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Resident Training in Clinical Chemistry

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Introduction

Clinical chemistry is broadly defined as "the chemistry of human health and disease" or "chemistry in connection with the management of patients, as in a hospital laboratory".[1] With advances in technology and the rise of modern medicine, the evolving disciplines of biochemistry and medicine found a common purpose in the development of formal clinical laboratories in the hospital setting.[2] At the present time, clinical chemists are primarily responsible for maintaining a wide array of testing services in the hospital laboratories – especially many of the high volume tests (e.g., basic metabolic panels, liver function tests).

The roles and daily responsibilities of the clinical laboratory director (and clinical chemist specifically) extend far beyond these simple definitions. George Lundberg has previously outlined the competency characteristics of laboratory directors, which include effective administration of laboratory services, strategic planning, defining standards of performance, and research and development.[3] Additional characteristics included communication of laboratory data, functioning effectively with regulatory and administrative groups, and providing educational direction.[3] Indeed, the behavioral objectives of clinical chemists, first thoroughly defined by Myrton Beeler in 1972, are remarkably accurate even today.[4] In 1995, Peter Wilding described the modern role of clinical chemists to include being "managers of a diagnostic service, laboratory personnel, technology acquisition and deployment, budget processing, and the business of laboratory operation," with specific needs for "efficiency…, proficiency, economy, awareness of legislation, and an obvious willingness to participate as a member of the healthcare team."[5]

With such a diverse set of roles and responsibilities, it is reasonable to inquire about how we should optimally train clinical chemists and also how we should teach clinical chemistry to pathology residents. What knowledge and skills should be acquired during pathology residency training? What should be included in a formal curriculum? What is the appropriate balance between didactic education and "bench" experience? How can one successfully integrate greater clinical consultation into chemistry rotations? Furthermore, as the vast majority of pathology residents are not interested in pursuing a career in clinical chemistry, what are the behavioral and educational objectives in training residents who perceive minimal or no future responsibility in clinical chemistry or other clinical pathology subspecialties (i.e. those interested in pursuing a primary career in anatomic pathology (AP), such as surgical pathology or cytopathology)?

The purpose of this article is to analyze the current state of clinical chemistry education in the United States, primarily through the analysis of anonymous, open-ended questionnaires

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completed by 52 practicing clinical chemists across the country. The article provides a glimpse of how clinical chemists currently perceive the training of the next generation of pathologists in this particular subspecialty. Many ideas for educational improvements were identified by survey respondents, as well as criticisms regarding aspects of clinical chemistry education that are not working particularly well. Many of these findings are generalizable to other subspecialties of clinical pathology (CP; also known as laboratory medicine). Hopefully through this analysis, readers will be able to compare their programs with national trends and identify new ways of improving clinical chemistry training at their institutions.

Background

Clinical chemists are trained in one of two ways.[6] Medical graduates typically enter clinical chemistry after the completion of residency training in CP. This pathway –the focus of the present article – is often combined with additional training in AP. In fact, the vast majority of pathology residents seek combined AP/CP training, with only a small minority (approximately 3%) seeking a CP-only career, and even fewer pursuing a career in clinical chemistry specifically.[7] AP and CP-only training programs are three years in duration; combined AP/CP residency programs are four years in duration, and many trainees who are interested in AP-oriented careers pursue CP certification as a means of enhancing their ability to obtain jobs in community practice. For example, a pathologist practicing at a community hospital may primarily do surgical pathology, cytopathology, or hematopathology but may have medical directorship over one or more clinical laboratories. It should be noted that for M.D. trainees pursuing a career in clinical chemistry, additional subspecialty certification is available from the American Board of Pathology (ABP), although it is generally not required to gain employment as a clinical chemist, and few MD-oriented clinical chemistry fellowships actually exist in the United States.

The second training pathway for clinical chemistry is geared towards Ph.D scientists. The American Board of Clinical Chemistry offers certification for those with doctoral or post-doctoral level training in programs accredited by the Commission for Accreditation in Clinical Chemistry (ComACC), or for those with 5 years of practical experience in clinical chemistry and prior Ph.D. training in a non-accredited program.

