminders to improve the quality of patient care and compensate for the "non-perfectibility of man" [20]. In 1974, Francois Gremy coined the term "medical informatics" to encompass the activities in this new field of work [21, 22].

Early medical informatics efforts led to funding of clinical computing systems, development of clinical computing research laboratories, and eventually to funding by the National Library of Medicine for training programs and individual training grants in medical informatics (See Chap. 2 for more details on the NLM training programs). Eventually the expanded field became known as "Biomedical Informatics" and included Clinical Informatics, bioinformatics, public health informatics, consumer health informatics, clinical research informatics, and other informatics domains [23]. Despite varied emphasis and curricula of initial academic training programs, a new generation of informaticians was minted who were instrumental in developing seminal, new clinical computing systems.

The recent past has been an exciting and challenging time for Clinical Informatics. After a gestation period of over 50 years, the Electronic Health Record (EHR) is now a reality in most healthcare facilities in the United States [24]. Clinicians, informaticians, patients, and politicians decided that widespread adoption of the EHR was inevitable and would improve caregivers' decisions and patients' outcomes [25]. In 2004, the Office of the National Coordinator (ONC) for Health

Information Technology was created as "the principal federal entity charged with coordination of nationwide efforts to implement and use the most advanced health information technology and the electronic exchange of health information". ONC's mission is to "improve the health and well-being of individuals and communities through the use of technology and health information that is accessible when and where it matters most" [26]. In 2009, the U.S. Congress and the Obama Administration enacted the Health Information and Technology for Economic and Clinical Health (HITECH) Act, which called for EHR certifications and an incentive program for "meaningful use" of the EHRs [27, 28, 29], accelerating EHR adoption. Meaningful use later became one of the four components of the new Merit-Based Incentive Payment System (MIPS) [30].

Development of Clinical Informatics Specialty Board Certification for Physicians

In 2016, there were 953,695 actively licensed physicians in the United States [31] as well as millions of nurses and pharmacists, who were using EHR systems. As early as 1995, the American Nursing Association (ANA) recognized nursing informatics as a clinical specialization and established a nursing informatics certification [32, 33, 34]. Certification is based on the 2015 revision of the ANA document entitled *Nursing Informatics*: *Practice Scope and Standards of Practice* first published in 1995 [35].

A 2003 Institute of Medicine report [36] called for the use of informatics in the training of health professionals to "reduce errors, manage knowledge and information, make decisions and communicate more effectively than had been the case in the past."

In 2004, President George W. Bush announced a national goal of storing and using health information of the majority of people in the United States in Electronic Health Records (EHRs) by 2014. In response, the American Medical Informatics Association (AMIA) set a goal of informatics training for at least one physician and one nurse for each of the nearly 6,000 hospitals in the United States to aid the implementation of EHRs [37]. A 2005 policy summit of AMIA and the American Health Information Management Association (AHIMA) [38] examined the workforce implications of President Bush's directive [39] and identified three key needs for success:

1. Investment in people, who can use technology wisely and well
2. Creation of an academically prepared health information specialist core group
3. Development of new educational curricula and learning environments

The AMIA/AHIMA summit estimated that more than 50,000 healthcare professionals would require *some* informatics training to support the proposed national health information infrastructure. This included physicians, nurses, pharmacists, and health information management professionals (medical records and office management staff).

An informal survey of National Library of Medicine's Biomedical Informatics training program directors at the time revealed that very few of the training programs had significant additional capacity to meet the expected physician and other healthcare professional workforce development needs. However, the distance graduate education program at Oregon Health & Sciences University (OHSU) offered a solution to workforce development [40] and morphed into the first site for AMIA's 10 × 10 education program with the goal of training 10,000 physicians and nurses by 2010.

The AMIA 10 × 10 program initiated Clinical Informatics training with one semester of graduate level introduction to the application of informatics and to clinical health care. The program was open to all healthcare professionals and healthcare students without restrictions. AMIA's aspiration included that some 10 × 10 participants would obtain more formal training in the field of informatics subsequently (see also Chap. 18 for more information on AMIA's 10 × 10 program).

In 2004, an AMIA "Town Hall" meeting to discuss Clinical Informatics workforce development resulted in a formal policy adopted by the AMIA Board of Directors to create a Clinical Informatics certification for clinical professionals starting with physicians. In 2007, the Robert Wood Johnson Foundation awarded a grant to AMIA to support the development of the documents required by the American Board of Medical Specialties (ABMS) to create a new medical subspecialty in Clinical Informatics [41, 42].

