Development of a postgraduate year 2 pharmacy residency in clinical pharmacogenetics

Cyrine E. Haidar, Pharm.D., BCPS, BCOP, Pharmaceutical Sciences Department, St. Jude Children's Research Hospital, Memphis, TN.

James M. Hoffman, Pharm.D., M.S., BCPS, Pharmaceutical Sciences Department, St. Jude Children's Research Hospital, Memphis, TN.

Roseann S. Gammal, Pharm.D., BCPS, Pharmaceutical Sciences Department, St. Jude Children's Research Hospital, Memphis, TN.

Mary V. Relling, Pharm.D., Pharmaceutical Sciences Department, St. Jude Children's Research Hospital, Memphis, TN.

Kristine R. Crews, Pharm.D., FCCP, BCPS, Pharmaceutical Sciences Department, St. Jude Children's Research Hospital, Memphis, TN.

Purpose. The structure and development of an innovative, ASHP-accredited postgraduate year 2 (PGY2) clinical pharmacogenetics residency program are described.

Summary. A 12-month PGY2 clinical pharmacogenetics residency was created at St. Jude Children's Research Hospital in accordance with the ASHP standards for advanced practice residencies. The purpose of this 12-month residency program is to prepare pharmacy residents to implement pharmacogenetics in clinical practice. The program helps residents develop expertise in the science of pharmacogenetics as well as an understanding of translational research, innovative pharmacy practice model development, and clinical informatics. The resident learns to optimize patient outcomes through the expert provision of evidence-based, patient-centered precision medicine as an integral part of an interprofessional team. After completing the program, residents are expected to have the clinical skills necessary to practice in the field of clinical pharmacogenetics and independently implement pharmacogenetic testing in other health-system settings. Because implementation of pharmacogenetics requires collaboration across many disciplines, residents works within an interprofessional team of physicians, nurses, informatics specialists, pharmacists, and clinical laboratory personnel to achieve program goals. Since the first resident graduated in 2012, the program has graduated 1 resident each year. Graduated residents have accepted pharmacogenetics positions at major academic medical centers and community hospitals, as well as academic and research positions with a pharmacogenetics emphasis.

Conclusion. A PGY2 clinical pharmacogenetics residency was successfully developed at St. Jude in 2013. After completion of the program, residents are equipped with the clinical skills and necessary experience to drive precision medicine forward and lead the implementation of pharmacogenetic testing in other healthcare settings.

Keywords: pharmacy; residency, pharmacogentics; residency, pharmacogenomics; training

Am J Health-Syst Pharm. 2017; 74:409-15

Postgraduate education is increasingly important across all areas of pharmacy practice. Initiatives have been launched by the American College of Clinical Pharmacy and the American Society of Health-System Pharmacists (ASHP) to increase pharmacists' involvement in direct patient care and to foster support for expanded postgraduate education through pharmacy practice residency programs.[1,2]

Pharmacogenetics, the study of how genetic variability influences drug response, is increasingly used to personalize medication therapy.[3] The importance of this burgeoning field has been emphasized at the national level through President Obama's Precision Medicine Initiative.[4] As medi-

Address correspondence to Dr. Haidar (cyrine.haidar@stjude.org).

Copyright © 2017, American Society of Health-System Pharmacists, Inc. All rights reserved. 1079-2082/17/0302-0409.

DOI 10.2146/ajhp160174

cation experts, pharmacists are well positioned to lead clinical pharmacogenetics (sometimes referred to as clinical pharmacogenomics) efforts.[5-7] The 2015 ASHP Statement on the Pharmacist's Role in Clinical Pharmacogenomics states that pharmacists have a "fundamental responsibility to ensure that pharmacogenomic testing is performed when needed and that the results are used to optimize medication therapy."[8] Pharmacy leaders have called for pharmacists to proactively lead the implementation of pharmacogenetics and be at the forefront of its clinical application to improve medication-use outcomes.[9,10]

As more health systems evaluate their ability to train pharmacy residents in specialty practice areas, summaries of the process to create an innovative residency program may be valuable to help other institutions anticipate potential problems while recognizing their strengths and using these strengths to their advantage. We describe the design, implementation, and ongoing evaluation of the first accredited postgraduate year 2 (PGY2) clinical pharmacogenetics residency program.[11]

KEY POINTS

- The need for pharmacist expertise in pharmacogenetics inspired the creation of an innovative, ASHP-accredited postgraduate year 2 residency in clinical pharmacogenetics.
- The clinical pharmacogenetics resident gains hands-on experience in running an interprofessional clinical pharmacogenetics service and completes learning experiences in direct patient care, research, leadership, and teaching.
- Residents learn the skills necessary to lead the implementation of pharmacogenetics in various healthcare settings.