For medical graduates, specific training in clinical chemistry is mandatory for those seeking CP board certification. The ABP states that applicants must complete pathology training through an accredited program,[8] and the Accreditation Council for Graduate Medical Education (ACGME) notes specifically that CP education must include didactics in chemical pathology (another term for clinical chemistry), as well as other areas commonly associated with clinical chemistry, including training in the interpretation of laboratory data, clinical consultation, and education in laboratory management.[9] Several articles have described in detail how these residency programs can be organized.[10–13] How a trainee's time is divided into CP-associated subspecialties (chemistry, microbiology, transfusion medicine, immunology, etc) can vary significantly between programs.

Indeed, CP training as a whole differs dramatically across the county, in terms of time spent on rotations, topics covered, resident responsibilities, and even resident interest. Training in clinical chemistry has also encountered the challenge of how to effectively teach a field that is being impacted substantially by increased automation and ongoing technological advances. No studies have specifically looked at how clinical chemistry rotations across the country differ, and understanding the variety of these training paradigms seems essential to the prospect of improving clinical chemistry education in the future.

Survey Methods

In an effort to assess how clinical chemists view the current state of chemistry in resident education, an open-ended questionnaire was developed. This survey was distributed to a list of clinical chemistry faculty across the country. The American Medical Association Fellowship and Residency Electronic Interactive Database (*FREIDA;* http://www.ama.assn.org) was used to generate a list of 150 residency training programs under the specialty search of "Pathology - Anatomic and Clinical." For each pathology residency program, the residency and affiliated hospital websites were searched for M.D. and/or Ph.D. faculty listed as Directors of Clinical Chemistry or Chemical Pathology (including Assistant and Associate Directors).

In instances where no director was listed online, pathology faculty with job profiles associated with clinical chemistry responsibilities were identified (Therapeutic Drug Monitoring, Toxicology, Protein Electrophoresis, etc.). Many smaller programs listed faculty with primary AP training as having clinical laboratory responsibilities; in these cases those faculty were also selected to receive surveys. Additional training in clinical chemistry was sometimes evident through inclusion in the American Association of Clinical Chemistry Online Membership Directory [http://www.aacc.org]. Finally, at institutions where no clinical chemist was identified, surveys were sent to either a director of hospital laboratories or the residency director, with a request to forward the survey to the most appropriate person at that institution. For two institutions, more than one clinical chemistry faculty responded to the survey.

It should be noted that as it was our desire to gain a practical insight into how clinical chemists perceive residency education, surveys were therefore preferentially directed toward clinical chemists and (indirectly) away from residency directors. Survey results therefore may not represent the stated goals of residency training in clinical chemistry at a given institution, but rather the opinions of those actually practicing and teaching clinical chemistry.

Of the original 150 pathology residency programs, an appropriate faculty member was identified at 135 of these institutions. The questionnaire (see Table 1) was emailed to each of these faculty members; follow-up emails were sent after one to three weeks. 52 faculty members from 49 institutions returned surveys or agreed to a telephone interview for an overall 38.5% response rate. Non-responses may have been due to inadequate time for survey completion, lack of interest, incorrect contact information, or misidentification of clinical focus while compiling the list.

The survey questions were written to provoke detailed responses regarding attitudes toward clinical chemistry education. The respondents were asked to elaborate on any other issues of concern. The survey guaranteed anonymity in an effort to gain as open of a dialogue as possible. Many provided additional information, including rotation requirements and residency manuals. Overall, respondents were very enthusiastic to share their thoughts on clinical chemistry and resident education, and we were delighted to see such a willingness to work toward improved training in this field. Common and repeated themes present among the responses enabled the general quantifications presented throughout this article, despite the essentially non-quantitative nature of the original survey. Numbers provided should not be interpreted for purposes of statistical significance, but rather as guidelines for prevalence of opinion.

Survey Results and Discussion

What aspects of your clinical chemistry rotation work particularly well?