Creating the Medical Subspecialty of Clinical Informatics

The non-profit ABMS represents 24 areas of specialty medicine and ABMS' member boards certify physicians in more than 150 medical specialties and subspecialties. Any new medical specialty or subspecialty must be first recognized by ABMS. ABMS member boards also decide on board eligibility of physicians, determine frequency of certification exams, and set requirements for the maintenance of certification [43].

Two documents were required by the ABMS to determine if a proposed subspecialty like Clinical Informatics indeed met the requirements for a new medical subspecialty: (1) the **Core Content** of the curriculum and (2) the **Clinical Training** Program. To create these documents, AMIA managed two working groups of AMIA members. Both groups met three times face-to-face (Core Content, Aug 2007—Jan 2008; Clinical Training, Jan 2008—Aug 2008) and worked remotely to establish consensus for the required documents [44, 45].

Development of the Core Content

The Core Content group consisted of professionals, who worked in "Clinical Informatics" including physicians, computer scientists, engineers, nurses, and other technologists and was led by Reed M. Gardner (Chair) and J. Marc Overhage (Vice

Chair). The Core Content for this new medical subspecialty defined the boundaries of the discipline and helped to inform Clinical Informatics fellowship training program requirements. The working group of 11 experts established that Clinical Informatics encompassed three domains [44]:

1. Clinical care
2. Healthcare system
3. Information and communication technology

Besides the subspecialty's content, the Core Content group decided on the name of the new discipline. The initially proposed name "Applied Clinical Informatics" was rejected as the term "applied" was considered redundant and the new subspecialty was named "Clinical Informatics". The Core Content group defined the activities of clinical informaticians as: "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:

1. Assess information and knowledge needs of healthcare professionals and patients,
2. Characterize, evaluate, and refine clinical processes,
3. Develop, implement, and refine clinical decision support systems, and
4. Lead or participate in the procurement, customization, development, implementation, management, evaluation, and continuous improvement of clinical information systems" [44].

Key concepts included that clinical informaticians must measurably improve care or care processes and must have the skills to collaborate with a wide array of disciplines and health professionals. In practical terms, a clinical informatician should be able to lead an implementation of an Electronic Health Record (EHR) or other clinical systems. This type of clinician may be called a Chief Medical Information Officer (CMIO) although a CMIO might have other responsibilities as well [46, 47].

Table 16.1 summarizes the four main topic areas described in the core content. Each of the topic areas had several sub-topics totaling 177 subtopics in the final document [44].

The Core Content group did not specify the relative weight for each of the main content areas listed in Table 16.1, which was done later by the American Board of Preventive Medicine (ABPM) [48]. The Core Content group elucidated subtopics, however the depth of subtopic detail was inconsistent across the main topics (e.g., 32 subcategories for fundamentals and 69 for health information systems). The level of specificity represented by subcategories also varied. There were 30 subcategories of information systems with 10 related to data (not including eight subcategories on data standards) while there were only five subcategories for effective communication. The Core Content group identified 177 subtopics defining the core content. The various levels of detail later presented some challenges for the test writing committee, who needed to associate and link items with content subtopics.

Table 16.1 Four topic areas describing the CORE CONTENT of Clinical Informatics [44]

Content (% of items on Board Exam)	Core content	Number of topics
1. Fundamentals (10%)		*32*
Clinical informatics	1.1	13
Health systems	1.2	19
2. Clinical decision making and care process improvement (30%)		*35*
Clinical decision support	2.1	23
Evidence-based patient care	2.2	8
Clinical workflow analysis	2.3	4
3. Health information systems (40%)		*69*
Information technology systems	3.1	31
Human factors engineering	3.2	5
HIS applications	3.3	5
Clinical data standards	3.4	8
Information systems lifecycle	3.5	20
4. Leadership and management change (20%)		*41*
Leadership models	4.1	8
Effective interdisciplinary teams	4.2	6
Effective communications	4.3	5
Project management	4.4	9
Strategic and financial planning	4.5	8
Change management	4.6	5
	Grand total	177

Update to the Core Content

Since the development of the core content that was used as the basis for the certification examination beginning in 2013, the field of Clinical Informatics has seen substantial and rapid changes (e.g., use of patient portals, mHealth, integration of artificial intelligence). Once these changes became mainstream, they had to be included in the curriculum and the examination processes. In response, AMIA conducted the Clinical Informatics Subspecialty (CIS) practice analysis in collaboration with ABPM and with the support of the American Board of Pathology (ABPath). This resulted in a CIS Delineation of Practice (DoP) comprised of 5 mutually exclusive and collectively comprehensive domains, 42 tasks, and 139 knowledge statements (see Table 16.2) [49]. The process utilized to develop, validate, and finalize the CIS DoP is depicted in Fig. 16.1. Three independent subject-matter expert panels drawn from and representative of the 1,695 CIS diplomates certified by the American Board of Preventive Medicine (ABPM) contributed to the development of a draft CIS Delineation of Practice (DoP).