Site description

St. Jude Children's Research Hospital (St. Jude) provides comprehensive inpatient and outpatient care for children with catastrophic illnesses, particularly childhood cancer, infectious diseases, and sickle cell disease. St. Jude provides care across the patient care continuum, including inpatient care, outpatient care (including home infusion therapy), and an onsite infusion center, to approximately 8,000 active patients each year. The pharmaceutical department provides comprehensive clinical services and all inpatient, clinic, and home prescriptions to approximately 4,200 patients annually. Since the early 1980s, the pharmaceutical department has operated both the clinical and laboratory aspects of the hospital's clinical pharmacokinetics service, which provides therapeutic drug monitoring for a variety of drugs used in the treatment of patients at St. Jude. A clinical pharmacogenetics service was created at St. Jude in 2007, as the hospital has a history of research and discovery in pharmacogenetics and genomics.[5] The initial focus was on single-gene tests, providing two pharmacogenetic tests (the gene encoding thiopurine methyltransferase [*TPMT*] and the gene encoding cytochrome P-450 isozyme 2D6 [*CYP2D6*])[12,13] directed to patients who were expected to receive drugs affected by these genes.[5] The hospital has an established pediatric oncology residency program that was started in 1990 and accredited by ASHP in 2007. In 2011, we used the knowledge gained from the PGY2 oncology residency to start the clinical pharmacogenetics residency. Funding for the residency program was obtained from institutional funds and from grant funding through the National Institutes of Health (NIH)–funded Pharmacogenomics Research Network.

Program development

The clinical pharmacogenetics residency program at St. Jude was developed in conjunction with the expansion of the institution's pharmacogenetics service. In 2011, an institutionwide preemptive pharmacogenetic testing program was launched with the goal of selectively migrating array-based pharmacogenetic tests into routine patient care, allowing the results to be available preemptively.[14] The preemptive pharmacogenetics program was launched with the goal of leading such efforts nationally. When we considered who would follow our lead in implementing a pharmacogenetics program, it became apparent that pharmacists are naturally positioned to lead such programs, yet few pharmacists at the time had the necessary specialized training. We developed and launched the PGY2 clinical pharmacogenetics residency simultaneously with this new preemptive pharmacogenetics program to integrate training into the effort. The goal was to train the next experts in clinical pharmacogenetics to lead emerging programs throughout the country. We sought and obtained ASHP accreditation for the clinical pharmacogenetics PGY2 residency in 2013, making this residency the first of its kind to be accredited.

The purpose of this 12-month residency program is to prepare pharmacy residents to implement pharmacogenetics in clinical practice. The program helps residents develop expertise in the science of pharmacogenetics as well as an understanding of translational research, innovative pharmacy practice model development, and clinical informatics.[11] After completing the program, residents are expected to have the clinical skills necessary to practice in the field of clinical pharmacogenetics and independently implement pharmacogenetic testing in other health-system settings. Because implementation of pharmacogenetics requires collaboration across many disciplines, residents work within an interprofessional team of physicians, nurses, informatics specialists, pharmacists,

and clinical laboratory personnel to achieve program goals.

Since there are no PGY2 residency standards for pharmacogenetics residencies, the objectives of our clinical pharmacogenetics program were based on the ASHP guidelines for PGY2 residencies in an advanced area of pharmacy practice.[15] The desired outcomes for each resident include the following:

- Serve as an authoritative resource on the optimal use of clinical pharmacogenetic tests to individualize medication therapy for patients,
- Establish oneself as an expert for pharmacogenetics-related information and resources within an organization,
- Demonstrate leadership in the field of clinical pharmacogenetics and practice management skills,
- Optimize the outcomes of patients through the expert provision of evidence-based, patient-centered medication therapy as an integral part of an interprofessional team,
- Demonstrate excellence in the provision of training and educational activities for healthcare professionals, healthcare professionals in training, and the public,
- Conduct research related to the clinical implementation of pharmacogenetics, and
- Contribute to the body of knowledge for clinical pharmacogenetics.