39% of respondents noted an emphasis on structured didactic review as critical to the success of their clinical chemistry rotations. Chapter by chapter textbook review was frequently mentioned, including *Clinical Diagnosis and Management by Laboratory Methods*[14], *Tietz*

Fundamentals of Clinical Chemistry[15], *Contemporary Practice in Clinical Chemistry*[16], and *Appleton & Lange's Outline Review Clinical Chemistry*[17]. This structured approach was noted to be ideal for CP board preparation purposes and defining the range of topics to be addressed in a given rotation, although it would not be desirable as a lone teaching modality. Others noted using specific articles from the literature as a way to stimulate discussion and to expose residents to current issues in clinical chemistry. A number of respondents mentioned specifically the recently proposed Academy of Clinical Laboratory Physicians and Scientists' (ACLPS) curriculum content guidelines as another way to guide the educational objectives of their clinical chemistry rotations.[18] These curriculum content guidelines are the logical next step beyond the Graylyn Conference Report, which recommended specific reforms in CP residency training.[19,20] The new curriculum guidelines, among other things, describe core competencies as well as chemistry-specific topics (divided into advancing tiers of skill level), and they provide an organized framework worth considering while evaluating an institution-specific clinical chemistry curriculum. It should be noted that a similar process of defining competencies and formalizing a clinical chemistry syllabus is ongoing in Europe.[21,22]

20% of respondents noted that reviewing case studies and/or correlation of selected results with actual patient history works well in educating residents. Multiple respondents noted that having the chemistry resident visit the clinical wards to review patient charts in selected cases was very engaging and informative. Additional tasks noted to be successful (but with lesser frequency) included involving residents in sign-out activities, on-call and clinical consultation responsibilities, individual discussion with faculty members, and attending daily rounds. The involvement of residents in evaluating esoteric and send-out testing provides an additional forum for the correlation of patient data with clinical history, and forces the resident to consider test appropriateness. An overly burdensome review policy, however, could hinder a resident's time available to other areas of clinical chemistry, so appropriate thresholds for review should be established and monitored.

At one institution, sign-out responsibilities include initial interpretation for most electrophoresis (serum, urine, CSF, lipids, and immunofixation), evaluation of toxicology unknowns, joint fluid reviews, and amino acid chromatograms. At other institutions, a range of molecular diagnostic tests are also initially reviewed by the chemistry resident. Sign-out responsibilities are by necessity constrained by the scope of testing within the clinical chemistry laboratory of a particular institution; for example, at some institutions, protein electrophoresis is done within immunology or another clinical laboratory. Nonetheless, most respondents noted at least some combination of clinical chemistry sign-out responsibility for pathology residents.

Having residents serve as the "first line of inquiry" in laboratory consultation is an ideal way of providing experience in how clinical chemistry interfaces with the various hospital services. Such responsibility initially requires supervision from professional staff, but as a resident's experience increases, many issues can be handled independently. Respondents at institutions with clinical chemistry fellowships noted that residents "share" first calls with fellows as they gain experience and familiarity. This notion of working toward independence, reiterated in many of the surveys, fits nicely with the overall goal of introducing graduated responsibility into CP education. Hobbs et al. have published a fascinating analysis of how an on-call system was successfully integrated into their clinical chemistry laboratory.[23]

A minority of respondents noted that clinical chemistry residents are placed in contact with outside departments, either serving as representatives at medicine or endocrinology conferences, or actually rounding with internal medicine subspecialty services. Residents are encouraged to research questions that they are not familiar with, as well as report back findings to the clinical teams.

These results acknowledge the broad range of successful teaching modalities used throughout clinical chemistry – indeed, most programs use a combination of these techniques to teach residents throughout their rotations.

Have you found especially effective methods to engage residents and integrate them into the clinical chemistry laboratory?

Active responsibilities such as on-call duties, case studies, rounds, sign-out responsibilities, and independent projects all ranked highly as effective ways to engage residents. Many programs mentioned specifically that weekly call-rounds provided an "integrated overview" of pathology where multiple subspecialties are considered together in the context of a patient's specific needs. Numerous respondents also emphasized the importance of daily and/or weekly meetings with the clinical chemistry faculty - to help guide resident progress and discuss relevant issues and case studies.

Resident attendance at routine meetings with laboratory staff, supervisors, and managers was also noted to be beneficial in providing exposure to the day to day operation of a clinical chemistry laboratory. An analysis of management training in pathology,[24] as well as descriptions of specific clinical laboratory management electives have been described in the literature and serve as models for topics that might be included in clinical chemistry rotations.[25–27] It should be emphasized that management training should in no way be considered limited to the clinical chemistry curriculum, although many residency programs place most or all of the management training within the clinical chemistry rotation. Finally, many respondents noted that resident presentation at regularly scheduled CP conferences, or as continuing education for the chemistry staff, was also a particularly valuable experience.

