The Discipline of Clinical Informatics: Maturation of a New Profession

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Learning Objectives

After reading this chapter, the learner will be able to

- Describe the evolution of clinical informatics as a profession;
- Provide an overview of how the clinical informatics subspecialty was created; and
- Discuss the roles clinical informaticians play in health care systems and settings.

Practice Domains: Tasks, Knowledge, and Skills

- K001. The discipline of informatics (e.g., definitions, history, careers, professional organizations)

Introduction

The roots of the applied informatics discipline date to the 1960s, when hospitals and other health-related entities first began to adopt the data processing capabilities that were taking hold in other aspects of business and science. Since the funds required to adopt such methods were substantial—this was the era of expensive mainframe computers before time-sharing or personal computers had been introduced—it is not surprising that the principal uses of computers were in large hospitals and that the applications were motivated either by clinical care or business operations. Thus, the beginnings of clinical informatics can be identified some 60 years ago, and the expertise in the area has had over a half-century to evolve and mature. During this period, the emerging discipline has been tracking the remarkable changes in computer science and communications technology, the underlying health sciences, and the delivery and financing of health care.

As growing numbers of individuals began to work at the intersection of computing and medicine, sometimes obtaining formal training in both areas, it became clear that a new profession was emerging—one that focused less on research per se and more on the effective practice of applied clinical computing and information management. Many questions regarding such individuals arose and were vigorously discussed early in the new century's first decade. How might mid-career individuals get training in the area? Was it really necessary for them to go back to graduate school full-time? Was there a role for informatics as an area of subspecialty training for physicians who wanted to devote significant portions of their careers to work in the area? How do other health professionals, such as nurses, pharmacists, and dentists, approach this set of challenges and opportunities? How could an individual demonstrate to employers (typically health systems, hospitals, other health-related entities, and public and private payers) that they were qualified for a formal position in clinical computing, focused on practice, strategic planning, and implementation rather than on research? Might there be a suitable way to get certified in the area without needing to return to school to get a formal graduate degree?

Although these questions were asked by individuals from a range of health professional backgrounds, they became especially pertinent for physician informaticians who saw chief medical information officer (CMIO) positions emerging within a culture of recognized medical specialties. In this chapter, we summarize what happened to address these questions, culminating in the creation of a formal subspecialty for board-certified physicians through the American Board of

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Medical Specialties (ABMS), the emergence of and growth in the Accreditation Council for Graduate Medical Education (ACGME) accredited clinical informatics fellowship programs, efforts by the American Medical Informatics Association (AMIA) to establish an AMIA Health Informatics Certification (AHIC) for applied informatics professionals who are not eligible for the clinical informatics subspecialty (CIS), as well as emerging issues as the specialty matures.

This volume is intended to help individuals preparing for their clinical informatics board examinations or who wish to refresh their knowledge of the field from time to time after they have been certified. Accordingly, readers will notice references to the clinical informatics subspecialty for physicians throughout the volume. There are, however, many other kinds of professionals who work in clinical informatics, and the book will be valuable for them as well. As described below, there is considerable similarity between the body of knowledge for the clinical informatics subspecialty for physicians (CIS) and the AMIA health informatics certification (AHIC). Thus, individuals preparing for either examination may find benefit from this book. Further, while this volume is intended for practitioners and does not prepare individuals to become researchers in clinical informatics, it conveys a body of knowledge and experience useful to researchers in the field.

Clinical informatics is an applied sub-discipline of the field of *biomedical and health informatics*, which AMIA has defined as "the interdisciplinary field that studies and pursues the effective uses of biomedical data, information, and knowledge for scientific inquiry, problem-solving, and decision making, motivated by efforts to improve human health" [1]. The term *clinical informatics* refers to the practice in health care settings where informatics concepts are applied to the care of both individuals and populations. With the advent of widespread use of electronic health records (EHRs), it is now possible to manage populations of patients routinely, thus bridging a gap between personal and population health that has existed for over a century. This is one of the transformative aspects of clinical informatics as a discipline. Since there has traditionally been a chasm in the United States between care of individuals and care of populations, clinical informatics offers the best opportunity for America to heal this regrettable historic oversight since excellence in *both* the care of individuals and populations is essential for a first-rank healthcare system.

In 2009, AMIA published two key papers that introduced the notion of a clinical subspecialty for informatics physicians and were pivotal to establishing the new subspecialty [2, 3]. They emphasized that 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;
- To characterize, evaluate, and refine clinical processes;
- To develop, implement, and refine clinical decision support systems;
- To lead or participate in the procurement, customization, development, implementation, management evaluation, and continuous improvement of clinical information systems.

Once the CIS was established, the *Core Content for the Subspecialty of Clinical Informatics* [2] became the foundation of the CIS certification examination. It informed fellowship program curricula, board review materials, and maintenance of certification programming.

Ten years later, in recognition of changes in CIS practice and the need to support the development of competencies on which fellows could be assessed, AMIA collaborated with the American Board of Preventive Medicine (ABPM) to update the CIS core content. That effort (described later in this chapter) resulted in the CIS Delineation of Practice (DOP) [4] which is now the basis for the CIS examination. This volume introduces and summarizes the concepts, methods, and tools included in the CIS DOP and provides case studies and illustrations of both effective approaches and those that have limited the success of the field to date.