An online survey was distributed to all CIS diplomates in July 2018 to validate the draft DoP. A total of 316 diplomates (18.8%) completed the survey. Survey respondents provided domain, task, and knowledge, and skill (KS) ratings, qualitative feedback on the completeness of the DoP, and detailed professional background and demographic information.

Table 16.2 CIS domains of practice

Domain 1: Fundamental Knowledge and Skills (no tasks, 25 knowledge statements) Fundamental knowledge and skills which provide clinical informaticians with a common vocabulary, basic knowledge across all Clinical Informatics domains, and understanding of the environment in which they function.
Domain 2: Improving Care Delivery and Outcomes (7 tasks, 27 knowledge statements) Develop, implement, evaluate, monitor, and maintain clinical decision support; analyze existing health processes and identify ways that health data and health information systems can enable improved outcomes; support innovation in the health system through informatics tools and processes.
Domain 3: Enterprise Information Systems (16 tasks, 33 knowledge statements) Develop and deploy health information systems that are integrated with existing information technology systems across the continuum of care, including clinical, consumer, and public health domains. Develop, curate, and maintain institutional knowledge repositories while addressing security, privacy, and safety considerations.
Domain 4: Data Governance and Data Analytics (10 tasks, 26 knowledge statements) Establish and maintain data governance structures, policies, and processes. Incorporate information from emerging data sources; acquire, manage, and analyze health-related data; ensure data quality and meaning across settings; and derive insights to optimize clinical and business decision making.
Domain 5: Leadership and Professionalism (9 tasks, 28 knowledge statements) Build support and create alignment for informatics best practices; lead health informatics initiatives and innovation through collaboration and stakeholder engagement across organizations and systems.

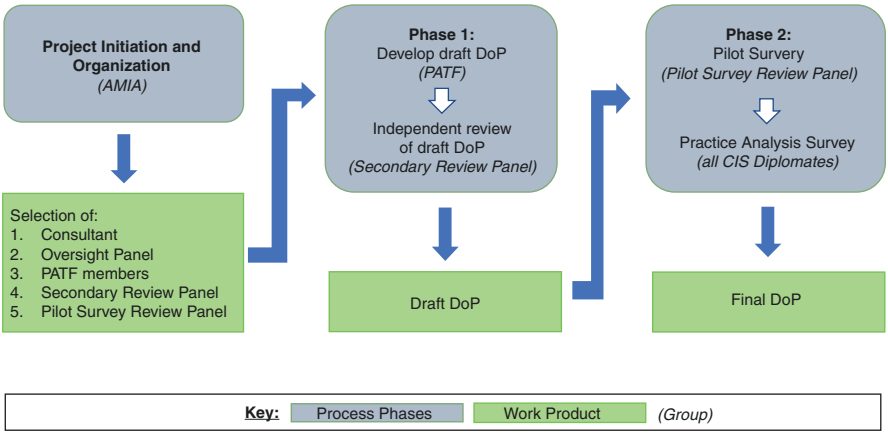

Fig. 16.1 CIS Practice Analysis Process Overview (DoP = Delineation of Practice)

The DoP that emerged from this study differed from the 2009 CIS Core Content in two respects. First, the DoP reflects the growth in amount, types, and use of health data through the addition of a practice domain, tasks, and Knowledge/Skill statements focused on data analytics and governance. Second, the DoP describes CIS practice in terms of tasks in addition to identifying knowledge required for competent practice. The authors of the study anticipate that the DoP will allow ABPM to

align the CIS certification exam with current practice and will result in an evolution of the Accreditation Council for Graduate Medical Education (ACGME) Clinical Informatics Fellowship Requirements. Twelve of the existing Clinical Informatics Fellowship directors subsequently participated in a detailed review of the DoP to gather complete, accurate, and relevant Program Director input for future ACGME Clinical Informatics Fellowship Program Requirement and Milestone revisions focusing on delineating tasks and knowledge fellows should acquire during training.

