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Original Article

Different tracks for pathology informatics fellowship training: Experiences of and input from trainees in a large multisite fellowship program

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Abstract

Background: Pathology Informatics is a new field; a field that is still defining itself even as it begins the formalization, accreditation, and board certification process. At the same time, Pathology itself is changing in a variety of ways that impact informatics, including subspecialization and an increased use of data analysis. In this paper, we examine how these changes impact both the structure of Pathology Informatics fellowship programs and the fellows' goals within those programs. **Materials and Methods:** As part of our regular program review process, the fellows evaluated the value and effectiveness of our existing fellowship tracks (Research Informatics, Clinical Two-year Focused Informatics, Clinical One-year Focused Informatics, and Clinical 1 + 1 Subspecialty Pathology and Informatics). They compared their education, informatics background, and anticipated career paths and analyzed them for correlations between those parameters and the fellowship track chosen. All current and past fellows of the program were actively involved with the project. **Results:** Fellows' anticipated career paths correlated very well with the specific tracks in the program. A small set of fellows (Clinical – one or two year – Focused Informatics tracks) anticipated clinical careers primarily focused in informatics (Director of Informatics). The majority of the fellows, however, anticipated a career practicing in a Pathology subspecialty, using their informatics training to enhance that practice (Clinical 1 + 1 Subspecialty Pathology and Informatics Track). Significantly, all fellows on this track reported they would not have considered a Clinical Two-year Focused Informatics track if it was the only track offered. The Research and the Clinical One-year Focused Informatics tracks each displayed unique value for different situations. **Conclusions:** It seems a "one size fits all" fellowship structure does not fit the needs of the majority of potential Pathology Informatics candidates. Increasingly, these fellowships must be able to accommodate the needs of candidates anticipating a wide range of Pathology Informatics career paths, be able to accommodate Pathology's increasingly subspecialized structure, and do this in a way that respects the multiple fellowships needed to become a subspecialty pathologist and informatician. This is further complicated as

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Pathology Informatics begins to look outward and takes its place in the growing, and still ill-defined, field of Clinical Informatics, a field that is not confined to just one medical specialty, to one way of practicing medicine, or to one way of providing patient care.

Key words: Clinical informatics training, clinical informatics, fellowship tracks, informatics fellowship training, informatics teaching, pathology informatics fellowship, pathology informatics training, pathology informatics

BACKGROUND

Pathology and Informatics

The fundamental role of Pathology is the study of fluids and tissues, looking for the presence and nature of disease. Pathology, as a field, provides the health system with accurate, relevant, and actionable information upon which clinical decisions can be made. As our understanding of disease has grown and become more complex, Pathology itself has responded in a least two important ways. It has become increasingly subspecialized, and it has increasingly applied informatics to more effectively analyze, classify, manage, integrate, and communicate the growing amount of complex information pathology labs generate.

Pathology Informatics is the study and management of pathology information, information systems, and processes. It is often considered a pathology subspecialty in its own right; however, if it is a subspecialty, it is highly atypical for at least two reasons: (1) it itself has deep and distinct subspecialties (e.g., vocabularies, data modeling, and analysis) and (2) it is embedded in virtually all other pathology subspecialties because of the profound and widespread relationship between Pathology and information. In many ways, informatics is a necessary and inseparable ingredient of Pathology, not a unique subsection of it.

The number of distinct informatics subspecialties and the broad scope of the field as a whole have significant implications for the fellowship level teaching of Pathology Informatics. A fellowship program must be able to teach both deep understanding of the subspecializations, as well as reasonable common knowledge sets across the breadth of the field. Furthermore, while it must be able to provide support for the goals of fellows seeking primarily informatics careers, such as a departmental Director of Pathology Informatics, a Chief Pathology Information Officer in a healthcare system, and even perhaps a Chief Information Officer, a fellowship program must also, increasingly, be able to support the training of a pathologist seeking to apply informatics to a single Pathology and Laboratory Medicine subspecialty.

In this paper, we discuss the goals of the fellows in our program (who are also the authors of the paper) and why they sought informatics training. We examine the various tracks that have evolved in our program to support those goals, and discuss in particular a track that combines formal fellowship training in a traditional Pathology or Laboratory Medicine subspecialty with formal fellowship training in Pathology Informatics.