History and Development of Clinical Informatics as a Medical Subspecialty

Clinical informatics developed over decades as computing and computer systems entered hospitals and clinics—primarily for billing purposes and laboratory results reporting and management. In a somewhat parallel fashion, radiology sought to digitize and store its images for analysis and retrieval, using communications technologies to deliver them wherever needed. A first-generation of clinicians emerged who were sufficiently interested in computing and computer science that they undertook formal study in these disciplines and then worked as researchers or practitioners at the intersection of computing and clinical care. By the early 1970s, the U.S. National Library of Medicine had begun to fund research and researchers' training in the emerging discipline. National meetings engaging those sharing these interests emerged during the late 1960s and 1970s. The introduction of an annual Symposium on Computer Applications in Medical Care (SCAMC), beginning in 1977, served as a particularly important catalyst to the creation of a national community that, in time, became known as the *medical informatics* community. By 1984, the American College of Medical Informatics (ACMI) was formed as an honorific society in which peers elected future members based upon

their contributions to the field. Building on a smaller professional society known as the American Association for Medical Systems and Informatics (AAMSI), AMIA was formed in the late 1980s through a formal merger of ACMI, AAMSI, and SCAMC, each of which had been formed as a separate corporate entity. AMIA quickly became the professional home where both senior and junior informaticians, including those focused on clinical care, could present their work and find out what was current in the field. Such informatics specialists were not necessarily physicians, however. Indeed, nursing informatics began educational programming on a broader scope and scale than medicine. From the beginning, AMIA welcomed all health professionals and other scientists (e.g., computer scientists, decision scientists, cognitive scientists, sociologists) interested in the application of computing and communications technology in health and health care. This integrative dimension of the field is one of its defining characteristics set within a healthcare landscape noteworthy for its 'siloes' of both knowledge and practice. While other groups did exist, they tended to be narrower in scope, and none was as large or influential as AMIA.

The term *informatics* was still new in the 1980s. Early informatics professionals in applied settings such as hospitals often referred to what they did as "health information technology" (HIT or health IT). While the use of the HIT and *health IT* designations by informaticians is less common today, there is still confusion regarding the relationships between clinical informatics and HIT. There was also confusion at the international level. Most other countries came to refer to HIT as HICT or health ICT, explicitly including "communications" and "information" in their acronym. Forty years later, with the digital revolution and the widespread implementation of EHRs, *clinical informatics* is being used in many job descriptions that do not always align with the CIS definition of practice (DOP). This has introduced a new source of confusion about the relationship between informatics professionals and those in related roles such as HIT or health information management (HIM). Furthermore, the emergence of data science is complicating the broad understanding of the clinical informatics discipline.

Today the U.S. HIT community has a large trade organization known as the Health Information Management Systems Society (HIMSS), whose annual conventions often attract clinical informaticians who want to interact with colleagues and track the newest technologies and products. With its annual informatics meeting, AMIA has complemented and cooperated with HIMSS while attracting a more knowledge-driven and scholarly audience, including researchers and professionals who look beyond the technology to educational needs and the conceptual underpinnings of knowledge and information management in health care settings. Since 2014, AMIA has organized the Clinical Informatics Conference that focuses on applied-informatics practice. In 2021, over 650 attended its virtual conference.

Today, while AMIA has formally identified individuals engaged in clinical informatics as informaticians, many prefer to identify themselves as informaticists. Only time will tell which term will dominate in the future. Suffice it to say that they are essentially synonyms in terms of common usage despite the use of clinical informaticians in this chapter.

Defining the Characteristics of the Profession

Following the release of a professional code for informaticians in 2004 [5], AMIA held a Town Hall meeting during its annual symposium to discuss the matter of formal training and certification in clinical informatics, regardless of one's area of clinical expertise or even one's previous health professional training, if any. The goal was to approach clinical informatics as an integrative health care discipline and as one practice domain within the larger 'house' of biomedical and health informatics. The AMIA Board decided to focus its initial efforts to establish informatics certification on one health profession rather than mounting a certification effort across all disciplines at the same time and engage all other clinical informaticians in the healthcare team as soon as feasible.

AMIA first pursued certification for physicians. Then, with insights and lessons from that effort, it pursued certification for other clinical informatics experts (see the discussion of this topic later in this chapter). It made sense to start with MDs because many existing clinical informatics subspecialists were also physicians, board-certified in one of the major clinical specialties (e.g., internal medicine, surgery, pediatrics, radiology) and because the notions of specialist and subspecialist, and the processes for their certification, were familiar and well defined. A subspecialty, in this context, is a field of narrower concentration for someone who is already certified as a specialist. For example, cardiology is a subspecialty of internal medicine. As was successfully argued, clinical informatics can be viewed as a relevant subspecialty for physicians trained and certified in any standard specialty—i.e., they may appropriately work in clinical informatics regardless of their primary training and practice.

Any new discipline within the medical profession seeking to obtain support for formal specialty or subspecialty status must first convince other medical specialists and subspecialists that the discipline is worthy of such designation. Thus, three critical sets of players were involved in addressing the challenge that faced AMIA:

1. Clinical informatics needed to be viewed formally as a separate discipline by other medical specialty groups. Such recognition is evident when a nationally recognized

organization representing the rising discipline is elected to formal membership in an organization such as the American Medical Association (AMA) or the Council of Medical Specialty Societies (CMSS). CMSS is an organization whose purpose is to provide a forum for collaboration among medical specialty organizations to influence policy, medical education, and accreditation from a broad, cross-specialty perspective.