Development of Clinical Training Program Criteria

The initial Clinical Training group was led by Charles Safran (Chair) and M. Michael Shabot (Vice Chair) and consisted of physicians, computer scientists, and other professionals, who worked with operational clinical systems and who had participated in clinical training programs. The Clinical Training group of 12 experts leveraged the "Core Content" document and was charged with determining how Clinical Informatics should be taught in a two-year fellowship training program [45, 50]. The Clinical Training group had to decide which of the 177 items of core content was taught best by didactic instruction and which required experiential learning. The group further realized that most of the existing biomedical informatics training programs, which were designed to produce system developers and researchers, did not cover the content areas completely. The Clinical Training group concluded that each training program should be able to certify that a trained clinical informatician could demonstrate the competencies shown in Table 16.3.

Table 16.3 Informatics competencies to be demonstrated at the end of training [45]

1. Search and appraise the literature relevant to clinical informatics;
2. Demonstrate fundamental programming, database design, and user interface design skills;
3. Develop and evaluate evidence-based clinical guidelines and represent them in an actionable way. All clinical informaticians should be able to represent such guidelines in a logical way, while others would be able to program them into computer code;
4. Identify changes needed in organizational processes and clinician practices to optimize health system operational effectiveness;
5. Analyze patient care workflow and processes to identify information system features that would support improved quality, efficiency, effectiveness, and safety of clinical services;
6. Assess user needs for a clinical information or telecommunication system or application and produce a requirement specification document;
7. Design or develop a clinical or telecommunication application or system;
8. Evaluate vendor proposals from the perspectives of meeting clinical needs and the costs of the proposed information solutions;
9. Develop an implementation plan that addresses the sociotechnical components of system adoption for a clinical or telecommunication system or application;
10. Evaluate the impact of information system implementation and use on patient care and users;
11. Develop, analyze, and report effectively (verbally and in writing) about key informatics processes.

To accomplish meeting the above noted objectives, the Clinical Training group determined that training programs should:

(a) Develop a curriculum with clear learning goals.
(b) Ensure fellow participation in scholarly activities that "advance fellows' knowledge of the basic principles of research, including how such research is conducted, evaluated, explained to patients, and applied to patient care."
(c) Provide didactic sessions to assure all "core content" is covered during a 2-year fellowship.
(d) Provide "rotations [that] are experiential assignments, of finite duration … designed to provide fellows with exposure to different types of clinical and health information systems, in a range of settings that includes inpatient, ambulatory, and remote applications" [45]. These rotations should comprise at least 15% of the two-year training experience.
(e) Provide a long-term assignment for each fellow of at least 12 months on a project team.
(f) Fellows must conceive, develop, implement, and evaluate a substantive, applied Clinical Informatics project and present the results of the evaluation in a peer-reviewed setting.

In addition to public presentations of the two documents requesting input, more than 80 people participated in developing and reviewing the Core Content [44] and the Training Requirements for Fellowship Education in the Subspecialty of Clinical Informatics [45]. The Clinical Training group's final document was adopted with minor modifications by ACGME and last revised in 2019; however, with the development of the new Delineation of Practice, we anticipate further modifications in the near future [49].

American Board of Medical Specialties Approval of Clinical Informatics as a Subspecialty

The American Board of Medical Specialties (ABMS) decided that Clinical Informatics was best suited as a subspecialty available to all physician specialists. Clinical Informatics is of interest to physicians trained in many of the other medical specialties, and on a practical level, a subspecialty was more feasible to establish. AMIA leaders contacted member boards of ABMS to identify which of the 24 boards might be willing to take the lead in creating the new subspecialty of Clinical Informatics. The American Board of Preventive Medicine (ABPM) became the lead board and won approval for creating the subspecialty of Clinical Informatics. ABPM was joined by the American Board of Pathology (ABPath) to create the certifying process and examination for Clinical Informatics. All of the 24 member boards of ABMS allow their diplomates to sit for the Clinical Informatics subspecialty examination. The ABMS granted final approval of Clinical Informatics as a board-certified medical subspecialty in September 2011 [51].

The board certified subspecialty of Clinical Informatics in the Unites States was a novel event globally. Belgium had a "Physician Specialist in Health Data Management" designation since 2001, Germany had a "supplement medical informatics" qualification since 1991, and there existed a "Certified Physicians in BioMedical Informatics" designation certified by the Korean Society of Medical Informatics in South Korea. No other country had a board certification for Clinical Informatics, although South Korea and Sri Lanka expressed interest in developing a board certification [52].