Program applicants must have successfully completed an ASHP-accredited postgraduate year 1 residency. Previous research experience or expertise in genetics is desirable (but not a requirement).

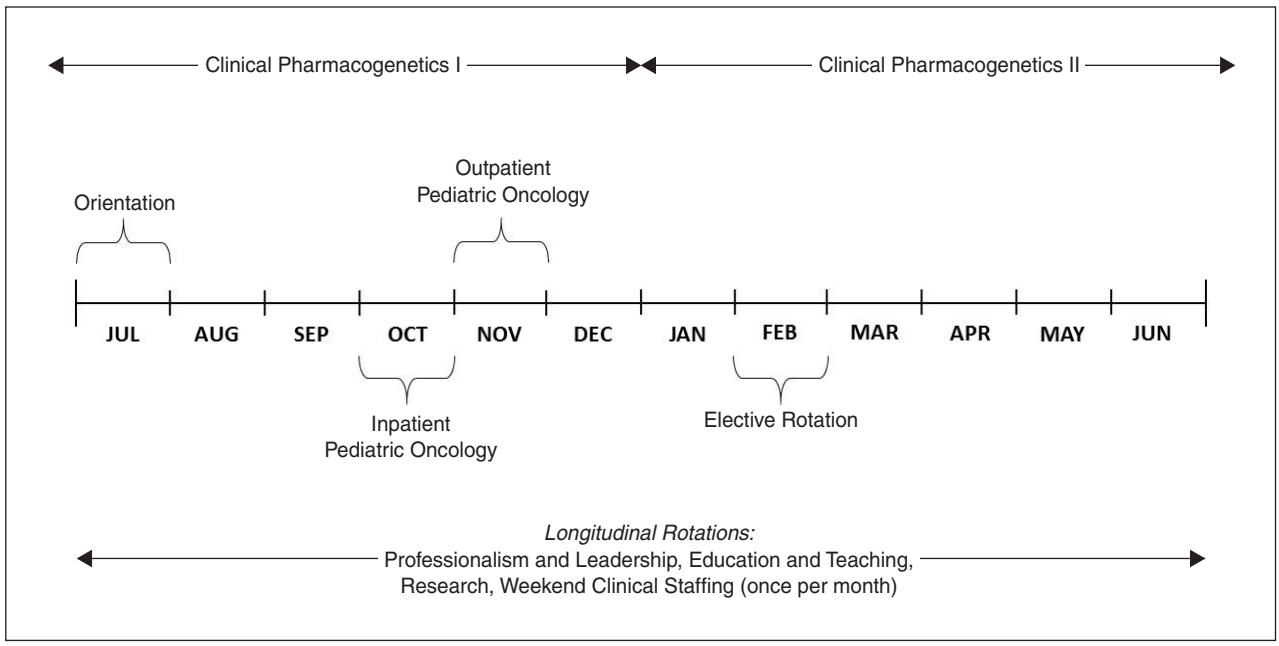
Structure of learning experiences

Similar to other residency programs, the first month of the clinical pharmacogenetics residency is dedicated to orientation activities, which include an overview of St. Jude's pharmaceutical services, exposure to all facets of pharmacy operations (inpatient, outpatient, and specialty pharmacy services), and didactic sessions focused on advanced pharmacotherapy topics for children with catastrophic diseases. An introduction to St. Jude's pharmacogenetics service and individualized training with the clinical pharmacogenetics coordinator are also provided.

The core educational experiences for the resident are longitudinal, and the resident plays an integral role in the clinical pharmacogenetics service throughout the year (Figure 1). The resident further develops clinical skills through 3 4-week direct patient care rotations that allow the resident to see both how pharmacogenetics is implemented in practice and how genetics fits into the overall care of children with catastrophic diseases.

Elective and customized learning experiences are also provided. Because pharmacogenetic data are often used to facilitate care in patients with cancer and because several of our residents have also had an interest in oncology, the program in-

Figure 1. Timeline of rotation experiences offered through the postgraduate year 2 clinical pharmacogenetics residency at St. Jude Children's Research Hospital. Longitudinal rotation experiences are common to all St. Jude residents.



cludes opportunities for an elective rotation in the inpatient or outpatient oncology setting. Informatics plays an important role in the implementation of pharmacogenetics, and the training plan for 1 resident was customized to include an elective rotation to conduct informatics projects with the clinical decision support officer.