2. The subspecialty needed to be recognized by the American Board of Medical Specialties (ABMS). ABMS is an umbrella organization for the certifying boards in all the various specialties and subspecialties of medicine; it formally recognizes specialties and subspecialties and, through its constituent boards, creates and maintains the certification examinations that attest to the competence of medical subspecialists.
3. The Accreditation Council for Graduate Medical Education (ACGME) must be engaged since the ACGME exists largely to review and accredit training programs capable of preparing candidates to sit eventually for the certification examinations of the constituent boards of the ABMS.

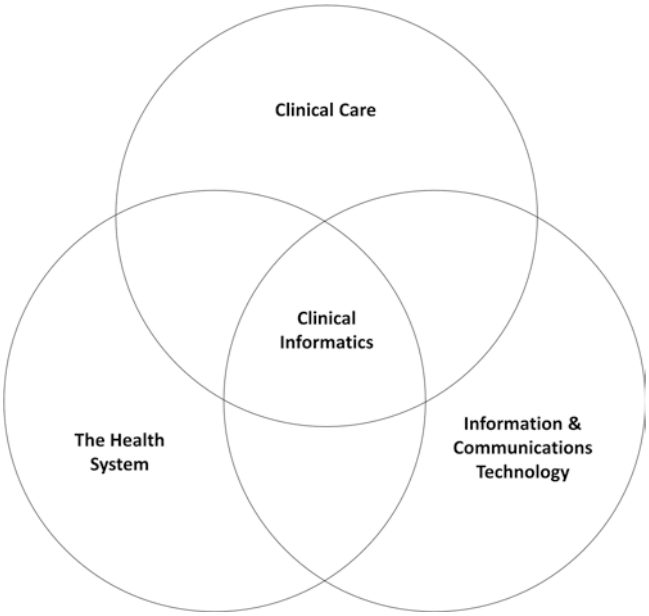

Fig. 1.1 Domains of clinical informatics (reproduced from reference [2] with permission from the American Medical Informatics Association and the Journal of the American Medical Informatics Association)

In mid-2006, John Lumpkin, Vice-President of the Robert Wood Johnson Foundation (RWJF) and AMIA President and CEO Don Detmer, met informally with the presidents of several medical specialty societies to discuss a new clinical informatics subspecialty. The result of this meeting was an expression of genuine enthusiasm accompanied by recognition that the formal process for establishing a new subspecialty would require considerable effort and time. To continue building the case for the new subspecialty, AMIA sought and achieved membership in CMSS in 2007.

In the same timeframe, RWJF awarded AMIA a grant to develop two key documents essential for formally approaching ABMS to consider a new subspecialty. Through that grant, AMIA engaged Benson Munger, a former executive director of the American Board of Emergency Medicine, to help to guide the process. Separate task forces were appointed to develop the core content of the field [2] and recommended fellowship training requirements [3]. After approval by the AMIA Board of Directors, these documents, along with a descriptive piece by Detmer and Lumpkin [5], were published in the *Journal of the American Medical Informatics Association* (JAMIA) in 2009.

Several key concepts were critical at this early development stage. As noted earlier, clinical informatics is intrinsically an integrative discipline. This was acknowledged by appointing non-physician clinical informaticians to each AMIA task force, where they functioned as full members. There was representation from nursing, pharmacy, and dentistry. The groups also emphasized the concept of a learning healthcare system committed to the principles outlined in the IOM reports, *Crossing the Quality Chasm* (2001) and *Health Professions Education: A Bridge to Quality* (2003) [6, 7]. Equally important, the role of a clinical informatician was to take both a clinical and a system view, emphasizing that qualified subspecialists should be capable of leading organizations strategically and tactically with respect to all major aspects of integrating information and communications technology with information needs as they might evolve. A key visual was created to represent this perspective (Fig. 1.1). This remains as a core set of insights and responsibilities for practicing the discipline of clinical informatics. Since then, an enlarging focus on both person- and population-based perspectives has emerged.

Seeking Approval for the Clinical Subspecialty

The next step in the process was to identify one or more ABMS boards that would agree to propose the formal creation of the CIS. Although many Boards were supportive and expressed an interest, the American Board of Preventive Medicine (ABPM) was most interested in submitting a formal proposal and becoming the administrative board. Detmer and his successor as AMIA President/CEO, Edward Shortliffe, committed to working with the ABPM to develop the application to ABMS for the new subspecialty. Verbal support from other boards was helpful in reassuring ABPM that there was enthusiasm within ABMS for the creation of the new subspecialty, and AMIA gathered data to demonstrate the potential demand for such a certifying exam.

In mid-2009, a senior leader from ACGME met with informatics program directors who, up until then, were most familiar with requirements for graduate (MS and Ph.D.) education and generally had less familiarity with formal fellowships that would need to be accredited if trainees were to become board-eligible within the ABMS certification model. The interactions at that meeting were crucial, not only because informatics educators began to understand the ACGME accreditation model but because ACGME leaders began to realize that if they were involved in accrediting informatics fellowships, they would encounter many issues that had not arisen previously. There were, for example, questions of whether masters' degrees would be required or optionally offered to clinical informatics fellows in training and how or whether ACGME would assess that option. Most fellowships have clinical and research requirements, but what was "clinical time" for a clinical informatics fellowship? Perhaps it could be a service component that affected clinical programs at the affiliated medical institution? Unlike most fellowships, it was unclear what a "direct patient care" component would be. Since fellows could come from various clinical backgrounds and specialties, it was not reasonable to expect the informatics fellowship formally to provide a panoply of direct patient-care opportunities in every specialty. ACGME began to realize that creating a clinical informatics subspecialty would require them to rethink the definition of the term "clinical". Shortly after the Colorado meeting, ACGME leaders began a discussion of this question, leading to the formal adoption of a new, expanded definition that was approved by their board and placed on the ACGME website in 2009 [8]:

> The word "clinical" refers to the practice of medicine in which physicians assess patients (in person or virtually) or populations in order to diagnose, treat, and prevent disease using their expert judgment. It also refers to physicians who contribute to the care of patients by providing clinical decision support and information systems, laboratory, imaging, or related studies.