Fellowship Training in Pathology Informatics

Residency programs have been teaching some level of Pathology Informatics since the early 1990s.[1-6] To our knowledge, the first formal fellowship in Pathology Informatics was established at the University of Pittsburgh in 1995 and Pittsburgh remained the only such program for many years. Recently, several other programs have been developed and as of April 2012, the Association for Pathology Informatics lists five non-ACGME accredited fellowship programs on its web site: Henry Ford Health System, Johns Hopkins Hospital, Partners HealthCare, University of Michigan, and University of Pittsburgh.[7] In the 2011-2012 academic year, these programs are training, in aggregate, ten active fellows.

Relevant Aspects of our Pathology Informatics Fellowship Training Program

Our Pathology Informatics fellowship program was established in 2007 (with the first fellow entering in 2008). It is a multiple site program that operates across two large academic medical centers and a large community hospital with a strong outreach practice. The fellowship is overseen by our healthcare system's Educational Committee that is responsible for all Graduate Medical Education throughout the system. It a has a formal charter, known as the "Program Description and Written Curriculum," that defines the structure and operation of the program and has been approved by the program director, the individual pathology departments, and the Educational Committee. This acceptance of the program's charter by the Educational Committee represents the healthcare system Graduate Medical Education Committee's (GMEC) approval of the program. Details of the fellowship program have been previously published.[8]

The program has 11 active faculty members and several additional associate faculty members distributed across the three main sites of the fellowship. Eight of the eleven faculty members are considered "clinical" faculty and practice a broad range of subspecialties within Pathology and Laboratory Medicine, combining their informatics

skills with their subspecialty knowledge. Three of the eleven faculty members are purely research based.

The fellowship program employs several key educational components that work together to prepare fellows to become pathology informaticians:

Operational Rotations
Fellows work with faculty and information services teams on active, usually complex, long-term projects in the department or health system in specific areas of informatics (e.g., data management, LIS operations, imaging, etc.).

Research Rotations
Fellows work in informatics research facilities under the mentorship of faculty.

Clinical Concentrations
Fellows attend traditional Pathology or Laboratory Medicine conferences in a subspecialty of the fellow's interest.

Core Didactic Course
Fellows attend a required, 92-hour series of didactic sessions taught by the fellowship program director over a two-year cycle. The course is guided by a formal curriculum and has a curated, comprehensive reading list covering the scope of Pathology Informatics (details of the core curriculum and didactic course have been submitted for publication).[9]

Retreats
Fellows attend a series of required, day-long, group activities taught by program and visiting faculty focused on decision making, management, and governance issues relevant to the practice of clinical (operational) and research Pathology Informatics.

Operational rotations, research rotations, and clinical concentrations are individualized to meet the interests and expected career paths of each fellow. An individualized schedule of rotations is developed in a series of meetings between each fellow and the program director, a process that starts before the fellowship begins and is fine-tuned throughout the remainder of the fellow's training. The overall goal is to provide a relatively specialized educational experience that fits the interests and needs of each candidate.

There are also required, standard components of the fellowship, including the core curriculum, core didactic course, and attendance at the retreats. These are designed to provide a broad, common informatics knowledge base across the entire field, independent of individual fellow interests (and ultimately career path). Together, the rotations and didactics are expected to create both specialization and a core breadth of knowledge in Pathology Informatics.

Tracks

In the current academic year (2011-2012), there are seven active fellows in the program. Most will have a two-year training experience in informatics, yet for each fellow, the experience will be different. These differences arise not only because fellows have selected different sets of operational rotations, research rotations, and clinical concentrations, but also because the program provides different structural alternatives within the program. These structural alternatives – or tracks – have evolved in the program because, in our experience, specific groups of fellows have distinct anticipated career paths and/or have prior experiences that require a different type of informatics fellowship.

To date, four distinct fellowship tracks have evolved since the establishment of the program.

When the program began in 2007/2008, it offered two basic options: a one or two-year clinical track with operational, research, and clinical concentrations, or a one or two-year research track with research rotations and an optional clinical concentration. The core didactic course was not established until 2010, with the core curriculum and retreats following in 2011.

Today, the program offers four distinct tracks [Table 1]:

The Clinical (Two-Year) Focused Informatics Track
This track is primarily designed for pathologists interested in a clinical career with a primary focus on Pathology Informatics. Graduates pursue positions such as a departmental Director of Pathology Informatics or Chief Pathology Informatics Officer within a healthcare system. The clinical two-year track involves operational and research rotations, a clinical concentration, the core didactic course, and the retreats.