Board Eligibility

The American Board of Preventive Medicine and the American Board of Pathology became the primary sponsors of the subspecialty board certification. Board certification remains available to physicians, who are board certified by any of the 24 ABMS boards. Physicians, who are board certified in pathology, must apply for the Clinical Informatics certification through ABPath. Applicants for Clinical Informatics certification, who are certified by any other ABMS Member Boards must apply through ABPM [53].

To achieve eligibility for the Clinical Informatics certification, the general eligibility criteria require that "the physician must have graduated from a medical school meeting ABPM standards, hold an active board certification from an ABMS Member Board, hold an unrestricted license to practice medicine in every state or territory in which the physician has a license to practice medicine, and provide a letter of reference from an ABMS-certified physician" [54]. In 2018, ABPM announced that "Diplomates certified by the American Board of Preventive Medicine (ABPM) in Clinical Informatics […] will no longer be required to maintain primary certifications in order to recertify in these subspecialty areas" [55].

The initial ABMS approval of Clinical Informatics allowed for two pathways for certification: A Fellowship Pathway and a Practice Pathway [41]. The Practice Pathway was initially available only until 2017, but a subsequent application by ABPM to extend it until 2022 was approved by ABMS [56].

Fellowship Pathway

Eligibility criteria for the Clinical Informatics Fellowship Pathway besides the general criteria (listed above) include a successful completion of a 24-month full-time ACGME accredited Clinical Informatics fellowship [57]. The first eligible applicants, who completed an ACGME accredited fellowship, took the examination in 2016.

The first Accreditation Council for Graduate Medical Education (ACGME) accredited fellowship programs included Stanford University, University of Illinois

at Chicago, Indiana University, and Oregon Health & Science University in 2014. By October 2019, 40 programs were accredited and listed by AMIA [58]. The program directors for the fellowship programs collaborate and provide leadership through the AMIA Community of Clinical Informatics Program Directors (CCIPD).

In 2019, ABPM announced that "surgical residents who have completed training in an ACGME-accredited fellowship in Clinical Informatics (CI) [are able] to sit for the ABPM's Initial Certification Examination in CI (the "Exam") prior to obtaining primary certification in surgery from the American Board of Surgery (ABS)." Eligibility criteria include (1) a guaranteed training slot to complete the requirements for primary certification in surgery and; (2) meeting all other then-current ABPM eligibility requirements for certification in CI [59].

Practice Pathway

Eligibility criteria for the Clinical Informatics Practice Pathway besides the general criteria (listed above) include the completion of a two-year biomedical informatics master's program or a 2 year fellowship sponsored by the National Library of Medicine or the US Department of Veterans Affairs. Alternatively, the applicant "must demonstrate 36 months of substantial broad-based professional activity with significant Clinical Informatics responsibility (at least 25% effort) in the five years preceding the application" [54]. For the 36-month professional activity, candidates may request partial credit for fellowships less than 24 months, AMIA 10x10 courses, or masters-level courses in health informatics, or ABPM approved research and educational activities in Clinical Informatics [60].

Developing the Board Certification Examination for Clinical Informatics

When ABMS approved Clinical Informatics as a subspecialty in 2011, the AMIA documents describing the core content and training requirements [44, 45] became the foundation for the Clinical Informatics subspecialty used to develop the examination and the accreditation of programs. The ABPM assembled an examination committee of 20 experts (17 nominated by AMIA, 3 by ABPath) to develop an item bank with more than 300 items for the certification examination [54]. When this committee became the Sub-board in 2014, Christoph U. Lehmann became the first Clinical Informatics Diplomate to chair this Sub-board for Clinical Informatics. The addition of the chairs from the original Core Content and Clinical Training groups (Reed Gardner, PhD and Charles Safran, MD) to the Sub-board provided continuity. A subset of the Sub-board (4–5 members) annually reviews the applications and makes recommendations to ABPM on board eligibility of applicants.

When designing a certification examination, item developers must strive to write items (questions) that are valid, reliable, and objective. The charge to the Sub-board for Clinical Informatics included the creation of an examination designed to test the basic lasting concepts within the field of Clinical Informatics. All Sub-board members were trained in item writing by a psychometric expert provided by the ABPM. The full Sub-board reviewed all items for accuracy and relevance. Annually, the Sub-board supplements the item bank by creating new and relevant items and retires or rewrites existing items to maintain the highest level of quality in the item pool.