This new definition became an extremely important factor in the subsequent discussions with ABMS as the subspecialty proposal was being considered. As discussed below, this remains a critical issue today since entities like the Centers for Medicare and Medicaid Services (CMS) have yet to develop appropriate payment mechanisms for both practice and education consistent with this definition.

By the autumn of 2009, the leadership of the ABPM had approved a plan to propose the new subspecialty to ABMS. As is customary for new subspecialties, there was a 5-year practice application period during which active clinical informaticians who were also ABMS-certified physicians could apply to be deemed board eligible and sit for the examination. After that, a formal fellowship in clinical informatics would be required to achieve board eligibility. As is the case for all residencies and fellowships, those fellowships would need to be accredited by the ACGME. In 2017, ABMS approved ABPM's application to extend the initial 5 year practice track through the 2022 exam cycle. The extension was predicated on the argument that an insufficient number of ACGME accredited informatics fellowship programs had been established, even though many had been implemented or were planned.

The initial ABMS approval process involved a year-long review. All the other boards in ABMS reviewed and then had to approve the notion of a new subspecialty certification. Shortliffe and AMIA staff worked with ABPM to prepare and submit the formal proposal and were delighted when it garnered support from the other boards. With unanimous support from their constituent boards, ABMS leadership agreed in late 2010 to initiate internal review of the proposal. Their Committee on Certification (COCERT) met twice to review and discuss the proposal before forwarding their positive recommendation to the full ABMS board.

The COCERT meetings in 2011 were crucial elements in the approval process because the committee was charged with determining whether there was adequate justification for treating the proposed subspecialty as a separate discipline. They also wanted to assure themselves that the field is a suitable area of specialization for practicing physicians. Shortliffe accompanied ABPM's executive director to those meetings in Chicago to support the proposal and answer questions about the discipline and the community of physicians who were likely to pursue certification if a board examination were offered. A key question that arose and debated at both committee meetings was whether clinical informatics was sufficiently "clinical" since some viewed the work as technology-oriented and not involved with direct patient care. Arguing that many other subspecialties have limited direct interaction with patients and that all clinical informaticians would also be board certified in an established patient-care specialty, Shortliffe also directed the COCERT members to the ACGME definition of "clinical", which by that time had already been approved by the ACGME board and posted on their web site. The updated definition, reproduced above, helped to allay concerns and, by the end of the summer of 2011, the ABPM's proposal had been approved by COCERT and was forwarded to the ABMS board for a final decision. The approval came in September 2011, capping a long study period and preparation by AMIA, RWJF, and the ABPM. The clinical informatics community was jubilant!

The Clinical Informatics Subspecialty in the Context of ABMS Evolution

The subspecialty of clinical informatics occupies an interesting space within ABMS. In 1972, ABMS initiated the process of approving new subspecialties [9]. American medicine

was early in the process of practice differentiation. Except for the surgical specialties, graduate medical education beyond a 1-year rotating internship was uncommon. The American Boards of Pathology, Internal Medicine, and Pediatrics had begun to develop subspecialties, and nine were created. These subspecialties directly related to one primary board (e.g., cardiology, gastroenterology, forensic pathology, hematology). The certificates were each issued by their primary board. In total, the decade of the 1970s saw 19 subspecialties approved by the ABMS.

During the 1980s, ABMS approved 21 new subspecialty certificates. This decade also brought the first discussions among ABMS boards about a subspecialty that might cross primary specialties and therefore require a different approach to examination development and administration. An example of this new approach was geriatric medicine. Both the American Board of Internal Medicine (ABIM) and the American Board of Family Medicine (ABFM) issue subspecialty certification in geriatric medicine. Both boards participate in the development of the examination, but ABIM takes responsibility for formal examination administration.

This cross-discipline subspecialty also created a challenge for ACGME's program accreditation process. It envisioned training programs sponsored by departments of multiple primary specialties and could theoretically accept fellows from more than one primary specialty. It also assumed that the training programs would have a common set of core training requirements, as the graduates of those programs would be taking a common certification examination. This period brought several other subspecialties that had were either in the same content areas or had shared training and certification across two or more primary boards. Examples would include critical care, sports medicine, and undersea and hyperbaric medicine.

During the 1990s ABMS approved certificates in 32 subspecialties. This period gave rise to discussions within ABMS about another new concept. As subspecialties involving multiple boards were developed, the diplomates of boards not directly involved in issuing certification in that joint subspecialty indicated an interest in accessing that training and certification. In many cases, the number of diplomates from other boards would not justify the direct co-sponsorship of their primary board. These discussions led to the concept of a co-sponsor allowing a diplomate of another board to access their training programs and certification system. This concept significantly expanded the scope of certification in some subspecialties.