The Research Track
This track is a one or two-year program for fellows interested in a career as a researcher in Pathology Informatics. The fellow focuses on mentored research in one or two related laboratories in an area of interest to the fellow. The research track includes research rotations, the core didactic course, and the retreats. Operational rotations and clinical concentrations are optional.

The Clinical (One-Year) Focused Informatics Track
This track, while not preferred over the two-year track, does fill some important needs. It has been used for pathologists who are already accomplished within the field of Informatics and for mid-career pathologists willing to commit one year for informatics training, but for personal, family, or practice reasons, cannot commit to two. For example, we have used this track to support a senior Forensic Pathologist taking a year from his career to learn informatics, and will use it to support a pathologist who has already completed a Ph.D. in Biomedical Informatics but who would like to have an additional year

Table 1: Pathology Informatics Fellowship Tracks

Track	Type	Career target	Core curriculum	Clinical concentration	Operational rotations	Research rotations
2-Year	Clinical	Director of pathology informatics, CPIO, CMIO	Required	Required	Required	Required
1-Year	Clinical	Pathology informatician, see text	Required	Optional	Required	Optional
1 + 1	Clinical	Subspecialty pathologist and informatician	Required	Required	Required	Required
Research	Research	Informatics researcher	Required	Optional	Optional	Required

Core Curriculum, Clinical Concentration, Operational Rotations, and Research Rotations make up the educational components of the Fellowship Program. CPIO: Chief pathology information officer, CMIO: Chief medical information officer

of clinical informatics training before taking an identified position at another institution. This track requires operational rotations, the core didactic course, and the retreats. Research rotations and clinical concentrations are optional. The one-year fellow is strongly encouraged to complete the two-year core course in one year through additional self-study and sessions with senior fellows or the fellowship director.

The Clinical 1 + 1 Specialty Pathology and Informatics Track

This track is designed for fellows planning subspecialty pathology careers in Pathology or Laboratory Medicine. These trainees plan to use their informatics training to enhance their subspecialty career and ultimately expect to advance into leadership roles within Pathology. The 1 + 1 track requires participation in two distinct fellowships at our healthcare system – a fellowship in a Pathology or Laboratory Medicine subspecialty and a one-year informatics fellowship. The fellowship experiences are linked, however, in two significant ways. First, during the traditional pathology fellowship, the trainees spend a significant portion of their elective time participating in informatics projects associated with their clinical specialty, and during the informatics fellowship the fellows spend some of their time working in their clinical subspecialty (through the clinical concentration, see above). Second, the fellows attend both years of the core didactic course throughout the entire length of both fellowships (the course is taught early in the morning to facilitate this) and participate in as many retreats as possible.

The Clinical 1 + 1 Subspecialty Pathology and Informatics track is now our most popular fellowship option.

The Potential Impact of Clinical Informatics as an ABP/ACGME Subspecialty

Last year, the American Board of Medical Specialties, American Board of Preventative Medicine, American Board of Pathology, and the Accreditation Council for Graduate Medical Education (ACGME) announced plans to make Clinical Informatics an officially recognized subspecialty, complete with ACGME accreditation and board certification.[10] It is likely that this decision will ultimately increase the number of Pathology Informatics fellowship programs. However, while the final decisions are not available, it is likely there will be rules pertaining to the structure and term of an accredited fellowship program, and it is possible that such rules might limit some level of innovation, such as our 1 + 1 track, in what is still a very immature field.

In fact, in 2009 the American Medical informatics Association (AMIA) published two documents (white papers) in anticipation of a medical subspecialty of Clinical Informatics and associated fellowship programs.[11,12] One of those documents, "Program Requirements for Fellowship Education in the Subspecialty of Clinical Informatics"[11] recommended both a required two-year clinical fellowship and that candidates not be allowed to begin their fellowship until after completion of their primary residency requirements.

MATERIALS AND METHODS

In our Pathology Informatics Fellowship Training Program, the fellows meet weekly as a group with the Program Director. One of purposes of this weekly conference is to evaluate the program, specifically addressing whether it is meeting, or not meeting, the needs of the fellows and the field. Last fall, as part of this evaluation, the group began discussion on whether the four tracks that had evolved in the program were valuable and appropriate. After several weeks, the fellows decided to formalize their discussion by documenting and analyzing information on their educational backgrounds, informatics experiences, anticipated career goals, and informatics fellowship tracks. They also answered and commented on three questions as discussed in the results section.