Longitudinal experience

The clinical pharmacogenetics learning experience is divided into 2 6-month components that span the residency year (Clinical Pharmacogenetics I and Clinical Pharmacogenetics II). Over the course of this longitudinal experience, the resident serves an integral role in the institution's preemptive pharmacogenetics service. These rotation blocks have distinct goals and activities that have been mapped to ASHP-outlined objectives (appendix).

Resident responsibilities include evaluating the clinical utility of gene–drug pairs in the literature, formulating specific drug selection and dosing recommendations based on an individual patient's genotype, writing clinical pharmacogenetics consultations, developing language for clinical decision support alerts, creating pharmacogenetics competencies for healthcare professionals, and providing clinician and patient education about pharmacogenetic testing. The resident takes a lead role in implementing at least one gene–drug pair into the St. Jude electronic health record from start to finish (from literature review to integration into the medical record and use in clinical care) over the course of the year. The resident also engages in other pharmacogenetics-related research and quality-improvement projects as well as fielding clinical pharmacogenetics-related consultations as they arise. The interprofessional pharmacogenetics team meets weekly, and the resident assumes a leadership role within this group early in the year. This responsibility involves identifying meeting topics, facilitating group discussion, and recording and circulating meeting minutes. The resident also participates in the quarterly meetings of the pharmacogenetics oversight committee, a subcommittee of the St. Jude pharmacy and therapeutics committee that governs the implementation of pharmacogenetics at the institution.

In addition to these opportunities, the clinical pharmacogenetics resident has the unique experience of working closely with leaders of the Clinical Pharmacogenetics Implementation Consortium (CPIC). CPIC is an NIH-funded international collaboration focused on creating evidence-based guidelines that describe how to interpret and use pharmacogenetics information in clinical practice.[16,17] The resident participates in all monthly CPIC conference calls and serves on the CPIC Informatics Working Group.[18]

Research

The resident is expected to complete at least one major research project. Other pharmacogenetics research projects arise frequently, and the resident often participates in multiple research projects to further expand his or her learning experience.[15] Before an incoming resident begins the program, potential topics are developed to provide the resident with a variety of project ideas to choose from. Results of practice-related projects have been reported as poster presentations at the ASHP Midyear Clinical Meeting and other national conferences, as platform presentations at a designated regional residency conference, and through other methods within and outside the institution. Research projects have resulted in a first-author publication for each resident who has completed the program.[19-23]

Professionalism and leadership

The longitudinal professionalism and leadership rotation provides all St. Jude residents a forum in which to actively discuss timely pharmacy practice topics with the St. Jude chief pharmaceutical officer. These meetings are held monthly to stimulate discussion on pharmacy practice issues at St. Jude and on national pharmacy practice trends. Residents learn about St. Jude's pharmacy organizational structure and reporting relationships, discuss relevant clinical and practice issues that confront pharmacy leaders, and provide input to department action plans. Broader pharmacy practice issues, such as provider status, prescribing privileges, reimbursement, and board certification, are also discussed. Personal and professional development are supported through critical review and the application of concepts presented in prominent leadership literature. These sessions also provide residents with the opportunity to discuss residency experiences and provide ongoing feedback directly to the chief pharmaceutical officer.

Education and teaching

A longitudinal learning experience focused on education and teaching provides the resident with opportunities to develop teaching skills in small- and large-group settings. If desired, St. Jude residents may complete a Teaching and Learning Certificate through the University of Tennessee Health Science Center's (UTHSC) College of Pharmacy. St. Jude residents are required to give oral presentations numerous times throughout the year, including case-based journal club presentations, inservices, and research project updates. The clinical pharmacogenetics resident also teaches at least one lecture in the pharmacogenetics elective for the College of Pharmacy at UTHSC. Each St. Jude resident prepares and presents at least one Accreditation Council for Pharmacy Education–accredited continuing-education seminar on a pharmacogenetics topic. Every formal resident presentation is evaluated by the audience with a standardized evaluation tool, and the resident meets with the pharmacy education preceptor to discuss these results. The resident is

expected to evaluate his or her own performance by discussing strengths and areas of improvement after each lecture. Together, the resident and the pharmacy education preceptor review the audience's evaluations and construct an action plan to improve future presentations.