Between 2000 and 2009, ABMS approved 34 subspecialty certificates. This number was significantly influenced by two new subspecialties, (a) hospice and palliative medicine and (b) sleep medicine. Hospice and palliative medicine has ten co-sponsors; sleep medicine has six.

The first 3 years of the 2010 decade saw ABMS approve 12 new subspecialty certificates and among them was clinical informatics. As we have described, this subspeciality certificate is officially sponsored by ABPM, which functions as the administrative board. Before the subspecialty received final approval by ABMS, the American Board of Pathology (ABPath) also chose to co-sponsor the new subspecialty. Furthermore, because of clinical informatics' unique nature, there was significant interest in training and certification by diplomates from a wide variety of ABMS boards. The result is that clinical informatics was the first subspecialty in medicine that allows training and certification from all 24 of the current primary boards. It is not surprising that this first occurred with clinical informatics since the clinical interactions and applications of the subspecialty apply to all specialties in medicine and the other health professions.

Creating and Offering the Board Examination

Once the subspecialty had been approved, ABPM moved quickly to create and offer the first subspecialty board exam. Because the ABPM did not have the internal content expertise to create the formal examination, they asked AMIA for nominees to sit on the question-development committee. As mentioned, the ABPath had submitted a request to ABMS and had been approved to be a co-sponsor of the subspecialty. Thus, both AMIA and ABPath forwarded proposed exam committee members to ABPM, and the committee was formed. ABPM ran the process and, in light of their long history of offering preventive medicine specialty boards and several subspecialty examinations, had ample internal expertise regarding the steps to be taken, including providing access to psychometric specialists who could guide the development of exam questions.

Initial Development of Fellowship Programs

Once ABMS approved ABPM to issue sub-certification in clinical informatics, the process moved to ACGME. As was mentioned earlier, ACGME is the organization responsible, in the United States, for the accreditation of graduate medical education programs in all medical specialties and subspecialties. AMIA leaders maintained contact with ACGME while the proposal was proceeding through the ABMS.

In 2011, ACGME appointed a Residency Review Committee (RRC) group to develop the new program requirements and recommend them to the ACGME Board. The committee was composed of graduate medical education experts in clinical informatics. The review committee began with the Draft Training Requirements developed and published by AMIA [2, 3]. The review committee also

requested feedback from the clinical informatics community and, based on that feedback, developed a recommendation that was submitted to the ACGME Board and approved in February 2014. As a parallel process, the ACGME staff began constructing the Program Information Form (PIF) to be used by programs to apply for ACGME accreditation. This PIF was made available to potential applicant programs in May 2014.

Although ABPM is the primary administrative board within the ABMS structure, with ABPath as co-sponsor, the fellowship training process is intended to avoid limiting sponsorship of fellowship programs exclusively to preventive medicine or pathology departments. It was always envisioned that many other primary specialties would be interested in sponsoring fellowship programs. Therefore, local medical schools and teaching hospital departments from various specialties would submit applications to ACGME.

When the original Program Requirements were approved and distributed, the list of primary specialties that could sponsor an ACGME fellowship program was limited. Ultimately, program requirements for clinical informatics approved in 2014 allowed for sponsorship by departments of nine primary specialties (anesthesiology, diagnostic radiology, emergency medicine, family medicine, internal medicine, medical genetics, pathology, pediatrics, and preventive medicine).

Concern about the lack of clinical informatics expertise among RRC members was mitigated by the presence of the Clinical Informatics Review Committee (CIRC) that the ACGME had approved and appointed. The CIRC provided a structure through which applications from clinical informatics fellowship programs could be pre-reviewed by a panel of experts with a recommendation provided to the relevant RRC responsible for the decision. The relevant Residency Review Committees have primarily absorbed the responsibility for reviewing and approving Clinical Informatics programs.

The ABPM application to ABMS contained a list of existing fellowship programs (many of which offered graduate degrees and had trained post-residency physicians) and a projection of programs that would likely emerge following the creation of the clinical informatics sub-certification. That list was a combination of fellowship programs that looked somewhat like the proposed ACGME fellowships and others with many years of experience and funding but were blends of degree and certificate programs. Many of the programs on the list were located in medical schools or had existing faculty relationships with one. Many were also funded by the National Library of Medicine and had been in operation for many years. One of the assumptions in the subspecialty application was that a significant number of the existing programs would move to create a parallel program that would train physicians using the ACGME program requirements.

In 2014 the first applications were submitted to the ACGME, reviewed by CIRC, and forwarded to the appropriate Resident Review Committees (RRCs). In late 2014 ACGME accredited the first set of clinical informatics fellowship programs [10, 11]. By 2021, the number and distribution of ACGME accredited programs have expanded significantly, with 48 currently accredited across 22 states. The largest number of programs can be found in California (7) and New York (6).

Updating the CIS Core Content

By 2018, a decade had passed since the CIS core content was first developed. During this time, CIS practice had evolved due to changes in health care generally, wider use of clinical/health information systems, and advances in informatics practice gained in part through extensive experience in incorporating EHRs into clinical processes. Other factors that shaped CIS practice included: evolving clinician and patient expectations for how they interact with information systems and applications; increased attention to and capabilities for analyzing data from the nearly ubiquitous EHRs for population health management, precision health, and research; burgeoning emerging data such as phenomic characteristics and patient-generated health data with the potential to be leveraged for clinical decision-making; and growing emphasis on value-based health care. As a result of these changes, the 2009 core content, which was the basis for the CIS certification exam, was inconsistent with current needs and practice. Also, during this period, clinical informatics fellowship programs were grappling with using the CIS core content to develop competencies on which fellows could be assessed and recognized that they needed more than a knowledge outline for this task.