All seven active fellows in our program and both of the graduates of our program (one graduated in 2009 and one in 2010) participated in the study and are authors on this paper. This represents a large majority of all active pathology informatics fellows in the country (to the best of our knowledge, including our seven active fellows, there are now a total of 10 fellows actively training in

formal non-ACGME pathology informatics programs in the country).

RESULTS

Educational Background

The educational background of our fellows is presented in Table 2. All completed an undergraduate degree in an area of science (physical, biological, or social sciences) or engineering. Seven of nine have either a Masters or PhD, including areas such as Biomedical Informatics, Biomedical Science, Public Health, and Structural and Computational Biology.

Post-Graduate Medical Training

Residency and fellowship training is presented in Table 3. Eight of nine fellows completed pathology residency. One, a fellow on the research track, did a residency in nephrology. Amongst the pathologists, four completed a combined residency in Anatomic and Clinical Pathology, three competed residency in Clinical Pathology and one completed residency in Anatomic Pathology. Five of the fellows served as Chief Resident during their residency. The nine fellows will, by the end of their training, have completed 16 separate fellowships representing 20 years of post-graduate medical training after residency. Significantly, two fellows used elective time from their pathology residency to complete a portion of their informatics fellowship.

Informatics Experience Prior to Fellowship

Eight of the nine fellows reported exposure to informatics during residency through elective rotations or projects [Table 4]. Four of nine had previous practical experience with informatics in academics and industry, with two fellows having created and run informatics-related companies prior to their fellowship. One fellow had previously performed a one-year research fellowship in Pathology Informatics.

Anticipated Career Goals and Informatics Fellowship Tracks

Anticipated career goals, defined here as the career the fellow wished to pursue upon entering the Pathology Informatics fellowship, are shown in Table 5. A majority of the informatics fellows in the study (5 of 9) planned a subspecialty pathology career in which they would use their informatics training to enhance their future Anatomic, Clinical, or Molecular Pathology practice. They all expressed desires to eventually advance into leadership roles in their respective fields. Three of the nine fellows entered fellowship wishing to pursue a clinical career focused primarily on informatics, for example as Directors of Pathology Informatics or eventually as Chief Medical Information Officers or Chief Pathology Information Officers. One fellow was interested in an informatics-based research career in Pathology. All of the fellows had a specific focused interest within informatics and there was a strong preference for continued research and involvement with academic medicine among almost all the fellows.

Table 5 also shows a close correlation between anticipated career goals and informatics fellowship track. All five of the fellows planning a subspecialist career in Pathology or Laboratory Medicine (enhanced with informatics) chose the Clinical 1 + 1 Subspecialty Pathology and Informatics

Table 2: Fellows' educational background

Fellow	Undergraduate school major and degree	Graduate school major and degree	Medical school (M.D.)
1	University of Chicago B.A. Anthropology	University of Chicago M.A. Social Sciences	University of Chicago
2	Boston University B.A. Medical Science	None	Boston University
3	Massachusetts Institute of Technology S. B. Chemistry	Vanderbilt University Medical Management Certification	New York Medical College
4	Massachusetts Institute of Technology S. B. Biology	Washington University M.A. Biomedical Science	Washington University
5	Hofstra University B. S. Biomechanical Engineering	Rockefeller University Ph.D. Structural and Computational Biology	Cornell
6	Boston University B. S. Biomedical Engineering	University of California, San Francisco M.S. Biomedical Informatics	Tufts
7	Boston University B.A. Anthropology	Harvard School of Public Health M.P.H.	Harvard
8	Massachusetts Institute of Technology S. B. Biology	Boston University M.A. Medical Science, Ph.D. Pathology	Boston University
9	Londrina State University, Brazil M. D. Medicine*	University of Tokyo Ph.D. Nephrology	Londrina State University, Brazil

Educational background includes undergraduate, graduate (non-medical), and medical degrees. *Denotes M.D. awarded as an undergraduate degree, training outside U.S.A. B.A.: Bachelor of arts, B.S.: Bachelor of science, M.A.: Master of arts, M.D.: Doctor of medicine, M.P.H.: Masters of public health, M.S.: Masters of science, Ph.D.: Doctor of philosophy, S.B.: Bachelor of science