As a practice site for advanced pharmacy practice experience (APPE) students from several colleges of pharmacy, St. Jude hosts many students on clinical rotations. The clinical pharmacogenetics resident is charged with developing and facilitating an "introduction to pharmacogenetics" discussion for APPE students. In addition, the resident serves as a copreceptor for the clinical pharmacogenetics APPE rotation at St. Jude. As a copreceptor, the resident guides the student through assigned project work, serves as the student's primary point of contact, and provides input at both midpoint and final student evaluations.

Pharmacy operations

During the orientation month, residents rotate through all pharmaceutical services units, allowing them to understand the units' functions and operating structure. The first staffing component—a 4-hour, once-weekly afternoon block of work in the hospital's central pharmacy—begins in July and runs through August. Through this learning experience, the resident becomes familiar with medication order review processes for chemotherapy and other supportive care orders, evaluates orders for consistency with protocol requirements, prepares and checks chemotherapy and other parenteral medications, verifies and dispenses outpatient medications, and performs other general operations of the pharmaceutical services units. The second staffing component starts in September and involves a weekend clinical call in which residents are included in the clinical pharmacy specialists' weekend coverage of all services of the hospital. Core functions on the weekend include medication profile review, order entry for total parenteral nutrition formulations, therapeutic drug monitoring, and discharge counseling.

Lessons learned

The St. Jude clinical pharmacogenetics residency is currently in its sixth year. The coordinators have learned a tremendous amount and continually refine the program. A primary challenge was structuring the resident's staffing responsibilities. Understanding the workflow of the pharmaceutical services units to become familiar with the operations, policies, and procedures of all inpatient and outpatient pharmacy areas is a key component of any pharmacist's job. Because our institution serves a pediatric specialty population, there is a steep learning curve to becoming skilled in all operations of pharmaceutical services. For that reason, the resident serves as an extra staff member when fulfilling his or her operations requirements early in the residency experience. Several conversations with the preceptors and clinical staff pharmacists were required for the staff to understand the role and expectations of the resident. Ensuring that the resident is scheduled to work with a designated pharmacist was very helpful in meeting the goals of this pharmacy operations learning experience.

Another consideration was how to ensure the resident is trained in all aspects of the emerging field of clinical pharmacogenetics. To work as a clinical pharmacogenetics specialist, a pharmacist must be well versed in many areas, including interpreting raw genotype results, translating laboratory test results into a phenotype, evaluating the primary genetic literature, mastering clinical informatics concepts, and educating other clinicians about the relationship between a gene and a drug or class of drugs. Our training model relies heavily on longitudinal experiences during which our PGY2 clinical pharmacogenetics resident is given a proportionate share of the responsibilities for running the service. The preceptors treat the resident as a peer from the start of the first rotation. The resident's office space is located next to the preceptor's office, which promotes frequent contact throughout each workday and allows for the provision of immediate support and feedback. Clinical teaching is incorporated into discussions of individual cases in real time. Weekly team meetings are led by the resident, ensuring that the resident has an understanding of all topics discussed and will be involved in the follow-up actions. Through this model, the resident gains small-group leadership skills and consequently masters each area of implementation. Our experience has shown that treating a trainee as a fully knowledgeable expert in clinical pharmacogenetics helps the trainee to quickly become that expert.

The PGY2 residency in clinical pharmacogenetics provides a unique opportunity for pharmacists to pursue clinical pharmacogenetics as a specialty area of practice and to become experts in the field. Empowering a resident as a peer practitioner ensures that the resident gains hands-on experience in all aspects of the service. After completion of the program, residents are equipped with the clinical skills and necessary experience to drive precision medicine forward and lead the implementation of pharmacogenetic testing in other healthcare settings. At the end of the residency year, our residents have accepted pharmacogenetics positions at major academic medical centers and community hospitals, as well as academic and research positions with a pharmacogenetics emphasis. As the field of clinical pharmacogenetics grows, the goals of the residency will expand with it.

Conclusion

A PGY2 clinical pharmacogenetics residency was successfully developed at St. Jude in 2013. After completion of the program, residents are equipped with the clinical skills and necessary experience to drive precision medicine forward and lead the implementation of pharmacogenetic testing in other healthcare settings.