In light of these factors, in 2018, AMIA and ABPM agreed to update the CIS core content and organized a formal practice analysis methodology for the revision [4]. Thirty-seven CIS diplomates participated in drafting and reviewing a description, or delineation, of CIS practice in terms of domains, tasks, and knowledge and skills required to perform those tasks. All CIS diplomates (nearly 1700) were invited to review the draft CIS Delineation of Practice (DOP) via survey. Over 300 diplomates completed the survey. Their responses were used to finalize the DOP published in 2019 that now serves as the basis for the CIS certification examination co-sponsored by the ABPM and the American Board of Pathology and administered by the ABPM.

The CIS DOP comprises five major domains of practice, 42 task statements, and 142 knowledge statements. There is considerable consistency between the 2009 CIS core content and the 2019 CIS DOP, but several differences exist. In terms of content, the increased use of health data from EHRs and

other electronic sources is reflected in an entire domain on data governance and analytics, and dimensions of quality and performance improvement are identified in greater detail (e.g., measures, safety standards, benchmarks). In terms of structure, the tasks provide context for the knowledge statements by highlighting how CIS diplomates use that knowledge in practice. In addition to informing the content and structure of the clinical informatics examination, the CIS DOP supports the development of clinical informatics fellowship curricula and updates to ACGME's Clinical Informatics Fellowship Program Training Requirements and national clinical informatics milestones for fellows. Further, the task statements may inform future job descriptions and help employers understand what constitutes informatics practice. The CIS delineation of practice will need to be updated regularly to reflect changes in clinical informatics practice.

Career Options for Clinical Informaticians

The 2019 CIS practice analysis survey provided the first glimpse of the CIS diplomate workforce. Over 80% of respondents to the 2019 CIS practice analysis survey reported working in healthcare delivery organizations or other healthcare providers. Other specified work settings included: universities, public health agencies, industry, and consultant firms. These respondents had an average of 16.2 years of experience and spent 62% of their time in activities directly related to clinical informatics [4].

As previously noted, a common title for an experienced clinical informatician is *Chief Medical Information Officer* (CMIO), sometimes called *Chief Clinical Informatics Officer* (CCIO) [12] or in the case of the U.S. Department of Veterans Affairs the *Chief Health Informatics Officer* (CHIO). This position in a healthcare organization is at a senior level within the executive structure and typically reports to the chief executive officer (CEO) or the chief medical officer (CMO). The role enjoys close interactions with the chief information officer (CIO) and the rest of the senior management team. Principal responsibilities relate to serving as the primary point of contact between the medical staff and the institution's clinical information systems, e.g., EHRs, data exchanges, data repositories, and systems to address clinical performance, such as quality and safety. When the CMIO role was first introduced the positions tended to report to the Chief Financial Officer (CFO) or the CIO and focused on information technology as infrastructure rather than as a strategic asset. With its new reporting structure, the role has evolved to be a strategic and operational position. Although the trend today is for the CMIO to report to the CEO or CMO, there is substantial variation. Furthermore, based upon one's attributes, experience, and aspirations, some clinical informaticians are beginning to find themselves pursued for CIO, CMO, or even CEO roles. Looking forward, it is likely that clinical data analytics, with an emphasis on clinician performance, quality, safety, and external reporting relating to these matters, will play a larger role in the CMIO job description. For example, the COVID-19 pandemic highlighted the need for better coordination between clinical and public health data, e.g., a seamless connection needs to exist between numerator (individual patient) and denominator (population) data.

As the numbers of trained clinical informaticians increase in the future, it is also possible that all major departments and units in major healthcare delivery systems may have a "Chief Surgical IO", a "Chief Pediatric IO", and other such individuals who work across the major departments and also link to other health professionals such as nurses, pharmacists, etc. Chief Nursing Information Officers (CNIOs) are already becoming common in larger health systems, as are Chief Research Information Officers (CRIOs). The Veterans Health Administration includes Chief Health Informatics Officers (CHIOs) within many of its medical centers, who represent various clinical backgrounds. The role of such individuals is to serve as members of a clinical informatics team whose job is to assure that HIT systems meet growing strategic goals—supporting clinical operations and research while engaging patients, community resources, and other relevant entities. A recent movement among several state departments of health is to create an equivalent position of CMIO to offer strategic advice and to provide oversight of public health considerations, linking with other health data experts in the state (including CMIOs in healthcare delivery systems).

Today, the CMIO role (under a variety of names) has various permutations within the Departments of Defense and Homeland Security, the Public Health Service, and the Veterans Health Administration, with a span of responsibilities that may involve hospitals as well as other types of care facilities and outpatient settings. Roles and responsibilities may involve planning, evaluation, or consultation depending on needs. Within the Department of Health and Human Services (DHHS), those departments that relate to health care payment, research, health policy, quality, and safety, such as the Centers for Medicare and Medicaid Services (CMS), the Food and Drug Administration (FDA), and the Agency for Healthcare Quality and Research (AHRQ), also offer opportunities. A few positions also become available as staff to Congressional representatives, health committees in Congress, or the White House for those interested in health policy. Today, these opportunities may best be described as emerging. Still, adventuresome clinical informaticians should not dismiss potential opportunities where their imagination and an entrepreneurial attitude may create positions of major value to society.