Table 3: Fellows' medical postgraduate education

Fellow	Residency, type, and location	Chief resident	Fellowship, location, and length
1	Pathology, AP/CP, University of Chicago Medical Center	Yes	Pathology Informatics, University of Chicago, 1 year Pathology Informatics, Partners, 2 years
2	Pathology, AP-only, Mount Sinai Hospital	No	Pathology Informatics, Partners, 1 year
3	Pathology, AP/CP, University of Massachusetts Medical Center	Yes	Forensic Pathology, NYC OCME, 1 year Pathology Informatics, Partners, 1 year
4	Pathology, CP-only, Massachusetts General Hospital	Yes	Clinical Chemistry, MGH, 1 year* Pathology Informatics, Partners, 1 year
5	Pathology, CP-only, Brigham and Women's Hospital	Yes	Pathology Informatics, Partners, 1 year** Molecular Genetics, Harvard, 1 year Transfusion Medicine, Harvard, 1 year
6	Pathology, AP/CP, Tufts-New England Medical Center	No	Pathology Informatics, Partners, 1 year Molecular Genetics, Harvard, 1 year
7	Pathology, CP-only, Massachusetts General Hospital	Yes	Pathology Informatics, Partners, 1 year** Clinical Microbiology, MGH, 2 years
8	Pathology, AP/CP, Massachusetts General Hospital	No	Hematopathology, MGH, 1 year Pathology Informatics, Partners, 1 year
9	Nephrology, University of Sao Paulo, Brazil	No	Pathology Informatics, Partners, 2 years

Past, current, and future fellowships are provided in the last column in the table above; fellowships are listed per fellow in order of completion. *Fulfilled requirements for non-ACGME accredited Clinical Chemistry fellowship during third year of residency. **A portion of the pathology informatics fellowship completed during residency. AP: Anatomic pathology, CP: Clinical pathology, NYC OCME: New York City Office of Chief Medical Examiner

Table 4: Fellows' informatics experience prior to informatics fellowship

Fellow	Graduate school projects	Medical school projects	Residency projects	Residency rotation	Other informatics experience
1	-	-	Yes	Yes	Prior pathology informatics fellowship
2	-	Yes	Yes	-	IT Industry
3	-	-	Yes	-	IT Industry
4	-	Yes	Yes	Yes	-
5	Yes	Yes	Yes	-	IT Industry
6	Yes	-	-	Yes	-
7	Yes	-	Yes	-	-
8	-	-	Yes	Yes	-
9	Yes	-	-	-	-

For the purpose of this table, "project' was not specifically defined. IT: Information technology

track. The fellows interested in a clinical career primarily focused in informatics (3 of 9 fellows) chose either the clinical (one or two-year) focused informatics tracks.

The two fellows in the Clinical one-year Focused Informatics track are worth further discussion. One was the first fellow in the program, who, after that one year, accepted a Director of Informatics position. The second is a mid-career Forensic Pathologist with years of clinical, leadership, administrative experience who joined our fellowship to add informatics knowledge to his already extensive skill sets. In both cases, these fellows chose to do only a single year of fellowship as they each had significant family and/or professional concerns that would have made an additional second year of training a significant burden.

Notably, the first job accepted after fellowship correlates significantly with the program's different informatics fellowship tracks. Between our seven active fellows and two graduates, five have accepted a non-training, post-fellowship position (four of five at different institutions). The fellow in the Research track took a research position; the fellows in the Clinical 1 + 1 Subspecialty Pathology and Informatics track took positions in Molecular Pathology and Microbiology, both with strong informatics components; and the fellows from the Clinical (one and two year) Focused Informatics tracks accepted leadership

and administrative director positions in Pathology Informatics.

Fellow Support for the Multiple Educational Tracks in the Fellowship Program

As part of this study, the fellows asked themselves three questions concerning the presence of the four educational tracks in the fellowship program:

"Is there value, to the fellows and to the field of pathology, in having the four tracks that have evolved in our Pathology Informatics fellowship?"

"Does the 1 + 1 Track (Subspecialty Pathologist and Informatics career path) have significant value to Pathology?"

"Would I have agreed to a formal, two-year informatics-only fellowship (the Clinical two year Focused Informatics Track or a two Research Informatics Track) if that was the only option for training in informatics?"

In response to the first two questions, all fellows (9 of 9) answered in the affirmative [Table 6].

In the response to the third question, only three of the nine fellows answered affirmatively [Table 6]. Of these three, one was a research fellow planning a research career in informatics (Fellow 9). The other two (Fellows 1 and 2) anticipated, and accepted, positions as Directors of Pathology Informatics at large academic medical centers.