Disclosures

The residency program described herein is funded in part by grant R24GM115264 from the National Institute of General Medical Sciences, National Institutes of Health, Bethesda, MD. The authors have declared no potential conflicts of interest.

References

1. American Society of Health-System Pharmacists. ASHP policy on pharmacy residency training (0917). www.ashp.org/DocLibrary/BestPractices/EducationPositions.aspx (accessed 2016 Feb 22).
2. Murphy JE, Nappi JM, Bosso JA et al. American College of Clinical Pharmacy's vision of the future: postgraduate pharmacy residency training as a prerequisite for direct patient care practice. *Pharmacotherapy.* 2006; 26:722-33.
3. Relling MV, Evans WE. Pharmacogenomics in the clinic. *Nature*. 2015; 526:343-50.
4. White House Office of the Press Secretary. Fact sheet: President Obama's Precision Medicine Initiative (2015). www.whitehouse.gov/the-press-office/2015/01/30/fact-sheet-president-obama-s-precision-medicine-initiative (accessed 2016 Jan 19).
5. Crews KR, Cross SJ, McCormick JN et al. Development and implementation of a pharmacist-managed clinical pharmacogenetics service. *Am J Health-Syst Pharm.* 2011; 68:143-50.
6. Owusu-Obeng A, Weitzel KW, Hatton RC et al. Emerging roles for pharmacists in clinical implementation of pharmacogenomics. *Pharmacotherapy.* 2014; 34:1102-12.
7. Johnson SG. Leading clinical pharmacogenomics implementation: advancing pharmacy practice. *Am J Health-Syst Pharm.* 2015; 72:1324-8.
8. American Society of Health-System Pharmacists. ASHP statement on the pharmacist's role in clinical pharmacogenomics. *Am J Health-Syst Pharm.* 2015; 72:579-81.
9. Ray MD. Personal reflections 30 years after the Hilton Head Conference. *Am J Health-Syst Pharm.* 2015; 72:972-6.
10. Stevenson JG. Bold goals for health-system pharmacy: perspectives of an experienced practice leader. *Am J Health-Syst Pharm.* 2014; 71:1958-9.
11. St. Jude Children's Research Hospital. Pharmacy residency programs: clinical pharmacogenetics. www.stjude.org/education-training/advanced-training/clinical-residents/pharmacy-residency-programs/ashp-accredited-pgy2-clinical-pharmacogenetics-residency.html (accessed 2016 Feb 22).
12. Relling MV, Gardner EE, Sandborn WJ et al. Clinical Pharmacogenetics Implementation Consortium guidelines for thiopurine methyltransferase genotype and thiopurine dosing: 2013 update. *Clin Pharmacol Ther*. 2013; 93:324-5.
13. Crews KR, Gaedigk A, Dunnenberger HM et al. Clinical Pharmacogenetics Implementation Consortium guidelines for cytochrome P450 2D6 genotype and codeine therapy: 2014 update. *Clin Pharmacol Ther*. 2014; 95:376-82.
14. Hoffman JM, Haidar CE, Wilkinson MR et al. PG4KDS: a model for the clinical implementation of pre-emptive pharmacogenetics. *Am J Med Genet C Semin Med Genet*. 2014; 166C:45-55.
15. American Society of Health-System Pharmacists. Program outcomes, educational goals, and educational objectives for postgraduate year two (PGY2) residencies in an advanced area of pharmacy practice (2008). www.ashp.org/DocLibrary/Residents/OGOs-For-PGY2-Residencies-in-an-advanced-area-of-Pharmacy-Practice.aspx (accessed 2016 Feb 22).
16. Relling MV, Klein TE. CPIC: Clinical Pharmacogenetics Implementation Consortium of the Pharmacogenomics Research Network. *Clin Pharmacol Ther*. 2011; 89:464-7.
17. Caudle KE, Klein TE, Hoffman JM et al. Incorporation of pharmacogenomics into routine clinical practice: the Clinical Pharmacogenetics Implementation Consortium (CPIC) guideline development process. *Curr Drug Metab*. 2014; 15:209-17.
18. Hoffman JM, Dunnenberger HM, Hicks J et al. Developing knowledge resources to support precision medicine: principles from the Clinical Pharmacogenetics Implementation Consortium (CPIC). *J Am Med Inform Assoc.* 2016; 23:796-801.
19. Dunnenberger HM, Crews KR, Hoffman JM et al. Implementing preemptive clinical pharmacogenetics: reporting on 2 years of experience. *Clin Pharmacol Ther*. 2014; 95:S13-4.
20. Hicks JK, Crews KR, Hoffman JM et al. A clinician-driven automated system for integration of pharmacogenetic interpretations into an electronic medical record. *Clin Pharmacol Ther*. 2012; 92:563-6.
21. Bell GC, Crews KR, Wilkinson MR et al. Development and use of active clinical decision support for preemptive pharmacogenomics. *J Am Med Inform Assoc.* 2014; 21:e93-9.
22. Dunnenberger HM, Crews KR, Hoffman JM et al. Preemptive clinical pharmacogenetics implementation: current programs in five United States medical centers. *Ann Rev Pharmacol Toxicol*. 2015; 55:89-106.
23. Gammal RS, Court MH, Haidar CE et al. Clinical Pharmacogenetics Implementation Consortium (CPIC) guideline for *UGT1A1* and atazanavir prescribing. *Clin Pharmacol Ther*. 2016; 99:363-9.