One respondent noted the value of "self testing" in engaging a resident's interest. In this educational model, a resident is required to "follow a specimen from order to result through the lab for a limited number of tests." The resident is permitted to use his or her own blood sample, or a surrogate sample from the laboratory, at their own discretion. The respondent noted that nobody had ever "opted out" from using their own blood, suggesting that the uniqueness of this experience successfully draws the resident into the laboratory; follow-up for abnormal findings is occasionally recommended. Most importantly, this approach emphasizes the entire process, including pre- and post-analytical components, and provides integration with didactic training and reading in clinical chemistry textbooks.

Another respondent noted a remarkably well-developed hands-on two week curriculum in the toxicology laboratory, where "residents begin at the bottom learning specimen procurement, extraction techniques, and the basic concepts in toxicology of primary analysis and confirmation…" In this curriculum, residents perform many of the assays in toxicology (with supervision), and are also assigned extensive independent reading. Other relevant issues, such as chain of custody, drug distribution, interpretation of therapeutic drug monitoring, and basic statistics and quality control are included in this approach.

It should be noted that the question of how to engage residents and integrate them into the clinical laboratory evoked a number of concerned responses. 10% of respondents mentioned that there was, in fact, no effective way to integrate residents into the clinical laboratory.

Many surveys mentioned the lack of resident interest in clinical chemistry in programs with predominately AP/CP trainees. Others noted a profound variability in resident capabilities when it comes to active responsibility. On-call and consultative roles are sometimes diverted away from trainees with poor communication skills and/or lack of interest in clinical chemistry, or those who do not respond promptly to pages, perhaps due to concurrent AP commitments. One might argue that these are the residents in the greatest need of acquiring these skills, as

the ability to effectively communicate with clinical staff is common to all subspecialties of pathology. As one respondent stated "the problem I have encountered is that the laboratory staff and clinicians are reluctant to call the residents, and tend to speak either to the technical staff or to one of the attending pathologists."

A number of respondents noted that multiple choice examinations (either during or after the rotation) are helpful ways to make sure that residents focus on course materials. Questions written in the style of the Pathology Resident In-Service Examination (RISE) or board examinations would have a dual purpose, and therefore might be resented less by residents. Another respondent noted the development of a specific evaluation rubric that "articulates specific competencies to be attained to achieve novice, advanced beginner, competent, and proficient status. The main areas of evaluation include test methodology, instrumentation, medical knowledge, quality control, lab supervision, and communication." No matter what the strategy, residents need some type of feedback to ensure progress. Extensive discussion of competency assessment is presented in the ACLPS curriculum content guidelines.[18] To summarize one respondent, the goal is "getting the residents involved with routine service activities, from the mundane…to the exciting…to all the behind the scene activities…[M]ost have no idea how these basic things get done."

What have been the major challenges in teaching clinical chemistry to pathology residents?

Consistent with the observations above, 59% of respondents noted that a lack of interest in clinical chemistry (and often CP in general) by trainees was the most challenging barrier to clinical chemistry education. As one respondent stated, "most residents like surgical pathology, hematology, and microbiology because they are used to visual stimulation and using the microscope. Chemistry is a relatively dry subject and making this interesting to residents with no research background is difficult and may be virtually impossible." Another stated "the major challenge in teaching chemistry to pathology residents is that most of them do not see themselves as specializing in clinical chemistry in their future career…" Other quotes include "I try to make it interesting, but QC [quality control] and Westgard doesn't seem to keep them on the edge of their seats," and "I have yet to teach a resident who plans on making CP the focus of their career."