Maintaining the Examination

Annually, the Sub-board reviews the performance of items that were present on the examination for that year. Items not performing within acceptable standards defined by ABPM are removed from scoring of the examination. Items found too difficult or too easy or those items that fail to differentiate between successful and less successful examinees (successful examination takers are as likely as unsuccessful takers to get this item correct) may also be eliminated from scoring. The examination is then rescored to arrive at final scores for each applicant.

Challenges

The Core Content was used to create the item pool for the board exam. It quickly became apparent that despite the great amount of details contained in the Core Content, it was underspecified for item creation and required interpretation by the Sub-board. Further, some subdomains such as “governance” or “workflow” were underrepresented in Clinical Informatics textbooks written prior to the first exam [23, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71] making item writing more difficult. Since that time, new journals and new textbooks for the field have been created and are available to the Sub-board for their task. The new Delineation of Practice developed by AMIA should make the work of the Sub-board easier [49].

Examination Results

Because the members of the Sub-board, who created the item pool, were not eligible to take the written examination, ABPM set up an oral examination for the Sub-board members, who were eligible. The examination was conducted by several Sub-board members not eligible for the board exam and occurred in the summer of 2013. The first written examination for board certification in the subspecialty of Clinical

Informatics occurred October 7–18, 2013. The examination remains a 200 multiple choice question online examination administered by Pearson VUE Professional Centers throughout the United States and at several international sites and has been administered yearly since 2013 [72].

Each year, the examination is composed of varying questions from the item pool. Performance on items that are repeatedly used allows an analysis of the examination difficulty each year and is used to determine the passing score, which varies from year to year to assure that the test difficulty remains constant. Despite the constant test difficulty from year to year, passing rates have declined continually since 2013 with the exception of 2016, where a number of candidates were given the opportunity to take the examination twice due to an inaccurate transcription of the test into the testing system. While the pass rate was 91% in 2013, the pass rate had decreased to 77% in 2017. The reason for the drop in pass rates is unclear, however the authors of this chapter speculate that the caliber of examinees may have been exceptionally high in the beginning with many very senior and experienced clinical informaticians taking the initial board exam. By January 2018, of 1976 examinees, 1687 (85.4%) passed the exam and became Diplomates. As in the first years of the examination all applications were on paper and there are no aggregate data available from ABPM on the distribution of primary board certification for Diplomates. However, the application process has now moved from paper to an online format and ABPM should be able to produce these numbers in the future. The American Academy of Pediatrics manually searched for the Clinical Informatics Diplomates from the first two years in the American Board of Pediatrics database and found that approximately 17% (132) of Board certified Clinical Informaticians were pediatricians. [73].

ACGME Accredited Fellowships in Clinical Informatics

As of October 2019, only 40 Fellowship Programs have been accredited by ACGME in Clinical Informatics [58]. Beginning with the examination in 2023, only candidates trained in an ACGME-accredited fellowship program will be eligible for the Clinical Informatics board examination. Until then, the Practice Pathway will be available including the possibility to gain eligibility by completing a two-year masters' program. For the fellowship positions starting in 2019, Clinical Informatics program directors were unable to fill all positions in the fellowship programs through the match that has been organized by the programs [74]. The applicant pool was too small to provide acceptable candidates for all programs. Because of the availability of the practice track until 2022, potential Clinical Informatics candidates can become board-eligible through employment as a Clinical Informatician and/or completing a Masters' program, which is financially more attractive than a fellow's salary. Program directors anticipate an increase in applicants starting in 2021 as 2020 will be the last time a potential candidate could use the two-year Masters' route.

As discussed earlier, Clinical Informatics Sub-specialty Board Certification is unique to the United States; however certification in Clinical Informatics for

individuals living and practicing outside the US is possible. ACGME accredits programs internationally [75], thus allowing board certified Diplomates to establish ACGME-accredited Clinical Informatics programs internationally. Any graduate from such a program must meet "all current ABPM requirements including, but not limited to, licensure and primary certification via an ABMS Member Board" [54].

How to Establish a Clinical Informatics Fellowship

Only a limited number of primary specialties are allowed to accredit a Clinical Informatics program. These include Anesthesiology, Diagnostic Radiology, Emergency Medicine, Family Medicine, Internal Medicine, Medical Genetics and Genomics, Pathology, Pediatrics, or Preventive Medicine. After an extensive application, often of over 200 pages, that includes a description of the educational resources, a block schedule for the fellow, and a description of the faculty has been approved by ACGME, a Graduate Medical Education (GME) institution is permitted to recruit fellows. GME institutions are limited to one fellowship program. Usually ACGME reviewers will evaluate the program on site within the first year. More specific training program requirements can be found on the ACGME website [76].