Appendix—Resident activities and associated ASHP objectives[15]

Clinical pharmacogenetics I (6-month longitudinal rotation)

- Compose accurate, concise, and timely clinical notes documenting direct patient care activities. (R2.13.2)
  - Provide clinical pharmacogenetic consultations for 6-thioguanine nucleotide (6TGN) erythrocyte test results for St. Jude patients.
  - Provide clinical pharmacogenetic consultations for thiopurine methyltransferase (*TPMT*) genotype test results for St. Jude patients.
  - Follow up appropriately with other members of the patient care team with pharmacotherapy recommendations.
- Assist with designing and implementing clinical pharmacogenetics strategies to identify high-risk gene–drug pairs with the objective of improving quality of care for patients. (R3.2.5)
  - Contribute expertise as a team member to the pharmacogenetics team.
  - Explain decision support rules that will alert clinicians when a high-risk drug is prescribed to a patient with a high-risk diplotype.
- Identify the need for new gene-based dosing guidelines that will improve patient care based on evidence in the literature. (R3.1.1 and R3.2.1)
  - Employ Clinical Pharmacogenetics Implementation Consortium (CPIC) search strategies to conduct a literature search for a gene–drug pair.
  - Present proposed guideline to appropriate committees (e.g., pharmacogenetics team, pharmacogenetics oversight committee, pharmacy and therapeutics committee).

- Explain the appropriate documentation needed to meet Clinical Laboratory Improvement Amendments standards for a pharmacogenetic test. (R3.4.1)
- Contribute to the design of educational programs. (R4.2.1 and R4.2.2)
  - Assist with the development of educational materials for patients and families regarding gene-based dosing.
  - Assist with the development of gene-based competencies for pharmacists and other clinicians.

Clinical Pharmacogenetics II (6-month longitudinal rotation)

- Explain how the hospital's clinical informatics components are essential in providing quality clinical pharmacogenetics services to patients. (R1.3.1 and R3.3.2)
- Assist with development of computational tools allowing for automatic integration of high-throughput genotyping results and pharmacogenetic interpretations into the electronic medical record through pharmacogenetics. (R1.3.1 and R3.3.2)
- Assist with designing and implementing clinical informatics interventions to identify high-risk gene–drug pairs with the objective of improving quality of care for patients. (R1.3.2 and R1.3.3)
  - Write decision support rules that will alert clinicians when a high-risk drug is prescribed to a patient with a high-risk diplotype.
- Identify opportunities for improvement in aspects of the organization's medication-use system affecting patients at St. Jude by comparing the clinical pharmacogenetics implementation at St. Jude to best practices (i.e., at other implementing institutions). (R3.3.3)
- Identify the need for new gene-based dosing guidelines that will improve patient care by comparing the applicability of existing dosing guidelines to the pharmacogenetic needs of the patient population. (R1.4.3, R3.5.1, R3.5.2, R3.5.3, and R3.5.4)
  - Assist in implementing a guideline for a new gene–drug pair. When possible, assist in writing a new CPIC gene–drug guideline.
  - Assess the results of the implementation of a guideline for a gene–drug pair.