27% of respondents noted that concurrent AP responsibilities (autopsies, AP sign-out, and/or conferences) interfered with clinical chemistry education. While this problem is unique to AP/CP residents, they are, in fact, the vast majority of pathology trainees, and most institutions have combined departments of pathology which may not clearly delineate rotation responsibilities. Some directors mentioned specifically that attendance and mandatory time in the laboratory were necessary to ensure that residents focused on clinical chemistry during their rotation. Others noted that residents have had a tendency to schedule vacation time more often during clinical chemistry than other pathology rotations – a problem that needed to be specifically addressed in residency training committee meetings. One noted having to discourage residents from using "the residents' lounge and office other than to review autopsy cases when called in to supervise. All other times they are expected to be in the lab or supervisor's office." A dedicated work area for residents (with a networked computer) was provided. As one respondent poignantly stated "I occasionally have to play the bad guy on the first day. They have until 9:30 a.m. to show up, then they are paged…usually the response is that they are finishing autopsy or surgical pathology reports. We have a brief discussion about whose service they are on and this problem resolves." It is hard to believe that such a widespread diversion from assigned clinical responsibilities would be tolerated for residents in internal medicine, pediatrics, or surgery, but it is evidence to the fact that in many programs CP rotations are still viewed as secondary to AP responsibility – a problem that is not limited to clinical chemistry as a subspecialty. Some of the respondents even indicated that the clinical chemistry

rotation is done concurrently with other rotations such as neuropathology, cytogenetics, and/or human leukocyte antigen (HLA) testing.

22% of respondents noted that the breadth of clinical chemistry as a field is a challenge to pathology resident education. As a subspecialty, clinical chemistry includes many additional subdisciplines - from endocrinology to toxicology to acid-base analysis, just to name a few. It is clearly not possible to become an expert in clinical chemistry in a two or three month rotation. An equal number of respondents also noted (in a related fashion) that there was insufficient time during the rotation to adequately teach trainees. Comments were directed both toward rotation length, as well as the availability of already overworked faculty and technologists.

It is worth noting that 16% of respondents commented specifically on the poor background knowledge and skills of trainees, especially quantitative, statistical, and abstract problem-solving skills. Clinical chemistry is arguably the most quantitative subspecialty of CP, and many residents apparently do not acquire adequate quantitative and statistical training in college and medical school. This can be quite evident while teaching therapeutic drug monitoring and toxicology, where many pathology residents have achieved only superficial understanding of pharmacokinetics in medical school. One respondent noted that limited understanding of statistics hindered pathology resident participation in a monthly quality control meeting. As effective quality control mechanisms are critical for reducing errors in laboratory medicine,[28] it is worth considering how we can more effectively teach this quantitative aspect of pathology.

A number of respondents clearly emphasized that pathology itself is not taught correctly in medical school, with an overemphasis on AP and a cursory treatment of the clinical utility of appropriate laboratory testing. As one respondent noted “when interviewing resident candidates, I always ask if they did any elective rotations in clinical pathology…99% of them have not…” Furthermore, there is little to no pre-rotation exposure to common clinical laboratory techniques such as electrophoresis, spectrophotometry, fluorometry, high performance liquid chromatography, gas chromatography, immunoassays, and mass spectrometry in medical school. While this technical knowledge may be of limited or no value to a practicing surgeon or internist, assay familiarity is vital for clinical chemists trying to provide these services in laboratory testing. Acquisition of this technical knowledge adds an additional burden to the body of information required to be taught during the short clinical chemistry rotation.

How has the shortening of the AP/CP and CP residencies impacted this teaching?

In 2002, changes were made to the duration of AP, CP, and AP/CP residencies (primarily an elimination of the former credentialing year requirement).[29] Respondents indicated that the shortening of the AP/CP and CP residencies either significantly (39%) or minimally (24%) affected the quality of clinical chemistry education. A fair number (31%) either did not address the question or assumed their role as clinical chemistry director after the change had taken place. 6% said the shortening had no effect at all. From the comments provided, any negative impact seems to affect not just the amount of training in the rotation, but also the ability to conduct any meaningful advanced projects (for example, development and validation of a new assay or detailed justification for a change in methods). Such projects are reserved for the select few who pursue an additional elective rotation. The idea of “research activities,” therefore, is often narrowed to short term projects such as investigating abnormal lab results or retrospective analysis of a limited series of cases. Others indicated that the effect of shortening the AP/CP and CP residencies was minimal due to the lack of resident interest in clinical chemistry to begin with.

Who does most of the residency teaching?