Opportunities also exist in the corporate world in those industries that have a large workforce. Many such companies already have CMOs who help address employee or customer health issues. Still, increasingly they also need someone whose skills reflect both strategic and management issues related to the HIT needs of the organization. Insurers and health system consultancies also come to mind. Finally, EHR vendors are beginning to hire such individuals to serve both internally and externally facing positions, both for ongoing relationship management, product development, and, in some instances, marketing.

Current Challenges for Clinical Informatics

As of June 2021, there were 2104 clinical informatics diplomates certified by the ABPM. Of these, 145 had completed an ACGME-accredited Clinical Informatics fellowship. The remaining diplomates applied through the ABMS approved practice track. As mentioned above, this practice track was originally scheduled to terminate in 2017 but was extended by ABMS through the exam administration in 2022. We expect a significant reduction in the number of clinical informatics subspecialists certified yearly when the practice track terminates in 2022.

Early experiences in creating fellowships suggest that some will arise from within specific specialty units or clinical departments within hospitals or medical centers. As was discussed earlier, those programs will need to be sponsored by or partner with one of the nine primary specialty programs approved by the ACGME. Complex relationships and partnerships may need to be created if the fellowship "home" is not in one of the nine specialties. Furthermore, there are questions about whether and how the RRCs will standardize how they evaluate the clinical informatics fellowships. Will there be uniformity in expectations across the specialties? As this volume emphasizes, clinical informatics is viewed as a broad and integrative discipline. Those completing fellowships need to have a broad knowledge of the field, regardless of their primary specialty or the "partnering" specialty responsible for the ACGME accreditation of their training program.

Perhaps the greatest hurdle for new and developing fellowship programs has been funding the fellowship positions that they offer [13, 14]. Interesting models have already been seen (e.g., funding of positions by a company through a grants program, by the hospital itself, by the physicians' group in the host department, or by existing informatics training grants that have been adapted to emphasize fellowship training for a few of their positions). Not all institutions can self-fund incremental fellowship positions, and it is politically difficult to reprogram existing fellowship training funds from another subspecialty to support clinical informatics fellowship slots. While many observers hope there will be new federal funding to support such training positions, health systems and training programs need to be innovative in funding clinical informatics fellows.

As with most fellowships, the program director for a clinical informatics fellowship is expected to be board-certified in the subspecialty. This created start-up challenges for institutions that did not have such expertise in-house. Furthermore, the fellowships require additional faculty who can define the curriculum, offer it to trainees, serve as mentors, and oversee projects. Thus, there has been a substantial need for new faculty at many institutions seeking fellowships. Accreditation of their program will require that they have the required local expertise. Given the potential shortage of board-certified subspecialists, especially after 2022, this is likely to continue to be a great challenge as the discipline seeks to increase the available fellowship training opportunities.

As organizations and institutions seek to find qualified individuals, they are faced with a confusing array of credentials. There are multiple organizations in the informatics certification field. These credentials cover a wide range, including basic certificates, degrees from academic entities, and training and certification based on accredited programs [15]. Employers looking at this landscape have difficulty identifying the training and skill base represented by each option. ABMS certification in clinical informatics is, of course, intended to help with this problem. By establishing an official subspecialty, ABMS and ABPM offer a credible reference certificate to employers who seek to engage physicians in their clinical informatics processes. But, as with any certificate, ABMS certification in clinical informatics cannot address every employer's needs, especially in the short term. The implementation and output of the ACGME-accredited training programs will continue to take several years, and physicians holding that certificate will not fill every position.

In addition to the "supply" concern just outlined, there are demand questions. Physicians in the informatics community have been decrying the lack of informatics content in the medical school curriculum for years [16, 17]. Until recently, there have been very few role models for medical students who might develop an interest in clinical informatics, and there is accordingly hope that the creation of the formal ABMS subspecialty, plus the introduction of fellows and faculty who have expertise in the area, will increase the credibility of this training option and draw more physicians into the discipline. The challenge, of course, will be to match the supply and demand so that there are not only applicants to fill the available fellowship positions (which does not currently seem to be a problem) but also enough positions to match an increasing number of residents who wish to pursue subspecialty training in clinical informatics.

Another dimension of importance concerning board certification is the issue of maintenance of certification (MOC).

This aspect of the current specialty certification landscape is particularly rocky at present, with rising concerns from specialists and others about several issues relating to MOC, including costs, relevance to actual competence on the job, and current professional practice profiles, among others. There is a movement in medical education to transition from "time in seat" to competency-based education wherein the criteria for professional performance are explicit, and learners can advance at their own pace, as evaluated by both written exams and observed demonstrations of knowledge and skills. Many hope that MOC will also eventually adopt this approach, both for clinical informatics and more broadly. However, major pedagogical, administrative, and political aspects will need to be accommodated before such new approaches will be adopted. Since clinical informatics is a relatively new entrant to formal recognition as a subspecialty and information management is its core capability, it is ideally positioned to offer leadership in transitioning from examinations 'at a distance' to an online review of current practice behaviors, processes, and outcomes. The field could offer a 'hands-off' yet valid, timely evaluation of current activities and competencies for those activities.

Complementary Developments

New Professional Recognition Opportunities

Beyond recognizing an individual's professional competence, there is now a way for CI diplomates to demonstrate their commitment to the discipline of clinical informatics. In 2018, AMIA launched "Fellows of AMIA" (FAMIA) to recognize members, with an applied focus to their informatics work, who have demonstrated professional achievement, leadership in the field, and sustained commitment to AMIA. By 2021, 435 individuals had been inducted as FAMIA.