Significantly, the majority of fellows (6 of 9) would not have entered into an informatics fellowship without an option that limited intense informatics training to one year (the Clinical one-year Focused Informatics track or the Clinical 1 + 1 Subspecialty Pathology and Informatics track). There were several reasons behind the fellows' preference for a one-year option, including the fact the majority of these fellows planned multiple fellowships, typically a one or two-year fellowship in a Pathology or Laboratory Medicine subspecialty in addition to the informatics fellowship. Given that these fellows planned careers primarily practicing pathology in their subspecialty and wished to use their informatics training to mainly to enhance their subspecialty career, a second year of intense informatics training seemed an unwarranted burden.

Table 5: Fellows' career goals

Fellow	Fellowship track	Anticipated career (Start of fellowship)	Actual position accepted (Out of fellowship)
1	Clinical 2-Year	Director of pathology informatics	Director of pathology informatics
2	Clinical 1-Year	Director of pathology informatics	Medical director of informatics
3	Clinical 1-Year	Medical leadership/Pathology informatician	Still in training
4	Clinical 1 + 1	Subspecialty pathologist and informatician	Still in training
5	Clinical 1 + 1	Subspecialty pathologist and informatician	Still in training
6	Clinical 1 + 1	Subspecialty pathologist and informatician	Molecular pathologist/Assistant director of pathology informatics
7	Clinical 1 + 1	Subspecialty pathologist and informatician	Clinical microbiology pathologist/Informatician
8	Clinical 1 + 1	Subspecialty pathologist and informatician	Still in training
9	Research	Informatics research	Research informatician in FISH imaging/Genomics

Both anticipated career paths and the actual job positions accepted by the fellows are presented above. Four fellows (still in training) have not yet begun or were in the process of applying for positions at the time of the study. FISH: Fluorescence *in situ* hybridization

Table 6: Fellows' perceived value of and commitment to different pathology informatics tracks

Fellow	Fellowship track	Question 1: Is there value to having four pathology informatics fellowship tracks?	Question 2: Does the clinical 1+1 subspecialty pathology and informatics track add significant value to pathology?	Question 3: Would you commit to a 2-year "Informatics only" fellowship if it was the only option available?
1	Clinical 2-Year	Yes	Yes	Yes
2	Clinical 1-Year	Yes	Yes	Yes
3	Clinical 1-Year	Yes	Yes	No
4	Clinical 1+1	Yes	Yes	No*
5	Clinical 1+1	Yes	Yes	No*
6	Clinical 1+1	Yes	Yes	No
7	Clinical 1+1	Yes	Yes	No*
8	Clinical 1+1	Yes	Yes	No
9	Research	Yes	Yes	Yes

Fellows were asked the three questions above and their answers logged. *Indicates Fellow would consider two-year informatics only program if informatics elective time in residency counted towards the two year requirement

Some fellows had significant prior experience in informatics, including industry and/or significant graduate school experience in informatics. In these cases, a single year devoted to the clinical nature of Pathology Informatics seemed useful, whereas two years did not.

Some fellows questioned whether two years dedicated solely to informatics training could be used in other useful ways, such as getting an advanced graduate degree (MA or PhD) in Biomedical Informatics, especially as their primary career goal (upon entering fellowship) was not to be a Director of Informatics.

Finally, for the fellows who wished to have a subspecialty Pathology career with some informatics, an additional (second) year of informatics training represented potentially significant financial and/or family burdens.

DISCUSSION

Snapshot of the Fellowship Program and the Goals of the Fellows

The structure of our program includes weekly continuous improvement discussions between our fellows and the director.[8] Over the past several years, these discussions have resulted in multiple developments, including a core didactic course with a comprehensive formal curriculum and curated reading list[9] and a series of Pathology Informatics management retreats. The study described in this manuscript was initiated through these same continuous improvement sessions, with the initial goal of the study to determine if the structure of our program, and more specifically the fellowship program tracks, were meeting the needs of the fellows.

To that end, the fellows documented their educational backgrounds, informatics experience prior to residency, informatics experience in residency, their track within the fellowship, and their pathology and informatics career goals. The two recent graduates of the program were also included, with the data representing a total of nine recent and active Pathology Informatics fellows.

Review of the data reinforces certain aspects about the fellows we already knew. For instance, Pathology Informatics fellows have deep educational backgrounds, with seven of nine holding MAs or PhDs. All of them (in our sample) became involved with informatics prior to their fellowship. This involvement was often extensive, including jobs in the IT industry, prior fellowships, and advanced graduate degrees in informatics [Tables 3 and 4].