The knowledge and skills required for fellows to acquire is substantial and many programs teach some content through online or local Clinical Informatics certification or master's programs. For practical experience, many fellows are embedded in health information technology operations to gain hands-on experiences with various health information technology systems.

Program Director Community

Following the ABMS approval of Clinical Informatics as a board-certified medical subspecialty in September 2011 and the resulting publication of Clinical Informatics Fellowship (CIF) Program Requirements, informal conversations between aspiring organizations and program directors began at AMIA meetings. These discussions focused on how various institutions were creating their CIF curriculum, funding, and ACGME applications which were all the more important and urgent since there were no accredited fellowships at that time. Representatives from the ACGME attended several of these early meetings since they too were figuring out how to adapt and apply accreditation processes and standards developed for clinical training programs in CIFs where direct patient care was not the focus.

These informal conversations evolved into a more structured set of regular meetings added to specific AMIA national meetings twice a year and attended by

Program Directors, CIF faculty, and key individuals from institutions aspiring to create a CIF. In 2016 this group composed and submitted a proposal to AMIA to form the Proposal for the Community of Clinical Informatics Program Directors (CCIPD) which was approved [77]. While the number of participants in this group has grown significantly over time in accordance to the number of new fellowship programs, the camaraderie and culture of collaboration established by the original group remains strong. The CCIPD group has been very productive including

- assisting aspiring programs, creating a coordinated "match" process for recruitment outside the National Residency Matching Program (NRMP) system
- enrolling fellowship programs in the Electronic Residency Application Service (ERAS®, the centralized online application service fellowship applicants use to deliver their applications and supporting documents to fellowship programs)
- administering an annual in-service examination
- organizing conversations regarding funding
- sharing best practices, and creating a national monthly case conference.

CCIPD encouraged and supported supporting the development of the AMIA Clinical Informatics Fellows (ACIF) which serves as the home within AMIA for Clinical Informatics Fellows nationwide.

Clinical Informatics Milestones

According to ACGME, "a milestone is a significant point in development. For accreditation purposes, the Milestones are competency-based developmental outcomes (e.g., knowledge, skills, attitudes, and performance) that can be demonstrated progressively by residents/fellows from the beginning of their education through graduation to the unsupervised practice of their specialties" [78]. All ACGME trainees are evaluated semi-annually based on a set of milestones that ACGME developed for each specialty and subspecialty. The results of this evaluation are reported to ACGME. For Clinical Informatics, milestones were initially developed over the course of a single afternoon by an expert panel based on a template from Internal Medicine. Program directors have proposed developing milestones where each required sub-competency (i.e., task) for fellows is uniquely mapped to a single milestone assessment grid and in turn each milestone grid is mapped to one or more sub-competencies [79]. This mapping has the advantage of facilitating use of milestones for individualized learning plans, curriculum planning and modifications, program evaluations, and, of course, fellow evaluations within and across programs. Program directors anticipate that ACGME will undertake an extensive revision of the milestones based on the 2017 AMIA needs assessment (see below) in the near future.

Financial Model

Clinical Informaticians provide substantial benefits to both patients and payers (e.g. private insurers, Medicaid, Medicare) through reduction of errors [80], increasing safety [81], reducing costs [82], and improving care coordination and efficiency. However, as of the fall of 2019, Clinical Informatics does not have any billing codes through which the efforts of informaticians could be reimbursed by payers of patients [83]. Thus, institutions that employ a clinical informatician provide benefits to patients and payers, but the full costs are borne by the healthcare institutions without patient or payer contributions.

Teaching hospitals in the United States are eligible for Medicare direct Graduate Medical Education payments and indirect medical education payments if they participate in the Medicare program [84]. As GME funding from the Centers for Medicare and Medicaid Services (CMS) has not kept pace with the number and size of training programs, the cost of training new Clinical Informaticians is currently shouldered by academic health science centers. There is a simple explanation why teaching hospitals are willing to incur the cost for clinical training. Trainees are extenders for teaching physicians. They allow the attending physician to focus on the critical portions of care delivery while trainees perform less important tasks allowing attendings to take care of more patients and increase billable services. However, for clinical informatics fellows this model breaks down due to the absence of billable codes leaving institutions having to cover the cost of Clinical Informatics fellows.

To sustain the benefits from training new clinical informaticians, in the best interest of patients, payers, and the US society, it is therefore critical to find viable financial models for Clinical Informatics fellowship programs. The AMIA Board of Directors supports the search for new models [83]. One potential funding source could be the Center for Medicare & Medicaid Innovation as Clinical Informatics fellows could be used to implement and demonstrate advances in safety, cost reduction, and efficiency [85].