Further, clinical informatics is also recognized internationally as a profession of note. Beginning in 2017, an International Academy of Health Sciences Informatics (IAHSI) was created through the auspices of the International Medical Informatics Association (IMIA). Individuals worldwide are elected to Fellowship based on prior performance in the broader discipline of health sciences informatics, but many members emphasize clinical informatics [18]. The IASHI seeks to disseminate knowledge and best practices, foster new ideas, and encourage global collaboration around expertise and resources.

The Faculty of Clinical Informatics of the United Kingdom is a multidisciplinary group that supports professional competency standards for informatics practice [19]. From a core group of 107 Founding Members in 2017, a robust organization has developed that now has a multidisciplinary faculty of hundreds of fellows, associates, and international fellows. The Faculty offers consultancy services to the NHS Digital (the public body responsible for developing and operating the National Health Service health information technology and data services) and fosters educational developments and scientific conferences.

Health Informatics Certification

After ABPM launched the new subspecialty, AMIA began working to establish certification for applied informatics professionals who are not eligible for CIS [20, 21]. In 2019, AMIA completed a practice analysis (similar to the one conducted for the CIS) to inform eligibility criteria and the examination blueprint for the new certification program [22]. In 2021, AMIA announced the eligibility criteria for AMIA Health Informatics Certification (AHIC). AHIC is intended for applied health informatics professionals who are in or seek senior roles. It is open to informatics professionals who come from a range of education and training pathways, including but not limited to dentistry, medicine, nursing, pharmacy, public health, health informatics, and computer science. The first AHIC examination was offered in autumn 2021.

AHIC constitutes an important development for the field of applied informatics. Now all members of the informatics team have a means of demonstrating their competence. This is particularly important in an environment where *informatics* in job titles has become quite common, even if the role does not align with the descriptions of informatics practice that emerged from the CIS and health informatics practice analyses. Of note, the CIS and health informatics delineations of practice have considerable overlap in terms of the knowledge statements and tasks [23]. These results reinforce our understanding of the shared knowledge base that informaticians bring to the various roles they fill.

Looking to the Future

Over the past decade, the clinical informatics discipline has made progress towards fulfilling the potential of health information technology to enable more effective health care delivery systems, a happier, more productive workforce, and enhanced, more equitable patient care, with improved outcomes for both individuals and populations. Yet, serious work remains so that emerging EHRs remove burdensome documentation requirements, accommodate emerging data, and create seamless data flows needed for both care and system management and improvement. As a result, the discipline will increasingly incorporate data sciences, data analytics, precision medicine, applications of artificial intelligence, and automated ways to capture patient clinical experiences accurately both for care documentation and to meet financial imperatives for payment. We also anticipate opportunities for clinical informaticians to contribute to the advancement of citizen

science and the development of informatics-enabled tools designed to address health inequities [24].

Transitioning from systems built upon thinking and practices that predate computer and information technology to those that take full advantage of the emerging power of today's interactive communication abilities, so that improved work design can direct greater attention to the patient-clinician interaction is both a research and applied challenge. Certainly, there is interest and a renewed commitment to making the technology aspects of the discipline less intrusive [25]. The ultimate aim is to capture all relevant information while doing so 'behind the screen'.

Despite biomedical informatics' relative youth as a scientific discipline, it is difficult to imagine an applied career for aspiring young health professionals that offers brighter prospects. Clinical informatics resides within a vortex of rapid changes in technology, scientific discovery, health-related information and communications applications, and rising expectations for improvements in health and healthcare. At the same time, legacies from the past continue to create inertia against desired changes. Thus, there is a need for well-educated and energetic informatics talent committed to moving health and healthcare forward. People who can span boundaries by combining specialized and general knowledge and skills will remain essential for continuing "sense-making" in environments where timely access to the right information at the right time can prove life-sustaining.

The details regarding the creation of the clinical informatics subspecialty are arguably less important than the larger lesson. Despite a 50-year history, clinical informatics is young and only now coming into its own as a broadly recognized professional discipline. The steps required to advance the cause were time-consuming, arduous, and met by setbacks along the way. But the dominating logic of recognizing the importance of informatics to our health and health care systems has inspired persistence on the part of the prime movers in the process and influenced the reception that the field has garnered as more people learn about its substance and strategic importance. Its broad interdisciplinary nature, coupled with a commitment to interprofessional training and exchange, is a model for others to follow as many people in health and medicine strive to break down traditional silos and to promote the inclusiveness and openness that are essential for the health of our people and the future of our world.

Questions for Discussion

1. What distinguishes the clinical informatics subspecialty from other medical subspecialties?
2. How does the emergence of the clinical informatics subspecialty reflect the evolution in understanding of what constitutes the practice of medicine?
3. How does clinical informatics enable achievement of this broader understanding of medical practice?
4. How might one characterize the clinical and public health (as opposed to technical or administrative) content of the field of clinical informatics?
5. If a healthcare institution lacks clinical informatics expertise, how would you convincingly explain to its leaders the rationale for recruiting a suitably trained expert to join their team?
6. How have the challenges facing clinical informaticians changed over the past decade and what challenges do you expect to see in the next decade?
7. What do you consider to be the biggest challenge facing the clinical informatics discipline?

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