Significantly, eight of nine fellows were involved with meaningful informatics projects in residency, with four fellows taking structured informatics rotations during residency. The only fellow who was not involved with informatics during residency was a research fellow who, uniquely, was trained in nephrology (never did a pathology residency) and became involved with informatics as part of a research career.

The background data most important in understanding the evolution of our fellowship program surrounds the large number of informatics fellows who also chose to perform fellowships in other pathology subspecialties. Of the nine fellows, six have, or will, complete at least one non-informatics fellowship as part of their training. We feel this has significant implications for Pathology Informatics fellowship programs and the relationship of informatics and the rest of Pathology (see below).

The Value of the Four Tracks

The fellows were unanimous in their support of the multiple track structure of the fellowship program. There was agreement on the value of a research track for physician researchers in Pathology Informatics (or physician researchers that want to move into Pathology Informatics). There was also agreement on the value of a one-year clinical focused informatics track, but the reasons were more varied. While there was agreement that the Clinical two-year Focused Informatics or the Clinical 1 + 1 Subspecialty Pathology and Informatics track should be preferred overall, actual and future potential scenarios have made, and will continue to make, a one-year track valuable (some of the real world scenarios we have experienced are discussed in the Results section).

There was general agreement, however, that the Clinical two-year Focused Informatics track and the Clinical 1 + 1 Subspecialty Pathology and Informatics track were the most important tracks in the program. These tracks attract two different groups of pathologists with very different career goals, and represent two very different, but complementary, views of the future of Pathology Informatics.

The Clinical Two-Year Focused Informatics Track

The Clinical two-year Focused Informatics track was designed for fellows anticipating a clinical career primarily in Pathology Informatics, leading to an informatics directorship position in a pathology department or a Chief Medical Information Officer in a health system. These are the trainees that one traditionally thinks of when developing a clinical fellowship in Pathology Informatics, with both the candidate's career goals and training very much aligned to the potential ACGME accredited subspecialty of "Clinical Informatics" envisioned by the American Board of Medical Specialties, American Board of Preventative Medicine, American Board of Pathology, and the Accreditation Council for Graduate Medical Education (ACGME).[10] Furthermore, the way the track is structured and implemented is very similar to the implementation of a "Clinical Informatics" fellowship proposed by the AMIA in a series of publications in 2009.[11,12] Candidates for the Clinical two-year Focused Informatics track are looking for an informatics intense

experience and are willing to sign on for a two-year, informatics only, commitment.

Fellows in the Clinical two-year Focused Informatics track are very important to the program. Their continuous, two-year perspective provides continuity to the program and they can serve as senior informatics fellows (similar to a Chief Resident in residency programs). Furthermore, there is a clear need for focused, pathology informaticians in pathology departments to help guide departmental level informatics projects, manage laboratory and departmental systems, and interact with enterprise level informatics or Information Technology initiatives and personnel. In larger, multi-hospital healthcare systems, there may be an eventual need for a pathology informatician to act in a similar role as a Chief Medical Information Officer, but instead focusing on Pathology Informatics related matters as a Chief Pathology Information Officer. To date, graduating fellows seeking directorship positions have been able to find jobs [Table 5].

The Clinical 1 + 1 Subspecialty Pathology and Informatics Track

The Research track and the Clinical (one or two year) Focused Informatics tracks are central to our fellowship program; however, over the past several years we have seen a third major group of fellows drawn to informatics for a different reason. Instead of following a traditional "Director" path as discussed above, these fellows want to use informatics to enhance a subspecialty career in Anatomic, Clinical, or Molecular Pathology, with the possibility of advancing to future leadership roles within Pathology. For instance, they include the fellow who wants to run a core, Clinical Pathology laboratory (e.g. Clinical Chemistry) and needs informatics knowledge to improve the laboratory operations; or the fellow who seeks a primary career signing out hematopathology cases, but secondarily also wishes to have knowledge concerning data quality, structured data, and image analysis in order to eventually enrich and improve her practice.

The issue, as we see it, is that this third group of pathologists is potentially large and very important to Pathology, especially given the highly technical, information-heavy nature of our field. The majority of our fellows (6 of 9) and virtually our entire clinical faculty (7 of 8, see Background) are part of this group. Many had extensive informatics skills prior to becoming pathologists (as undergraduates, in graduate school, or industry) and now seek to use these skills for very specific purposes in their careers. Our data [Table 6] indicates that they will definitely do a single year of informatics fellowship training (or do an ACGME approved "specialty year" as part of their residency), but requiring two years of dedicated informatics training on top of the one to two years of subspecialty pathology training is considered a high burden. In fact, our data indicates that if the only option for informatics training was a required, two-year "informatics only" fellowship, we could imagine a scenario where the number of informatics trained pathologists would decrease substantially (in our case by 67%), even if the two-year commitment led to a board certification in clinical informatics.