Integrated Training Experiences

It is not uncommon that trainees select joint training programs (e.g. joint program in internal medicine and pediatrics). For fellowships, these combined training programs or combined fellowships generate significant amount of work for program directors and the involved boards as a combined schedule for the fellow must be created and approved by the boards in advance. To reduce the effort required and provide clarification, ABPM developed the ABPM's Integrated Training Experience (ITE) [86]. ITE allows a program to accommodate a single physician, who wishes to shorten training time and complete two residencies or fellowships. ABPM will provide the ITE guidelines to program directors upon request. The implications of

the ITE for programs include the ability to accommodate the needs of an individual provider, who seeks training both in CI as well as another subspecialty. For trainees this may result in a reduced combined training period as research rotations may be counted for both subspecialty training efforts.

Maintenance of Certification

Once board certified, Clinical Informatics Diplomates must comply with the Maintenance of Certification (MOC) process, which is designed to assess continuing competencies [87]. The process has four components: (1) Professionalism and Professional Standing (Diplomates are required to maintain an active, valid and unrestricted medical license in all States, US territories, or Canadian Provinces where they are licensed to practice medicine). (2) Lifelong Learning and Self-Assessment (LLSA) (Diplomates must complete continuing medical education and self-assessment activities in Clinical Informatics including safety courses. AMIA is a major provider of ABPM-approved LLSA courses), (3) Assessment of Knowledge, Judgment, and Skills (Diplomates must pass an exam during each certification cycle with content similar to the initial certification exam), and (4) Improvement in Medical Practice (Diplomates must complete two Improvement in Medical Practice activities).The annual MOC fee for Diplomates certified after 2018 is $175 per year and the examination fee is $1750. A ten-year certification cycle (not considering the application fee) amounts to $3500 [88]. Since the first recertification examination is required ten years after initial certification, the first Clinical Informatics recertification examination is anticipated to be given in 2023.

Advanced Health Informatics Certifications

The American Medical Informatics Association (AMIA) has long been dedicated to the evolution of informatics as a profession. This includes commitment to developing certification for all clinical informatics professionals – not just physicians. Upon establishment of the Clinical Informatics Subspecialty (CIS), AMIA turned its attention to establishing certification for "other members of the clinical team" [42]. In 2011, two AMIA task forces clarified the focus of Health Informatics (HI) certification by concluding that the certification should: (a) focus on certifying the shared or "core" competencies rather than profession-specific competencies, (e.g., public health or nursing informatics); (b) be founded on a core content and level of rigor that are commensurate with those of the CIS; and (c) be targeted for informatics professionals in roles that directly affect the practice of health care (i.e. operational or applied informatics). In 2014, a multidisciplinary work group considered the core content and proposed eligibility criteria for the future certification program [89, 90].

To inform HI certification development, AMIA conducted a needs assessment in 2017. Over 2,000 health informatics professionals responded to the workforce survey, the first of its kind in the field of informatics. Following best practices for the certification industry, in 2018, AMIA directed a formal practice analysis of HI, in parallel with the CIS practice analysis described earlier in this chapter. The HI practice analysis produced a delineation of major content areas/domains of practice, the specific tasks performed by individuals in a profession, and the knowledge and skills required to perform the tasks [91]. In 2019, AMIA formed a certifying body (the Health Informatics Certification Commission) to finalize eligibility criteria, create policies and procedures to govern certification and recertification, and to develop and administer the first certifying exam. Finally, in recognition of the essential nature of accredited educational and training programs to robust professional certifications, AMIA and the Commission on Accreditation for Health Informatics and Information Management Education (CAHIIM) continue to collaborate to assure that applied health informatics programs are qualified to impart to their graduates the current competencies necessary to succeed in the field of health informatics [92].

Summary of Lessons Learned

- Clinical Informatics has a long history in the US and has advanced into a clinical subspecialty for physicians with board certification.
- AMIA was instrumental in developing this new medical subspecialty and provided the experts and guidance to develop the core content and the training requirements.
- AMIA is actively supporting a certification process for other clinical specialties in the form of the Advanced Health Informatics Certification.
- The core content of the Clinical Informatics subspecialty has been revised since the subspecialty's inception, but may need future revisions since Clinical Informatics has been, and remains, a rapidly evolving field.
- As the field continues to advance, the requirements for training and certification of physicians and others will likely evolve as well.

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