As expected, most respondents (clinical faculty by definition) stated that they conduct most of the residency teaching in clinical chemistry. There may be some survey bias, as those who responded to the questionnaire may be particularly committed to resident education. A small number of programs have clinical chemistry fellows that assist in instruction. One respondent described teaching clinical chemistry residents as an “apprenticeship model.” Surprisingly, 57% felt that they had minimal or no contribution from the technical staff - medical technologists (MT) and medical laboratory technicians (MLT) - while 43% reported that the technical staff assisted in the teaching of residents. Elaboration on these responses, however, revealed that this was primarily due to the heavy workload imposed on the technical staff, combined with the decreased staff availability. As one respondent stated “the senior technologists are very enthusiastic, but their time is limited.” Some used section supervisors to conduct lab tours through important stations of the clinical chemistry laboratory. While most respondents wanted the technical staff to play a larger role in residency teaching, and often described residents as frequently “looking over the shoulders” of technical staff, they felt that additional demands on their time were not appropriate. A related concern is the closing of many MT and MLT training schools that were associated with institutions having pathology residency programs. A number of respondents commented that the losses of the MT and MLT training programs have, unfortunately, degraded the overall “teaching atmosphere” of the clinical chemistry laboratory. Any modification to the educational paradigm in clinical chemistry needs to keep these constraints in mind, such that the resident is not viewed as a burden to the workflow in the laboratory by the technical staff.

Do residents spend much time at the various benches within the laboratory?

While this question is inextricably linked to the topic of technical staff availability described above, it also provoked a wide array of philosophical views on clinical chemistry education. Respondents provided a surprisingly mixed set of answers on the value of bench time in clinical chemistry training. 28% noted that bench rotations are a significant part of a resident’s time in the laboratory. 35% stated that minimal rotations (or rotations only in selected areas, such as toxicology) by the residents should be performed. 41% indicated that residents should perform essentially no bench rotations whatsoever in clinical chemistry. This question evoked extensive discussion ranging from the denial of any value of sitting in front of “black box” analyzers, to assertions of the absolute importance of running blood samples on a variety of machines, either with technicians or in a training laboratory with older equipment. Of respondents who commented that their residents spend time at the benches, toxicology and protein electrophoresis were frequently mentioned.

The value of bench work certainly involves more than learning how to “push buttons”, but extends to understanding work flow, sample limitations, and machine complexity. It also provides a greater skill set for troubleshooting as problems arise. Whether or not to incorporate bench time depends on the preferences of individual training programs, but it is undeniable that familiarity with general laboratory protocols and/or standard operating procedures adds meaning and relevance to the more common text-based learning outlined above.

What do you see as the major challenges for the future of residency training in clinical chemistry?

This final question reiterated many of the points presented above. 49% of respondents noted a lack of resident interest in clinical chemistry – a troubling finding given the well-acknowledged need for additional clinical chemists in the near future. It is intriguing to ponder whether this lack of interest contributes to the observation that residents make only minor improvements over time in clinical chemistry scores by the end of their residency training as measured by the RISE. The improvements in clinical chemistry scores over the course of

residency training are far less than in the improvements seen in surgical pathology, hematopathology, or cytopathology.[30; see also article by McKenna, BJ, this issue]

35% of respondents commented that the continued expansion of clinical chemistry, including increasing automation, incorporation of molecular techniques, as well as the pending growth of proteomic and genomic technologies, will pose additional challenges and opportunities in training residents. As one respondent stated "clinical chemistry has already evolved beyond the point where the majority of pathologists with CP training can effectively run a sophisticated laboratory service; it really requires a trained clinical chemist."

Other respondents noted that the expansion of complex regulations involved in running a clinical laboratory will also prove challenging to resident education. One respondent stated that it is important to learn "the role of the pathologist relative to CLIA and CAP requirements for the laboratory director; if you really look at what is expected of the director and compare it to the bench level training that is commonly seen, they are inconsistent and the resident is poorly trained to fulfill the mandated role." Paralleling these demands is a movement toward "value added laboratory medicine,"[31] an interesting concept in the context of clinical chemistry, where there is little interpretative reimbursement, cost savings are often unrecognized by hospital administrators, and the assumption that automation should justify decreased personnel (even in the context of increased workflow) is placing an incredible burden on the technical staff.