The solution that has evolved in our fellowship for this large group of pathologists is the Clinical 1 + 1 Subspecialty Pathologist and Informatics track. As discussed above, in this track a candidate does two fellowships, consisting of at least one year of a Pathology or Laboratory Medicine subspecialty and a single year immersion in Pathology Informatics. These two fellowships are linked together through multiple mechanisms, including (1) the two-year core curriculum and didactic course in Pathology Informatics, (2) appropriate informatics projects during elective time in the subspecialty fellowship, (3) two years of informatics management retreats, and (4) subspecialty activities as part of the "clinical concentration" during the informatics year.

The 1 + 1 track is currently our most popular track (5 of 9 fellows) and we believe that demand for this track will continue to grow given the expanding use of data management, analysis, and computation in virtually all of the pathology subspecialties. Furthermore, as subspecialization continues to gain traction throughout Pathology and more job opportunities require subspecialty fellowship training, this track will continue to provide advanced pathology subspecialty and informatics training within a reasonable time commitment.

Finally, programs like the 1 + 1 track may have an important, long-term effect in both the fields of Pathology and Pathology Informatics. As 1 + 1 fellows progress through their career, we expect they will eventually bring deep informatics insight and experience to traditional leadership positions in Pathology.

The Applicability of our Data and Conclusions

This study focused on the experiences and opinions of a group of fellows from a single Pathology Informatics fellowship program. There were several reasons for this, not the least of which is that the manuscript began as internal discussions on how well this single program was serving the needs of its fellows. That said, even though we are only one of the five formal Pathology Informatics training programs in the country, our survey's nine fellows represent a fairly large sample of all active and graduated Pathology Informatics fellows from the past four years (to the best of our knowledge, 9 of 13 total fellows).

We fully intend to extend this avenue of research to include others, including other fellowship programs, future fellows in our own program, pathology residency programs, and employers that may be seeking to hire pathology

informaticians. During this time when Pathology is considering incorporating Pathology Informatics within the formal subspecialty of (General) Clinical Informatics, we feel that the voices of active and recently graduated Pathology Informatics fellows' are particularly important. They have committed one or more years of their lives training in this field, and they likely have insights into its formalization that others may not fully appreciate.

CONCLUSIONS

Compared with Pathology as a whole, Pathology Informatics is a very new field. It is a field that is still defining itself and its relationship with Pathology as a whole, even as it begins formalization, accreditation, and likely board certification. Examination of our training program – its structure and fellows – indicates that this relationship is growing and becoming more granular (from an operational tool at the department level to an analytical tool aligned with subspecialty practice) and that fellowship programs are evolving to meet these growing needs.

It seems clear from our internal evaluation of our Pathology Informatics training program that a "one size fits all" fellowship structure is becoming increasingly suboptimal. Looking towards the future, a fellowship program in Pathology Informatics must be able to accommodate the needs of fellows anticipating a wide range of Pathology-based career paths. It must also be able to accommodate itself within the increasingly subspecialized structure of Pathology today. Furthermore, Pathology Informatics must also be outward looking and take its place in the growing, and still ill-defined, field of Clinical Informatics, given that Clinical Informatics is not confined to just one medical specialty, to one way of practicing medicine, or to one way of providing patient care. The Pathology Informatics training programs of the future must be organized, structured, and efficient in order to train fellows that can support the informatics needs of pathology subspecialties, pathology departments and, through Clinical Informatics, the needs of hospitals and health systems – and do so in a way that respects the increasingly long time commitments needed to become a subspecialty pathologist and pathology informatician. In this paper we have discussed our fellowship program's initial response to this challenge in the form of a number of complementary fellowship tracks optimized to the career goals of our fellows, connected by the teaching of a core common knowledge set and experiences.

Given the rate of change in Pathology and in Healthcare, informatics training that covers the fundamental nature of information, information systems, and processes that generate, use, and communicate information must itself be dynamic in nature. In fact, we believe that the best scenario, especially at this early stage of Pathology Informatics development, is one where we continually evaluate the needs of our fellows and our field – and allow training that evolves to fit these needs.

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