There is hope that the issue of diminished resident interest in clinical chemistry may change. As the molecular, genomic, and proteomic aspects of laboratory testing begin to permeate nearly all areas of pathology and medicine, residents are beginning to see these fields as novel and important. As one respondent noted "as medicine is becoming more scientific…I find the teaching of pathology residents easier." Another, however, had an opposing response: "I'm not convinced that there is a future for clinical chemistry as regards pathology residents. I see there is a future for science graduates in this field, particularly those with a molecular background."

It should be noted that a number of respondents stated that former residents, now conducting AP services in community practice (e.g., primarily surgical pathology or cytopathology duties at a community hospital), have expressed regret at not placing more focus on clinical chemistry. These former residents now have some component of CP oversight responsibility (e.g., medical directorship of clinical chemistry or microbiology) but feel ill-prepared in dealing with instrumentation evaluations, CAP inspections, and quality control. These observations provide a strong reason to promote clinical chemistry education, even for residents who perceive during residency training that they have no interest in CP (let alone clinical chemistry itself).

Summary

A need for improved clinical chemistry education certainly exists, and it will involve the challenge of finding additional ways to teach more information, in less time, and in a more engaging manner. The results of the present study suggest that while the curricula in most clinical chemistry rotations is founded in some sort of text-based review, additional components, including clinical consultation, review of send-out/esoteric testing, sign-out responsibility, on-call duty, routine meetings with faculty, as well as some type of active responsibility or hands-on experience in the chemistry laboratory are important in engaging a resident's interest and creating a successful rotation. Finding additional ways to adapt these components also provides a more accurate portrayal of the complex roles and responsibilities of clinical chemistry directors, and more importantly, it might serve to influence additional pathology residents to pursue a career in clinical chemistry.

In an effort to leave the reader with additional ideas to consider when evaluating an institutions clinical chemistry curriculum, the questions in Table 2 may be worth review. While it is unrealistic to expect every resident that rotates through clinical chemistry to want to become a clinical chemist, the technical, quantitative, and managerial skills that can be acquired during such a rotation should prove to be invaluable no matter what a trainee's area of specialization ends up becoming.

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Table 1

Questionnaire.

• What aspects of your clinical chemistry rotation work particularly well?
• Have you found especially effective methods to engage residents and integrate them into the clinical chemistry laboratory?
• What have been the major challenges in teaching clinical chemistry to pathology residents?
• How has the shortening of the AP/CP and CP residencies impacted this teaching?
• Who does most of the residency teaching?
• Do residents spend much time at the various benches within the laboratory?
• What do you see as the major challenges for the future of residency training in clinical chemistry?

Table 2

Summary Questions for Review

- How does the clinical chemistry rotation create a structural framework for education? Is it through textbooks or articles? What mechanisms are in place to ensure that residents are absorbing the information presented? Does the framework incorporate clinical chemistry-related topics outlined in the ACLPS curriculum content guidelines?
- To what extent does the curriculum engage residents in consultative activities within the clinical chemistry service? Is there a formal on-call system? How are questions triaged to the resident? Are the residents contacted by both clinical services and technical staff? Does this consultative service have adequate attending oversight and graded responsibility?
- Do residents participate in approvals of esoteric testing and/or send-outs? Is the process engaging or burdensome?
- Do residents participate in the initial sign-out process of any tests in the clinical laboratories?
- Are the residents in contact with other clinical services, either through rounds or as a clinical chemistry representative at clinical conferences?
- Are case studies and/or clinical correlations integrated into the curriculum?
- Do attendings have regularly scheduled meetings with residents? Do residents regularly meet with technical staff, supervisors, and/or laboratory managers? How can residents provide useful information at those meetings?
- Are residents gaining adequate experience in laboratory management, quality control, and regulations? Is there any exposure to basic statistical techniques?
- Do residents have bench-time activities in the clinical laboratory? Does the clinical chemistry laboratory have a particular area of specialization that would be favorable toward bench work by the resident?
- Are there adequate feedback mechanisms in place to help improve the rotation and guide resident interest? How is poor performance, including diversion to anatomic pathology activities, dealt with?